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On Design of Low-Operation-Cost Ice Arenas with Energy Saving Approaches

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Abstract

Ice arena is a kind of public buildings with high operation cost due to its huge building volume and high energy consumption for refrigeration and heating. Good building design can contribute to the reduction of energy consumption during its operation. Manipulation of shapes, control of height of interior space, skylight setting and insulation of arena are major design approaches we can take. Energy saving effects of these building design elements are analysed from the standpoint of operation cost control, and some suggestions are given.

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Keywords: Ice arenas; Operation cost; Energy consumption

1. Introduction

Ice arenas have special characteristics. Firstly, they have larger play fields compared to other arenas, for example, hockey and figure skating field size is 30 m x 61m, speed skating fields size is 68 m x 182 m. Secondly, ice arenas competition field is finished with ice, the hardness and evenness of the ice surface is important for the athletes. Thirdly, the ice surface requires low temperature, while the area of the spectators and the athletes need a relatively comfortable temperature so space is divided into distinct temperature zones. To date, the research literature has focused more on the equipment operating cost saving, for example, selection and optimization of equipment or energy recovery, etc. In architectural design research, researchers pay more attention to the innovation of building shapes and the study of the materials used in the outside surface of the arenas. Although equipment optimization helps the ice arenas save in operating cost. However, under the existing conditions of the building design, the

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benefits of cost savings equipment are significantly lower. This paper studies the following aspects from the perspective of building design： (1) to expound distribution of the main energy consumption operating cost in the ice arenas; (2) to analyse influence of building design elements in relation to operation cost of the energy consumption; (3) based on the analysis results, to propose the design strategy to reduce energy consumption.

2. Operation Cost Shares

Ice arenas operation demands on significant amount of energy. As it is estimated, the typical ice arenas consume averagely 1,138 MWH/year. Hence, the cost of energy consumption is the main operating cost of the ice arenas. Saving operation cost is the key to the sustainable development of arenas. For the cost savings, it is very important to find the shares of energy systems consumption. The main energy system consumption of the ice arenas includes refrigeration, heating, ventilation, and lighting systems. The refrigeration system and heating system is usually the largest consumer of the total energy consumption. Through a statistical study of more than one hundred ice rinks in Sweden it is revealed that the refrigeration system has the largest share in total energy consumption, 43% (in average) as indicated in Fig 1 [1]. Heating with 26% share is the second biggest energy consumer. Lighting, ventilation system fans and dehumidification system are the next largest energy consumers.

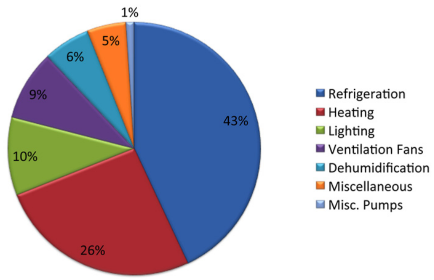

Fig. 1. Energy systems consumption shares [1]

3. The Influence of Building Design Elements in Relation to Operation Cost of Energy Consumption

3.1. Skylight setting

Window is an important element of building design, usually including side-windows, high side-windows and skylight. Because the heat transfer coefficient of the hollow glass material can reach 2.0 below, influence of indoor heat load is very small in the winter. However, in the summer, cooling load is dynamic variation, change with the passage of time and angle of the solar radiation. Then daylight streams into the skylight, opening area and the transmittance of the glass of the skylight are greater influence on cooling load. A simple hockey hall is given to show, its plan size is 75 m x 80 m, floor area and roof area of building are 6000 m^2, skylight is horizontal direction, the construction site is Beijing, roof cooling load and skylight cooling load are calculated according to the following formula:

(1) The hourly cooling load of roof can be expressed by the following equation:

$$Q\tau = K \cdot F \cdot \Delta t\tau\text{-}\xi \tag{1}$$

Where：

- K—coefficient of heat transfer (W / m^2 • k);
- F—surface area (m^2);
- $\Delta t\tau$-ξ—on the calculate time, cooling load temperature difference (°C)

(2) Cooling load of skylight includes hourly temperature difference heat transfer cooling load and hourly solar radiation cooling load.