The heat gain-based generation method of coincident weather data for walls with a large thermal lag

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Abstract. The coincident weather data (CWD) means the combination of weather data that affect a moment of indoor heat gains at the same time. It includes the coincidence of dry-bulb temperature, wet-bulb temperature and solar irradiation. The selection of design solar irradiation in the current ASHRAE and CIBSE design handbooks is independent on design dry-bulb and wet-bulb temperature. And the generation methods of CWD in those are based on the original weather data itself. Furthermore, the generation methods in some related literatures are either ignoring the thermal delay and decay of building envelope or not appropriate for engineering using. Hence, a new method based on the hourly heat gain formula, three weather parameters, building heat characteristics and risk factor was developed for the generation of coincident solar irradiance, dry-bulb and wet-bulb temperature. The method was applied to historic weather records of 25 years in Hong Kong and data of 302 kinds of walls to generate coincident design weather data. The result shows that the design dry and wet bulb temperature can be lowered and the solar radiation values are more regular, compared to traditional weather data. In a category of walls, the deviation between the representative parameter and CWD is less than 5%. It’s means that using the new CWD can reduce the building energy consumption, and engineering heat gain calculations can be more precise and concise.

1. Introduction

Design outdoor coincident weather data means the combination of weather data that affect a moment of indoor heat gains at the same time. The coincident weather data is required in confirming the actual indoor peak load for sizing air-conditioning systems [1,2]. The actual load is different with the traditional indoor design load which is simulated by independent weather data conditions. In general, the actual load is less than the traditional design load. Improper independent design weather data conditions may lead to oversized HVAC system, which will result in unnecessary extra capital cost and low part-load efficiency or frequent failures in providing sufficient cooling or heating. Hence, coincident solar irradiation, dry-bulb and wet-bulb temperatures should be properly selected, and corresponding calculated method should be generated at the same time, so that the engineer could gain the approximate actual load.

Tingyao Chen and Zhun Yu [3] developed a statistical method for selection of sequences of coincident weather parameter. The method combined with the radiant time series factors and z-transfer coefficients to calculate the indoor hourly cooling load, then select the peak load and coincident weather parameters from results. They consider that the coincident weather parameter is effected by window types, wall types, window-to-wall ratio, wall face, the number of air change per hour and so on, not only measured and record weather data. Combination of all these properties of zone design yields 1440 cases. Hence, they applied the method and 1440 cases to the hourly weather records of 25 years in Hong Kong to generate the hourly cooling loads and coincident weather parameters. And then, the analysis result shows that the peak cooling load resulted from the traditional design weather data is always much higher, 12-50%, than the results from the new design coincident weather data.

Y.M Chen and T.Y Chen [4] indicated that the selection of design solar irradiance in the current ASHRAE [1] and CIBSE [2] design handbooks is independent on design dry-bulb and wet-bulb
temperatures. It will lead to that the indoor design load is greater than the actual load, so that the design load would not matching the HVAC system capacity. Hence, they developed a statistic method to select coincident solar irradiance, dry-bulb and wet-bulb temperatures. This method applies to the buildings whose thermal lag is less than one hour. The conclusions show that the current design solar irradiance could be more than 19% higher than the rational value, and the current design coincident dry-bulb and wet-bulb temperatures could be more than 6 degrees centigrade higher as compared to the newly generated design dry-bulb and wet-bulb temperatures.

ASHRAE Handbook [1] and Civil Building Air Conditioning Design [5] put forward the methods and design parameters suitable for indoor load calculation. The difference between them is that the dry and wet bulb temperature of ASHRAE is the form of dry bulb temperature & mean coincident wet bulb temperature, while the dry and wet bulb temperature of Civil Building Air Conditioning Design is independent. And the calculation of solar radiation load is different. The common point of the two is that the influence of each meteorological parameter on the indoor load is calculated independently.

