Energy-Saving and Environmental-Friendly Gymnasium Project Evaluation Research

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Abstract. As a complete urban space individual, the gymnasium must be considered to build energy conservation and environmental protection requirements. Based on this research background, the thesis analyzes whether it can be energy-saving and environmentally friendly by exploring natural ventilation technology and intelligent lighting for green buildings, using CFD and airpark combined with thermal comfort and body temperature. Research has shown that through the CAN bus intelligent lighting system, combined with the opening and closing of the building gymnasium roof to meet the ventilation conditions, the gymnasium's necessary energy-saving and environmental protection can be realized.

1. Introduction

In recent years, with the development of economy and culture and the needs of urban development and construction, many different sports buildings have been built across the country under the background of promoting national health sports in my country. In today's energy shortage in my country and even the world, green and environmentally friendly ecology has increasingly become a global trend. The green building design concept of "green ecology, energy saving, environmental protection, and sustainable development" has spread from foreign countries to China and has become the construction industry's latest design concept. Mainstream. As a large-scale public building, the stadium has substantial indoor venues, prominent body shape, super-large structural span, complex functional organization, and high maintenance and management costs after the game. The daylighting and ventilation of the enormous stadium space, air conditioning balance and energy consumption, daily operation, and maintenance require comprehensive consideration and solution for the stadium's existence and development [1]. Besides, the use of a variety of energy-saving technologies and design techniques in the design of the stadium, economical and reliable and can reflect the beautifully shaped structural design, the combination of space sections, the processing of nodes, the detailed composition, the use of indoor local air-conditioning, and the use of new materials Use, etc., these aspects enable the building to fully reflect the architect's intention, while also enabling the building to reduce energy consumption and eco-energy conservation. Based on the above elements, the stadium's energy-saving ecology has been related to the survival, development, and reasonable existence of the stadium, and "ecological energy-saving, environmentally friendly, sustainable green buildings" has become an essential indicator of excellent sports buildings.

2. Realization of natural ventilation technology for the stadium project
2.1. Human thermal comfort index and body temperature
The thermal comfort index refers to the higher temperature and the increase of relative humidity, the higher the temperature actually experienced by the human body. The body temperature is often different from the actual temperature due to humidity and solar radiation. According to the atmospheric boundary layer theory, ventilation and air quality have a positive correlation, and the absorption of heat by air will be directly affected by some factors, such as relative humidity and density. The air (such as inhalable particulate matter) that the human body can contact with the content is affected by wind speed [2]. The composition and content of the air that the human body can contact are directly proportional to the wind speed, which is the theoretically defined "wind chill index."

2.2. The relationship between human comfort and natural ventilation
If the indoor environment is closed, the indoor air environment will be lacking at this time, and the human body in the indoor environment will feel different degrees of discomfort. Therefore, to dilute air pollutants and keep indoor air clean, the most convenient method is to maintain natural ventilation. The architectural design content of natural ventilation is directly related to the changes in the human body's metabolism in the new city and ultimately affects the human body's comfort. Because the human body's perception of temperature has the most extraordinary relationship, when the moving human body is in a moving state and a static state in the gymnasium, its thermal comfort is essentially different. There is also an individual correspondence between somatosensory temperature and human sensation, as shown in Table 1.

| T/℃ | Human perception | Physiological stress level |
|------|------------------|---------------------------|
| <4   | Very cold        | Extremely cold            |
| 4-9  | cold             | Severe cold               |
| 9-13 | cool             | Medium cold               |
| 13-18| Slightly cool    | Slightly cold             |
| 18-23| Comfortable      | No heat                   |
| 23-29| warm             | Slightly hot              |
| 29-35| warm             | Moderate heat             |
| 35-41| heat             | Intense heat              |
| >41  | It's hot         | Extreme heat              |

2.3. The energy-saving features of the roof of the open and closed stadium building.

2.3.1. Experimental process. In this study, CFD and airpark were used to set the ventilation windows on the north and south facades of the stadium roofs in a particular area when they were opened and closed (the windows are calculated according to the actual construction the size of the accessories). For draughts. To achieve a good simulation effect, the exhaust gas is assumed to be discharged from the exhaust chimney. At the same time, part of the air can be discharged under negative pressure, and the heat state of the air is set to be the same. To shorten the time used in this simulation experiment, when the roof of the stadium building is opened, it is assumed that the glass building material does not function as an enclosure, so no material is required [3].

