

Integrated design for daylight and electric lighting in Olympic competition venue

ETFE inflatable pillow, daylight harvesting and High-power LED Lighting in National Aquatics Center

In National Aquatics Center, daylight was brought into the competition area. Combined with high-power LED and intelligent control lighting system, this venue improves the race experience for athletes and meets the requirements for various competition modes in winter and summer.

The project

The National Aquatics Center (NAC), better known as “Water Cube” will serve as a curling site of the 2022 winter Olympics in Beijing & Zhang jia kou, and the original site lighting system is used for aquatics, such as swimming, diving and synchronized swimming. The retrofitted site lighting system needs to be considered simultaneously for using as ice sports and aquatics in winter and summer, also needs to adapt to the requirements of site conversion to achieve energy saving and efficient operation. NAC is located in Beijing, which has abundant natural light resources (Fig. 2 and Fig. 3). In this project, daylight is used as an important design strategy.

Daylighting and lighting design

The building envelope of the “Water Cube” adopts a new type of ETFE inflatable pillow, and the indoor spaces are sufficiently lighted. The average daylighting factor of the



Figure 1. The National Aquatics Center.

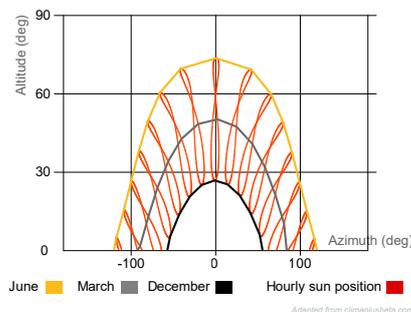
competition hall is 2.2%, while it is 2.1%, 3.8%, 2.4%, and 3.1% for the leisure pool, the bubble bar, the South Commercial Street, and the multifunctional large space respectively (Fig.4).

In order to meet the needs of the game, the air pillow on the east facade of the game hall is shielded during the game to reduce glare (Fig. 6). The high illumination required for broadcasting is guaranteed by artificial lighting (Fig. 5 and Fig. 6).

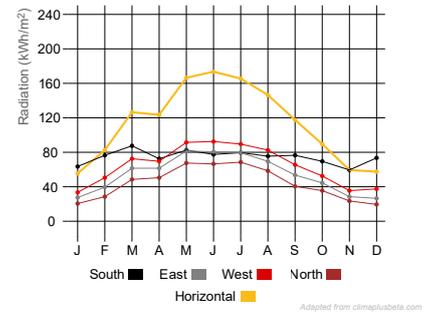
Before the renovation, the original site lighting was 1 KW (without ballast) metal halide lamp, and switching the lighting mode through the switch could only meet the needs of



Location: Beijing, China
40.60,103.46



Sun path for Beijing, China



Global horizontal and vertical radiation for Beijing, China



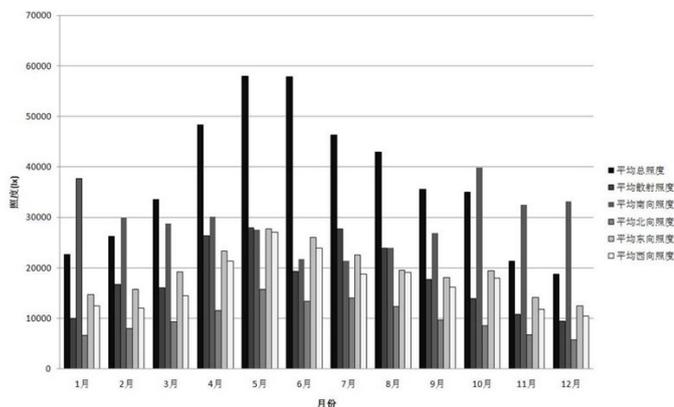


Figure 2. Annual illuminance distribution in Beijing.

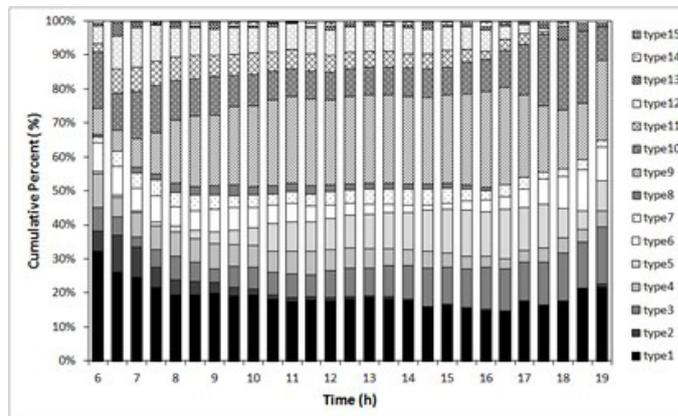


Figure 3. Sky type distributions observed at different times in a year in Beijing.