2. Method

2.1. Indoor heat gains calculation model

There are many factors that need to be considered in the actual heat gain calculation method with thermal delay. In order to describe the heat lag and decay of envelope and the heat gain-based coincidence weather data, the paper presents a coincidence weather data generation method to generate the three-parameter coincidence weather data that includes the characteristic of the building envelope. This generation method is based on the fundamental simulation method of building heat gain:

\[ Q(k) = \sum_{j=0}^{n} (UA_j) (t_e(k) - t_w) + m_0 c_{pa} (t_{db}(k) - t_{i}) + m_0 h_i (W_0(k) - W_{rec}) + A_{wd} (IAC)[SHGC(\theta(k))E_D(k)] + <SHGC >_D E_d(k) \] (1)

In the fundamental simulation method, \( k \) is the discrete time (h), \( t_e \) is the sol-air temperature, \( A_{wd} \) is the window area (m\(^2\)), \( A \) is the area of external envelope of building or room (m\(^2\)), \( h_1 \) is the latent heat (2430 × 10\(^3\)/kg), \( c_{pa} \) is the sensible specific heat capacity of air (1010/J/(kg · °C)), \( E_D \) is the direct irradiance (W/m\(^2\)), \( E_d \) is the diffuse sky irradiance (W/m\(^2\)), \( E_{dt} \) is the diffuse irradiance (W/m\(^2\)), \( E_r \) is the ground-reflected irradiance (W/m\(^2\)). IAC is the inside shading attenuation coefficient, \( SHGC \) is the direct solar heat gain coefficient as a function of incident angle \( \theta \), \( <SHGC>_D \) is the diffuse solar heat gain coefficient, \( t_{rc} \) is the presumed constant room air temperature (°C), \( U \) is the overall heat transfer coefficient of walls, roofs or windows(W/(m\(^2\) · K)), \( m_0 \) is the outdoor air mass flow rate introduced into room (kg/s), \( W_{rec} \) is the presumed constant room air humidity ratio (kg/kg), \( \theta \) is the incident angle (rad), \( n \) is the total number of external envelope components of a building or room.

There need use dynamic calculation method to calculate the heat gains of building envelope. Professor Wang & Professor Chen proposed a method that use FDR method [10] to solve the z-transfer function of multilayer wall and then calculate those z-transfer coefficient \( b_k \) & \( d_k \). Hourly heat gains of the wall could be calculated succinctly, quickly and clearly.

When indoor air temperature \( T_{rec} \) is constant, hourly heat gains of the wall is \( Q(\tau)_n \), that

\[ Q(\tau)_n = \sum_{i=0}^{n} b_i T_{out}(\tau_n - i) - \sum_{i=1}^{m} d_i Q(\tau_n - i) - T_{rc} \sum_{i=0}^{r} c_i \] (2)

Use \( Q(\tau)_n \) replace the part which means the wall heat transfer of the fundamental simulation method. On one side wall, there is:

\[ Q(k) = A \left[ (1 - \varepsilon) \left( \sum_{i=0}^{r} b_i t_e(\tau_n - i) - \sum_{i=1}^{m} d_i Q(\tau_n - i) - t_{rc} \sum_{i=0}^{r} c_i \right) + \varepsilon U_{wd}(t_{db}(k) - t_{rec}) \right] + m_0 c_{pa}(t_{db}(k) - t_{rec}) + m_0 h_i (W_0(k) - W_{rec}) + \varepsilon A(IAC)[SHGC(\theta(k))E_D(k) + <SHGC>_D E_d(k)] \] (3)
\( \varepsilon \) is the window-wall ratio.

### 2.2. Derived parameters for CWD generation

Importing the outdoor meteorological which includes dry-bulb temperature, wet-bulb temperature and horizontal face total irradiance, the indoor hours-heat-gain could be calculated, after figuring out the characteristic parameters of room or building. But the calculation is complicated for engineers even though they already know the characteristic parameters of building, because the calculation method is a dynamic algorithm. So, the calculation method needs to be further simplified.

Defining equivalent dry bulb temperature without delay (EDTD)

\[
EDTD(k) = \frac{Q_{ep}(k)}{U_{ep}} + t_{rc}
\]

Where \( Q_{ep}(k) \) is calculated by Eq. (2), \( U_{ep} \) is wall heat transfer coefficient. It means that after we calculated and generated the coincident weather data by the original dynamic formula, the engineer could use it in a simpler way.

Meanwhile, another derived parameter coincident equivalent integrated temperature (CET) is defined as

\[
CET(k) = \frac{Q(k)}{A \cdot U_{ep}}
\]

### 2.3. Selection of coincidence design weather data

There is an example-room to introduce the generation process of coincident weather data. The room consists of one east facing outer wall and three inner walls. The outer wall 240mm thick and the outer surface is coated with 20mm thick lime mortar. The thermal delay time of this wall is 7.87h, and the thermal attenuation coefficient is 10.94. The windows are type I, and the window-wall ratio is 0.4, indoor design temperature is 24\(^\circ\)C, ventilation quantity is 3m\(^3\)/h\( \cdot \)m\(^2\). The original weather data is time-measured data from the Hong Kong Observatory, 1979-2003.

