Analysis of Building Load and Energy Consumption for Pingyi Passive and Ultra Low-Energy Consumption Science Museum

Wenyin Song[1, a], Zhao Wang[2, b]

[1]Department of Green Building, Shandong Provincial Academy of Building Research, Jinan, 250031, China

[2]Department of Green Building, Shandong Provincial Academy of Building Research, Jinan, 250031, China

[a]email: nethardtsong@163.com, [b]email:sdjkt@163.com

Keywords: Passive and Ultra Low-Energy Consumption Building; Load and Consumption Analysis; Annual Simulation Design

Abstract. The “passive house” was first presented by Prof. Adamson (Lund University, Sweden) and Dr. Wolfgang Feist (Germany) in 1988. Nowadays, “passive house” has been widely used as a kind of a low-energy consumption and high comfort energy saving building around the world. In 2014, the Passive and Low-Energy Consumption Green Building Memorandum of Understanding has made between Shandong Provincial Housing and Urban-Rural Development Bureau and Deutsche Energie-Agentur (DENA), the first 11 projects are classified as the provincial projects. This paper will analyze the building load and energy consumption of Pingyi Science Museum, in order to conform the consumption index that suit for Shandong Province.

Introduction

Since the reform and opening policy in 1970s, the high-speed development of industry and large scale of energy consumption has brought a double crisis of haze pollution and energy shortage to the whole society which cannot be ignored. Especially in the field of architecture, the annual completed building area in China makes up about half scale of the world’s building area, and a large part of which is non-energy-efficient and non-friendly-environmental buildings. Nowadays, the Chinese’s government has already promulgated many regulations and specification standards for building energy efficiency and energy saving. However, compared with the buildings of developed countries in the same climatic conditions, the building heat consumption index in China was still more than 50% higher. Ever most of China’s cities has strictly executive the 65% energy-saving standard.

It is well-known that Germany is one of the most developed countries in the world. The passive house assessment standard that established by the Passive House Institute (PHI), which is necessary and great useful for the research of buildings energy efficiency in China. At present, the foreign experts have reached a consensus that the most important part of improve energy efficiency of buildings is the passive house technology. 2014, the Passive and Low-Energy Consumption Green Building Memorandum of Understanding has made between Shandong Provincial Housing and Urban-Rural Development Bureau and Deutsche Energie-Agentur (DENA), the Pingyi Passive and Ultra Low-Energy Consumption Science Museum is classified as one of the provincial project.

© 2016. The authors - Published by Atlantis Press

Project Description and Simulation Parameters

Pingyi Passive and Ultra Low-Energy Consumption Science Museum is one of the provincial project, it is located in the west of Binhe Road, north of Yinhua Road in Linyi City, Shandong Province. The main building function include city's urban planning, high-technology development exhibition and electronic library. The museum contains 3 floors, 5.1 meters high per each floor, frame structure and the total construction area is 5556.93m^2.

Exterior Envelope Structure: according to the thermal calculation of the building exterior envelope structure with the architecture design drawings and instructions, all the thermal parameters are meet the requirement of GB 50189-2015 "Public Building Energy Efficiency Design Standard", see Table 1.

Table 1 Structure practice of building exterior envelope

Each part of exterior envelope structure	Main practice	Thermal transfer coefficient
Wall	220mm graphite polystyrene insulation + 200mm aerated concrete block wall	0.15 W/(m^2·K)
Fire barrier wall	220mm mineral wool + 200mm aerated concrete block wall	0.20 W/(m^2·K)
Roof	250mm extruded polystyrene insulation + 120mmreinforced concrete roof	0.15 W/(m^2·K)
Floor between heating AC area and non-heating AC area	220mm extruded polystyrene insulation + 120mm reinforced concrete floor	0.15 W/(m^2·K)
Partition between heating AC and non-heating AC area	20mm adhesive polystyrene granule + 200mm aerated concrete block partition + 20mm adhesive polystyrene granule	0.65 W/(m^2·K)
Window	PA double low-e, radiation rate ≤0.25, 6+12Ar+6+12Ar+6	0.80 W/(m^2·K)
Door	Passive door	1.00 W/(m^2·K)