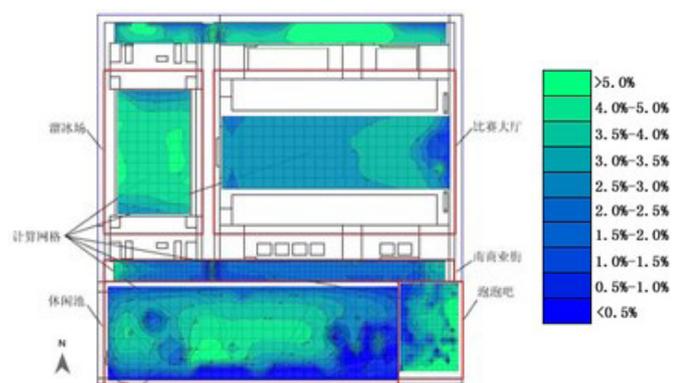


Figure 4. Distribution of Daylight Factor at the NAC.

swimming and diving. After a long time of use, the light decay was large, the color of the light source also appeared different, and the ballast and other accessories also had some problems. It was difficult to meet the lighting requirements for high-level sporting events.

After the renovation (Fig. 7), the venue lighting fixtures have been all high-power LED lamps, which can not only

meet the requirements of curling events of the Winter Olympic Games, but also meet the requirements of curling, ice hockey, swimming and diving competitions, realizing two application modes of winter and summer, indicated as Mode A and Mode B respectively in Table 1.

Through the intelligent lighting control technology, the scene (or mode) can be quickly switched. With the help of the new control system and new control strategy, the overall energy consumption of the project has been greatly reduced, which can meet the goal of achieving the lighting system energy saving rate of no less than 60%.

All LED lighting is used in this renovation, among which 186 sets of lamps are used in curling mode, and the power of single lamp is 1200 W (Fig. 8).

A venue for winter Olympic games requires an innovative approach when it comes to lighting. High quality LED lighting providing perfect illumination and high colour rendering is must. In this project an in-depth study of power

Table 1. Test results for the lighting in the curling mode.

Test items	Mode A	Mode B	OBS requirements
Average Horizontal of illuminance	3731 lx	5425 lx	/
Minimum illuminance of main camera	1871 lx (3 m) 1961 lx (6 m)	2300 lx (3 m) 2540 lx (6 m)	1600 lx
Vertical minimum illuminance (A)	1718 lx	2144 lx	1200 lx
Vertical minimum illuminance (B)	1843 lx	2617 lx	1200 lx
Vertical minimum illuminance (C)	1436 lx	2245 lx	1200 lx
Vertical minimum illuminance (D)	1903 lx	2864 lx	1200 lx
Average Horizontal of illuminance of the audience	1154 lx	1855 lx	/
Average vertical illuminance of the auditorium	496 lx	764 lx	/
Glare index	13.1	12.2	≤30
Glare index to the camera	13.2	10.1	≤40
Correlated color temperature T_{cp}	5490 K		/
Color rendering index R_a	92		/
Special color rendering index R_9	66		/
TLCI	94		>85

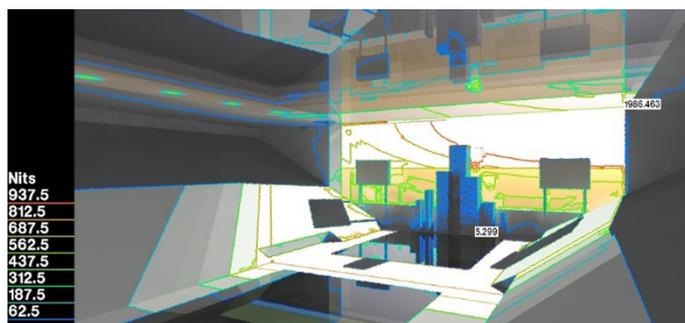


Figure 5. Glare simulation for the NAC.