After importing the measured meteorological parameters and using the aforesaid building heat gain model to calculate the hourly heat gain of the building, removing some of the extreme heat gain and obtaining the peak heat gain according to the set risk factor. Next, 10-30 daily parameters were selected from the source data according to the obtained peak heat gain. Then select the most appropriate set of daily parameters from these daily parameters according to the filter rules.

The screening rules briefly include:

- In the hourly heat gain generated by the selected day parameter, the peak heat gain is the maximum heat gain for that day.
- Among the peak heat gain generated by the selected daily parameters, the proportion of heat gain affected by various meteorological factors in total heat is the most representative

For the above example room, a part of daily coincident weather data obtained by filtering are shown in the following table 1.

**Table 1. Daily coincident weather data for example-room (part)**

| Time | DBT | WBT | THR | DTR | DFR | RFR | EDTD | CET |
|------|-----|-----|-----|-----|-----|-----|------|-----|
| 1-6  |     |     |     |     |     |     |      |     |
| 7    | 28.8| 26.7| 52.8| 18.2| 63.3| 6.6 | 33.4 | 54.7 |
| 8    | 29.1| 26.5| 238.9| 160.7| 238.5| 29.9| 33.0 | 79.8 |
| 9    | 29.8| 26.8| 441.7| 166.9| 301.6| 55.2| 32.8 | 88.6 |
| 10   | 30.5| 26.8| 558.3| 139.6| 316.5| 69.8| 33.0 | 89.1 |
| 11   | 31.0| 27.2| 475.0| 24.6| 304.5| 59.4| 33.9 | 81.7 |
| 12   | 30.4| 26.5| 488.9| 7.1 | 260.2| 61.1| 35.4 | 75.8 |
| 13   | 30.7| 26.5| 522.2| 0.0 | 220.5| 65.3| 37.1 | 75.6 |
| 14   | 31.1| 27.1| 563.9| 0.0 | 189.1| 70.5| 38.6 | 74.9 |
| 15-24|     |     |     |     |     |     |      |     |
Where DBT is the Dry-bulb temperature (℃), WBT the Wet-bulb temperature (℃), THR the Total horizontal radiation(W/㎡), DTR the Direct radiation of vertical(W/㎡), DFR the Vertical diffuse radiation(W/㎡), RFR the Ground reflected radiation(W/㎡).

The table 1 is the generation hourly coincident weather data and corresponding hourly measured data of the example-room, in the case of risk factor of 0.4, based on peak heat gain. These data show that the peak heat gain occurs at 10 o’clock, and the THR, DBT and WBT are not maxima or minima at 10 o’clock. It’s means that the indoor peak heat gain is combined maximum effected by all weather data, not a sum value of the maximum value of all kinds of heat gain.

Table 2. Coincident weather data in eight orientations and for risk factors

| Orientations | N     | NE    | E     | SE    | S     | SW    | W     | NW    |
|--------------|-------|-------|-------|-------|-------|-------|-------|-------|
| Wall=1, Glazing class=1, E=0.4, Tr=24, Risk factor=0.4% | CET 75.9 | 82.5 | 89.1 | 86.8 | 89.2 | 101.1 | 111.1 | 101.5 |
|             | EDTD 33.6 | 33.9 | 33.0 | 31.8 | 35.2 | 34.8 | 35.0 | 35.9 |
|             | DBT 32.0 | 29.6 | 30.5 | 30.2 | 31.6 | 29.5 | 30.4 | 30.8 |
|             | WBT 25.7 | 26.4 | 26.8 | 26.9 | 26.8 | 25.3 | 25.2 | 27.3 |
|             | TR 296.2 | 434.3 | 526.0 | 504.7 | 458.2 | 712.8 | 824.2 | 644.8 |

| Wall=1, Glazing class=1, E=0.4, Tr=24, Risk factor=1.0% | CET 73.9 | 78.6 | 84.8 | 83.1 | 85.4 | 96.2 | 105.5 | 94.8 |
|             | EDTD 32.4 | 32.0 | 32.7 | 30.8 | 31.5 | 31.5 | 36.6 | 35.4 |
|             | DBT 32.9 | 30.4 | 30.1 | 29.6 | 29.1 | 26.7 | 32.4 | 30.5 |
|             | WBT 25.1 | 24.7 | 26.2 | 26.5 | 24.5 | 23.1 | 27.5 | 25.8 |
|             | TR 253.5 | 406.5 | 474.5 | 468.3 | 529.3 | 739.0 | 662.2 | 594.5 |

