

Thermal Environment of Natural Ventilation Condition and Energy Conservation of Air-conditioning

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Abstract: Test the thermal environment in a residential building of natural ventilation condition, analyse the main influence factors of indoor thermal environment, and evaluate indoor thermal comfort with effective temperature ET and thermal comfort index TCI, etc. discuss the methods of energy conservation of air-conditioning. Suggest that the natural ventilation and interval natural ventilation should be the main fundamental methods of improving the building thermal environment of seaside city in hot days.

Keywords: energy saving, comfort, thermal environment, natural ventilation, building

NOMENCLATURE

Symbol	Description [Units]
ET	Effective temperature
TCI	Thermal comfort index
T_a	Indoor air temperature [K]
T_r	Mean radiant temperature [K]
P_v	Pressure of water vapour in air [Pa $\times 10^3$]
u	Air velocity [m/s]

1. INTRODUCTION

The good and comfortable environment is beneficial to the health, and can improve working efficiency, make people imbued with more creativity. This means strengthening the competitiveness, increase economic efficiency. So, creating the good building environment not merely has a meaning on technology, and has social effect and economic meaning.

With the settlement of the adequate food and clothing, people pay attention to one's own life living environment more and more, indoor climate and human body's comfortable problem cause people's attention day by day. But pursue the increase that the comfortable cost is energy consumption excessively, with the fast development of economy, the proportion of taking total energy consumption of the building of energy consumption of the air conditioner increases day by day, is up to 30%~40%. So how base on the premise that it is satisfied for the thermal comfort, utilize natural environment fully, it should be our basic point of consider in the course of such decision as planning, designing, etc. to realize air conditioning energy-conservation in way that "it is the no-air-conditioning".

2. THE MAIN FACTORS OF INFLUENCING INDOOR THERMAL ENVIRONMENT

2.1 Air Temperature

To the air temperature, we refer to dry-bulb temperature in indoor environment which has direct impact on the heat exchange between human body and environment through convection and radiation. In the context where the pressure of air remains the same, the rise of the air temperature will cause the rise of the skin temperature and perspiration, while the declining of the air temperature will make tiny blood vessels under skin contract and the skin temperature will lower. Even under the same temperature, different individuals will have different thermal response because of different age, sex and health. GB 50019-2003 [1] stipulates that in summer the favourable temperatures range from 24 to 28 centigrade degrees.

2.2 Air Humidity

Comparative humidity exerts direct or indirect impact on human body's thermal comfort because humidity can influence not only the evaporation of the water in the surface of the skin but also the perspiration. Either the humidity is too high or too low will make human being uncomfortable. Usually, when the humidity increases, body will feel warmer or hotter. GB 50019-2003 [1] mentioned above stipulates the indoor favourable humidity falls into 40%~65%.

2.3 Average Radiation Temperature

Environment heat radiation is composed of the sun radiation which is capable of entering the room and the radioactive heat exchange between human body and surrounding environment. When the environment temperature is higher than that of body, the body will gain heat through radioactive heat exchange. In the hot area, the indoor temperature is too high not only because of the high temperature of the summer, but also the heat radiation of the surface

of the enclosing walls and the sun radiation coming through the windows.

2.4 Indoor Air Speed

In summer, airflow has obvious impact on human body's convection and perspiration and evaporation. When the air temperature is lower than that of the skin, air flows faster to intensify the body's heat radiation, making human feels cooler. When the air flows faster by 1m/s, human being will feel the air temperature lowers by 2-3 centigrade degrees. When the air flows at the speed lower than 0.254m/s, human being can not sense the wind; at 0.254~0.5m/s, human feels comfortable; at 0.508 ~1.016m/s, human feels the wind but acceptable; but at 1.016~1.524m/s, human feels strong wind and uncomfortable. The STANDARD stipulates that the indoor air should flow at speed lower than 0.3m/s.

In addition to the above objective elements, colour and intensity of irradiation also have influences on body's thermal comfort toward the rooms.

3. SAMPLING OF THERMAL ENVIRONMENT OF NATURAL VENTILATION CONDITION

The residential thermal environment testing is introduced in the nether content. Base on the weather datum, in Xiamen, highest temperature and humidity was occurred on the last ten days of July and the first ten day of Aug in a year, so that, a day was selected on the last ten days of July, 24-July 2005.

