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Original Research Article

Summer overheating of a passive sports hall building

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ABSTRACT

Reported measurements were intended as a preliminary check of a free run of a sports hall passive building in summer conditions. Indoor microclimate measurements lasted for three hot summer days and were carried out at the time when there was no building occupancy. In adverse conditions of high ambient air temperature and switched off ventilation acute overheating was observed. Night cooling, easily available measure of overheating protection was not applied, so there was no chance for discharge of high internal capacity of this building. A specific mode of building management had a critical impact on its internal microclimate and would raise user dissatisfaction. In close perspective of widespread implementation of near zero energy building standard, often reported overheating problem becomes an important issue. It was also shown that thermal comfort measurements may be unexpectedly and substantially affected by window location and solar radiation geometry.

1. Introduction

Common process of low energy building design is usually oriented on minimization of heating demand and enough attention is still not paid to protection against overheating. A lack of precise knowledge and also deficiency of designing tools, that would make it possible to predict dynamic course of indoor temperature in relationship to expected heat gains, thermal storage and possible heat sinks often result in low consumption of heating energy in winter but big cooling load, thermal discomfort or even unbearable thermal conditions in summer and in transition periods [1–4]. Traditional buildings with poorly insulated massive walls, intensive ventilation, leaky outer shell and moderate window area, were very forgiving to extra energy gains or design modifications. On the other hand, low energy buildings with robust thermal insulation, airtight building shell and often oversized window area are extremely vulnerable to overheating [1,5–7]. It is quite obvious by now that within the sustainable building development process the only reasonable approach is to minimize simultaneously heating and cooling loads and to avoid – if possible – extra investment, operation and maintenance costs of mechanical cooling system [8,9]. To achieve this goal, the designer has to assess, as accurately as possible, heat gains and their reduction measures, building

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thermal capacity and heat rejection capabilities [1,6,10]. Contemporary designing practice is based on routine procedure that starts with architectural concept and is followed by the subsequent engineering stages. The first crucial decisions regarding building orientation and window sizing are usually made only based on esthetic or fashion reasons. Further engineering steps are aimed at meeting heating and cooling demand of designed object by means of available technical systems. In this procedure no optimization or rational modifications are possible or even expected. On the contrary, it was proved that optimum south window area is in the given climate conditions a complex function of building heat transfer index and internal gains, its thermal capacity and glazing characteristic [11]. Further control of solar gains may be achieved by the standard shading measures and building operation mode [6,7]. Unfortunately, technical requirements do not usually stipulate any form of optimized design and are restricted to control measures only [8]. In [12] an approach based on the wide concept of the ideal indoor environment was presented to determine the suitability of dwelling-houses for living. Unfortunately, constant air temperature value was selected as a single thermal comfort criterion.

Optimization of south window area is also a good example of the necessity of an integrated approach to building design process. Not only total energy demand but also internal thermal comfort is, to a significant degree, a direct consequence of the design decisions made at the initial stage of the whole process [4]. Author of [13] stated that in some places people feel uncomfortable, realizing that they are not suitable for the activities they attempt to do in them. On the other hand, in existing building the actual monitoring and control solutions usually are not able to meet all the requirements and prevent overheating [2]. Jenkins [4] proposed a probabilistic tool, based on dynamic simulation results, that allows to assess overheating in a designed standard dwelling building. Unfortunately, there are no tools and reports available for sports buildings.

Below reported measurements of internal microclimate in a passive sports hall building prove that design oriented on low heating demand only may be not successful in hot summer conditions. The direct aim of the presented study was to examine and analyze thermal conditions in summer and explain why the passive protective measures against overheating were not sufficiently effective in this case.

2. Sports hall of Cracow University of Agriculture

Sports hall of Cracow University of Agriculture has been designed according to the German passive building standard. This standard, devised by Passive House Institute, requires yearly demand on final energy for heating no higher than 15 kWh/m^2. Sports hall envelope is efficiently insulated and airtight. Thermal transmittance U-value of the external walls is 0.1 W/(m^2 K) (40 cm of EPS Neopor). Flat green roof is insulated with 12 cm of polyisocyanurate foam and 40 cm EPS, floor on the ground with 40 cm of high density EPS. U-value of the triple glazed windows is 0.8 W/(m^2 K). The main load bearing structure is made of reinforced concrete and filled with silica brick, 25 cm thick, thus assuring high thermal capacity and low built in energy.

Total area of the three story building is equal to 18,000 m^2. The main part of the building is playing field with the stands for 150 spectators and furthermore cloakrooms, fitness, technical rooms and storage. The main entrance is located in south part of the building, Fig. 1. East and west elongated facades are substantially glazed, Figs. 2 and 4. Unfavorable building orientation (large east and west windows) was due to the specific shape of building site and its limited area and it was a conscious decision of architects and investor. Building height is 10.35 m to the top of attic wall. Roof inclination angle is equal to 2°. Vegetation was designed on the whole roof area and partially on the building facades to increase biologically active area of the building site. Mechanical exhaust–supply ventilation system combined with air heater and recuperator was designed (heat recovery efficiency 75%). Additionally, building may be heated by the radiant water floor system. Sports hall building is located in Polish III climatic zone with outdoor design temperature equal to −20 °C. Indoor air setpoint temperature was designed as [14]:

24 °C – cloakrooms and bathrooms
20 °C – playing field
16 °C – vestibules.

Measured air-tightness of the building envelope meets with an excess the requirements of the Passive House Institute with ($n_{50} = 0.2$ l/h). Electric external blinds provide protective shading of east and south oriented windows against excessive solar gains. Total solar transmittance coefficient g of window glazing is 60%.

3. Monitoring conditions and basic assumptions of evaluation

Reported measurements were intended as a preliminary short test of a passive building without mechanical cooling in summer conditions. The authors did not influence in anyway building operation and use during the testing period. Sports hall internal microclimate measurements lasted for two summer days with high outdoor temperatures, maximum ambient air temperature in this period raised to the level of 39 °C. Integrated microclimate data logger BABUC A was used for data collection. Single measuring device was placed on the playing field floor, next to the east emergency exit, Fig. 2.

Device location was a compromise between equipment safety and expected quality of measurement. All the data were recorded in 5 min intervals, at mean height of 1.35 m above the floor level. Measurements were carried out at the time when there was no occupancy of the sports hall, so there were no extra heat gains from people and lighting. It is very important to emphasize that only thanks to the fact that the building was not used it was possible to carry out continuous testing and leave measuring equipment unattended and unprotected for