| Wall=1, Glazing class=1, E=0.4, Tr=24, Risk factor=2.0% | CET 71.9 | 74.7 | 79.6 | 79.5 | 81.5 | 91.7 | 97.3 | 87.7 |
|             | EDTD 35.1 | 33.1 | 31.5 | 32.6 | 23.6 | 27.5 | 40.4 | 34.5 |
|             | DBT 31.1 | 28.4 | 29.6 | 30.2 | 22.4 | 23.8 | 30.9 | 29.1 |
|             | WBT 26.5 | 26.1 | 25.0 | 26.9 | 17.8 | 19.8 | 26.6 | 25.1 |
|             | TR 254.4 | 385.6 | 423.7 | 399.7 | 742.0 | 797.4 | 557.3 | 534.4 |

The table 2 is the DBT, WBT, total radiation (TR) and so on in eight orientations under given conditions. The risk factor is 0.4, 1 and 2 respectively. The coincident weather data of outer wall in different directions showed regular differences with the change of direction. Further analysis revealed that the solar radiation accounts for a large proportion of total indoor heat gain for the example thermal insulation outer wall. Therefore, coincident weather data of the example-room with different orientations changes regularly with the position and angle between the earth and the sun.

3. Comparison and verification

3.1. Comparison with tradition weather data

As shown in the previous table, when the risk factor is 0.4, coincident weather data is dry-bulb temperature 30.5℃, wet-bulb temperature 26.8℃, total vertical radiation 526W/㎡, EDTD 33.3℃, CET 89.1℃. For the example room, the calculation parameters of outdoor air conditioning in summer in Hong Kong listed in HVAC system reference book “Civil Building Air Conditioning Design” [8] are dry-bulb temperature 32.4℃, wet-bulb temperature 27.3℃, east radiation values in 509W/㎡ ~541W/㎡. The maximum value of coincident dry-bulb temperature is 1.9℃ lower and coincident wet-bulb temperature 0.5℃ than the value of reference book, respectively.

In addition, for other orientations, the generated coincident dry-bulb temperature and the difference between the coincident dry-bulb temperature and the reference dry-bulb temperature in reference book is as following table:
The daily design reference calculation weather data given in the “Civil Building Air Conditioning Design” do not include the solar radiation value parameters, and the indoor solar radiation is calculated separately. The coincidence of three weather parameters influenced by architectural features is not considered in this reference book.

In the 2017 ASHRAE Handbook, the design and calculation weather parameters of building HVAC system are the combined parameters of dry-bulb temperature and mean coincident wet-bulb temperature or wet-bulb temperature and mean dry-bulb temperature. The design dry-bulb temperature is 33.0°C and mean wet-bulb temperature 27.1°C in Hong Kong. The design dry-bulb temperature and wet-bulb temperature generated by the new method 2.5°C and 0.3°C lower than the ASHRAE Handbook, respectively. Indoor solar radiation is also calculated separately in the ASHRAE, and the reference value of peak radiation are shown in table 4:

| Orientation | N | NE | E | SE | S | SW | W | NW |
|-------------|---|----|---|----|---|----|---|----|
| DBT(℃)      | 32.0 | 29.6 | 30.5 | 30.2 | 31.6 | 29.5 | 30.4 | 30.8 |
| DIF(℃)      | 0.4 | 2.8 | 1.9 | 2.2 | 0.8 | 2.9 | 2.0 | 1.6 |
| WBT(℃)      | 25.7 | 26.4 | 26.8 | 26.9 | 26.8 | 25.3 | 25.2 | 27.3 |
| DIF(℃)      | 1.6 | 0.9 | 0.5 | 0.4 | 0.5 | 2.0 | 2.1 | 0.0 |

The peak solar radiation generated by new method as follow:

| Orientation | N | NE | E | SE | S | SW | W | NW |
|-------------|---|----|---|----|---|----|---|----|
| Direct(W/m²) | 106 | 442 | 524 | 299 | 21 | 299 | 524 | 442 |
| Diffuse(W/m²) | 97 | 149 | 178 | 193 | 197 | 193 | 178 | 149 |
| Total(W/m²)   | 203 | 590 | 702 | 492 | 218 | 492 | 702 | 590 |