The measurement was put in practice. A dwelling house with four rooms was selected for this study. Hereinto, the living room was about 6m×4m×3m (length×width×height) with only an external wall southward, the building material was composed of air bricks, thick was 200mm, and wall tiles; The size of the veranda-window was 2.5m×2.5m (width×height).

The test meter is CENTER 313, digital data-logger Humidity / Temperature meter. The meter measurement range is Humidity: 0%~100%, Temperature: -20℃~+60℃, and accuracy is Humidity warps 2.5%, Temperature warps 0.7℃. The test meter was placed in the distance floor one meter.

The test result of Humidity / Temperature is showed in the following Figure 1 and Figure 2.

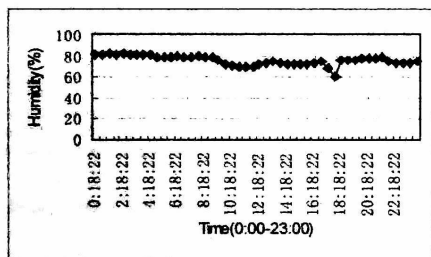


Figure 1: 1-hour relative humidity on 24-July.

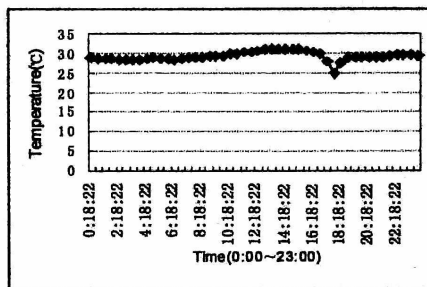


Figure 2: 1-hour relative humidity on 24-July.

In a majority of time of one day, the indoor Humidity / Temperature were tested by natural ventilation condition. But during fifth-hour to sixth-hour, an air conditioner was entered start-up and running.

4. THERMAL ENVIRONMENT EVALUATION

The environment factors that affect human thermal comfort include air temperature, relative humidity, and air velocity and mean radiant temperature, for sedentary occupants in summer clothing (ASHRAE 1992) [2] [3]. The influences of these factors on thermal comfort are discussed in the following sections.

Reference [4] calculates the four factors, air temperature, relative humidity, and air velocity and mean radiant temperature, synthetically, think of that their influence degree for thermal feeling include: 0.53, 0.27, 0.14 and 0.06. Therefore know, the influence of radiation temperature is much smaller than other factors. Because effective temperature, ET index, mainly to have a rest and easiest manual labor state, and the thermal feeling while wearing light and thin clothes [5], and the research object of the subject is the private residence and resident in summer, its state is in conformity with ET index. So choose ET as reference index of thermal environmental quality.

As Fig. 3, offer the comfortable district of effective temperature of summer and the line graph of effective temperature under effecting together in dry bulb temperature, wet bulb temperature and air velocity. It is some researchers draw by indoor observing experiment result according to in inactive state and in normal clothing adult.

We choose the representative several groups data of temperature and humidity from Fig. 1 of Fig. 2, utilize the effective temperature graph to analyze.

The straight line 1 has expressed the situation when air temperature, relative humidity are 29.5 degrees Centigrade/75% (wet bulb temperature is 25.7 degrees Centigrade), it is representative air state in most period in the room.

The straight line 2 has expressed the situation when air temperature, relative humidity are 28.6 degrees Centigrade / 82.1% (wet bulb temperature is 26 degrees Centigrade), it has represented the moment indoor air state, at 1:18:22, has the largest humidity at this moment during one day.

The straight line 3 has expressed the situation when air temperature, relative humidity are 31.1 degrees Centigrade / 71.5% (wet bulb temperature is 26.6 degrees Centigrade), it has represented the moment indoor air state, at 14:48:22, has the highest temperature at this moment during one day.

The straight line 4 has expressed the situation when air temperature, relative humidity are 25 degrees Centigrade / 61% (wet bulb temperature is 19.5 degrees Centigrade), it represent indoor air state on the 17:48:22 moment, when it at this moment, running air conditioner (air conditioner running time as from 17:30:00 to 18:30:00).

Find out from Fig. 3, straight line 1, 2, 4 represented temperature/humidity's state are in the comfortable area when the velocity of air is higher than or equal 0.5m/s. The situation of the straight line 3 is for the hottest air state in one day, the occupant feels hot at this moment, need to open the air conditioner.