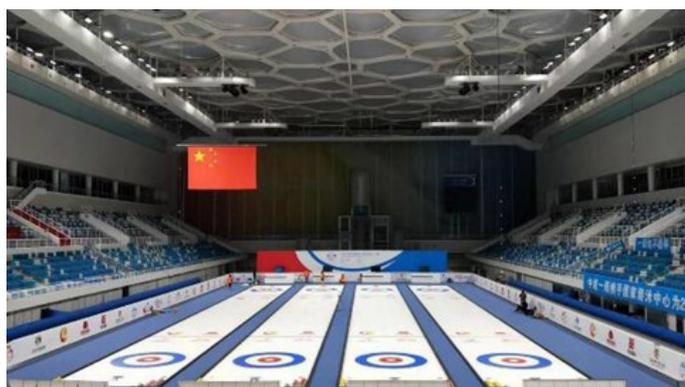


Figure 7. Demonstration after renovation.

supply and control technology was also required. It helped pushing forward the choice of LED products, by selecting those providing excellent technical performance. Since high-power LED luminaires are required for such venue, the choice of top products was key to achieve both high quality illumination - as needed for high-level sport events which are also broadcasted - and reduce the energy use for lighting.

The lighting scheme here presented is used for the curling hall of the Winter Olympics. The hall has a height of 30 m, and the renovated lighting area is about 8000 square meters. After the renovation, the lighting can not only meet the requirements of curling competitions of the Winter Olympics, but also meet the requirements of high-definition TV broadcast of swimming and diving competitions after the Games.

We use DMX512 system, constant current technology, for lighting control. During each type of competition, each venue lighting fixture can use an independent DMX512 channel, which can achieve 5%-100% dimming. Considering the characteristics of harmonic control and LED dimming performance curve, the minimum dimming ratio is controlled at about 15%. Switching between different types of matches can still be done using the switch mode.

Monitoring

Energy

Lighting energy saving is not only reflected in the system energy efficiency of LED luminaires, but also very important in actual operation. The actual operation and usage mode of the control scheme have a very important influence on lighting energy consumption.

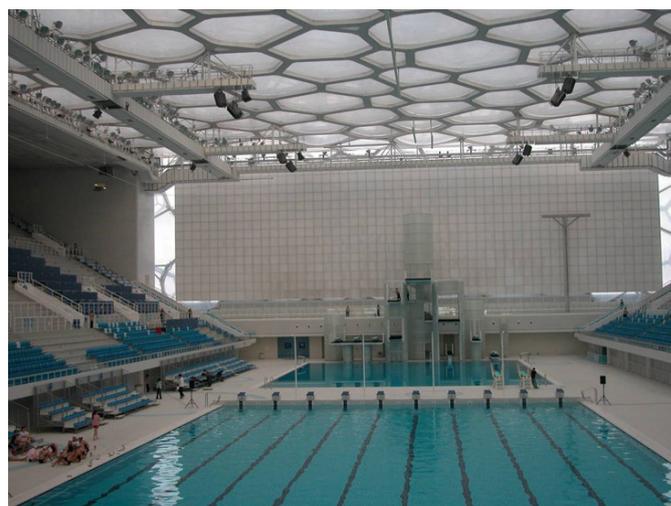


Figure 6. Glare control at NAC.

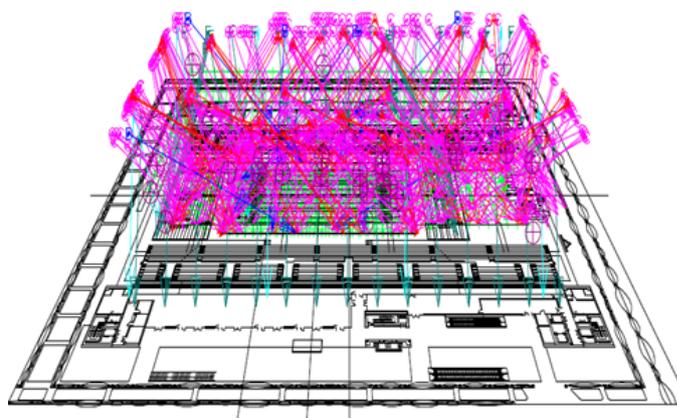


Figure 8. Lighting layout.

Compared with Chinese standard JGJ 153, lighting power density in swimming mode is 290 W/m^2 (Height is 25 m to 30 m), and the lighting total power in actual modified swimming mode is 217.6 kW, with the lighting power density to be 174 W/m^2 , which corresponds to energy saving of about 40%. Considering the accurate control of LED luminaires, there will be an extra 20% power reduction, which means the overall energy saving is more than 60% compared to the standard.

Referring to current operating mode, we can set the run time as 200 hours per year in curling mode and swimming mode, 300 hours per years in diving mode. If supposing the average load is 50%, annual energy consumption of the modified site lighting system is about 60 000 kWh.

Photometry

From December 1 to December 11, 2019, before and after the junior open curling competition, the research team conducted a comprehensive test on the lighting environment of the curling arena.

The research group selected two modes of curling for testing, and the test results are shown in the Table 1.

