Evaluating Ground Reaction Curves from Single to Multiple Trapdoor Tests

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Abstract: Ground reaction curves (GRCs) are increasingly used to simulate the progressive development of soil arching resulting from differential movement in soil. In this study, 20 single, double, and multiple trapdoor tests were conducted under a simultaneous displacement mode (i.e., trapdoors settle simultaneously), while 8 double trapdoor tests were carried out under a successive displacement mode (i.e., trapdoors settle successively) to examine the evolution of soil arching including the parameters related to the GRCs. This study identified and analyzed the key parameters of the GRCs. For the trapdoor tests conducted under the simultaneous displacement mode, an increase of the fill height led to a decrease in the minimum pressure and its corresponding trapdoor displacement. Furthermore, the ultimate normalized pressure and recovery rate exhibited a decreasing trend with an increase of the fill height. As compared to the single and double trapdoor tests, the multiple trapdoor tests had similar initial soil arching, minimum normalized pressure, and its corresponding trapdoor displacement but a relatively lower stress recovery rate. In the trapdoor tests conducted with the successive displacement mode, the pressure on the first settled trapdoor decreased while it increased on the later settled trapdoor during the settlement of the first settled trapdoor. Conversely, during the settlement of the later settled trapdoor, the pressure on the first settled trapdoor increased, while it decreased on the later settled trapdoor. Analyzing the GRCs on the later settled trapdoor under the successive displacement mode revealed that the initial slope and ultimate pressure of the GRC decreased as the fill height increased. **DOI: 10.1061/JGGEFK.GTENG-12187.** *© 2024 American Society of Civil Engineers.*

Author keywords: Ground reaction curve (GRC); Soil arching; Trapdoor test; Analogical soil.

Introduction

Soil arching is an important load transfer mechanism in various geotechnical applications, such as retaining walls (Paik and Salgado 2003; Cai et al. 2017; Chen et al. 2018; Rui et al. 2020), tunnels (Lee et al. 2006; Lin et al. 2019), and pile-supported embankments (Han et al. 2017; Rui et al. 2019, 2022; Zhang et al. 2023a). Terzaghi (1943) defined the soil arching effect as load transfer between a yielding portion and adjoining stationary portions (also called supports) under or within a fill, and involves a redistribution of stresses in the fill. A comprehensive understanding of soil arching behavior is essential for the safe design of geotechnical projects. Numerous studies have been conducted to investigate the mechanism, behavior, and implications of soil arching. For instance, Handy (1985), Paik and Salgado (2003), Khosravi et al. (2013), and Rui et al. (2020) reported that the active earth pressure at the toe of retaining walls decreases with the increase of the wall depth due to the soil arching effect. In geosynthetic-reinforced and/or unreinforced pile-supported embankments, the soil arching effect helps reduce the stress on the soft subsoil and soil arching efficiency is influenced by factors such as embankment height, pile net spacing, and fill material properties (Rui et al. 2022; Zhang et al. 2022, 2023b). In the tunneling process, the vertical stress in the loosening zone transfers to the adjacent stable zone, leading to a decrease in the stress acting on the tunnel lining due to the soil arching effect (Lee et al. 2006; He et al. 2023). Overall, positive soil arching contributes to the reduction of the vertical pressure on the yielding zone, thereby enhancing the safety of earth structures (e.g., retaining walls and tunnels).

To provide a more comprehensive understanding of soil arching effects, Iglesia et al. (1999) introduced the concept of the load–displacement curve based on a trapdoor test, also known as the ground reaction curve (GRC). The GRC represents the relationship between a normalized pressure and a corresponding normalized trapdoor displacement. Normalized pressure is defined as the ratio of the vertical stress on the trapdoor at a certain displacement to the initial vertical stress on the trapdoor at zero displacement, while normalized trapdoor displacement is the ratio of the trapdoor displacement to the trapdoor width. The normalized pressure is also

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