Study on Natural Ventilation Potential of Ordinary Office Buildings in Guangzhou Based on Architectural Factors

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Abstract. As a traditional architectural design technology, natural ventilation has the functions of improving thermal comfort, indoor air quality and energy saving, which is in line with the architectural development concept of green and healthy buildings. Guangzhou is located in the hot-humid area of Lingnan, where is rich in wind resources and attaches great importance to the natural ventilation of buildings. Natural ventilation potential (NVP) are evaluation indexes that can effectively assist and optimize the natural ventilation design of buildings. With abundant relevant studies at home and abroad, various NVP evaluation indexes and calculation methods have been proposed, and strategies for natural ventilation design of buildings in different regions have also been given. Based on the parametric building performance simulation platform, this paper introduces a new NVP evaluation method to carry out parametric simulation research on the ordinary office buildings suitable for natural ventilation in Guangzhou. The results showed that the main factors that limit the NVP of ordinary office buildings in Guangzhou is condensation in summer, and low building density, building toward southwest, high glazing ratio or cross ventilation will bring about high NVP. Meanwhile there is an optimal value for the thermal resistance of the roof, and the greater the thermal storage coefficient of the main material, the greater the night natural ventilation potential.

Keywords: Guangzhou area, office buildings, NVP, parametric method, design optimization.

1. Introduction
Natural ventilation has the functions of improving indoor air quality, improving comfort and reducing energy consumption. Even with the development and perfection of air conditioning system today, natural ventilation still has its irreplaceable advantages. Firstly, the use cost of natural ventilation is almost zero, because wind is one of the renewable energy resources that human beings can use endlessly. Secondly, natural ventilation can provide clean and fresh air, which is beneficial to people's physical health. Finally, compared with the mechanical ventilation with monotonous wind speed changes, natural ventilation with more random wind speed changes can make people feel the stimulation of irregular airflow and get closer to nature psychologically, which is beneficial to people's mental health. In order to facilitate the study of buildings natural ventilation, many evaluation indexes of NVP have been
proposed by scholars, with which can be classified as direct natural ventilation potential (DNVP) and indirect natural ventilation potential (INVP) according to the ventilation function. DNVP refers to the potential of a building to meet acceptable indoor thermal comfort and air quality only by relying on natural ventilation during building use time. INVP, also known as night ventilation cooling potential, refers to the potential of natural ventilation cooling and cooling storage in buildings during non-use time.

There are three main factors affecting NVP, namely climate, architecture and technology. Early studies on NVP were mainly aimed at climatic factors, whose researchers used formula derivation to deduce outdoor climatic conditions that met the requirements of indoor thermal comfort and ventilation rate, or were conducive to night ventilation, so as to study the NVP of climate adaptability in different regions. For DNVP, Fracastoro G V [1], based on the theory of natural ventilation, expressed the effective pressure difference as a function of indoor and outdoor temperature difference and wind speed, and used the effective pressure difference method to evaluate the NVP of climate adaptability. Yang Lina [2] and Zhang Guoqiang et al. [3] evaluated NVP in different cities of China by using effective pressure difference method on the basis of predecessors. Axley J W and Emmerich S J [4] deduced the outdoor temperature and humidity range that can meet the requirements of indoor thermal comfort and ventilation rate at the same time based on the building thermal balance equation, and used the building thermal balance method to evaluate the NVP of climate adaptability. Jing Feng et al. [5] evaluated the NVP of office buildings in major cities in different climate regions of China by using the building thermal balance method on the basis of predecessors. For INVP, Givoni B [6] proposed the temperature difference ratio coefficient (TDR) to measure the night NVP of non-air-conditioned buildings. Fu Xianzhi [7] used the average outdoor temperature difference to measure night NVP in hot-summer and cold-winter zone in China. Artmann N et al. [8] proposed climatic cooling potential (CCP) to measure the cooling effect of night natural ventilation.

