Experimental study on natural ventilation of cotton tent in summer

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Abstract. Cotton tents are frequently used in the army and disaster relief. Because of the special structure of the cotton tent, its heat preservation and heat insulation performance is poor in the summer. In order to improve the rest environment of soldiers, experimental studies on improving the internal thermal environment of tents by natural ventilation were done at Tianjin in the summer. The thermal environment parameters of tents with different natural ventilation schemes were recorded and analyzed. The experimental results show that the natural ventilation plays a certain role in adjusting thermal environment of tents.

1. Introduction
Because of the low thermal resistance and thermal inertia, the indoor thermal environment of tent is relatively poor, the summer is hot and the winter is cold [1]. When the tents are used in the field, the refrigeration and heating facilities can’t be used because of the restrictions, which seriously affect the indoor comfort. Natural ventilation is an ecological and environmental protection ventilation technology [2].Therefore, it is very important to study the use of natural ventilation to improve the thermal environment and the comfort in the tent.

2. Basic experiment conditions

2.1. The experiment object: the cotton tent
The experimental object is a cotton tent most widely used in the army and disaster relief. There is a door on one side of the tent, and there are two windows on two opposite sides of the tent, respectively. The use area is 20.24m². Fig.1 shows the appearance of the cotton tent. To simulate the field environment, two experimental tents were set up in the open space with the doors facing the east. The interval between the two tents measures more than 5 meters, does not affect the ventilation and lighting.

2.2. The purpose of the experiment and experiment time
The purpose of the experiment is to study the influence of different natural ventilation schemes on the indoor thermal environment of the tent. The experiment time is June 2, 2016 and June 25, 2016.
2.3. Experiment instrument and the arrangement of the instrument

Mercury thermometers are used in the experiment. In order to know the temperature field inside the tent, the temperature was measured in the tent. 23 thermometers were hung in the tent. In five directions of the southeast, southwest, northwest, northeast and central, 4 thermometers were hung at the height of 0.1m, 0.5m, 1.0m and 1.5m, respectively. In addition, 3 thermometers were added under the roof of the tent at the height of 2.0m in order to measure the temperature under the roof of the tent. The experiment was made during the period of 8 - 18 on June 2 and June 25 of 2016. The data were recorded every 1 hour. The arrangement of the mercury thermometers in the tent is shown in Fig.2.

![Figure 1. Appearance of the cotton tent](image)

![Figure 2. The arrangement of the mercury thermometers in the tent](image)

2.4. Weather and ventilation scheme

It's sunny on the experiment day. The ventilation scheme used in the experiment is shown in Table 1.

| Time       | 8:00-11:00          | 11:00-14:00         | 14:00-16:00         | 16:00-18:00         |
|------------|---------------------|---------------------|---------------------|---------------------|
| June 2,    | Cotton tent 1: open | Cotton tent 1: open | Cotton tent 1: open | Cotton tent 1: open |
| 2016       | all the doors and   | all the doors and   | all the doors and   | all the doors and   |
|            | windows             | windows             | windows             | windows             |
|            | Cotton tent 2: close| Cotton tent 2: close| Cotton tent 2: close| Cotton tent 2: close|
|            | all the doors and   | all the doors and   | all the doors and   | all the doors and   |
|            | windows             | windows             | windows             | windows             |

| Time       | 8:00-11:00          | 11:00-14:00         | 14:00-16:00         | 16:00-18:00         |
|------------|---------------------|---------------------|---------------------|---------------------|
| June 25,   | Cotton tent 1: open | Cotton tent 1: open | Cotton tent 1: open | Cotton tent 1: open |
| 2016       | all the doors and   | all the doors and   | all the doors and   | all the doors and   |
|            | windows             | windows             | windows             | windows             |
|            | Cotton tent 2: close| Cotton tent 2: close| Cotton tent 2: close| Cotton tent 2: close|
|            | all the doors and   | all the doors and   | all the doors and   | all the doors and   |
|            | windows             | windows             | windows             | windows             |
3. Experimental data and analysis

3.1. Experimental data and analysis of the first ventilation scheme

Fig.3 shows the average indoor temperature and outdoor temperature of the two tents using the first ventilation scheme on June 2, 2016.

![Figure 3. The average indoor and outdoor temperature change of the two tents on June 2, 2016](image)

On June 2 of 2016, the ventilation scheme of tents is: opening all the doors and windows of No.1 cotton tent, closing all the doors and windows of No.2 cotton tent. As can be seen from Fig.3, the indoor temperature and outdoor temperature trends are basically the same. The temperature increased first and then decreased. The outdoor temperature reached the highest with the value of 31.7°C at 3 p.m. The maximum measured value of indoor temperature in No.1 cotton tent appeared at 1 p.m., with a temperature of 40.8°C. No.2 cotton tent at twelve noon, with the highest indoor temperature of 46°C. The basic characteristic of indoor and outdoor temperature is that the indoor temperature is higher than the outdoor temperature, and the indoor temperature of No.2 cotton tent is higher than that of No.1 cotton tent. The reason is the ventilation scheme of No.2 cotton tent in all the day is closing all the doors and windows, there is little indoor air flow and it is difficult to dissipate the heat to the outdoor, resulting in too high indoor temperature and very bad indoor thermal environment.

Fig.4 shows the temperature values at different heights of the two cotton tents and the vertical temperature difference on June 2, 2016.

