Case Studies in Thermal Engineering 9 (2017) 122–127

Contents lists available at ScienceDirect

Case Studies in Thermal Engineering

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

Effect of retro-reflective materials on temperature environment in tents

Lili Zhang[a], Xi Meng[a,*], Fei Liu[a], Long Xu[b], Enshen Long[c]

[a] College of Architectural and Urban-Rural planning, Sichuan Agricultural University, Chengdu, China
[b] Institute of Building Energy Efficiency, Sichuan Academy of Architecture, Chengdu, China
[c] College of Architecture and Environment, Sichuan University, Chengdu, China

ARTICLE INFO

Keywords:
Retro-reflective material
Temperature environment
Indoor air
Tents

ABSTRACT

Due to the low thermal inertia and poor thermal insulation of ultrathin envelope in tents, its indoor temperature environment is extremely bad and its occupants are tormented. Especially under the high solar radiation, both indoor air temperature and inner surface radiation temperature increase rapidly. And thereby, decreasing radiation heat gain in summer is necessary to refine indoor temperature environment in tents. Retro-reflective materials make it a reasonable choice due to their high reflectivity for solar radiation. To reveal the temperature environment improvement of tents by integrating with retro-reflective materials, a comparative experiment is carried out under the summer climatic conditions of Chengdu city, China. Experimental results show that due to integrating with retro-reflective materials, indoor air peak temperature in the tent can be reduced by more than 7.7 °C, while inner surface radiant temperature can be lowered up to 4.8 °C in the day time. It shows retro-reflective materials could refine indoor temperature environment in tents. Through a comparison of the walls in different orientations, on which retro-reflective materials are covered, the top, east and north walls are found to be better choices, while the north wall is the worst one for retro-reflective materials.

1. Introduction

Tents are widely used as temporary shelters, temporary houses after a disaster and temporary offices for construction projects, due to their easy transport, rapid construction, low cost and so on. In the Wenchuan earthquake (2008) and the Lushan earthquake (2013), tents played a significant role as temporary shelters. Only in the Wenchuan earthquake, more than 1.5 million tents are used as relief supplies. Before the completion of permanent buildings, victims had to live in these tents for a long time.

However, due to the poor thermal performance of tents, indoor temperature environment were very poor, and thereby victims were tormented mentally and physically. According to the experimental data [1–3], during the day in summer, indoor air temperature can b up to above 40 °C in the open tents and 52 °C in the closed tent. Especially under the high solar radiation intensity, indoor temperature environment will be worsened further. And this poor thermal environment has a negative influence on occupant's health, so it is a very urgent task to improve the indoor temperature environment in tents.

As per the indoor thermal environment improvement in tents, some studies have been done. Wang et al. [1,2] analyzed indoor thermal environment and the health status of residents in disaster relief tents after the Wenchuan earthquake. Their results showed that the high temperature and high humid environment in tents can lead to the anorexia, high morbidity, mental fatigue and even

* Correspondence to: Sichuan Agricultural University, No. 288, Jianshe Road, Dujiangyan, Sichuan Province, China.
E-mail address: mengxihvac@163.com (X. Meng).

http://dx.doi.org/10.1016/j.csite.2017.02.001
Received 20 October 2016; Received in revised form 11 January 2017; Accepted 5 February 2017
Available online 07 February 2017

the worse. And they proposed a new tent structure with the double-layer enclosure, which can improve indoor thermal environment, and the best distance between two layers is 0.2 m. Meanwhile, Yuan [3], Liu et al. [4], Wang et al. [5] and Kadoya et al. [6] had also carried out the studies on improving the indoor thermal environment in tents from the tent materials, the tent shading and the integrating with the phase-change materials.

Moreover, Zhang et al. [7] and Tang et al. [8] established the mathematical models on heat transfer mechanism of tents and proposed that the thermal performance of the tent envelope is a key factor affecting its indoor thermal environment. Hu et al. [9] and Wang [10] had researched the influence of the water spraying on indoor temperature environment in tents and showed that the passive evaporation technique can improve the indoor thermal environment effectively. In addition, Li [11] had studied indoor thermal environment improvement by the ventilation and achieved that the air supply way with the static pressure combination of side feed air and jet air supply was the better way.

