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Assessing the thermal performance of temporary shelters

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Abstract

The aim of this study is to improve conditions inside temporary shelters for non-displaced populations from natural disasters. Field studies on transitional settlements were conducted after the Wenchuan M8.0 earthquake in 2008 and the Lushan M7.0 earthquake in 2013. Then three bamboo-wood shelter models were made in the laboratory. The temperatures and humidity were measured inside the shelters with different thermal comfort improvement approaches in cold weather conditions. Data were compared and the most effective and economical method will be recommended to the shelter occupants. The study provides the foundation of laying down the applicable guidelines for disaster relief in China.

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Keywords: Temporary shelter; thermal comfort; model test; insulation material

1. Introduction

In the last seven years, western China experienced several high profile natural disasters including the Wenchuan M8.0 earthquake in 2008 and the Lushan M7.0 earthquake in 2013, which resulted in 5 and 2 million homeless victims, respectively [1][2]. Three recovery stages planned by the Chinese State Council in residence form were emergency shelter, temporary shelter and permanent housing. The typical emergency shelter was a tent in which victims usually spent 3 to 6 months. Then they needed to live in temporary shelters for 1 to 5 years before permanent houses were constructed. Both urban and rural temporary shelters were mostly sponsored by the government or domestic and international NGOs. By the end of 2013, victims of Wenchuan Earthquake had almost passed the second recovery and relief stage and moved into their permanent houses. The same happened to the majority of the non-displaced population from Lushan Earthquake by the end of 2015, in accordance with the displacement plan by the Chinese government [3]. Now only a few victims are still living in temporary shelters. From 2008 to 2013, several on-site investigations showed that the living environment of the temporary shelters was very poor. Shelter occupants suffered from extreme heat and humidity in summer and coldness and bitter wind in winter, which was detrimental to their recovery from the disaster, both physically and psychologically.

This work forms a part of a research project funded by Hong Kong Jockey Club to study the thermal environment in transitional shelters and the health condition of shelter occupants, aimed to reduce the vulnerability of earthquake victims forced to adopt temporary shelters and develop field guidelines for practitioners.

Through field work in different seasons questionnaire surveys were conducted on shelter occupants who were distributed in different transitional settlements [4], and the thermal condition of shelters was tested and analyzed [5]. In Wenchuan, the research group had given occupants some advice on cooling the shelter in hot weather with homemade approaches based on experimental comparison research [5]. At the end of 2013, the group started to focus on thermal comfort improvement in winter. By studying cold climate shelter in both the laboratory and the field, the effect of envelope improvement on heat preservation

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and ventilation reduction has been evaluated. Currently, the project is in the process of incorporating renewable energy systems into temporary shelter to achieve thermal comfort effectively and economically.

This paper describes an on-site measurement of thermal parameters and a series of experiments to test performance of three shelter prototypes in cold weather.

2. Field work

During the 8 months after Lushan Earthquake, the first-hand information was obtained through several visits to earthquake zone.

2.1. Shelter material improvement

The temporary shelters adopted in the two earthquakes were very different: one kind is the prefab house with color steel laminboard in Wenchuan, and the other kind is the bamboo-wood shelters in Lushan, shown in Fig. 1. The lessons from Wenchuan's recovery were that a large number of prefab house cost a huge sum of money; and EPS or XPS boards in prefab houses were hardly degradable. As a consequence, more eco-friendly local materials, bamboo and wood, were commonly adopted in Lushan's transitional settlements.

a b

Fig. 1. (a) prefab house after Wenchuan Earthquake, 2008; (b) bamboo-wood shelter after Lushan Earthquake, 2013.

2.2. On-site measurement

To learn the thermal performance of the temporary shelter, a typical bamboo-wood room occupied by a family was chosen for study. Two sets of Testo 175 H1 Data Loggers were installed 1.8m above the floor both inside and outside the room. The instrument recorded the temperature and relative humidity (RH) of air at regular intervals. A comparative test was carried out in an empty bamboo-wood room. Each room had an area of about 15m^2. The test started at 19:00 on Nov. 30th and ended at 9:00 on Dec. 1st, 2013. The occupied room had a small coal stove for heating overnight. The results are illustrated in Fig. 2 and Fig. 3.

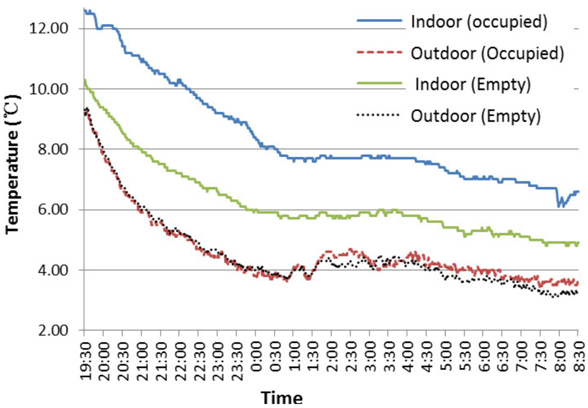

Fig. 2. temperature comparison between two shelters.

