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Analysis and design methods of screw piles: A review

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Abstract

The focus of this review is the design of axially loaded screw piles. Through a comprehensive collation of all relevant literature regarding the design of screw piles, comparisons are made and relations are drawn which will ultimately be relevant to future efforts associated with the design of screw piles. Contemporary design approaches to screw piling are covered and the consequential relationships among the various geotechnical design parameters are asserted. The review is centred on vertically loaded axial piles in compression and tension in both cohesive and cohesionless soils. Through a rigid analysis of all viable design methods, in relation to the bearing capacity of helical piles, comparisons are made among the different design methods and attention is brought to the need for more research on the settlement of screw piles in order to allow for a more complete design.

Keywords: Screw piles; Helical; Pile design; Geotechnical; Deep foundations

1. Introduction

The first sections of the review present background information, including the introduction of the context of screw piles through accentuations centred on the history and the implications of screw piles, in regard to their advantages and disadvantages, and finally their place in contemporary construction. The objectives of the review are then discussed and design essentials follow. These essentials highlight the main framework by which all design processes related to screw piles should abide. Consequently, design methods are given which are clustered through an axial capacity agenda via various methods, such as the cylindrical shear model, the individual bearing model and the relationship between the installation torque and the bearing capacity. Ultimately, the work is culminated by a comparison of the discussed design methods, including various other design processes which are beyond the scope of this review, such as lateral load design and the use of grout, for which careful recommendations are formed. Vertically loaded axial piles, in compression and tension in both cohesive and cohesionless soils, form the basis of the review, as is evident in Fig. 1.

1.1. Literature review: background

Screw piles differ from traditional piles in that they are most commonly made of high strength steel consisting of helices which are fixed to the shaft at specific spacings and have a pointy toe to allow for better installation into the ground (Arup Geotechnics, 2005). There are various dimensions of screw piles specific to certain conditions under which shaft and helix diameters, helix spacings and embedment depths prove to be points of difference. Screw piles were initially used mostly as anchors, and hence, were centred around tensile loads such as transmission towers and buried pipelines. However, their use has been expanded to structures subjected to compressive and lateral loading (Livneh and Naggar, 2008). Screw piles offer structural resistance to tensile,

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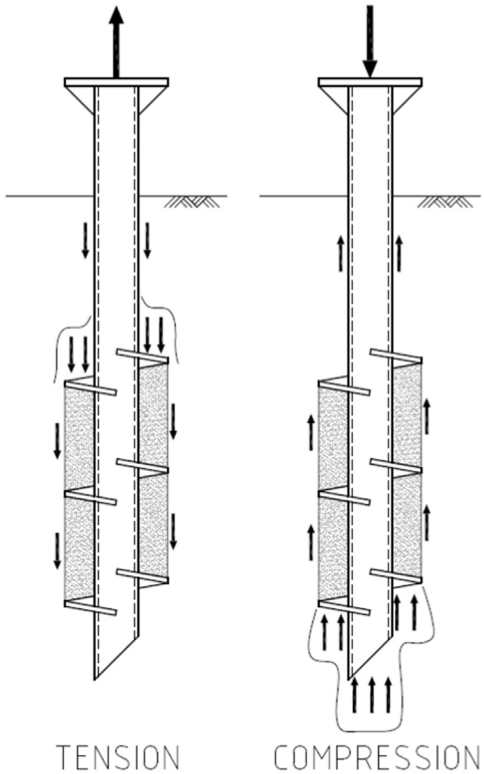

Fig. 1. Screw piles axially loaded in tension and compression, respectively.

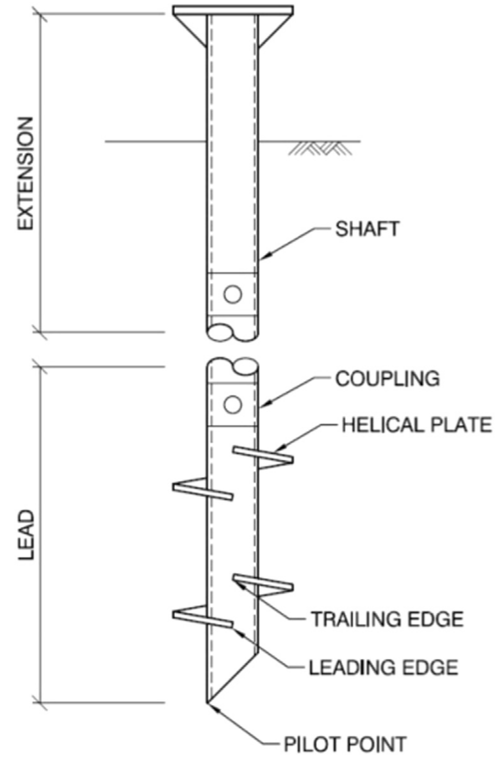

Fig. 2. Elements of a screw pile.

compressive and lateral forces along with overturning moments (Schmidt and Nasr, 2004). Fig. 2 shows the basic elements of a screw pile.

The context surrounding the utilisation of screw piles as foundations of structures has included various trends. Screw piles were first utilised by Alexander Mitchell in England in 1836 for supporting lighthouses (Perko, 2009). However, their use began to fade as the steam hammer was developed which complemented driven piles as opposed to the man power required for screw piles. As technology evolved, hydraulic torque drives engendered growing impetus for screw pile use around the world where initially tension loads were resisted which were soon followed by compressive loads.

The common analysis of screw piles was first recognised in literature by Trofimenkov and Maruipolshii (1965) who developed the individual bearing method of analysis for single helix anchors, whilst Adams and Klym (1972) were the first to adapt this method to multi-helix anchors. Mitsch and Clemence (1985) and Mooney et al. (1985) then introduced the cylindrical shear method of analysis which examines all bearing plates acting together. The present paper examines the relationship between both of these methods of analysis and particularly their differences as compared to the embedment ratio or spacing ratio. As is evident in this paper, research into screw piles continues as awareness of their use in construction continues to grow.

1.2. Implications of screw piles

The advantages and disadvantages of screw piles are important for determining the conditions under which they are most appropriate and beneficial compared to other traditional piling methods. Common advantages of screw piles are that they are easy to install, require minimal equipment, can be quickly installed where loading can soon follow, are suitable for areas with limited access, are removable and reusable, require minimal dewatering, offer high tensile and acceptable compressive capacities, can work on slopes, produce minimal noise and vibration during installation and are cost effective (Zhang et al., 1998; Schmidt and Nasr, 2004; Livneh and Naggar, 2008; Sakr, 2009, 2011).

Schmidt and Nasr (2004) assert the disadvantageous soil conditions for screw piles such as rocky soils, bedrock and boulders. However, mitigation for these disadvantages does exist, for example, a sharper toe surface can be used when weak rock is encountered to improve the passage into the rock (Arup Geotechnics, 2005).

Ultimately, the relevant positives and negatives associated with screw piles determine their validity of use under certain conditions.

1.3. Current situation

Considerable progress has been made with regard to enhancing the axial capacities and installation processes of screw piles in recent times (Sakr, 2010). This progress is also supported by Pack (2000) and Perlow Jr. (2011) who purport that advances are being made toward the utilisation of screw piles as anchors and foundations of structures. Nonetheless, there is still a lack of design methods related to screw piles which require continued investigation (Livneh and Naggar, 2008). Thus, it is apparent that further research is essential to ensuring that screw piling continues

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