Basic Parameters of Main Room: according to the room function and actual use of the building, the basic parameters for each room are set up in Table 2

Table 2 Basic parameters of each room

Room function	Temperature range	Relative humidity	AC area	Design person	Fresh air	AC
Planning exhibition hall 1	20~26	40~60	243.44	40	30	yes
Planning exhibition hall 2	20~26	40~60	402.24	60	30	yes
Planning exhibition hall 3	20~26	40~60	354.76	50	30	yes
Science exhibition hall	20~26	40~60	1329.62	80	30	yes
Movie hall	20~26	40~60	330.22	50	30	yes
Monitoring office	20~26	40~60	31.88	2	30	yes
Leisure	20~26	40~60	291.09	35	30	yes
Office 1	20~26	40~60	107.59	4	30	yes
Office 2	20~26	40~60	54.97	4	30	yes
Office 3	20~26	40~60	51.21	4	30	yes
Dinning hall	20~26	40~60	291.66	28	30	yes
Coffee	20~26	40~60	102.67	8	30	yes
Internet cafe	20~26	40~60	97.73	10	30	yes

Illumination, Lighting and Equipment Power density: according to the requirements from Table B.0.4-3 and B.0.4-0 on GB50189-2015 "Public Building Energy Efficiency Design Standard". The illumination (LX), lighting and equipment power density (W/m^2) are shown on Table 3.

Table 3 Illumination, lighting and equipment power density

Category	Room function	Illumination LX	Lighting power density W/m^2	Lighting power density W/m^2
Public Building	Planning exhibition hall	200	9	5
	Science exhibition hall, movie hall	200	9	15
	General office	300	8	15
	Leisure	300	9	0
	Dinning	200	9	2.5
	Coffee	150	5.5	2.5
	Internet cage	200	9	10
	WC	75	3	0

Lighting, Occupancy and Equipment Usage Rate Timetable: according to the actual usage, the museum will open on Wednesday to Sunday from 9am to 17pm in summer and 9am to 16pm in winter. Monday and Tuesday will be closed for rest. During the project's simulation, the lighting, occupancy and equipment usage rate timetable will refer to the requirements from table B.0.4-4, B.0.4-6, B.0.4-10 on GB50189-2015 "Public Building Energy Efficiency Design Standard".

Air-Conditioning System: it contains fan coil and fresh air system, which will operate from November to the following February for winter heating and from June to September for summer cooling. The AC operating timetable in China is different from the foreign public buildings' timetable, it is not the 24 hours continuous operation. In this project, the AC operating time is the same as the museum working timetable.

Outdoor Design Parameters: the requirement of thermal transfer coefficient of passive ultra-low-efficiency building exterior envelope is very strictly. There is a clear indicators on the maximum heating and cooling load as well as the energy consumption technologies. This project takes the above simulation parameters, and then calculates an 8760 hours simulation model by Design Builder software to analyze the indoor environment and the air conditioning system. During the process of calculation, this model uses the Linyi city typical meteorological parameters as the basis of building load calculation. Moreover, the simulation software has fully considered the effect of wall materials on the attenuation and delay of the temperature wave.