The peak solar radiation values in coincident weather data

| Orientation | N | NE | E | SE | S | SW | W | NW |
|-------------|---|----|---|----|---|----|---|----|
| Direct(W/m²) | 0 | 108.3 | 139.6 | 106.7 | 186.9 | 535.0 | 617.7 | 437.7 |
| Diffuse(W/m²) | 225.0 | 235.3 | 316.5 | 323.0 | 177.8 | 98.3 | 129.4 | 129.0 |
| Reflected(W/m²) | 71.2 | 90.6 | 69.8 | 75.0 | 93.4 | 79.5 | 77.1 | 78.1 |
| Total(W/m²)   | 296.2 | 434.3 | 526.0 | 504.7 | 458.2 | 712.8 | 824.2 | 644.8 |

| Orientation | N | NE | E | SE | S | SW | W | NW |
|-------------|---|----|---|----|---|----|---|----|
| Direct(W/m²) | 98.6 | 63.0 | 53.4 | 54.6 | 0.9 | 128.6 | 535.2 | 306.9 |
| Diffuse(W/m²) | 73.9 | 276.7 | 301.9 | 263.8 | 244.5 | 227.5 | 95.0 | 188.7 |
| Reflected(W/m²) | 82.0 | 45.8 | 68.4 | 81.3 | 65.3 | 77.4 | 42.7 | 38.9 |
| Total(W/m²)   | 254.5 | 385.6 | 423.7 | 399.7 | 310.7 | 433.5 | 672.9 | 534.4 |

It can be found from the above table that the solar radiation values given in ASHRAE Handbook are roughly symmetrical distribution. For example, the orientations of northeast (NE) and northwest (NW) are both 590W/m², and the east (E) and west (W) are both 702 W/m², etc. The reason is that the solar radiation value given by ASHRAE is the reference value obtained from the statistical analysis of solar radiation, and the solar radiations is roughly symmetrical in the east-west axis. For
the example room, the coincident solar radiation generated by new method is lower than the reference value given by ASHRAE in partial orientations, and larger in other orientations.

When the wall and window materials remain unchanged and some architectural characteristics (such as window-wall ratio, risk factor, etc.) change, coincident weather data will change correspondingly. Take the solar radiation value as an example, when the risk factor increases from 0.4 to 2.0, the generated total solar radiation value in all orientations decreases. The change of radiation value is consistent with the risk factor of 0.4. And when the risk factor remains unchanged and the window-wall ratio decreases from 0.4 to 0.3, the generated total radiation value doesn’t change much.

3.2. Comparison within the same classification group

Through calculation and statistics, it is found that although the composition of some walls is different, the overall thermal decay coefficient, thermal delay time and heat transfer coefficient are relatively close. For the wall with similar thermal decay coefficient and thermal delay time, its heat transfer characteristics are also similar. In the coincident weather data generation method, for each type of wall, a set of corresponding coincident weather data can be generated for heat gain or load calculation.

The walls within the same range are divided into a group, and the coincident weather data of the wall in the same group are replaced by a set of unified coincident weather data.

Take a group of walls as an example, the group contains the following walls:

- Wall-1: thermal decay coefficient 10.94, thermal delay time 7.87 hours, heat transfer coefficient $2.049 \frac{W}{(m^2 \cdot ^\circ C)}$.
- Wall-4: thermal decay coefficient 12.71, thermal delay time 8.46 hours, heat transfer coefficient $1.963 \frac{W}{(m^2 \cdot ^\circ C)}$.
- Wall-20: thermal decay coefficient 10.71, thermal delay time 7.89 hours, heat transfer coefficient $2.135 \frac{W}{(m^2 \cdot ^\circ C)}$.
- Wall-210: thermal decay coefficient 12.78, thermal delay time 7.67 hours, heat transfer coefficient $2.037 \frac{W}{(m^2 \cdot ^\circ C)}$.

Take the above example room as an example, under the condition that the risk factor is 0.4, calculating the heat gain in the room with different walls and generating the coincident weather data, respectively. The peak CET of all orientations of each wall was obtained for comparison, as shown in the following table.