With the improvement of computer performance and the popularity of building performance simulation software, more and more researchers began to use computer simulation method to study NVP. Compared with the formula derivation method, the computer simulation method is more accurate and can better reflect the influence of architectural factors on NVP, but its shortcoming lies in the large amount of calculation, making it difficult to compare the NVP of climate adaptability in different regions. Yao R et al. [9], Qi Xiaoping [10], Zhou Junli[11], Qin Xinghong[12], Bu Gen[13], Yang Yulan et al.[14], Tong Z[15] and Cheng J et al.[16] all used computer simulation method to study NVP based on climate or architectural factors.

The existing domestic and foreign studies on NVP focus mainly on climatic factors, while few studies focus on the influence of architectural factors on NVP, and the consideration of architectural factors is mainly based on case studies. Guangzhou is located in the hot-humid area of Lingnan with abundant wind resources, whose local traditional buildings attach great importance to natural ventilation. At present, there are many studies on natural ventilation of traditional buildings in Guangzhou, but relatively few studies on natural ventilation of modern public buildings such as office buildings. Thus, this paper will be based on Rhinoceros & Grasshopper, a parametric architecture design platform, call EnergyPlus and its ventilation module COMIS and adopt two NVP evaluation indexes to carry out parametric simulation, in order to study the influence of architectural factors on NVP which provides reference for natural ventilation design of Guangzhou ordinary office buildings, and provide a new idea for more accurate NVP calculation.

2. Research methods

2.1. Simulation platform and its reliability
Based on Rhinoceros & Grasshopper, this paper uses the ladybug & honeybee building performance simulation plug-in to call EnergyPlus & COMIS to carry out parametric modeling and performance optimization simulation of Guangzhou ordinary office buildings.

An important part of the development of EnergyPlus is to conduct industry standard testing of the software. By comparing the load calculation results of 18 different functional buildings with 8 kinds of
building energy consumption simulation software specified by EnergyPlus and IEA, in more than 100 kinds of basic and in-depth tests, EnergyPlus meets the reliability requirements, and the maximum deviation from other software is not more than 5.2% [17][18][19]. As for the reliability of multizone model that COMIS uses for natural ventilation simulation, a study [20] reviewed the relevant experimental verification in the past, and the results showed that for natural ventilation driven by wind pressure and thermal pressure, the multizone model could reasonably predict ventilation rate and air flow between zones. At present, COMIS has been incorporated into EnergyPlus as the core of its ventilation module. Therefore, EnergyPlus has certain accuracy for natural ventilation calculation, which can be used in this study.

2.2. Research object

In this paper, the model of typical ordinary office buildings is established according to the Design Standard for Energy Efficiency of Public Buildings (GB 50189-2015[21]). The building is 10 stories high, 3.6m high each floor, 45m wide and 17.4m deep. The total building area is 7830m², the external area is 5275.8 m², and the shape coefficient is 0.187. The architectural plan and model diagram are shown in Figure 1, and parametric modeling is shown in Fig 2.

![Figure 1. Building plan and model diagram.](image1)

![Figure 2. Parametric modeling.](image2)
2.3. Parameterization of architectural factors and other parameter Settings

For a typical ordinary office building, the main variables of climatic, architectural and technical factors that influence NVP can be seen in the Table 1.

| Factors                  | Main variables                                             |
|--------------------------|-------------------------------------------------------------|
| Climatic factors         | Outdoor temperature, humidity, wind speed, wind direction, solar radiation |
| Architectural factors    | Building orientation, building density, thermal performance of materials, glazing ratio, ventilation mode |
| Technical factors        | Occupancy heat gain, equipment heat gain, lighting heat gain |

