The Effects of Vertical Stress on the Liquefaction Potential Originated from Buildings in The Urban Areas: A Case Study

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ABSTRACT

Main purpose of this paper is to study the influence of vertical stress on soil liquefaction in urban areas. The literature provides limited information on vertical stress analysis of multiple footings, and, as a result, there is no accurate way to account for the effect of the foundation depth on liquefaction. Additionally, practical methods do not exist for considering the interaction between the neighboring foundations vertical stress and seismic forces in the urban area. Vertical stress distribution was calculated in examining the soil liquefaction potential exhibited by building foundations as a case study. The vertical stresses were chosen randomly for some buildings with foundation depths of 3.00 m; 4.50 and 6.00 m at the Burkent site (Burdur-Turkey). The influence of 5-storey buildings on the liquefaction potential of sandy soils was evaluated in terms of the safety factor (F_S) against liquefaction along soil profile depths for different earthquakes. Standard Penetration Test (SPT) results were used based on simplified empirical procedure.

KEYWORDS

Burdur, Factor of Safety, Foundations, Geotechnical, Liquefaction, Site Investigations

INTRODUCTION

Liquefaction is a phenomenon when there is loss of strength in saturated and cohesionless soils in consequence of increased pore water pressure and hence reduced effective stresses due to dynamic loading. In other words, strength and stiffness of a soil is reduced by earthquake shaking or other rapid loading. This phenomenon is usually accompanied by a large amount of ground surface subsidence. Occurrence of soil liquefaction beneath shallow foundations can also lead to excessive permanent deformations of buildings and other structures (Shahir & Pak, 2010).

Many authors have suggested solutions for seismic loads; Meyerhof (Meyerhof, 1953; 1963) considered a pseudo-static approach in which an inclined load could lead to similar stress conditions, although without concerning the inertial effects on the loaded soil mass. Other authors (Sarma & Iossifelis, 1990; Richards et al., 1993; Budhu & Al-Karni, 1993; Chien et al., 2002; Kumar, 2003; Choudhury & Subba Rao, 2005; Buchheister & Laue, 2007; Shafiee & Jahanandish, 2010) also considered the effect of seismic forces on both the structure and the loaded soil mass. Vessia and Venisti (2011) developed liquefaction damage potential PDL at Barletta site, located in Puglia Region while Assimaki and Li (2012) studied liquefaction effect specifically to site conditions and ground motion synthetics in southern California. The most widely used method for liquefaction potential

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evaluation initiated by Seed and Idriss (1967). The simplified procedure was developed based on field observations as well as field and laboratory tests with a strong theoretical basis. However, the simplified procedure (Seed et al., 1985; Youd et al., 2001; Çetin et al., 2004; 2012; Boulanger & Idriss, 2012a; 2012b; Idriss & Boulanger, 2006; 2010; 2014) relied almost entirely on case histories of liquefaction/no-liquefaction. The method was developed from field liquefaction performance cases at sites that had been characterized with in situ SPTs. Using a deterministic method, liquefaction of soil is predicted to occur if the factor of safety \( F_s \) is less than or equal to one. No soil liquefaction is predicted if \( F_s > 1 \). Despite the significant uncertainties in the different variables involved in this deterministic method, practical liquefaction risk assessment is still rooted in deterministic analysis. Reliability calculations provide means of evaluating the combined effects of uncertainties and logical framework for choosing factors of safety that are appropriate for the degree of uncertainty and the consequences of failure. Thus, as an alternative or a supplement to the deterministic assessment, a reliability assessment of liquefaction potential seems to be useful in providing better engineering decisions (Jha & Suzuki, 2009).

This paper presents an example of applications of vertical stress distribution calculations to investigate the soil liquefaction potentials exhibited by 5-storey buildings in the study area. The vertical stresses were chosen randomly for some buildings with foundation depths of 3.00 m, 4.50 m and 6.00 m at a selected area (Burdur, Turkey). The influence of 5-storey buildings on the liquefaction potential of soils was evaluated in terms of the factors of safety \( F_s \) against liquefaction along soil profiles for different earthquakes using SPT, based on simplified empirical procedure. Afterwards, vertical stress distribution was calculated in examining the soil liquefaction potential effects of 10 buildings.

GEOLoGIC ANd SEISMo-TECTONIC SETTING

Burdur city is located in the most seismically active zone in SW Turkey. Burdur fault extends in the direction of NE-SW, but it was segmented in various lengths by several faults tilted in NW direction. These fault systems pass through the city center of Burdur and cause a stepwise topographical feature. The unconsolidated sediments consist of cross-bedded sands, mudstones and present slope-debris deposits (Bozkurt, 2001; Verhaert et al., 2004; Balkaya et al., 2009). A geological map of the study area is shown in Figure 1. Burdur fault zone is one of the most important active fault zones in the region causing a number of earthquakes. The Burdur fault generated two large destructive earthquakes in October 1914 (\( M_w = 7.0 \)) and May 1971 (\( M_w = 6.2 \)) causing serious damage and casualties. The fault consists of three main segments NE–SW direction, namely Gölbasi-Gökcebağ, Burdur and Çendik-Yassıgümе (Ertunç et al., 2001). The Burdur basin, which is a NE–SW trending half graben, is located on the eastern edge of the west Anatolian extensional province (Şengör et al., 1985; Price & Scott, 1991). The area is composed of allochthonous Gökcebağ ophiolitic complex which is made up of limestone, diabase, serpentinite, peridotite, gabbro, radiorarite and chert. The autochthonous Burdur formation comprises Akdere, Yaka, Gölçük units, lacustrine alluvium sediments and alluvial cone. The Tertiary aged Burdur Formation consists mainly of pebblestone, sandstone, claystone, mudstone and marl, composing of three units known as the Akdere, Yaka and Gölçük. Stream and lacustrine sediments constitute the Akdere unit. The Quaternary lacustrine alluvium including clay, sand, silt and gravel extends along the Burdur Lake. The Quaternary alluvial cone mainly consists of clay, gravel and sandy layers. The alluvium is a productive aquifer as a result of the water present within the sand and gravel beds. The Yaka unit was interpreted as a travertine. The Gölçük unit is composed of tuff, tuffite and agglomerate.
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