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Verification of a simplified method for intelligent glazed façade design under different control strategies in a full-scale façade test facility – Preliminary results of a south facing single zone experiment for a limited summer period

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ABSTRACT

The research aims to verify a simplified calculation method for intelligent glazed facade under different control strategies (night shutter, solar shading and natural ventilation). The method is developed to simulate the energy performance and indoor environment of an office room installed with intelligent facades. The calculation results of heating and cooling needs are verified by experimental data collected in a full-scale test facility (Cube) with south-facing façade at Aalborg University (DK) during summer period from 18th to 22nd June 2014. According to the results of the comparison, the calculated air temperature has good agreements with the measurements, with the R^2 value of 0.8. Additionally, the total cooling energy consumptions measured in the experiment are 30% lower than the calculated. The experiment was conducted in the test facility with only south-facing façade and during a short summer period, which limits the verification of the method.

When using water system in the chilled beam to cool down test room, it needs to be noticed that the forward water temperature should be controlled not to be higher than the air temperature of the test room when there is no cooling need in the test room; otherwise the chilled beam will release heating to the test room, which could influence the accuracy of the result.

National Instrument (NI) CompactRIO is used to acquire measured data from different sensors and send signal to control building services like ventilation, heating, cooling and artificial lighting. The whole process is realized with the help of Labview.

1. Introduction

Given highly glazed facades are more and more popular in modern buildings, solar heat load and light transmittance through facades in summer and the heat transmittance through them in winter are of great importance to the energy consumption and indoor environment of high performance buildings. To decrease the energy demand and improve the indoor comfort of buildings, intelligent façades with controlled façade elements is one of the effective solutions [1,2]. Appropriate control of all these technologies (night shutter, solar shading and natural ventilation, etc.) can greatly reduce the heating and cooling load and optimizes the visual and thermal comfort in a building. A simplified method has been developed to compare energy performance of different control strategies and optimize the entire system in the early stage of building design [3–6]. Comparisons have been conducted between the simplified method and Danish Building Simulation Tool BSim [7,8]. However, its accuracy still needs to be evaluated by experimental measurements in full scale test facility.

Experiments have been conducted to verify parts of the simplified method like methods for double glazing and glazing with insulated shutter [3–5]. Other parts (method for blind, etc.) and the holistic system of the method also need to be verified by experimental measurements. Experiments have been conducted by researchers to evaluate methods or performance of different façade elements (blind and shutter, etc.) [9–20]. Advantages of setup and method in these experiments have been studied to be made use of

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in this experiment. The room model in the simplified method is developed according to EN 13790 [21], of which the general criteria and validation procedures are shown in EN 15265 [22]. Previous experiments have been implemented in the same facility to investigate performance of different building elements [23,24].

The experiment test is designed and implemented specifically for evaluating the accuracy of the simplified method, which is necessary for future application of the method on predicting the energy and comfort performance of intelligent facades of different control strategies.

The purpose of this study is to verify the accuracy of the simplified methodology by comparing its calculation results with experimental measurements. The paper describes the full-scale test facility used for the experiment in Aalborg University (Cube) [23,24]. The setup, instruments, procedure and the results of the experiment are also demonstrated in the paper.

2. Description and research method

The simplified method of intelligent glazed façade is developed to calculate the energy and comfort performance of buildings with intelligent façade controlling insulated shutter, venetian blind, natural ventilation and night cooling. Energy consumption (heating, cooling, lighting and ventilation) and indoor operative temperature are calculated by the method under different control strategies. The façade part of the method is developed to be integrated into BSim and BE10 to fulfil their functions of simulating different control strategies, but the entire method can also work independently. Capability of hourly calculation of an office room in the whole reference year and flexibility of modelling new control strategies make the method a great advantage in the design and certification of buildings with intelligent façade. It is named simplified method because of its simple one zone room model according to the simple hourly model in EN ISO 13790, which has only one control point for thermal mass, surface and indoor air each. Therefore, the calculation of the indoor air and thermal mass is homogenous, but this limitation can be improved when integrating the façade part of the method into BSim or BE10. The method has been described and presented in Refs. [3–6]. The experimental verification of the method is presented in this paper.

