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Analysis of load sharing characteristics for a piled raft foundation

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Abstract. The load sharing ratio (α_{pr}) of piles is one of the most common problems in the preliminary design of piled raft foundations. A series of 3D numerical analysis are conducted so that special attentions are given to load sharing characteristics under varying conditions, such as pile configuration, pile diameter, pile length, raft thickness, and settlement level. Based on the 3D FE analysis, influencing factors on load sharing behavior of piled raft are investigated. As a result, it is shown that the load sharing ratio of piled raft decreases with increasing settlement level. The load sharing ratio is not only highly dependent on the system geometries of the foundation but also on the settlement level. Based on the results of parametric studies, the load sharing ratio is proposed as a function of the various influencing factors. In addition, the parametric analyses suggest that the load sharing ratios to minimize the differential settlement of piled raft are ranging from 15 to 48% for friction pile and from 15 to 54% for end-bearing pile. The recommendations can provide a basis for an optimum design that would be applicable to piled rafts taking into account the load sharing characteristics.

Keywords: piled raft foundation; 3D numerical analysis; load sharing ratio; sand; optimum design

1. Introduction

Piled raft foundations, which are composed of a raft and piles, are being especially recognized as an economical foundation system for high-rise buildings. Piles as settlement reducers have been discussed for over a quarter of a century (Burland *et al.* 1977), and some significant applications have been reported (Hansbo and Kallstrom 1983, Katzenbach *et al.* 1996, Sommer 1991, Viggiani 1995). Fig. 1 shows the schematic diagram of the design concept applied to a piled raft foundation. The distribution of the contact pressure below a rigid raft is well known. If this contact pressure distribution can be generated below a flexible raft that is subjected to uniform loading, the differential settlement of the raft can be significantly reduced. This can be obtained by installing a pile group in the central area of the raft, reducing the raft contact pressure in that zone.

An optimized design of a piled raft can be defined as a design for the construction of the foundation with minimum cost and satisfactory bearing behavior for a given geometry and raft loading. Not only bearing, but also settlement and different settlement need to be considered (Randolph 1994). Hence, for an optimum design, it is essential to investigate factors influencing the load-sharing ratio of the piled rafts under axial loads.

Numerous research studies have been conducted to investigate the characteristics of the load sharing behavior of piled raft foundations. However, very few case histories on the monitoring of load sharing between the raft and the piles as well as the settlement are available in the literature (Katzenbach *et al.* 2000). Limited field measurement and model test cases have been published concerning this topic from the 1970s to the 2000s. Among these research studies, field measurements (Cooke 1986, Katzenbach *et al.* 2000, Mandolini *et al.* 2005) and model tests (Akinmusuru 1980, Al-Mosawi *et al.* 2011, Al-Omari *et al.* 2015, Conte *et al.* 2003, Fattah *et al.* 2013b, Fattah *et al.* 2015, Horikoshi and Randolph 1996, Sawada and Takemura 2014, Thaher and Jessberger 1991) have been considered the appropriate method for investigating the real behavior of the piled rafts, but field measurements and model tests have some limitations and require major investments of money and time. Although numerical methods are approximate and must be additionally verified, the numerical methods are simple and less costly and can be used to consider many more types of different geometries than model and field testing, so numerical methods have been extensively developed in the last two decades. The numerical modeling techniques based on the finite element method (Comodromos *et al.* 2016, de Sanctis and Mandolini 2006, Fattah *et al.* 2013a, Fattah *et al.* 2014, Ko *et al.* 2017, Lee *et al.* 2010, Reul and Randolph 2003, Reul and Randolph 2004, Saha *et al.* 2015) provide versatile tools that are capable of modeling soil continuity, soil nonlinearity, soil-structure interface behavior, and 3D boundary conditions.

In this study, the nonlinear 3D FE analyses varying the

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