Thermoactive Foundations for Sustainable Buildings

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Series Editors' Preface

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Guest Editor Preface

This monograph is part of ASME efforts to promote exchange of innovative ideas, leading edge concepts, new technologies, ongoing research and development related to the theme of sustainable buildings. Specifically, these efforts have been initiated by the ASME Research Committee on Integrated and Sustainable Building Equipment and Systems (ISBES). It is hoped that this monograph would document the current of state-of-art in thermo-active foundations suitable for efficiently and sustainably heat and cooling buildings. Indeed, Thermo-active foundations (TAFs), also referred to as thermal or energy piles, offer innovative and sustainable alternatives to ground-source heat pumps as well as other conventional heating, ventilating, and air conditioning (HVAC) systems to heat and cool commercial as well as residential buildings in several regions in the world. TAFs have a dual function since they are installed within elements that are already needed for statical, structural, and geotechnical purposes. Reported studies have shown that TAFs can save up to 55% of energy used to heat and cool both residential and commercial buildings compared to conventional HVAC systems. These systems have been reported to be more energy efficient than geothermal borehole ground-source heat pumps since concrete has higher thermal conductivity than most soil types. In addition, TAFs do not require any land availability which is one of the main challenges for conventional geothermal borehole heat pumps especially those using horizontal heat exchange loops.

The main objective of the current monograph is to present the current advances in designing and operating TAFs as well as the latest knowledge about their structural and thermal performance. Three peer-reviewed chapters written by research active experts in geothermal systems have been selected and included in the monograph to present three different aspects of TAFs including:

(i) The current understanding of soil-structure interaction effects that can occur due to their thermal expansion and contraction during heating and cooling cycles (Chapter 1).
(ii) The latest thermal models developed to assess the performance of TAFs as heating and cooling systems for both commercial and residential buildings (Chapter 2).

(iii) The results of monitoring analyses of full scale TAFs to evaluate both their structural and thermal performance over several years (Chapter 3).

Specifically, the first chapter starts with an overview of the current models to evaluate thermo-mechanical stress profiles in TAFs, along with the theoretical relationships between axial stress, axial strain, side shear stress, and axial displacement. Then, the first chapter presents relevant design criteria for the axial stress and displacement as well as thermo-mechanical load transfer analyses that can be used to predict the behavior of TAFs. Finally, the first chapter presents a comparative analysis of experimental results from two full-scale, instrumented TAFs in different soil layers. The results presented in this chapter indicate that TAFs can be designed to meet safety requirements in terms of structural criteria for both foundations and the soil strata where drilled shaft foundations are typically employed.

In the second chapter, an overview of thermal analysis of TAFs is presented including integration approaches of TAF models into detailed whole-building energy simulation tools. In particular, the analyses presented in the chapter evaluate the impact of several design and operating TAF parameters on both building heating and cooling energy end-uses. Specifically, the thermal interactions between TAFs and building thermal loads are discussed and quantified. Moreover, the energy efficiency and cost-effectiveness of TAF systems is compared against conventional air conditioning systems for both commercial and residential buildings. In particular, the results of the thermal analyses show that TAFs can be more cost-effective than ground source heat pumps (GSHPs) due to lower installation costs and comparable energy performance.

The third chapter presents experimental results obtained from two studies conducted on full scale TAFs installed in a university at Melbourne, Australia. The first study evaluates the thermal and thermo-mechanical behavior of a single TAF, installed in December 2010. The second study considers two TAF systems recently installed as part of a foundation system of a multi-story residential building. The measured results for both studies are summarized in this chapter with some discussion of the main findings and observations. In particular, the experimental data for the first study indicate showed that TAFs do not exhibit any losses in foundation pile shaft capacity after full heating and cooling cycles. Moreover, initial measurements from the second study indicate that concrete was initially in tension due to the cement hydration process but reversed to compressive strains once it cooled down and its temperature was in equilibrium with the surrounding soil.

In summary, the monograph collects the latest multi-disciplinary advances in modeling, designing, and monitoring TAFs. Ultimately, it is hoped that this monograph would provide a comprehensive reference for both researchers and professionals interested in structural and thermal performance of TAFs and their applications in developing integrated and sustainable equipment and systems for the built environment.

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Guest Editor

Table of Contents

Abstract

This monograph documents the current of state-of-art in Thermo-Active Foundations (TAFs) suitable for efficiently and sustainably heat and cooling buildings. TAFs, also referred to as thermal or energy piles, offer innovative and sustainable alternatives to ground-source heat pumps as well as other conventional heating, ventilating, and air conditioning (HVAC) systems to heat and cool commercial as well as residential buildings in several regions in the world. In summary, this monograph collects the latest multi-disciplinary advances in modeling, designing, and monitoring TAFs. Ultimately, it is hoped that this monograph will provide a comprehensive reference for both researchers and professionals interested in structural and thermal performance of TAFs and their applications in developing integrated and sustainable equipment and systems for the built environment.