![Figure 4. The temperature values at different heights of the two cotton tents and the vertical temperature difference between 0.1m and 2 m on July 2, 2016](image)

From Fig.4, because the indoor air and the outdoor air can’t convect to dissipate the indoor heat of No.2 cotton tent, there is a wide variation in the temperature values at the same heights of the two
tents. The indoor temperature at 2m height of No.1 cotton tent reached the highest at 1 p.m. with the value of 40.8°C and measured the lowest temperature of 27.5°C at 6 p.m. The indoor temperature at 2m height of No.2 cotton tent reached the highest at twelve noon. with the value of 46°C and measured the lowest temperature of 27.9°C at 6 p.m.

It can also be seen from Fig.4 that at the same time point, the temperature increases with the increase of height and the temperature in No.2 cotton tent is higher than that of No.1 cotton tent at the same height. The temperature difference of the two tents also increases with the increase of height. Due to the weak ventilation, the vertical temperature difference in No.2 cotton tent is always larger than that of No.1 cotton tent. The vertical temperature difference of No.2 cotton tent reached the highest at 11 a.m. with the value of 10.6°C and No.1 cotton tent measured the lowest vertical temperature difference of 0.1°C at 4 p.m.

3.2. Experimental data and analysis of the second ventilation scheme
The average indoor and outdoor temperature of the two tents using the second ventilation scheme on June 25 of 2016 is shown in Fig.5.

![Figure 5. The average indoor and outdoor temperature change of the two tents on June 25, 2016](image)

On June 25 of 2016, the ventilation scheme is adjusting the corresponding windows according to the direction of the sun, so as to study whether opening or closing the corresponding windows to the direction of the sun can improve the internal thermal environment of the tents. As can be seen from Fig.5, for the whole day of June 25, the outdoor temperature increased first and then decreased. The temperature measured at 8 a.m. is 26°C and it is the lowest temperature of the day. The temperature reached 36°C at 2 p.m. which is the highest value of the day. The indoor temperature and outdoor temperature change trend of the tents is basically the same. The indoor temperature gradually increased from 8 a.m. to 2 p.m. After midday the indoor temperature decreased with the outdoor temperature. The highest indoor temperature is 39.4°C, which was measured in No.2 cotton tent at 2 p.m., and at the same time No.1 cotton tent also reached the highest value of 37.9°C. The basic characteristics of indoor and outdoor temperature showed that indoor temperature is higher than outdoor temperature, and the indoor temperature of No.2 cotton tent is higher than that of No.1 cotton tent. This shows that in the summer, although the closure of the corresponding window to the sun direction can reduce the amount of solar radiation into the tent, but because it affects the natural ventilation at the same time, the tent temperature will be higher. So, the windows should be opened for natural ventilation in order to make the tent temperature not to rise too high.

Fig.6 shows the temperature values at different heights of the two cotton tents and the vertical temperature difference on June 25, 2016.

As can be seen from Fig.6, on June 25 of 2016, the indoor temperature difference at the 0.1m and 1.0m height of the two tents is not too large, and the temperature difference between the two height of the same tent is in the stable of 1 ~ 2°C. For No.1 cotton tent, at 2m height, the indoor temperature is the lowest at 8 a.m. with the value of 30.7°C, and is the highest at 2 p.m. with the value of 43.5°C. For
No.2 cotton tent, at 2m height, the indoor temperature is the lowest at 6 p.m. with the value of 32.7°C, and is the highest at 1 p.m. with the value of 43.6°C.

![Temperature graph](image)

**Figure 6.** The temperature values at different heights of the two cotton tents and the vertical temperature difference between 0.1m and 2m on July 25, 2016

The temperature change trend at 2.0m height is: from 8 a.m. to 2 p.m., the temperature in the No.2 cotton tent is 3~4°C above that of No.1 cotton tent. At twelve noon, the difference reached a maximum of 6°C. The ventilation scheme of two tents is opening all the doors and windows of No.1 tent, closing the doors and windows to the sun direction of No. 2 cotton tent, that is, from 8 a.m. to 10 a.m., close the eastern door, from 10 a.m. to twelve noon, close the windows on the south side.

By the experimental study on different conditions of opening or closing the doors and windows on the sunny side, it can be seen that, closing doors and windows on the sunny side during the period from 8 a.m. to 2 p.m. resulted that the indoor temperature rose faster. For ventilation and shading, ventilation is better for reducing the indoor temperature of the tent, especially the temperature under the roof. After 2 p.m., the indoor temperature difference at 2.0m height of the two tents is not too large.

4. Conclusions

It is found by experiment that:

1) During the experiment, the change trend of the indoor temperature of the tent remained the same with the outdoor temperature. But because of the characteristics of the retaining structure of the tent, the tent continues to absorb the sun radiation and can’t timely exchange the heat with outdoor air, so the indoor temperature of the tent is always higher than the temperature outside.

2) Compared with the fully enclosed tent, opening windows for the natural ventilation can improve the indoor thermal environment of the tent.

3) In the summer, the sunshine is strong, comparing opening the windows to the sunny side for natural ventilation with closing these windows for sun-shading, opening the windows can decrease the indoor temperature of the tent, which shows that opening the windows can strengthen the he indoor and outdoor natural ventilation, take out the indoor excess heat, which is better for lowering the indoor temperature.

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References

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