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Experimental Study on the Radiant Cooling Load of Floor Based on the Radiant Time Series Method

Chen Huang*, Tianyu Bai, Jiao Cai, Liugen Lv, Jianchang Chen, Li Li

School of Environment and Architecture, University of Shanghai for Science and Technology, 516 Jungong Road, Shanghai,200093, China

Abstract

A calculation method about the radiant cooling load of floor which is based on radiant time series (RTS) method is presented: With the use of radiant time factors, radiant cooling load can be easily calculated from the radiant heat gain. Based on experimental data of total heat gain and total cooling loads collected within 24-hours, radiant heat gain of floor can be calculated through convection and radiation separating method, using PRF/RTF Generator software to calculate the radiant time factor of floor; the radiant cooling load of floor is calculated and compared with the measured values. The results for the 5 experimental conditions show that the radiant cooling load of floor peak error is less than 2.3% comparing with the value which is calculated by radiant time series method, and average error is not more than 3.2%. Its mean absolute error is 1.2% and 1.7% respectively. The experimental study indicated that convection and radiation separating method on wall could calculate the radiant cooling load of floor.

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Keywords: Radiant heat gain; Radiant cooling load of floor; Radiant time factors

1. Introduction

The radiant time series (RTS) method [1,2] is a new method for performing design cooling load calculations, which was recommended by ASHRAE TC4.1(the design load calculations technical committee). In this method the heat gain of the room is divided into two parts: convection heat and radiation heat. Convection part directly becomes the cooling load. As for radiant heat gain in a room, radiant cooling load is calculated by using a 24-term radiant

* Corresponding author. Tel.: +86-021-55273409; fax: +86-021-55270680.
E-mail address: hcyhyywj@163.com; huangc@usst.edu.cn.

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time factors (RTF), which provides huge significance of avoiding iterative calculation as in the transfer function method [3,4]. Radiant time factors of building envelope should be present to calculate radiant cooling load in radiant time series method. There are two kinds of radiant time factors calculation: one is based on the heat balance method and there is a calculation software existed [5,6]. The other one is the database of transfer function established by ASHRAE [7,8,9], through extracting transfer function coefficients according to the building envelope material properties and then the radiant time factor is obtained by matrix operations. The radiant time factor calculated in the two methods is for the whole enclosed room envelope, thus the radiant load calculations is also for the whole room. If you make use of software to calculate, you can get the solar radiant time factor of indoor floor, it is also called the radiant time factor of floor.

The paper presented a calculation method of the radiant cooling load of floor, which is based on radiant time series method. By using PRF/RTF Generator software to calculate the radiant time factors of room floor, we can calculate the radiant load according to the radiant heat gain of floor, and then compared it with the measured values. The study on its change trend with the change of wall heat flow and air volume, research results will provide a new thought for the application of radiant time series method in the calculation of radiant cooling load of floor. Then it provides direction for the calculation method of radiant transfer from non-air conditioning area to air conditioning area in large space.

Nomenclature

q_τ	radiant load at time τ, W
$Q_{\tau\text{-}n\Delta\tau}$	the part of the heat gain radiant at time n, W
r_n	the radiant time factor at time n
q	Radiant hourly load column vector
Q	Radiant hourly heat gain column vector
R	irradiant time factor vector
$Q_{ii\lambda}$	thermal heat, W
Q_{id}	convection heat, W
Q_{iR}	radiant heat, W
ε_i	wall emissivity
A_i	wall area, m^2
σ	blackbody radiant constant, $5.67\times10^{-8}W/(m^2\cdot K^4)$
θ_i	wall temperature, K
J_i	effective wall radiant W/m^2
X_{ij}	angular coefficient

2. Methods

2.1. Principles of radiant time series methods

When radiant time series method is used to calculate the radiant load, radiant load at time τ is related to radiant heat gain at time τ and its previous time steps, using the radiant time factors in the corresponding time to reflect the effects of radiant load at time τ. In time radiant series method, radiant hourly load can be obtained through:

$$q_\tau = r_1 Q_\tau + r_2 Q_{\tau-\Delta\tau} + r_3 Q_{\tau-2\Delta\tau} + \cdots + r_{24} Q_{\tau-23\Delta\tau} \tag{1}$$

For the entire period, radiant load can be written in matrix format: