Chapter 13
Optimization of Pile Groups Under Vertical Loads Using Metaheuristic Algorithms

Cihan Öser
Istanbul University, Turkey

Rasim Temür
Istanbul University, Turkey

ABSTRACT
Construction of foundations on soft/loose soil deposits causes some big problems in geotechnical engineering. The vertical loads can cause failure and/or extreme settlement in soft/loose soil deposit. Constructing piles under foundations to transfer the loads to stiff soil layer is one of the widely used solutions to prevent these problems. The interaction between the piles in a group of piles is described as “group efficiency” and this interaction causes the reduction in the load-bearing capacity of the piles. For a safe and economical design, optimization must be done to estimate the optimum number of piles in the group. This chapter aims to investigate the robustness of commonly used optimization algorithms and determine the most efficient algorithms for pile group optimization problems. Consequently, the proposed methods are going to help engineers to make fast, safe, and economical designs for pile groups under vertical foundation loads. In this chapter, bearing capacities and optimization of bored pile groups constructed in soft soils are discussed.

INTRODUCTION
One of the main problem in geotechnical engineering is construction of foundations on soft/loose soil deposits. If the foundation soils are soft/loose, highly compressible and too weak to support the vertical loads, than some additional precautions must be taken. If the required precautions are not applied, than bearing capacity failure and/or extreme settlement problems occur. Excavating the soft/loose soil layer and replacing it with a high-strength material, improving the strength and stiffness properties of soil by compacting (vibro compaction, stone columns, dynamic compaction, etc.), forming columns in soil
by injecting cement and some other chemical binders (jet grouting, deep mixing, etc.) and constructing driven or bored piles under foundations are some of widely used soil improvement techniques.

Considering the ease of construction and cost, piles are commonly used under foundations to transfer vertical loads stiff soils layers. If the soft/loose soil layer is thick, than it may not be possible to embed the pile into stiff layer. In this case, piles must be designed as friction piles. But if the piles are embedded into the stiff layer enough, than this type of piles are described as point bearing piles. Both for point bearing piles and friction piles, ultimate and allowable bearing capacity of a single pile is calculated with the same principles as described in Das (2010) and Bowles (1996). The piles constructed under the foundations are classified according to the displacements they cause in the soil (BS8004, 1986):

1. Piles those cause a lot of displacement in the soil (driven piles),
2. Piles those cause little displacement in the soil (H section, open tube steel piles),
3. Piles those cause no displacement in the soil (bored piles).

Bored piles are more economical than other types of piles and the installation process can be controlled easily. They can be constructed at any length and they cause less disturbance than other pile types. In this chapter, authors preferred to study on bored piles considering these advantages.

Generally, there will be more than one pile under a foundation element of footing to allow for misalignments and other inadvertent eccentricities when considering the dimensions of foundation and superstructure loads as mentioned in Bowles (1996). The behavior of a single pile in a group is influenced by the behavior of other piles. This interaction between the group piles is described as “group efficiency”. If the piles in the group are close enough to each other, than the stresses transferred to the soil overlap. For this reason, the total load that can be carried by the group is less than the sum of the loads that can be carried by each pile separately.

It is very important to estimate the pile number in a group to make a safe and economical design. For a proper design, optimization must be done to calculate the bearing capacity of a single pile and estimate the optimum number of piles in the group. In the previous studies, some optimization methods had been used for pile groups. (Hurd & Truman, 2006; Chan, Zhang, & Ng, 2009; Leung, Klar, & Soga, 2010; Hwang, Lyu, & Chung, 2011; Liu, Cheng, & Wang, 2012; Bengtlars & Väljamets, 2014; Letsios, Lagaros, & Papadrakakis, 2014). In addition, various optimization algorithms and artificial neural networks had been also used for various geotechnical problems, such as retaining wall design, footing design and slope stability problems. (Temur & Bekdaş, 2016; Singh, Kanchan, & Saigal, 2004; Singh, Verma, & Singh, 2005; Das, Purohit, & Das, 2016; Camp & Assadollahi, 2013; Ukritichon, Chea, & Keawsawasvong, 2017). In this chapter, bearing capacity of the single pile and pile groups are calculated by using conventional methods that are used in geotechnical engineering. Differently from other studies in literature; Particle Swarm Optimization (Kennedy & Eberhart, 1995), Big Bang-Big Crunch Optimization (Erol & Eksin, 2006), Harmony Search Algorithm (Kennedy & Eberhart, 1995), Teaching-Learning-Based Optimization Algorithm, Particle Swarm Optimization (Rao, Savsani, & Vakharia, 2011), Moth-Flame Optimization (Mirjalili, 2015), Grey Wolf Optimizer ((Mirjalili, Mirjalili, & Lewis, 2014) and Jaya Algorithm (Rao, 2016) has been applied to optimize the pile groups for a safe and economical design.