

Degree-days of Heating Cooling and Their Characteristics of Distribution in Shandong Province

Yongan Li, Jing Chang, Weiguo Rong, Xuelai Liu

Shandong University of Architecture and Engineering, Ji'nan, China

Abstract: The composing of standard year weather parameters is researched and average months in Shandong Province, P.R. China are selected by use of 10 years measured meteorological data based on analysis of regular pattern of meteorological change. Heating degree-day (HDD) and cooling degree-day (CDD) of every place in Shandong Province are figured out and their distribution characteristics are discussed. Firm foundation is laid for calculating heating energy consumption, air-conditioning energy consumption and researching building energy efficiency.

Keywords: Heating degree-day, Cooling degree-day, Characteristics, Standard year, Weather parameters.

1. INTRODUCTION

Now in China heating energy and air-conditioning energy have accounted for 27.6% of national energy consumption. With the development of economy and improvement of people's life, heating energy and air-conditioning energy will keep rising. Since 30 years researches and practices of energy field have proved building energy efficiency is the most potential, direct and efficient of every energy saving methods and is also the most efficient measure of relieving energy tension and handling the contradiction between the development of economy and the shortage of energy supply^[1]. At present calculating heating and air-conditioning energy correctly, taking proper measures on the premise of satisfying the comfort standard, and saving the energy consumption of heating and air-conditioning can improve building heat environment, increase energy usage of HVAC, then radically change the condition of building energy waste, and contribute to realizing the national stratagem of saving energy and protecting environment and to carrying out policies and laws concerned.

There are many calculation methods of heating and air-conditioning energy consumption. Calculation methods are divided into two types on the basis of mathematics models: one is dynamic simulation method based on unstable heat transfer theory. In this method all influencing factors are considered and more accurate results can be obtained. But when making energy calculation by use of it, the computer is a must and it's difficult for common untreated engineers to grasp enormous programs. The other is simple calculation method based on stable heat transfer theory and its characteristics are simplicity. In the simple calculation method energy consumption of heating and air-conditioning is calculated according to stable heat transfer while heat storage of none part of the envelope is considered. The method of calculating energy consumption of heating and air-conditioning by

degree-day belongs to the latter type. Since the energy consumption index of energy saving building is linear with heating degree-day (HDD) and cooling degree-day (CDD)^[2,3], researches on HDD and CDD lay foundation for energy consumption analysis.

2. COMPOSING OF STANDARD YEAR WEATHER PARAMETERS

Shandong Province is located in the east of North China Plain, on the lower reaches of Yellow River. Byland part of Shandong Province faces Bohai Sea on the north while northeast and south parts are adjacent to Yellow Sea. It lies in warm temperate zone with grassland monsoon climate and is influenced greatly by the oceans. In Shandong Province it is dry and windy in the spring, hot and rainy in the summer, dry and cold in the winter, and autumn comes tardy and it tends to be droughty in the autumn. The yearly average temperature of the province is 11~14.5℃, and the average temperature in January is -5~ -1℃ and 24~28℃ in July. On the whole the average temperature of east Shandong Province is lower while that of southwest Shandong Province is higher. The annual range and the daily range of air temperature of east coastland are smaller while those of west inland are larger. The extreme minimum air temperature is -27℃ and the extreme maximum is 43.4℃. Fig.1 shows the daily change curve of air dry-bulb temperature of Ji'nan City in July.

When making one year's energy consumption of heating and air-conditioning, degree-days of one year are necessary. Since weather parameters are stochastic, it is unreasonable to take the data of some random year in the calculation, yet the data must be singled out from a standard year, and then the energy consumption of heating and air-conditioning derived from the weather parameters of standard year is representational. So it is critical how to define standard year weather parameters in the calculation of energy consumption of heating and air-conditioning.

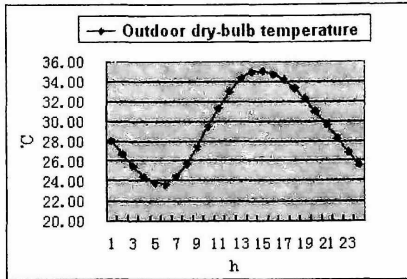


Fig.1 The daily change curve of air dry-bulb temperature of Ji'nan City

So-called standard year weather parameters can be acquired as follows: from latest 10 years' samples of local weather facility, namely 120 months' statistic samples of weather parameters, 12 representational average months which can show weather laws are singled out; and then hourly weather parameters of every average month are applied to dynamic load calculation; those 12 months are linked up in turn and then the weather parameters acquired are defined as standard year weather parameters

Outdoor weather factors influencing building cooling load comprise 7 parameters: temperature, humidity, solar direct radiation, solar diffuse radiation, cloud cover, wind direction and wind velocity. In order to decrease the workload of selecting average months Tian Shengyuan^[4,5] discussed the relativity between those 7 parameters and air-conditioning load against classical buildings. His research results showed temperature, humidity and solar radiation were the most influencing parameters and their multiple correlation coefficients with analysis was found out air-conditioning load approached 10 years load average in the years when the average of three weather elements approached 10 years average. And this is the basis for selecting weather data of average months.