Shi et al. [12] and Yang et al. [13] had studied on improving the thermal environment of tents by the highly reflective materials, whose main function is to reflect the solar radiation by the diffuse reflection in a thin layer. However, this diffuse reflection only reduces the heat gain of the target building but increases the heat gain of the surrounding buildings and even deteriorate the surrounding thermal environment.

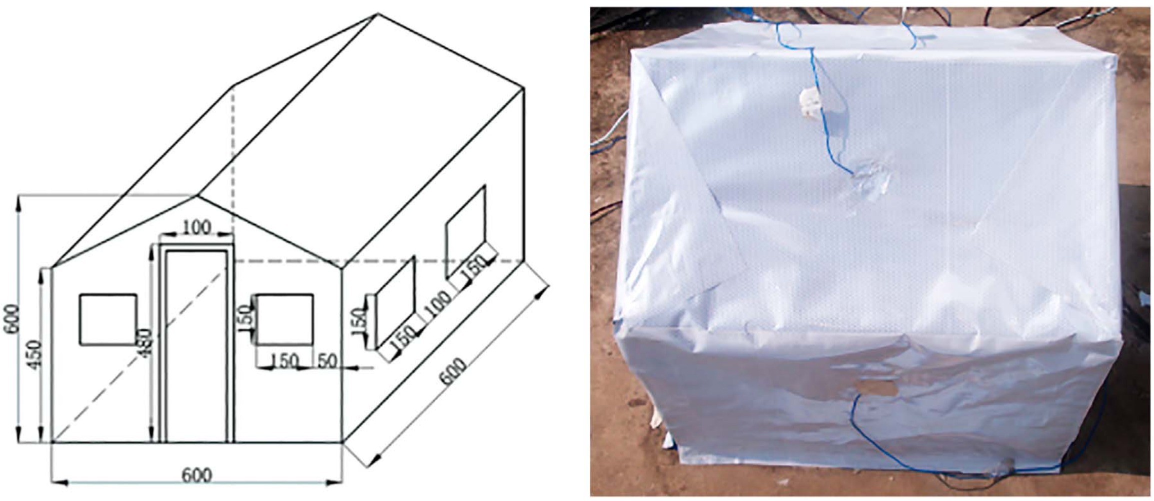
In order to overcome this shortcoming of diffuse reflection for highly reflective materials, retro-reflective materials are proposed in this study due to the fact that they can reflect the solar radiation back in the opposite direction, also in a thin layer, which is different from the specular reflection of highly reflective materials. Sakai et al. [14] and Nishioka et al. [15] were the first to research these retro-reflective materials and measure their retro-reflective properties. Yuan et al. [16] proposed a method to measure the retro-reflectance and durability of retro-reflective materials for building outer walls and measured the changes in solar reflectance and retro-reflectance of retro-reflective materials exposed to the outdoors over about 25 months. Meanwhile, Yuan et al. [17] studied the accuracy of the method proposed in Yuan et al. [16] on determining the retro-reflectance of retro-reflective material by means of a heat balance. In addition, Yuan et al. [18] researched the effect of retro-reflective materials on building cooling loads. Rossi et al. [19,20] assessed the angular reflectance of retro-reflective films for several inclination angles of solar radiation and the urban heat island mitigation of capsule retro-reflective materials. Meng et al. [21] studied the effect of retro-reflective materials on building indoor temperature conditions and heat flow analysis for walls by a comparative experiment and the numerical simulation and their results showed that, due to the addition of the retro-reflective materials, the inner surface heat flow can be reduced by more than 30% and that the outer surface peak temperature can be reduced by 10–20 °C. The above research paid more attention to the retro-reflective properties and the engineering application in conventional buildings. There is lacking of the influence of retro-reflective materials on the tents, where indoor environment is poor in summer.

According to above problems, to further study the improvement effect of retro-reflective materials on the temperature environment in tents, two tent models were built, one of which covered retro-reflective materials (Model 1) and the other taken as a comparative one, an conventional tent (Model 2) under the summer climate of Chengdu, China. Surface and indoor air temperatures are measured to evaluate the comprehensive effect of retro-reflective materials.

2. Description of the experimental system and retro-reflective materials

2.1. Description of the experimental system

To reveal the influence of the retro-reflective materials on the temperature environment in tents, a comparative experiment was



(a) (b)

Fig. 1. (a) The tent building physical model and (b) the tent model covered with retro-reflective materials.