Fig. 1 shows the structure of the simplified method. The core part of the method is the algorithms of façade elements (red dish frame), which contains algorithms of different façade elements: double glazing unit (triple glazing unit), insulated shutter, solar shading (venetian blind), natural ventilation and night cooling. By setting the input of weather data and indoor comfort requirements, the parameters of energy demand, thermal comfort and visual comfort will be calculated. The method is flexible to evaluate different control strategies.

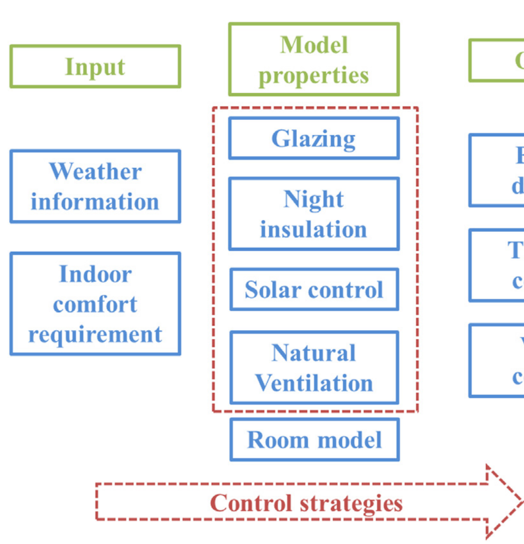

Fig. 1. Structure of the simplified method.

The simplified method is compared with Danish building simulation tool BSim on calculating the yearly energy consumption (heating, cooling, lighting and ventilation) and indoor environment parameters (indoor air temperature, solar transmittance and daylight level on the reference point) under different control strategies that exist in BSim. According to all the comparisons (Fig. 2), difference of energy calculation between the two methods is below 10%.

Fig. 3 presents the calculated results by the simplified method for indoor air temperature under the four control conditions as a function of the corresponding results calculated by BSim. The result shows that, under the condition of façade with different control, the calculated results of the simplified method have acceptable agreement with that of BSim software in terms of the indoor air temperature, with the average value of R^2 at 0.92.

The purpose of this study is to evaluate the accuracy of the simplified method in terms of calculating the energy and comfort parameters of the test room. The verification of the simplified method is implemented by the measurements performed in the test facility "The Cube" at Aalborg University. The indoor air temperatures and heating and cooling loads were measured during a summer period at the end of June 2014 (18th–22nd), and the calculations by the simplified method are conducted through all the time the measurements were implemented.

3. Experiment setup

The measurements are implemented in the full-scale test facility (The Cube at Aalborg University [23,24]) (Fig. 4) consisting of one south-facing test room with the internal dimension of $2.76 \times 2.7 \times 3.65$ m^3 (H × W × D). The glazed facade system faces south and has a dimension of 2.76×1.6 m^2. All the enclosures of the test room except the south façade are surrounded by a guarded zone to minimize heat transfer through the enclosures. The entire heat capacity of the test room is 1700,000 J/K (47 Wh/Km^2).

The glazing type used in the experiments is a double glazing unit with a 22 mm argon-filled cavity and low-E coating on the internal pane. The air-tightness between the test room and outdoor has been tested by performing a blower door test, both in over- and under-pressure. The infiltration rate has been measured and is

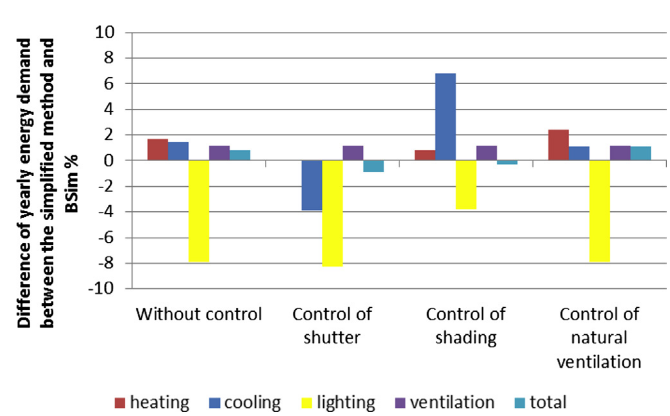

Fig. 2. Difference of energy demand on the four control conditions between the two methods.