When average months are selected with DM method, firstly those are singled out primarily by principle of the average of three weather elements of some a month approaching the average of the month past years. That is, three weather elements must satisfy the following equation:

$$\left| X_{Ri,n} - \bar{X}_{Ri} \right| \leq \sigma_{Ri} \quad (1)$$

where R is 1, 2 or 3 corresponding to air dry-bulb temperature, humidity content or total radiation intensity respectively; $X_{Ri,n}$ is month average of parameter R on the month i in the year n of those ten years; $\bar{X}_{Ri}$ is 10-year average of parameter R on the month i and σ_{Ri} is 10-year standard variance of parameter R on the month i .

But, in those 10 years not all months which satisfy Eq. (1) exist in only a year, so overall target DM

determining average months ultimately is introduced from the viewpoint of heat load. DM is as follows:

$$DM = (X_{1i,n} - \bar{X}_{1i}) + K_2 (X_{2i,n} - \bar{X}_{2i}) + K_3 (X_{3i,n} - \bar{X}_{3i}) \quad (2)$$

where K_2 is weight coefficient of humidity content influencing air-conditioning load and

$K_2 = \Delta CL_x / \Delta CL_t$, and K_3 is weight coefficient of solar radiation influencing air-conditioning load and $K_3 = \Delta CL_s / \Delta CL_t$, were all over 0.7. Thus those 3 parameters are called three weather elements. According to load therefore it is obvious that the closer DM of one month of months satisfying Eq. (1) is to 0, the more weather parameters of the month are of representation and that it should be select as an average month^[4,6].

The calculation of K_2 and K_3 is as follows.

In the foregoing equations of K_2 and K_3 , ΔCL_t , ΔCL_x and ΔCL_s represent load increment caused by per unit increment of outdoor temperature, humidity content and solar radiation respectively.

$$\Delta CL_t = A_w \left[(1-m) K_w + M \cdot K_R \right] \cdot \frac{1}{2} \cdot A_n \cdot \frac{1}{2} K_n + A_{RO} \cdot K_{RO} + 1.2 \times 0.24 GF \quad (3)$$

$$\Delta CL_x = 1.2 \times 0.597 GF \quad (4)$$

$$\Delta CL_s = \frac{1}{24} V_s \cdot A_w \left[(1-M) \frac{\rho_w}{\alpha_w} K_w + MG_j \right] + \frac{1}{24} A_{RO} \cdot \frac{\rho_{RO}}{\alpha_{RO}} K_{RO} \quad (5)$$

where A_w , A_n and A_{RO} is area (m^2) of external walls (including windows), inner wall and roofs respectively; K_w , K_R , K_n and K_{RO} is conductivity ($w / m^2 \cdot ^\circ C$) of external walls, windows, inner walls and roofs respectively; G , F is new wind rate ($m^3 / m^2 \cdot h$) of unit building area and building area (m^2); M , G_j is aperture opening ratio and radiation load through grass windows respectively, and V_s is reduction coefficient of vertical walls against horizontal walls radiation accumulated value.

$$V_s = \frac{1}{4} \frac{\int_{\tau_1}^{\tau_2} (J_e + J_s + J_w + J_n) d\tau}{\int_{\tau_1}^{\tau_2} J_A d\tau}$$

Where J_e , J_s , J_w , J_n and J_h is total solar radiation intensity of east, south, west, north vertical walls and horizontal walls respectively^[7,8].

3. DISTRIBUTION CHARACTERISTICS OF HDD AND CDD

Degree-day is defined as per day per degree difference between daily average temperature and specified reference temperature. Namely degree-day of some day is the difference between the average temperature of the day and the reference temperature. With weather parameters of local standard year adopted, when in winter 18℃ is taken as reference temperature and in summer it is 26℃, heating degree-day HDD18 and cooling degree-day CDD26 are described as:

$$HDD18 = \sum_{i=1}^{365} (18 - t_i) \quad (^\circ\text{C} \cdot \text{d}) \quad (6)$$

$$CDD26 = \sum_{i=1}^{365} (t_i - 26) \quad (^\circ\text{C} \cdot \text{d}) \quad (7)$$

where t_i is daily average temperature of day i of standard year, D is a day and namely $D = 1d$.