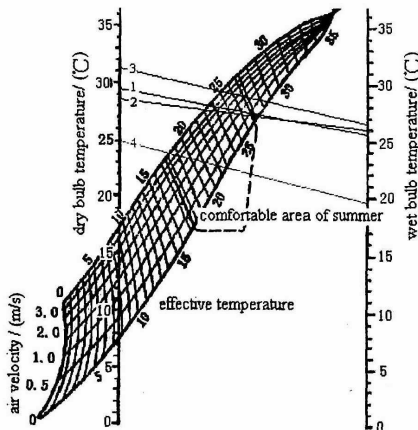


Figure 3: the effective temperature (ET) figure.

Such the making differently up of the factor as the air temperature, relative humidity and near air velocity, etc., the human body can produce the same cold and hot feeling. Can find out of the graph, are up to the increase of air velocity when air temperature/humidity keeps intact from pursuing to have, effective temperature is reduced; Up to the increase of air relative humidity when air temperature (higher than 7.5 degrees Centigrade) and velocity must, effective temperature rises.

According to the effective temperature (ET) figure, we can find that ET on basic thermal environment is satisfied with human comfortable feel.

It is moderate on human thermal feel when ambient environment hasn't hot load, colligation hot load is zero, and the temperature of the body is tenability with which heat energy balance can be maintain by blood vessel below skin shrink and

stretch. The thermal comfort index (TCI) is calculated to integrate the four physics parameter, the four environment factors, and value can be calculated with using the following experimental regressive formulation:

$$TCI = 61.449 - 0.1T_a - 0.0968T_r - 0.279P_v + 0.3636 \times (310.78 - T_a) \cdot u^{1/2} \quad (1)$$

A correlation is shown between TCI and the thermal responses of human body, as Table 1.

Table 1: Grade of thermal feeling of human body

TCI	Feeling
7	Cold
6	Cool
5	Slight cool
4	Comfortable
3	Slightly warm
2	Warm
1	Hotter

Based on the test results of the temperature and humidity in the Figure 1 and Figure 2, the value of TCI can be computed out by Equation (1) in representative day of July, listed in Table 2.

Table 2: The value of TCI on representative days of July

The air temperature, K(°C)	The air Humidity (%)	TCI
302.7(29.5)	75	3.0
301.8(28.6)	82.1	3.4
304.3(31.1)	71.5	2.2
298.2 (25)	61	5.4

Note: For the Table 2, the partial pressure of water vapour in the air, P_v , can be count by the air temperature and the air Humidity; the air velocity, u , is 0.5 m/s; and the mean radiant temperature, T_r , is considered go beyond one degree than the indoor air temperature.

Compare the Table 1 and Table 2 shows, during one day except that in little period, e.g. at 14:48:22, people are difficult to accept to the extreme hot environment, within other most of the time, people can accept the thermal environment when natural ventilation.

5. ENERGY CONSERVATION OF AIR-CONDITIONING

Raising wind speed can improve the indoor thermal environment. Experiment research indicates, takes 0.8m/s as the upper limit of speed of the airflow,

look on it as the relative humidity in 60 to 70%, SET value is 25 to 26°C, receivable air temperature can reach 30°C, the temperature value to be 4 degrees Centigrade higher than 26 degrees Centigrade, the recommend value of air conditioning of the design manual. So, under saving the capacity of air conditioning and reducing running time of equipment, the energy can be saved.

Take an example of a common restaurant with an area of 10000 m², about ninety days operation of air-conditioning system each summer, the operation for 1 hour less every day, can economize the fund of about 21,240 RMB each summer (some power consumption of motive force of air conditioner is about 40W/m² for the area of air conditioner, The price of non-industry electricity is counted according to 0.59 Yuan for 1 degree electricity). Therefore the expectation, a city with millions of square meters of air conditioners building, can save millions of fund in one year. Economize a large amount of energy; make considerable society, economy and environmental protection profits.

6. CONCLUSIONS

In sum, draw the following conclusions:

(1) In Xiamen summer, the hot environment under the natural ventilation condition can be accepted by people basically by testing and assessing. And only need to run the air conditioner during a few period of every day.

(2) For a residential building, especially the private residence, should consider the impact on indoor thermal environment of many kinds of factors synthetically, the thermal environmental evaluation index of formulation and air conditioner standard rationally; Under the natural ventilation condition, reduce the temperature and humidity standard of the start-up air conditioner.

(3) Ones that fully can improve themselves thermal comfortable in natural wind energy of rational utilization are, realize the energy-conservation of air conditioning. So, suggest that the natural ventilation and interval natural ventilation should be the main fundamental methods of improving the building thermal environment of seaside city in hot days.

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