An ice rink floor thermal model suitable for whole-building energy simulation analysis

Junghyon Mun, Moncef Krarti*

Department of Civil, Environmental, and Architectural Engineering, CB 428, University of Colorado, Boulder, CO 80309, USA

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**Abstract**

This paper presents a thermal model for an ice rink floor system that is integrated into EnergyPlus, a whole-building energy simulation tool, to improve design, evaluation, and operation of ice rink facilities. The developed ice rink floor thermal model, based on the conduction transfer function method, is validated against experimental data obtained under laboratory testing conditions. Two control strategies for indoor ice rink floor systems were modeled and evaluated including a brine temperature control strategy and an ice surface temperature control strategy.

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1. Introduction

Ice rink arenas are among the most energy intensive entertainment facilities with annual energy consumption of 750 kWh/m², almost 3 times the energy use intensity of office buildings [1]. There are several thousands of indoor ice rinks in North America used for various spectator events and recreational activities such as hockey games, figure skating, or public skating. Most of the arenas are operated continuously for over 8 months to 11 months per year and thus consume significant levels of energy when compared to other recreational facilities. According to a DOE report, a typical indoor ice rink arena in Massachusetts had an average electric consumption of 730 MWh which accounted for $70,500 in 2010 for just a 7–8 months season [2]. Another study showed that the energy costs to operate an ice rink facility in Canada for 8 months are on average $86,000 [3]. According to the international ice hockey technical guides, the energy consumption by three ice skating rinks in Europe ranges from 900 to 1500 MWh/year and the average energy bill can range from $50,000 to $90,000 [4]. Unfortunately, there is no clear guidelines and analysis tools to help improve the energy performance of ice rinks. In particular, it is difficult to estimate refrigeration load and energy use of ice rinks using currently available whole-building energy simulations due to lack of detailed models for ice rink floor systems.

Early numerical and experimental analysis studies of indoor ice rink arenas were usually focused on indoor air quality [5]. Recently, ASHRAE has sponsored a research project to better estimate ice sheet cooling loads [6]. In particular, a numerical analysis was performed as part of this project to estimate daily heat flux profiles at the ice sheet surface under steady and periodic meteorological conditions [7,8]. As an extension of this ASHRAE project, a zonal model is developed to calculate thermal interactions between indoor air and ice sheet surface within an ice rink arena. This zonal model is used with TRNSYS to estimate annual energy consumption for ice arenas [9–11]. However, the model is a standalone algorithm and cannot be easily implemented in a whole-building simulation program.

The main objective of the work presented in this paper, is to develop a detailed heat transfer model for a typical ice rink floor suitable for integration within a whole-building simulation tool. While existing models [6–11] can estimate heat transfer along the ice sheet surface, they do not consider thermal coupling of the ice rink floor system with its surroundings. In this paper, a thermal model for the ice rink floor system is developed to account for thermal interactions between the floor system, ground, and ambient air of the indoor arena. Moreover, the developed ice rink floor system model was integrated into a state-of-the-art energy analysis simulation program, EnergyPlus, to assess energy performance of ice rink facilities under various design and operating conditions.