It can be seen that all the indicators meet the requirements of Chinese standards and OBS. Figure 9 shows the space

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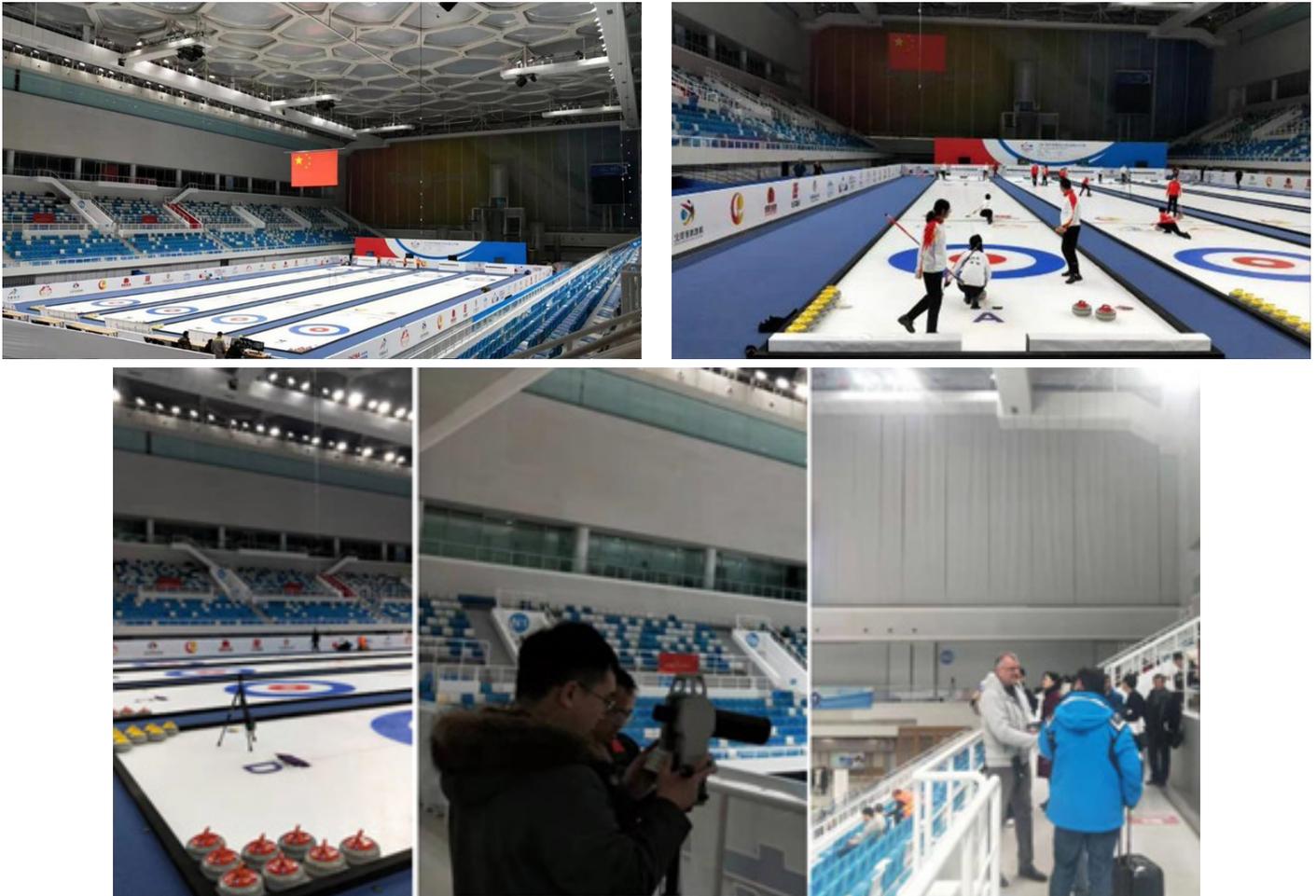


Figure 9. Site inspection.

during the measurement campaign.

Circadian potential

In this project, circadian potential has not been considered.

User perspective

Athletes and visitors are satisfied with the luminous environment, especially interested in the introduction of natural light into the venue. They feel happier and more active.

Lessons learned

Daylighting serves not only an energy-saving strategy, but also an important factor for luminous environment promotion. For high-level competition venue, which requires to avoid the effects of light fluctuations, there is usually the need to completely block out the natural light. But to our experience, the introduction of natural light could make people happier and more active. The daylighting strategy for high-level competition venue should be reconsidered.

For ice sports, LED luminaires have more advantages

than other sources, due to less thermal radiation, more efficiency and easier commissioning.

Acknowledgements

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