Considering the daylighting needs, the long side of the building should face south as far as possible, so the parameters of the long side orientation of the building are divided into -40° ~ 40° (due south is 0°, southwest is positive), and the difference is 10°. The parameters of building density are divided into low density, medium density and high density, corresponding to 0.1, 0.3 and 0.5 respectively. The thermal performance parameters of the main structure can be divided into two parts: wall (including external wall) and floor (including roof). For the wall, the thermal performance is mainly determined by the main material when the basic structure is unchanged. Therefore, according to the thermal conductivity from small to large, five main materials, namely air brick, clay brick, silicate brick, lime sand brick and reinforced concrete, are selected. For the floor, because the main material is reinforced concrete, the main factor affecting NVP is the thermal performance of the roof. Therefore, under the condition that the basic structure of the roof remains unchanged, the thermal performance parameters can be divided by reasonably changing the thickness of the roof insulation. In this paper, the thickness of the roof insulation (aerated concrete) is divided into 60mm, 100mm, 140mm and 180mm. Referring to the Design Standard for Energy Efficiency of Public Buildings and the National Technical Measures for Design of Civil Construction: Special Edition--Energy Conservation (2007 Edition), the main structure and material thermal parameters setting of the building model are shown in Table 2 and Table 3. Considering the daylighting of the building and the thickness of floor slab and beam and column, the parameters of the glazing ratio of the exterior walls wall were divided into a range of 0.2 ~ 0.8, with a difference of 0.1. The ventilation mode is divided into single-sided ventilation and cross ventilation according to whether the corridor is equipped with high ventilation window and opened. In this simulation experiment, the glazing ratio of the corridor high ventilation window is 0.1.

| Main structure | Concrete structure                                      |
|----------------|--------------------------------------------------------|
| Exterior walls | 5mm face brick +20mm cement mortar +14mm EPS+ main material +20mm mixed mortar |
| Interior walls | 20mm mixed mortar + main material +20mm mixed mortar |
| Roof           | 20mm cement mortar +30mm LWAC+ aerated concrete +14mmXPS+100mm reinforced concrete |
| Floors         | 5mm brick +20mm cement mortar +100mm reinforced concrete |
| Windows        | 6mm simple glass                                       |
### Table 3. Material thermal parameters.

| Material name        | Thermal conductivity (W/(m·K)) | Density (kg/m³) | Specific heat capacity (J/(kg·K)) |
|----------------------|--------------------------------|-----------------|----------------------------------|
| Face brick           | 1.09                           | 2090            | 1000                             |
| Cement mortar        | 0.93                           | 1800            | 1050                             |
| EPS                  | 0.039                          | 20              | 1380                             |
| Air brick            | 0.58                           | 1400            | 1050                             |
| Clay brick           | 0.76                           | 1700            | 1050                             |
| Silicate brick       | 0.87                           | 1800            | 1050                             |
| Lime sand brick      | 1.1                            | 1900            | 1050                             |
| Reinforced concrete  | 1.74                           | 2500            | 920                              |
| Mixed mortar         | 0.87                           | 1700            | 1050                             |
| LWAC                 | 0.67                           | 1500            | 1050                             |
| Aerated concrete     | 0.19                           | 500             | 1050                             |
| XPS                  | 0.032                          | 35              | 1380                             |
| 6mm simple glass     | U value (W/(m²·K))             | SHGC VT         |                                   |

The meteorological parameters used for simulation in this paper are selected from the typical meteorological year data of Guangzhou downloaded from the official website of EnergyPlus, and the setting of technical parameters includes various schedules and internal heat gain refer to the relevant suggestions and introductions in the Design Standard for Energy Efficiency of Public Buildings and the reference documents of EnergyPlus.

2.4. Calculation of NVP

Based on the previous NVP calculation methods, considering the use characteristics of office buildings, this paper proposes the following NVP calculation methods for office buildings.