2.3.2. Experimental results. From the thermal comfort score analysis, the two change elements of wind speed and temperature have different degrees of induction in the open and closed state of the stadium roof and ultimately affect the thermal comfort. The specific performance is: the difference between the maximum wind speed and the minimum wind speed is 6 times, and the difference between the maximum temperature and the minimum temperature is 10%. It can be seen from Table 2 that when PMV is 3, the corresponding thermal sensation is hot; when PMV is 2, the corresponding thermal sensation is warm; when PMV is 1, the corresponding thermal sensation is slightly warm; when PMV is 0, the
corresponding. The thermal sensation is moderate, that is, the best human sensation and the human body comfort is the best; when the PMV is -1, the corresponding thermal sensation is slightly cool; when the PMV is -2, the corresponding thermal sensation is relaxed; when the PMV is -3. The corresponding hot feeling is cold, the most unsatisfactory state. The human body is not comfortable at all.

| Hot feeling | heat | warm | Slightly warm | Moderate | Slightly cool | cool | cold |
|-------------|------|------|---------------|----------|---------------|------|------|
| PMV value   | 3    | 2    | 1             | 0        | -1            | -2   | -3   |

When the roof of the stadium building is closed, the body temperature increases by 8.19%, the indoor PMV value is between 0.063 and 0.250 (slightly warm), and the human body feels thermal comfort as an acceptable state; when the roof of the stadium building is opened, the wind speed, air volume, temperature, humidity, etc. The parameter conditions have been optimized. The simulated body temperature is 23.87°C, and the human body feels the best thermal comfort, as shown in Figure 1.

**Figure 1.** The relationship between PMV and PPD.

2.4. Research discussion

The body temperature corresponding to the open and closed state of the stadium roof has different induction degrees. The circulation in the stadium becomes stable with the closing of the roof, changes with the roof's opening, and the ventilation and wind speed increase at the same time. The optimal comfort of the human body has no destructive influence [4].

3. The impact of smart lighting in stadium projects on energy conservation and environmental protection

3.1. The main content and planning of the stadium bus network system

The decentralized control of the entire stadium's lighting is the purpose of the network planning of the stadium's intelligent lighting control system, which ultimately realizes scientific, reasonable, and unified
management and maximizes energy saving. The intelligent lighting control network is a multi-layer and multi-level network structure. These structures are composed of multiple nodes, such as unit nodes, primary control nodes, and sub-control nodes. The central control node is responsible for the implementation monitoring and control output of the entire system; the unit node is responsible for the status monitoring and control output of the lighting scene [5]. The system uses the bus technology to control the bus node relay's opening and closing, thereby controlling and changing the stadium scene. Figure 2 shows the intelligent lighting bus distribution.

![Intelligent lighting bus distribution](image)

Figure 2. Intelligent lighting bus distribution.

3.2. Hardware design
The CAN bus controller SJA1000 has two reads and write modes, Intel mode and Motorola mode, and is connected to 52 single-chip microcomputers. Because the controller's pins are set in the off-chip RAM (random access memory) of the 52 single-chip microcomputers, the data address bus AD0-AD7 and the ALE address latch control terminal are similar, so it can be used as an extended data memory application in 52 single-chip microcomputers. It is embodied explicitly as: when entering data, it can be understood as storing the data in an external data storage. The CAN bus controller SJA1000 connected with the single-chip STC89C52 machine. The structural connection is shown in Figure 3. In the hardware circuit, connect the address line, data line, control line of the microcontroller, and the device's corresponding pins to be expanded. SJA1000 sends and receives data is connected through two pins, such as the 0th pin (TX0 pin and RX0 pin). For the connected driver, the data sending pin and the receiving pin should be connected correctly. To facilitate later observation and debugging, two LED indicators can be added at the sending and receiving ends to indicate data sending and receiving.
3.3. Lighting design software
The article uses lighting design application software for actual calculations. The calculation results include horizontal illuminance distribution values, vertical illuminance distribution values, and uniform illuminance values in various modes. The calculation method of horizontal illuminance value and vertical illuminance value is based on the direct illuminance calculation method of point light source, and the calculation formula is:

\[ E_h = \frac{I_{\theta}^{1000} \Phi K}{1000h^2} \cos^3 \theta \]  

\[ E_v = \frac{I_{\theta}^{1000} \Phi K}{1000h^2} \cos^2 \theta \sin \theta \]

Where: \( E_h \) is the horizontal plane illuminance produced by a point light source (lamp) at a certain point, \( L_x \); \( E_v \) is the vertical plane illuminance produced by a point light source at a certain point, \( L_x \); \( I_{\theta}^{1000} \) is the light intensity in the illumination direction when the luminous flux is 1000lm, cd; \( h \) is the distance from the point light source to the illuminated horizontal plane, called the calculated height, m; \( \Phi \) is the actual luminous flux of the point light source, lm; \( K \) is the maintenance factor; the vertical angle is the ratio of the horizontal distance from the illuminated point to the lamp and the lamp installation height \( h \) The arctangent value of.

