‘Low-invasive’ measures for improving the indoor climate in school buildings, particularly with consideration of warmer summers due to climate change

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Abstract

The drive for adapting school buildings to future weather conditions and better indoor environments is spreading around the world. Many mid-size European cities, like Karlsruhe in Germany, count with a significant building stock that date back either to the late XIX Century, or the mid XX Century, as a result of the necessity of a rapid reconstruction of the cities in the post-war decades. These buildings will be the focus of refurbishments in the next few years to improve their sustainability performance, and, although energy consumption is the primarily concern, awareness about the synergy between climate change, user satisfaction and cognitive performance is rising amongst the building authorities. Thereby, the retrofit strategies require innovative solutions that guarantee Indoor Environmental Quality while maintaining energy efficiency. This research project aims to find low-invasive measures for school buildings that take into account these mentioned aspects in combination.

The first stage of this study analysed the school building stock of the city in order to find a relation between the building properties and their energy performance and through that, define the sample to simulate. The second, and current phase, uses Dynamic Thermal Simulations to establish their base case scenario, study their potential to improve the indoor environment, and test possible refurbishment measures to adapt to climate change.

Keywords: Building energy efficiency, summer thermal comfort, energy efficient schools, building refurbishments.

Background and objective

School buildings pose considerable challenges to meet demanding and interrelated design requirements in terms of high occupant densities, indoor air quality, energy performance, and future climate conditions. Ensuring a good Indoor Environmental Quality delivery is essential

for children, as it can impact the long-term health and cognitive performance of this vulnerable group [1, 2, 3].

The city of Karlsruhe is one of the warmest in Germany and the temperatures will increase around 1.5 °C in the near future and 3 °C in the far future, with double climatological event days (hot days and tropical nights) [4].

The city authorities are then, engaged with these two conditions and expect to find new solutions without implementing air conditioning units. This research project aims to evaluate and find better options for the design and development of building refurbishments for the schools in the city, to ensure energy efficiency, and health and wellbeing of all the occupants. It is expected that the solutions can be used in the Action Plans of the city.

Building selection

To establish a suitable sample of buildings to study, the building stock of the city was analysed, creating a matrix with the following information:

- Generalities: building category (primary school, high school, etc.), location, year of construction, main façade materials.
- Geometrical properties: orientation, areas, number of floors, form, classrooms heights, window to wall ratio (estimated), surface area to volume ratio (estimated).
- Energy: heating and electricity consumption (2013 – 2015), heating and electricity savings (2015 vs. 2013), related CO_2 emissions.
- Equipment: HVAC, windows types.

The point of interest was the analysis of the energy performance. Nevertheless, the relation between the energy consumption and properties such as year of construction, orientation, window to wall ratio (WWR) or surface area to volume ratio (SAV) was not conclusive. It is considered that this behaviour could be attributed to the users and the building management, due to the fact that there are no automated lighting or ventilation, or the fact that some of these properties were estimated. Thus, to select the sample, the buildings with the major energy consumption were chosen, mixing with central urban and suburbs buildings from different epochs. Eight school buildings were selected.

Model validation

Even though the database of the city is quite large, not all the information required to create the models was available. Consequently, some assumptions were required. For instance, the building constructions were selected matching the information from questionnaires made to architects related to buildings, site visits, typical construction types according to the literature, and building layouts. The final selection was validated by architects, experts on the field.

Temperatures measures are also made during the summer of 2017 to get a clearer view of the indoor temperatures in the classrooms and the window opening practices. Additionally, the energy consumption predictions of the models are compared with the actual data of energy consumption. Although this information is available, in this study it cannot be taken as a direct validation method, since the data of heating and electricity consumption corresponds to school totals and in many cases a school has more than one building. Nevertheless, the comparison between the model calculations and the reality gives an overview of the assumptions made and the actual performance of the building. The data is also compared with the benchmarks of the region.

Further plausibility checks are made personally. Once the inputs are double checked, I plotted several graphs to guarantee that the model is representing the conditions as desired. For example, I revised that the rooms are heated just during the winter months, and that the airflow corresponds to the assumed profile (i.e. during the day or night, etc). Additional checks made, included the internal gains, which do not vary during the year but are off during weekends and school breaks, as it was previously established.

Initial results

As the focus of the study is the Indoor Environmental Quality of the classrooms in the summer, the initial analysis is made at the warmest days. According to the Test Reference Year for the region, the current warmest month is August, however, schools are on break during this month. Therefore, the initial analysis is made for a week in July where the warmest day achieves almost 33 °C. It is worth mentioning that the simulations are run for the entire year, to take into account the storage capacity of the thermal mass of the building, and also for the entire school building, to take into account the effect of the partitions.

During the school visits, it was found that it is common that the windows in the classrooms remain closed or a just tilted to ensure children's safety and, in some cases, avoid external noise. Therefore, this practice was taken for the base case scenario. The models predict that in this case, temperatures above 28 °C are easily reached from 11:00. A complete window opening, especially during the early morning, helps reducing the indoor temperature around 1 °C, while the night ventilation could help reduncing this temperatures up to 3 °C, depending on the school conditions. Aditionally, only night ventilation allows that the classrooms get indoor temperatures below 20 °C at the beginning of the day.[1]

Further and more specific results will be available as the study goes on. For questions please contact me at: Carolina.montano@partner.kit.edu

[1] These are preliminary results. Therefore, the data is susceptible to change while the models are calibrated and validated.

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