DNVP<sub>ob</sub> refers to the potential that office buildings can meet acceptable indoor thermal comfort and air quality only by natural ventilation during working hours (8:00-18:00). Because it’s needs to consider people’s health and comfort demand of buildings during the working hours, this evaluation index will estimate the natural ventilation performance from three aspects: ventilation rate, condensation and indoor thermal comfort. On the basis of the effective hours of natural ventilation proposed in reference 4, this paper puts forward the following improved calculation formula of DNVP<sub>ob</sub> quantitative index.

\[
DNVP_{ob} = \frac{h_{D,e}}{h_{e}}
\]  

(1)

Where \(h_{D,e}\) is the effective hours of direct natural ventilation in office buildings throughout the year, that is, the hours that can meet the requirements of ventilation rate limit, non-condensation and thermal comfort at the same time when using natural ventilation during working hours. The thermal comfort criterion refers to the previous study on thermal comfort calculation of human body in Guangzhou area [22]. The non-condensation criterion is that the temperature of the inner surface of the building is not lower than the dew point temperature. According to the specification [23], the hourly ventilation rate limit of office buildings is 1 ach. \(h_{e}\) are the effective hours of direct natural ventilation in Guangzhou in the whole year, standing for the maximum potential to meet the requirements of natural ventilation in working hours only considering climatic factors in Guangzhou, that is, the hours that can meet the
thermal comfort requirement of human body when the outdoor meteorological conditions act on it directly.

INVP\textsubscript{\text{ob}} refers to the cooling potential of office buildings through natural ventilation during non-working hours (18:00-8:00). Since only the energy-saving performance of natural ventilation needs to be considered in non-working hours, it is more reasonable to measure INVP\textsubscript{\text{ob}} from the perspective of energy. After comparing the evaluation indexes of INVP proposed in reference 8, this paper proposes the following improved calculation formula of INVP\textsubscript{\text{ob}} quantitative index.

\[
\text{INVP}_{\text{ob}} = \frac{\sum_{n=1}^{N} \sum_{h=1}^{h_f} H R_{n,h}(T_{i,n,h} - T_{o,n,h}) \rho_c}{\sum_{n=1}^{N} \sum_{h=1}^{h_f} H R_{n,h}(T_{i-csp,n,h} - T_{o,n,h}) \rho_c} = \sum_{n=1}^{N} \sum_{h=1}^{h_f} R_{n,h}(T_{i,n,h} - T_{o,n,h})
\]

Where \(n\) and \(h\) are the days and times of indirect natural ventilation, and the calculation interval is summer (May to November) in Guangzhou, referring to the method of dividing the climatic seasons in the Division of Climatic Season (QX / T 152-2012\[23\]). \(T_i\), \(T_o\) and \(T_{i-csp}\) represents indoor air temperature, outdoor air temperature and indoor cooling set point temperature respectively, only if \(T_i > T_o\) and \(T_{i-csp} > T_o\) the calculation of INVP\textsubscript{\text{ob}} is carried out. \(R_{n,h}\) and \(\dot{R}_{n,h}\) is the hourly ventilation rate and the maximum hourly ventilation rate that can be achieved under ideal conditions, \(\rho\) is air density (1.29kg/m\(^3\)) and \(c\) is air specific heat capacity, (1.005kJ/(kg\cdot K)). The numerator of the formula refers to the total cooling capacity per unit area during indirect natural ventilation. And the denominator means the maximum total cooling capacity per unit area that can be achieved under ideal conditions, that is, the building is only composed of columns and floors, and the indoor wind speed is equal to the outdoor wind speed, so \(\dot{R}_{n,h}\) can be calculated by the following formula.

\[
\dot{R}_{n,h} = \frac{v_{o,n,h} 3600}{D}
\]

Where \(v_{o,n,h}\) is hourly outdoor wind speed, and \(D\) is building depth.