| Orientations | N     | NE    | E     | SE    | S     | SW    | W     | NW    |
|--------------|-------|-------|-------|-------|-------|-------|-------|-------|
| Glazing class=1, E=0.4, Tr=24, Risk factor=0.4% |       |       |       |       |       |       |       |       |
| W-1          | 75.9  | 82.5  | 89.1  | 86.8  | 89.2  | 101.1 | 111.1 | 101.5 |
| W-4          | 77.5  | 84.7  | 91.6  | 89.3  | 91.5  | 103.6 | 114.0 | 104.0 |
| W-20         | 73.3  | 79.6  | 86.0  | 83.8  | 86.0  | 97.4  | 107.2 | 97.9  |
| W-203        | 75.5  | 82.3  | 89.0  | 86.7  | 89.2  | 101.0 | 111.1 | 101.4 |
| Mean         | 75.6  | 82.3  | 88.9  | 86.7  | 88.2  | 100.8 | 110.9 | 101.2 |
| Max-1        | 3.14% | 3.39% | 3.37% | 3.46% | 3.61% | 3.49% | 3.45% | 3.37% |
| Max-2        | 5.73% | 6.41% | 6.51% | 6.56% | 6.39% | 6.37% | 6.34% | 6.23% |

For the walls in the same group, when the mean value is used as the representative value of the group, the maximum deviation between the values in the group and the mean value (Max-1) is only 3.14%~3.61%. If the maximum value in the group is used as the representative value of the group, the deviation between the minimum value and the maximum value (Max-2) in the group is 5.73%~6.56%, which is within the acceptable range also.

Of course, the rationality of parameters is not only limited to the verification of the maximum value, but also includes the verification of the rationality of all-day parameters and the applicability of building characteristic parameters within the range of small changes, etc. The current research results are not perfect, and further research and discussion are needed.
4. Conclusion
This paper briefly describes the concept of heat gain-based coincident weather data and its generating method, and then compares the generated coincident weather data with traditional weather parameters and the data of the same group of walls. The advantage of coincident weather data is that it can more accurately describe the relationship between meteorological data and building characteristic parameters with indoor heat gain and load. And more accurate coincident weather data will be more conducive to engineers to estimate the indoor load and equipment energy consumption.

From the comparison with the traditional parameters, the coincident weather data can reduce the design dry-bulb temperature and wet-bulb temperature to a certain extent, and make the solar radiation value more consistent with the reality. Different orientations and different architectural features have different coincident weather data values, which can better meet the needs of architectural design and calculation.

Of course, for a wide variety of coincident weather data, it is necessary to simplify the type of coincident weather data in order to facilitate the use of engineers in practical projects. In this paper, only one of the various simplifications -- wall type simplification is briefly described. In this description, the verification should include not only the verification of peak data, but also the comprehensive verification of all-day parameters. Moreover, the simplified verification of parameters not only includes the simplification of wall type, but also other architectural characteristic parameters (including but not limited to the window-wall ratio, ventilation frequency, orientation, etc.). In addition, there are indoor heat gain and indoor load of relevance and correction. Research on coincident weather data is still ongoing.

References
[1] ASHRAE, ASHRAE Handbook---2017 Fundamentals, American Society of Heating, Refrigerating, and Air-Conditioning Engineers Inc., Atlanta, 2013.
[2] CIBSE, Environmental design, CIBSE Guide A, The Chartered Institution of Building Services Engineers, London, 1999.
[3] Tingyao Chen, Zhun Yu, A statistical method for selection of sequences of coincident weather parametersfor design cooling load calculations, Energy Conversion and Management 50 (2009) 813-821.
[4] Tingyao Chen, Youming Chen, Francis W.H. Yik, Rational selection of near-extreme coincident weather data with solar irradiation for risk-based air-conditioning design, Energy and Buildings 39 (2007) 1193-1201.
[5] Zuiliang Ma, Yang Yao, Civil Building Air Conditioning Design (2015), Chemical Industry Press.
[6] D.G. Colliver, H. Zhang, R.S Gates, K.T. Priddy, Determination of the 1%, 2.5%, and 5% occurrences of extreme dew-point temperature and mean coincident dry-bulb temperature, ASHRAE Transactions 101 (2) (1995) 265-286.
[7] T.Y. Chen, F. Yik, J. Burnett, A rational method for selection of coincident climate design conditions for required system capacity reliability, Energy and Buildings 35 (2005) 555-562.
[8] K.G. Hubbard, K.E.K. Kunkel, A.T. DeGaetano, K.T. Redmond, Sources of uncertainty in the calculation of design weather conditions, ASHRAE Transactions 111 (2) (2005) 317-326.
[9] Qishen Yan, Qingzhu, Zhao, Building Thermal Process, China Building Industry Press.
[10] Wang S W, Chen Y M. Transient heat flow calculation for multilayer constructions using frequency-domain regression method, Building and Environment, 2003, 38(1): 45-61.