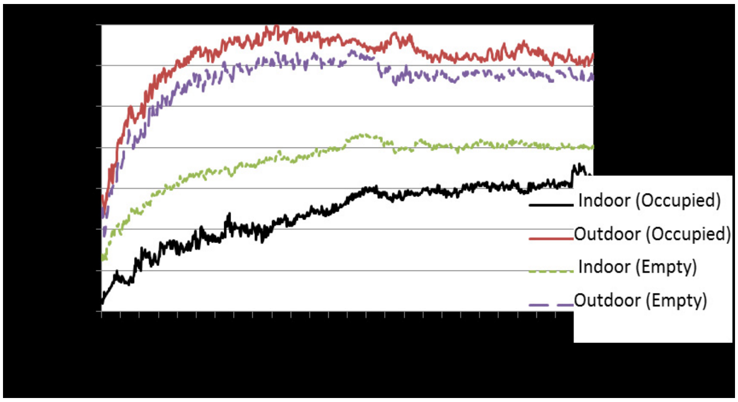

Fig. 3. relative humidity comparison between two shelters.

Fig. 2 suggests that temperatures dropped quickly from 19:00 to 24:00 (0:00) and slowly after 0:00 in all four scenarios. The highest temperature in the occupied room with weak heating was 12.8℃, only 3~4℃ higher than the outdoor temperature, and it also fell below 8℃ after 1:00. In comparison, the temperature inside the empty room was approximately 2℃ higher than that of outdoors and dropped below 6℃ after 0:00.

Fig. 3 depicts that the indoor RH difference between the empty and the occupied room was 6%~9%. Though the value of indoor RH of the occupied room was always lower than that of the empty room, it still rose to 80% after 2:30. With the temperature remained less than 8℃ at that time, it was a fairly cold and uncomfortable situation.

3. Model experiment

In view of the poor thermal performance of the shelter, , three bamboo-wood shelter models, M1, M2 and M3, were made to evaluate the effectiveness of different thermal-comfort improvement measures. All three models had the same size of 1.2m×1.0m×0.8m(H), with bamboo slivers bonded to inner polypropylene sheet as walls. One model used color-coated steel sheet roof, shown in Fig. 4. Other two roof materials were fiberglass cement and synthetic resin.

Fig. 4. model of bamboo-wood shelter.

The experiment lasted four weeks from 28th Dec. 2013 to 25th Jan. 2014. Automatic thermal tester JTRG-Ⅱ was used to record the temperatures measurement from 37 thermocouples at 15-minute intervals.

The experiments could be classified as 4 categories: comparison (1) between with and without the inner heat source; (2) among three roof materials; (3) among different insulation materials in wall; (4) among combined measures of roof and wall. A

Electric blanket of 55w was used as the inner heat source to simulate human body's heat. Figs. 5 to 8 illustrate some of these comparative tests with the inner heat source.

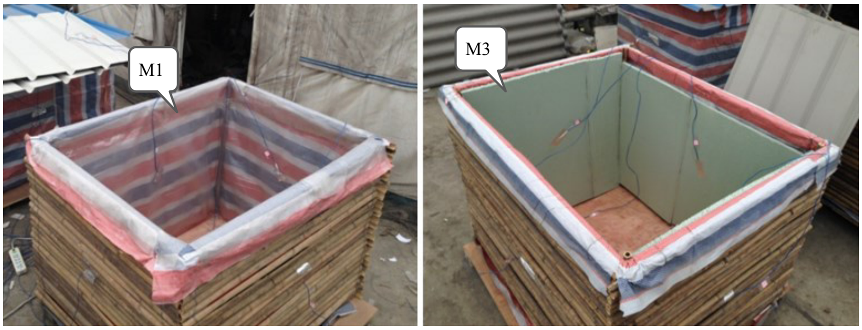

Fig. 5. (a) insulated by air-bubbled polythene sheet; (b) insulated by XPS board

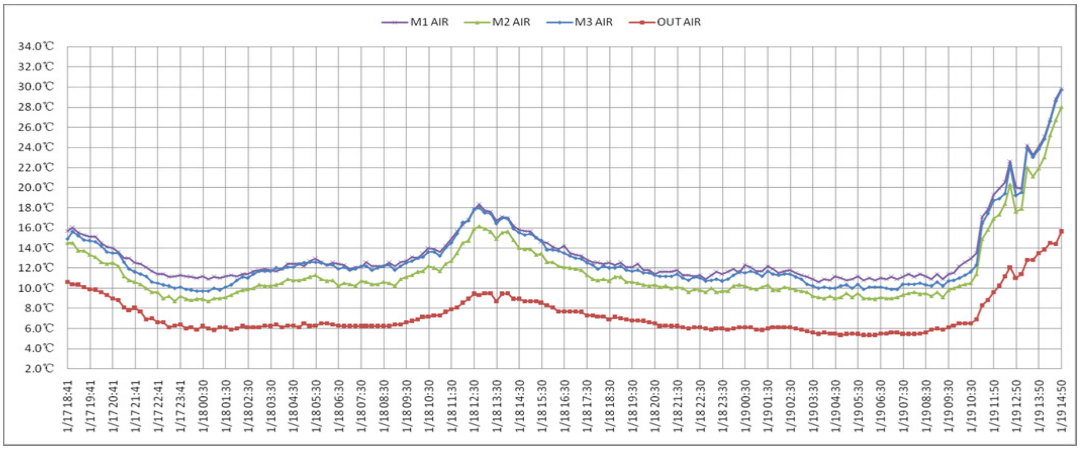

Fig. 6. Indoor temperature comparison of two insulation materials in Fig. 5.