The above NVPs weaken the influence of climatic factors to study the influence of architectural factors on NVP, and they can also be used to study the NVP of a certain type of building in different regions. This study will take DNVP\textsubscript{\text{ob}} as the main evaluation index and INVP\textsubscript{\text{ob}} as the auxiliary evaluation index (when DNVP\textsubscript{\text{ob}} is the same, compare INVP\textsubscript{\text{ob}}) to evaluate NVP of ordinary office buildings in Guangzhou, And the parametric NVP calculation module is shown in Fig. 3.
3. Result

3.1. NVP optimization analysis

A total of 7560 working conditions were simulated in this study, and the setting of working conditions and optimization results of NVP are shown in Table 4 and Table 5 respectively.

Table 4. Setting of working conditions.

| Independent variables          | Parameter setting                        | Number |
|--------------------------------|-----------------------------------------|--------|
| Building orientation           | -40°, -30°, -20°, -10°, 0°, 10°, 20°, 30°, 40° | 9      |
| Building density               | 0.1, 0.3, 0.5                            | 3      |
| Thickness of roof insulation   | 60mm, 100mm, 140mm, 180mm               | 4      |
| Main material of wall          | air brick, clay brick, silicate brick, lime sand brick, reinforced concrete | 5      |
| Ventilation mode               | Single-sided ventilation, cross ventilation | 2      |
| Glazing ratio                  | 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8        | 7      |

7560 working conditions in total

Table 5. Optimization results of NVP.

| Variables          | When DNVP<sub>ob</sub> is optimal | When INVP<sub>ob</sub> is optimal |
|--------------------|-----------------------------------|----------------------------------|
| Independent variable | Building orientation 40°          | 10°                              |
|                    | Building density 0.1              | 0.1                              |
|                    | Thickness of roof insulation 140mm| 60mm                             |
|                    | Main material of wall reinforced concrete | reinforced concrete         |
|                    | Ventilation mode cross ventilation| cross ventilation               |
|                    | Glazing ratio 0.8                 | 0.8                              |
| Dependent variable  | DNVP<sub>ob</sub> 0.8494          | 0.8389                           |
|                    | INVP<sub>ob</sub> 0.0344          | 0.0354                           |

It can be seen from Table 5 that the maximum DNVP<sub>ob</sub> is 0.8494 under the above working conditions. The main reason why h<sub>D,e</sub> is less than h<sub>e</sub> is that the indoor heat gain should be considered and the condensation criterion is added.

Under the working condition of optimal DNVP<sub>ob</sub>, h<sub>D,e</sub> is 1387h, accounting for 38% of the annual working hours (3650h), while the annual effective hours of natural ventilation in office buildings is 2904h, accounting for 33.2% of the annual hours (8760h). And h<sub>e</sub> is 1633h, accounting for 44.7% of the annual working hours, while the annual effective hours of natural ventilation oriented by climatic factors in Guangzhou were 4349h, accounting for 48.5% of the annual hours. It can be seen from the above analysis that the proportion of h<sub>e</sub> in working hours is less than that in non-working hours when only considering climatic factors, while the proportion of h<sub>D,e</sub> in working hours is greater than that in non-working hours after introducing architectural factors. Since the above effective hours all take into account the thermal comfort of users, it can be seen that architectural factors can improve DNVP<sub>ob</sub> by increasing the proportion of thermal comfort hours of working hours in the whole day.

Under the working condition of optimal DNVP<sub>ob</sub>, if the monthly cumulative proportion of thermal comfort hours, non-condensation hours, hours of meeting the ventilation rate limit and effective hours of natural ventilation in working hours are separately investigated, the results are shown in Fig. 4.
It can be seen from Fig. 4 that the meteorological conditions in Guangzhou can meet the requirements of ventilation rate limit for office buildings throughout the year. For January, February, October, November and December, the main factor limiting $\text{DNVP}_{ob}$ is thermal comfort index, and other months are non-condensation index. Throughout the year, the adverse phenomenon of condensation in Guangzhou in summer restricts $\text{DNVP}_{ob}$, and through building dehumidification measures, $\text{DNVP}_{ob}$ can be further improved.