From equations (1) and (2), it can be seen that since the distance between the lamps and the illuminated point is far enough, all lamps can be regarded as point light sources, and the horizontal plane illuminance and vertical plane illuminance generated at that point can be summed separately. The horizontal plane illuminance and vertical plane illuminance of this point under these lamps' illumination can be obtained.

3.4. The impact of smart lighting on energy conservation and environmental protection
The intelligent lighting control system uses modern science and technology such as computer technology, network communication technology, automatic control technology, and microelectronics technology to automatically collect various information in the system according to environmental changes, objective requirements, and user predetermined needs. It can be the collected information is subjected to corresponding logical analysis, reasoning, and judgment. Simultaneously, the results are stored, displayed, transmitted, and feedback control is processed in a specific form to achieve the best
control effect. The lighting system and other subsystems in the stadium are networked to form a compatibility system, integrate data, and perform intelligent analysis. Dynamic and effective configuration, and management of electric energy control and consumption. The program meets the requirements of sports lighting and achieves a low-carbon environment, and raises stadiums' lighting management to a new level.

4. Other measures for energy conservation and environmental protection in the gymnasium

4.1. Use of natural lighting
The gymnasium roof uses a circular roof composed of flat steel pipe trusses in a radial shape to set a roof skylight. The stadium's roof is designed with a combination of the glass roof and refracting plates, which allows natural lighting and avoids direct light damage to the venue floor. On the circular roof truss, circular movable shutters are designed. Openable external windows are set on both sides of the long end of the field to supplement the roof's ventilation and lighting. They are closed during competitions and open during training and regular activities to use natural light to save electricity [6].

4.2. Reasonable structure system
In the structural system, a large-span reinforced concrete inclined truss is used to form the stands. The roof adopts a large-span reinforced concrete frame (bent frame) + steel tube truss roof structure. The entire roof truss is circular, with a span of more than 120 meters. With the reasonable treatment of the entire roof truss structure, the building is like a volley, giving people a strong visual experience, which fits the extreme sports' design theme. The reasonable structure saves the construction cost, provides space for the ventilation and lighting of the ceiling, and at the same time forms a huge extraction space, forms a gray space at the entrance layer, achieves the building shading effect, and uses the negative pressure area formed by the entrance to promote the airflow within the stadium.

5. Conclusion
The article understands the energy consumption of gymnasiurms from various professions, profoundly studies the causes and solutions. The gymnasium is one of the representatives of high-energy-consumption buildings. Although the building has been designed for energy-saving, there are still many places where the subsequent operators can reduce energy consumption.

References
[1] Dong, Y., Qin, T., Zhou, S., Huang, L., Bo, R., Guo, H., & Yin, X. Comparative Whole Building Life Cycle Assessment of Energy Saving and Carbon Reduction Performance of Reinforced Concrete and Timber Stadiums—A Case Study in China. Sustainability, 12(4) (2020) 1566-1576.
[2] Huang, C., Zou, Z., Li, M., Wang, X., Li, W., Hu, W., ... & Xiao, X. Measurements of indoor thermal environment and energy analysis in a large space building in typical seasons. Building and Environment, 42(5) (2007) 1869-1877.
[3] Militano, L., Iera, A., Molinaro, A., & Scarcello, F. Energy-saving analysis in cellular–wlan cooperative scenarios. IEEE Transactions on Vehicular Technology, 63(1) (2013) 478-484.
[4] Li, X., Liu, Z. R., Ren, X. Y., Li, X., & Wang, Y. S. Characteristics of PM10 and PM2.5 during summer time of 2007 and 2008 at Beijing National Stadium. Trans. Atmos. Sci, 35(2) (2012) 197-204.
[5] Katsaparakis, D. A., Dakanali, I., Zidianakis, G., Yiannakoudakis, Y., Psarras, N., & Kanouras, S. Potential on energy performance upgrade of national stadiums: a case study for the Pancretan stadium, Crete, Greece. Applied Sciences, 9(8) (2019) 1544-1556.
[6] Zhang, Z., Zhang, H., Tan, Y., & Yang, H. Natural wind utilization in the vertical shaft of a super-long highway tunnel and its energy saving effect. Building and Environment, 14(5) (2018) 140-152.