Building and Environment 46 (2011) 1205–1210

Contents lists available at ScienceDirect

Building and Environment

journal homepage: www.elsevier.com/locate/buildenv

A numerical and field investigation of underground temperatures under Urban Heat Island

Chun Liu [a,b,*], Bin Shi [a], Chaosheng Tang [a], Lei Gao [a]

[a] School of Earth Sciences and Engineering, Nanjing University, Nanjing, 210093, PR China
[b] Department of Geological and Environmental Sciences, Stanford University, Stanford, CA 94305-2115, USA

ARTICLE INFO

Article history:
Received 27 September 2010
Received in revised form
12 December 2010
Accepted 13 December 2010
Available online 21 December 2010

Keywords:
Underground temperature
Moisture
Numerical simulation
Heat island
Concrete surface
Soil surface

ABSTRACT

This paper introduces a simplified model for underground temperature prediction in summer hot weather. The data of 14 observation sites show that the surface temperature curves are close to trapeziums, and surface temperatures are related to air temperatures. Therefore, approximated temperature trapeziums that are determined by high- and lowest air temperatures can be used to simulate the underground temperature variation. Two observation sites respectively in the urban and suburban areas were used as examples. Good agreement was obtained between simulated- and measured temperatures. Measured data indicate the average temperature under urban concrete surface is 3.70 °C greater than that of suburban bare surface. The deviation is due to the heat urban environment effect and different surfaces effect, which are about 1.68 °C and 2.02 °C, respectively. Combined with soil volumetric water content (w_v), 'Heat' Islands associates with 'Dry' Islands, which means urban soil moisture is lower than suburban soil moisture (13.9%). According to the variation of w_v and temperature deviation graphs, Urban Heat Island, ground surface types and rainfall are important factors that influence the underground soil moisture and temperatures.

1. Introduction

In an age of urbanization and global warming, the influence of Urban Heat Island (UHI) is more and more significant [10,19]. Temperature variation impacts on the engineering properties of urban soils, and consequently changes the strength and stability of various engineered structures. Many previous studies show that the increase of shallow soil temperature influences soil permeability, suction of unsaturated soils, and soils shear strength etc [11,24]. Underground temperature prediction therefore plays an important role in the research of issues related to environment, energy sources and engineering [7,16,22].

The causes of UHI are not the same in different climates or city features. Therefore, many models and approaches, including observation and simulation techniques, have been proposed to understand the causes of UHI formation and to mitigate the corresponding effects [9,15,26]. Santamouris [21] reviewed observational studies of UHI for European cities. Mirzaei [15] presented a review of the techniques used to study UHI, and discussed the abilities and limitations of each approach for the investigation of UHI mitigation and prediction. Huang et al. [9] investigated the diurnal changes of urban and rural air temperatures in four types of ground cover and Urban Heat Island of Nanjing. Their study indicates that the Urban Heat Island Intensity varies in time and on different surface types. However, surface temperatures, underground temperatures, and corresponding UHI effect are not involved.

Continuous monitoring of underground temperature is expensive. Analytical methods and computer technologies can provide cheaper, alternative ways to predict the underground temperatures. However, the underground temperature field is influenced by many factors, including solar radiation, air temperature, wind speed, rainfall, shelter, and soil properties [5,14]. Most of these factors change irregularly and as a result, the prediction and estimation of underground temperature is complex. In previous studies, many analytical models [23], semi-analytical models [6,27], empirical models [1,2], numerical methods [12,18], Fourier models [8] and neural network methods [3] have been used to solve various heat transfer problems [17]. Most of these methods require many measured parameters, some of which are hard to obtain under real field conditions.

On the basis of the relationship between air temperatures and surface temperatures, a simplified model is introduced to simulate the variation of underground soil temperatures during summer hot weather. The method has been used to estimate the underground

* Corresponding author. Department of Geological and Environmental Sciences, Stanford University, Stanford, CA 94305-2115, USA. Tel.: +1 650 862 1059.
E-mail addresses: oxtown@gmail.com, chunliu@stanford.edu (C. Liu).

0360-1323/$ – see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.buildenv.2010.12.015