Study on the Indoor Environment Quality of Green Office Buildings in Beijing

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ABSTRACT

By selecting 4 typical room of green office building in Beijing, this paper tests the actual data of indoor environment quality parameters, such as indoor temperature and humidity, illumination, CO2, PM2.5, and horizontally comprises the air-conditioning season to the transition season, analysis the fluctuation range, intrinsic variation, influence factor, mutual relationship of IEQ, provides reference for designing and evaluating indoor environment of green office building in Beijing area and cold area.¹

INTRODUCTION

The Assessment standard for Green Building (GB/T50378-2014, 2014) [1], clearly states that the Green Buildings are the buildings which maximize resources (energy saving, land saving, water saving, and material saving) throughout the life of the building, protect the environment, reduce pollution, provide people with healthy, applicable and efficient space, and live in harmony with nature. The Assessment Standard for Healthy Building[2] (T/ASC02-2016, 2016) proposes that the Healthy Buildings are the buildings which provide occupants with a healthier environment, facilities and services, promote the physical and mental health of building occupants, and achieve the improvement of building performance. In October 2016, China's State Council issued the Outline of ‘Healthy China’ Plan, proposing that ‘Co-construction, Sharing and Universal Healthy’ is the strategic theme of building a healthy China. Therefore, the study of indoor environmental quality in buildings is of great significance. Lei Yu (2013) [3] selected an office building in Beijing to

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conduct spring indoor thermal environment testing and evaluation. It was concluded that natural ventilation in the spring transition season can meet the user's thermal comfort requirements, and the building roof insulation performance should be strengthened. Zilong Xu (et al., 2013) [4] studied the thermal environment of large public buildings and considered that the actual summer operative temperatures were lower than the minimal requirement in the current standard, and the actual winter operative temperatures were higher than the normative maximum value, which caused energy waste and indoor occupants’ discomfort. Therefore, exclusive indoor HVAC design parameters should be established. Yan Chen (2015) [5] conducted a field test on the indoor thermal environment of an office building in northern China, then proposed an indoor environment optimization design strategy. However, there is still a lack of measured data on the indoor environmental quality of office buildings in the cold regions in China during the summer and transition seasons. This study has screened the important environmental parameters of green office buildings and has conducted long-term monitoring of an air-conditioning season and a transition season. Through the horizontal comparative analysis, the actual operating states of the building, the internal relationship between the environmental parameters, the influencing factors and the fluctuation range of each parameter were studied. This study is of great significance for reducing the energy consumption of green office buildings in Beijing and other cold regions and improving the quality of indoor environment.

TEST CONDITIONS

There are many environmental quality parameters of green buildings, among which CO2 index, PM2.5 index, PM10 index, radon concentration, benzene concentration, and formaldehyde concentration, etc. have a great impact on indoor environmental quality. And each parameter is affected by many other environmental parameters. By combing these key parameters, they can basically be divided into dynamic data and static data. Dynamic data, that is, indoor environmental parameters that change over time due to indoor and outdoor influences, such as CO2 index, PM2.5 index, noise value, temperature and humidity, illuminance, etc.; static data, that is, parameters are less affected by indoor state, mainly depends on the material or its own characteristics, such as formaldehyde, TVOC, radon, etc., which are mainly related to interior decoration materials and decoration degree.

According to the requirements of the Assessment standard for Green Building (GB/T50378-2014, 2014)[1], this study selected the main parameters of indoor environmental quality, such as indoor temperature and humidity, illuminance, CO2 index and PM2.5 index for long-term monitoring from September 1st to December 30th in 2017. This study used the Qing Jianzihuan iBIEM-B3 intelligent environmental instrument developed by Tsinghua University. And used thermocouple temperature measurement and electronic temperature sensing. The inhalable laser continuously detected the concentration of particles. The non-
dispersive infrared principle was used to detect the presence of CO2 in the air. In addition, an illuminance transmitter (illuminance sensor) was used for indoor illuminance detection.

| Number | Key parameters | Main influencing factors |
|--------|----------------|--------------------------|
| 1      | illuminance    | Lights on/off; Occupants/ No occupants |
| 2      | CO₂            | Fresh air rate; The number of occupants |
| 3      | Temperature    | HVAC on/off; The number of occupants |
| 4      | PM₂.₅          | The number of occupants; Metabolic rate; Window, door on/off |
| 5      | TVOC           | Decoration material; Duration; Fresh air rate |

**INDOOR TEMPERATURE AND HUMIDITY ANALYSIS**

**Indoor Temperature Analysis In Air Conditioning Season**

Four offices were continuously monitored in typical air conditioning days from September 4th to September 8th. The indoor temperature and humidity change trends are shown in Figures 1 and 2. Combined with Office A, the horizontal contrast of daily indoor temperature changes is shown in Figure 3.

Figure 1. The indoor temperature and humidity curves for four offices in air conditioning days.
According to the temperature changes in the four offices, it can be analyzed that the indoor temperatures in the day were basically 26.5-28 °C. A trough in temperature appeared around 10 am, then the temperature was adjusted to a stable peak. This illustrates the feedback effect of the air conditioner during the indoor temperature adjustment process. In the afternoon, the room temperatures were generally higher than the morning room temperatures. At night, natural ventilation can maintain the indoor temperature at 28.5-29 °C, which was delayed relative to the outdoor night temperature. The indoor humidity was greatly affected by the outdoor humidity. Basically, the humidity in the four office rooms changed similarly, and were maintained between 25% and 60% in occupancy hours.