In the calculation process if $18 - t_i$ or $t_i - 26$ is minus, $(18 - t_i)$ or $(t_i - 26)$ is taken as zero.

Table 1 shows HDD^[9] and CDD of central cities in Shandong Province.

Table 1 : HDD and CDD of Shandong Province

Cities	HDD18 (℃·d)	CDD26 (℃·d)
Ji'nan	1757	170
Qingdao	1881	50
Heze	1903	72
Linyi	1926	60
Weifang	2132	61
Zibo	2054	70
Dezhou	2124	160
Yantai	1943	54

From the table the distribution characteristics of HDD and CDD of Shandong Province are found out. Ji'nan faces Yellow River on the north, lays aboard Mountain Tai on the south, lies below the circumference and then its heat island effect is prominent, and its CDD26 can reach 170℃·d, the maximum of overall province, so Ji'nan has been always named as one of four burners. In winter it has 110 heating days and its HDD18 is 1757℃·d.

In north Shandong Province heating period is 110~120 days, HDD18 is 1700~2300℃·d and CDD26 is 160~170℃·d. Judging from the climate, Dezhou is a very special area. The extreme minimum air temperature -27℃ and the maximum 43.4℃ of Shandong Province both appear in Dezhou. In heating period outdoor average temperature of Binzhou is -1.3

℃, the lowest of Shandong Province.

In middle Shandong Province heating period is 111~115 days, HDD18 is 2050~2150℃·d and CDD26 is 60~70℃·d.

In south Shandong Province heating period is 100~110 days, HDD18 is 1650~1950℃·d and CDD26 is 60~75℃·d.

In Jiaodong Byland heating period is 110~130 days, Weihai's is the most long, 127 days and HDD18 is 1800~2350℃·d. Jiaodong Byland lies in marine climate zone and has cool summer, so CDD here is small universally and CDD26 is 50~60℃·d.

4. CONCLUSIONS

- (1) Shandong Province is in cold zone. In winter heating period is 101~127 days, HDD18 is 1757~2337℃·d and outdoor average temperature of heating period is -1.3~0.9℃.
- (2) In Shandong Province it is hot and rainy in summer. CDD26 of inland is 60~170℃·d and the maximum 170℃·d appears in Ji'nan. Jiaodong Byland lies in marine climate zone, it is cool there in summer and CDD26 is 50℃·d or so. In addition, Weihai City is tied as the World's Top City to live in by U.N.
- (3) The energy consumption index of energy efficiency building is linear with HDD and CDD, therefore figuring out HDD and CDD lays good foundation for the following energy consumption analysis, controlling energy index of heating buildings and air-conditioning buildings and researching building energy efficiency.

REFERENCES

- [1] Jiang Yi. 2005. Current building energy consumption in China and effective energy efficiency measures. HV&AC. Vol 35, No 5 : 30~33. China.
- [2] Chen Guoyi, Lei Liying, Lang Siwei et al. 2001. Designing standards for resident building energy saving. Beijing: China Planning Press: 45~60. China.
- [3] Long Weiding. 2005. Energy efficiency and management of building efficiency. Beijing: China architecture & building press: 77~79. China
- [4] Tian Shengyuan, Li Baizhan. 1988. Study on composing of weather parameter for energy consumption analysis. Proceedings of HV&AC in China: 246~249. China
- [5] Chen Yiwu, Xu yong, Jiang Zhiliang et al. 2005. Establishment of outdoor meteorological mode for building energy consumption analysis. HV&AC. Vol. 35, No. 7: 20~25. China
- [6] Li Yongnan. 1993. Research and application of standard year weather parameters. Ventilation & Dust Control. Vol 12, No 2: 23~25. China.
- [7] Li Yongnan. 1995. Research on weather data for building energy consumption analysis. Energy Saving in Buildings. No. 2: 34~35. China.
- [8] Crawley D B, Lawrie L K, Winkelmann F C, et al. EnergyPlus: creating a new-generation building energy simulation program. Energy and Buildings, 2001. No. 3: 319~331. U.K
- [9] China academy of architecture science. 1996. Energy conservation design standard for new heating residential buildings. Beijing: China planning press: 17~21. China