Data from the Fig. 6 suggest that the temperature in these two insulated models (M1, M3) was about 1~2℃ higher than that in M2, which was not insulated. The air-bubbled polythene sheet was slightly more effective in heat retention than that of professional insulation material, the 2cm-thick XPS board.

According to Fig. 8, M2 with color-steel-sheet roof tended to have the highest indoor temperature and the biggest temperature fluctuations. For instance, the indoor temperature of M2 was higher than 30℃ with about 18℃outdoor temperature in the afternoon of 20th Jan. 2014. The indoor temperature was so high that it was not even comfortable in winter. In contrast, the fiberglass cement roof had the best performance in terms of temperature stability. The qualitative interpretation on the phenomena could be the low specific heat and the low emissivity of the steel sheet compared with other two non-metallic roofs.

4. Online license transfer

The analysis of all 4 categories, 11 groups' experimental results came to the following conclusions:

(1) The cheapest windproof measure was wrapping outer polypropylene sheet around original wall of model shelter. Although this was also a relatively effective heat preservation method in winter, it would become a barrier of ventilation in summer.
(2) Some low-cost and easy-to-get materials, such as cardboard and air-bubbled polythene sheet, played so effective roles in heat preservation that they were not inferior to some professional insulation materials such as 2cm-thick XPS board.
(3) Among three roof materials, the fiberglass cement roof had the best performance in terms of temperature stability.

One common feature of the different improvement measures in this study is that they all helped windproof or reduce ventilation rate. This feature is clearly beneficial in winter, but could have opposite effect in summer, since deterring air penetration could aggravate heat and stuffiness in the shelter. To solve this problem, it is important to adopt a convenient approach and environmentally friendly materials which are easy to be installed and removed.

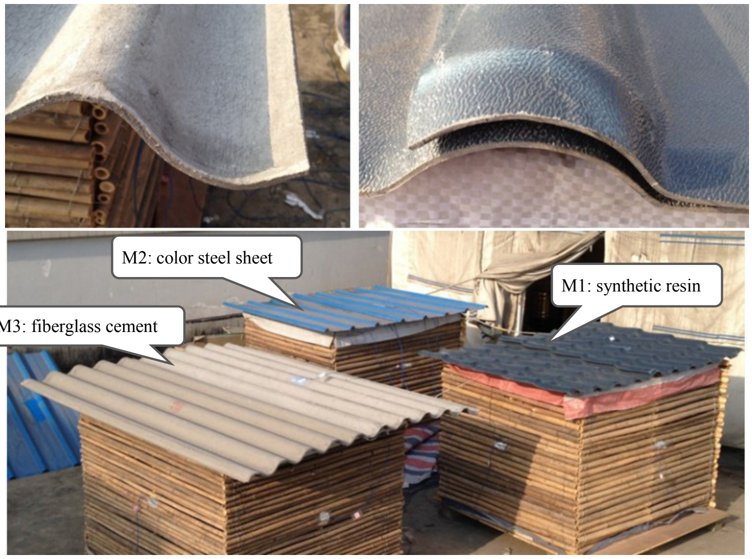

Fig. 7. Comparison test among three roof materials

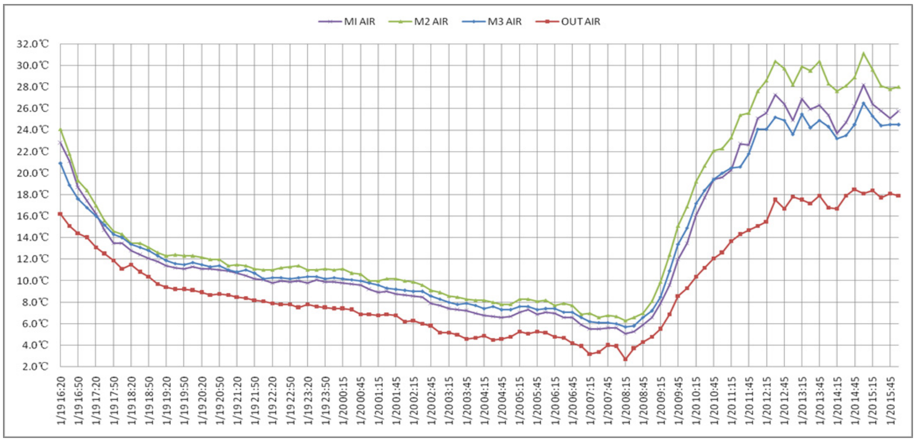

Fig. 8. Indoor temperature comparison of three roof materials in Fig. 7

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