**Indoor Temperature and Humidity Analysis in The Transitional Season**

The four offices were continuously monitored in a transition season from October 23rd to October 27th. The indoor temperature and humidity change trends are shown in Figures 4 and 5. Combined with Office A, the horizontal contrast of daily indoor temperature changes is shown in Figure 6.
According to the indoor temperature changes of the four offices in the transition season, the following conclusions can be drawn: the indoor temperature and outdoor temperature changed between 21-26 °C basically during the day, and reached the peak around 3 pm. The indoor humidity was greatly affected by the outdoor humidity. Basically, the humidity in the four office rooms changes similarly and were maintained between 30% and 50% in occupancy hours. When the office D was cleaned every morning, the indoor humidity would reach an instantaneous high point.

![Figure 4. The indoor temperature curve for office D in a transition season.](image)

**INDOOR ILLUMINANCE ANALYSES**

Since the main factors affecting indoor illuminance are occupants’ behavior, lighting opening, curtain opening, etc., a typical working week (September 4th - September 10th) was selected for the detection and analysis of indoor illuminance under actual operating conditions. The four rooms test data was analyzed and the actual indoor illuminance changes were as follows:

![Figure 5. Actual illuminance curves of four office rooms.](image)

The illuminance in the occupied hours was basically stable. The natural lighting is beneficial to improve the indoor light environment and reduce the lighting load.
Office A was selected separately for daily illuminance analysis, and the trend was as follows:

![Figure 6. Indoor illuminance changes in office A.](image)

Combined with the daily illuminance and occupants’ behavior record of the single room, it can be concluded that: during the occupancy hours, the indoor illuminance was basically stable at 500lx. When the luminaire was partly turned on, the indoor illuminance fluctuated. Although affected by outdoor illuminance, it was still greater than 300lx requirements and was concentrated between 380-500lx, which can meet indoor illuminance requirements.

**INDOOR CO2 INDEX ANALYSIS**

According to Indoor Air Quality Standard (GB/T18883-2002,2002), Code for Indoor Environment Pollution Control of Civil Building Engineering (GB50325-2001 (2006 edition),2006), and Code for Indoor Environment Pollution Control of Civil Building Engineering (GB50325-2010,2010), etc., this study has monitored the indoor CO2 concentration. The typical air-conditioning season from September 4th to 8th, and the typical transition season from October 23rd to 27th were selected for analysis.

![Figure 7. CO2 index curves of four office rooms in conditioned and transition season occupied hours.](image)
The horizontal comparison of four offices indoor CO2 index changing in conditioning and transition season were shown in figure 9, the analysis was as follows:

The indoor CO2 concentration was basically between 450-550 ppm in conditioning season, and 700 ppm in transition season.

The fluctuations of CO2 concentration were basically peak values at 9:30-11:00 and 14:00-17:00.

Open-plan offices’ CO2 concentration can be maintained below 750 ppm. When the indoor occupancy density was large, and the naturally ventilation was limited, the indoor CO2 concentration would rise sharply and would exceed 1000 ppm, which could reduce working efficiency.

**INDOOR PM2.5 CONCENTRATION ANALYSIS**

The indoor PM2.5 concentration of the four monitoring points was analyzed in typical days of the air-conditioning season and typical days of the transitional season, and the changing trends are shown in Figure 11, respectively.

![Figure 8. Analysis of indoor PM$_{2.5}$ concentration in air conditioning season and transition season.](image)

By the figure, it can be judged that the outdoor PM2.5 concentration was the biggest influence factor of the indoor PM2.5 concentration, and the indoor PM2.5 concentration was generally 40-80 ppm lower than the outdoor PM2.5 concentration. When the outdoor PM2.5 concentration did not exceed 40 ppm, the indoor PM2.5 concentration also in an excellent state. In the air-conditioning season, the peak of indoor PM2.5 concentration was easy to reach 50-75 ppm.
Through the daily average accounting of 5 days, 30 days, and 60 days for the four offices, the daily average PM2.5 concentrations were shown in Figure 13 and were basically maintained at no more than 40.3ppm.

CONCLUSIONS

In this study, four office rooms in Beijing were monitored the indoor environmental quality through monitoring points. The indoor temperature, humidity, illuminance, PM2.5 concentrations and CO2 concentrations were monitored and analyzed. The conclusions are as follows:

- The indoor illumination of office buildings is greatly affected by the opening of curtains, the opening of lamps, and the energy-saving behavior of occupants; natural lighting can meet the illumination requirements of indoor work before 2:30 pm.
- Reasonable arrangement of indoor work stations and lighting control loops are conducive to behavioral energy conservation;
- The indoor carbon dioxide concentration is basically be maintained below 750ppm, meeting the standard requirement of not exceeding 1000ppm; the carbon dioxide detection probe is more suitable for open-plan offices.
- In the air-conditioning season, the indoor temperature would show trough at around 10:00, and it can be maintained at 26.5-28 °C during the day, and the natural fresh air can be effectively utilized in the transition season. At the same time, the indoor humidity has a great relationship with the outdoor humidity, and basically meets the requirement of not exceeding 60%.
- The indoor PM2.5 concentration is most affected by the outdoor PM2.5 concentration. In the air conditioning season and the transition season, the daily average PM2.5 concentration can be basically lower than 40ppm.

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REFERENCES

1. Standards Press of China. 2014. Assessment standard for Green Building GB/T50378-2014.
2. China Academy of Building Research. 2016. Assessment Standard for Healthy Building T/ASC02-2016.
3. Yu, L. 2013. The Test and Evaluation of Indoor Hot Environment in Green Office Building in Spring. CCSAC, 2013(4): 5-10.
4. Xu, Z. Di, Y. and Liu, Y. 2013. Large Public Building Indoor Thermal Environment Research and Design of the Status Quo. CCSAC, 2013 (6): 134-135.
5. Chen, Y. Research on Winter Indoor Thermal Environment Test of North Office Building. Shanxi Architecture. 2015(33): 188-189.