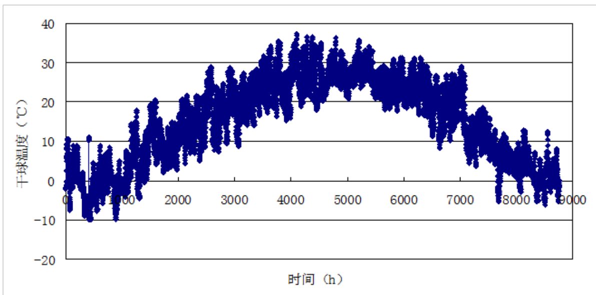

Fig. 1. Linyi typical meteorological parameters

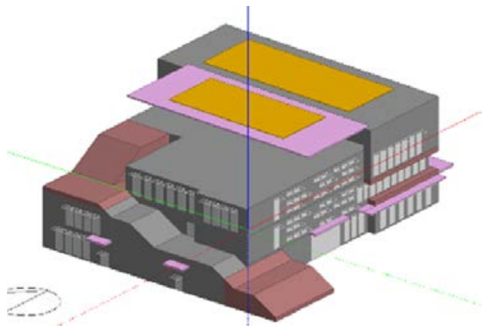

Fig. 2. 8760 hours simulation model

Simulation Results

The simulation result ignored the impact from air permeability, without considering the AV load during the transition season. The windows and doors are closed, so the impact from natural ventilation to the AC load consumption in summer can be ignored also. Simultaneously, it considered the effect of sun shading, after 8760 hours' calculating, the monthly energy consumption demand of heating and cooling load can be see Table 4.

Table 4 Monthly energy consumption demand of heating and cooling load

Month	Zone Heating kWh	Total Cooling kWh	AHU Heating kWh	Sensible Cooling kWh
January	16288.66	0	24237.25	0
February	10777.87	0	13026.89	0
March	0	0	0	0
April	0	0	0	0
May	0	0	0	0
June	0	16698.08	0	14603.77
July	0	26649.32	0	14525.07
August	0	27541.97	0	15624.37
September	0	8757.32	0	6548.23
October	0	0	0	0
November	6690.18	0	0	0
December	13274.33	0	17794.25	0

Then, according to the above simulation data, this project's building load and energy consumption are shown in the following Table 7. It is noted that all the index results are calculated with air-conditioning area. The annual maximum heating load time is 09:00 in January 19th. The annual maximum cooling load time is 09:00 in July 24th.

Table 5 Building load and energy consumption

Item	Unit	Result	Item	Unit	Result
Annual maximum heating load	kW	350.78	Heating load index	W/m^2	72.69
Annual maximum cooling load	kW	508.97	Cooling load index	W/m^2	105.47
Annual heating energy consumption	kWh	47031.04	Annual heating energy consumption index	kWh/m2·a	9.75
Annual cooling energy consumption	kWh	79646.69	Annual cooling energy consumption index	kWh/m2·a	16.50

Finally, the primary energy consumption include heating, cooling and lighting is:

Table 6 Primary energy consumption

	Total Energy kWh	Energy Per Total Building Area kWh/m^2	Energy Per Conditioned Building Area (kWh/m^2)
Total Site Energy	247098.96	44.47	51.20
Total Source Energy	782552.92	140.82	162.16

Conclusion

According to the above dynamic simulation, the annual heating energy consumption index is 9.75 kWh/m^2·a, it has met the requirement of PHI limit index that is not greater than 15 kWh/m^2·a. The annual cooling energy consumption index is 16.50 kWh/m^2·a, which is a little higher than the limit index. However, the project's local outdoor meteorological conditions in summer is different with the conditions in Germany, this paper considered with the actual situation that the simulation results can be accepted.

Moreover, there are many China's cities have strictly executive the 75% energy-saving standard from October, 2015. Compared with 75% energy saving standard, the passive ultra-low-energy consumption building's energy-saving rate can be reached on at least 85%.

Acknowledgement

In this paper, the research was sponsored by the Key Technologies of Passive Ultra Low-Energy Consumption Green Building Research from Ministry of Housing and Urban-Rural Development of the People's Republic of China (Project No. K12015109).

References

[1] GB50189-2015 Public Building Energy Efficiency Design Standard, [S], 2015.

[2] PHI, Passive Houses for Different Climate Zones

[3] GB37/T 2397-2013 Standard on Inspection and Evaluation of Application Projects of Renewable Energy Buildings, [S], 2013

[4] DB37/5026-2014 Design Standard for Energy Efficiency of Residential Buildings, [S], 2015

[5] Chen Yan, the Twelfth Five Year Plan to Promote the Construction of Energy Efficient Policy, [A], China's Economic Analysis and Outlook (2010-2011), [C], 2011