3.2. Single factor analysis
In order to study the influence of different architectural factors on NVP, this paper will change the single independent variable respectively while keeping the others unchanged under the working condition of optimal $\text{DNVP}_{ob}$ and analysis the simulation data. The results are shown in Fig. 5–10, which demonstrate that the building orientation, building density, ventilation mode and glazing ratio have great influence on NVP, while the thickness of roof insulation and the main material of wall have little influence on NVP.

It can be seen from Fig. 5 that there are larger NVP in the southwest working conditions, while that in the south is the smallest. After analyzing the monthly proportion of different evaluation indexes (the same below), it shows that compared with the south working condition, the thermal comfort hours in southwest working conditions decrease in summer (from May to November), and increase in winter,
while the non-condensation hours change little. In general, $h_{D,e}$ in the southwest working conditions increase in winter, and change little in summer because of low non-condensation hours, which means that the increase of thermal comfort hours in winter leads to the improvement of $DNVP_{ob}$. Similarly, compared with southeast working conditions, there are larger NVP in southwest working conditions for the same reason. The above results may be due to the fact that the dominant wind direction in Guangzhou is north in winter, followed by southeast, and the building towards the southwest can avoid excessive indoor wind speed in winter, which will cause thermal discomfort.

![Figure 6. Influence of building density. Figure 7. Influence of thickness of roof insulation.](image)

It can be seen from Fig. 6 that the smaller the building density, the greater the NVP. After analysis, the smaller the building density is, the greater the thermal comfort hours in winter and the smaller in summer, and the greater the non-condensation hours in the whole year, especially in summer. In general, $h_{D,e}$ increases most obviously in April, May, September and October. The above results may be due to the fact that the smaller the building density is, the less the surrounding buildings block the sunlight, which increases the temperature of the inner surface of the building and then increases the non-condensation hours of the whole year. However, due to excessive sunlight, the thermal comfort hours from June to August are greatly reduced. Therefore, $h_{D,e}$ increases the most in April, May, September and October finally.

![Figure 8. Influence of main material of wall.](image)

![Figure 9. Influence of ventilation mode.](image)

It can be seen from Fig. 7 that there is an optimum thickness of roof insulation, and the moderate thermal resistance of roof is more conducive to the improvement of NVP. After analysis, the thermal comfort hours in winter will decrease when the thermal resistance of roof is low, while the thermal comfort hours in summer will decrease when the thermal resistance of roof is high. The above effects are more obvious on the top floor, and the thermal resistance of roof has little effect on the non-condensation hours. The above results may be due to the fact that the low thermal resistance of roof will make the top floor heat dissipation serious in winter, while the high one will make it difficult for the top floor to dissipate the heat in summer, both of which will lead to the reduction of thermal comfort hours.
It can be seen from Fig. 8 that the influence of the main material of wall on DNVP\textsubscript{ob} is limited, DNVP\textsubscript{ob} will slightly increase when the thermal conductivity increases. And the influence of the main material of wall on INVP\textsubscript{ob} is approximately linear with the thermal storage coefficient, and the greater the thermal storage coefficient, the greater the INVP\textsubscript{ob}. After analysis, the larger the thermal conductivity of the main material, the greater the thermal comfort hours in summer, and the annual non condensation hours have little change. In general, \( h_{D,e} \) has a little increase when the thermal conductivity increases, which may be because it’s more conducive to the indoor heat dissipation in summer when the thermal resistance of the external wall is low, so as to increase the indoor thermal comfort hours in summer. The relationship between the thermal storage coefficient of the main material and INVP\textsubscript{ob} is shown in Fig. 11, in which we can find that when the thermal storage coefficient is low, it is approximately proportional to INVP\textsubscript{ob}. It may be that the larger the thermal storage coefficient of the main material is, the more cooling capacity can be stored in it during night natural ventilation. And when the thermal storage coefficient is too large, the growth trend of INVP\textsubscript{ob} slows down, which may be because the main material has not reached the maximum cooling storage capacity at night due to the limitation of meteorological conditions in Guangzhou.

It can be seen from Fig. 9 that the working condition with cross ventilation has greater NVP than that with single-sided ventilation. After analysis, compared with single-sided ventilation, the thermal comfort hours in the working condition with cross ventilation increase in winter and decrease in summer, and there was no significant difference in non-condensation hours between two ventilation modes. In general, the working condition with cross ventilation has a greater \( h_{D,e} \) in winter which results in larger DNVP\textsubscript{ob}. The above results may be due to the fact that under the cross ventilation, the indoor air flow is more uniform and the maximum wind speed is smaller in winter, and it can better let indoor air mixing between the south room and the north room, which cause a more uniform temperature to avoid the north room too cold in winter.

![Figure 10. Influence of glazing ratio on NVP.](image)

It can be seen from Fig. 10 that the larger the glazing ratio is, the greater the NVP is. For DNVP\textsubscript{ob}, when the glazing ratio is greater than 0.5, the growth trend begins to slow down. And INVP\textsubscript{ob} is approximately proportional to the glazing ratio. After analysis, the larger the glazing ratio is, the greater the thermal comfort hours in winter, the smaller in summer, and the greater the annual non condensation hours, especially in summer. In general, \( h_{D,e} \) increases in all months except from June to September, this may be because the room can be exposed to more sunlight directly in winter when the glazing ratio increases, which increases the indoor temperature and then increases the thermal comfort hours. In summer, especially from June to September, the indoor solar heat gain increases when the glazing ratio increases, which makes the indoor temperature rise so as to diminish the thermal comfort hours. But for the non-condensation hours increasing due to the rise of the glazing ratio, \( h_{D,e} \) remains unchanged under the mutual influence of the above reasons.
As for the growth of DNVP, beginning to slow down after the glazing ratio exceeds 0.5, it may be because excessive glazing ratio will also increase the indoor and outdoor air exchange ratio in winter, which will offset the increase in solar heat gain caused by the increase of glazing ratio.

![Figure 11](image-url) Relationship between the thermal storage coefficient of main material and INVP$_{ob}$.

4. Conclusions

This paper proposed a new NVP evaluation method and carried out the parametric simulation optimization of ordinary office buildings in Guangzhou on the basis of it. After analyzing the comprehensive and single factor effects of building orientation, building density, thickness of roof insulation, main material of wall, ventilation mode and glazing ratio on NVP, it can be concluded that low building density, building toward southwest, high glazing ratio or cross ventilation will bring about high DNVP. Meanwhile there is an optimal value for the thermal resistance of roof, and the greater the thermal storage coefficient of the main material of wall is, the greater the INVP is. And the main factors that limit the DNVP of ordinary office buildings in Guangzhou is condensation in summer, the DNVP can be improved if appropriate measures are taken to prevent it.

The NVP evaluation method proposed in this paper can provide reference for architects’ natural ventilation design, but there are also some shortcomings. Firstly, because many factors should be considered in architectural design, there will be many restrictions in practice. For example, in this paper, the best building orientation is 40° SBW, but in the actual design, many factors such as daylighting and surrounding environment need to be considered, which means that building orientation of 40° SBW is not necessarily the best. And the building density of 0.1 is often not practical in actual design. Secondly, although the calculation results of NVP by computer simulation method is more accurate, it is also more time-consuming. Therefore, in practical use, it is often necessary to reasonably divide the parameters and optimize the parameters within the acceptable range of independent variables. Thirdly, with no anti-condensation measures taken in this simulation experiment, the optimization suggestions of architectural factors in the above conclusions are mainly to improve the thermal comfort hours in winter, and the results may be different for buildings that value anti-condensation. Finally, due to the limitation of computer performance and simulation time, the simulation experiment in this paper has some deficiencies in the selection, range and divided numbers of parameters, which will be further improved in the following study.

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