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INFLUENCE OF NATURAL AND MECHANICAL VENTILATION ON ELIMINATION OF HEAT LOAD IN THE LOFT SPACE

A purpose of this submission is a dynamic analysis of indoor environment on the suitably chosen classrooms, which are situated in the loft spaces of Civil Engineering Faculty in Kosice. The evaluation was doing by using energy simulation tool and is oriented on evaluation of heat load during summer period. The subject of analysis is to consider influence of selected mode of natural and mechanical ventilation on a modification of operative temperature in classrooms. The purpose of the whole submission is to obtain a dynamic view of indoor environment changes that are determined by internal and external factors, to compare the suitability of evaluated ventilation modes and possibility of their application in these areas.

Key words: dynamic analysis, heat load, ventilation.

Здійснено динамічний аналіз внутрішнього середовища вибраних класів, розташованих в мансарді будівельного факультету в Кошице. Аналіз виконувався з використанням інструментів моделювання і проводився для оцінки теплового навантаження в літній час. Предметом аналізу є оцінка впливу окремих режимів природної та механічної вентиляції на зміну робочої температури в класах. Мета аналізу полягає в отриманні динамічної картини змін у внутрішньому середовищі під дією внутрішніх і зовнішніх факторів, а також для порівняння придатності оцінюваних режимів вентиляції та можливості їх застосування.

Ключові слова: динамічний аналіз, теплове навантаження, вентиляція.

Introduction

Since 2003 Civil Engineering faculty in Kosice has had the loft spaces at its disposal, which have developed from the reconstruction of loft spaces at that time. At this time these spaces are used as lecture-halls and classrooms within the education process. An architectural, constructional and material design of the whole loft reconstruction causes high heat gains in following months May and June each year. The subject of analysis is to consider the impact of selected mode of natural and mechanical ventilation on operative temperature in these spaces. For analysis purposes there was selected the reference classroom with south-west orientation (classroom SW, Fig. 1, Fig. 2) where are significant heat gains from solar radiation mainly afternoon. Results are output from dynamic energy simulation tool DesignBuilder.

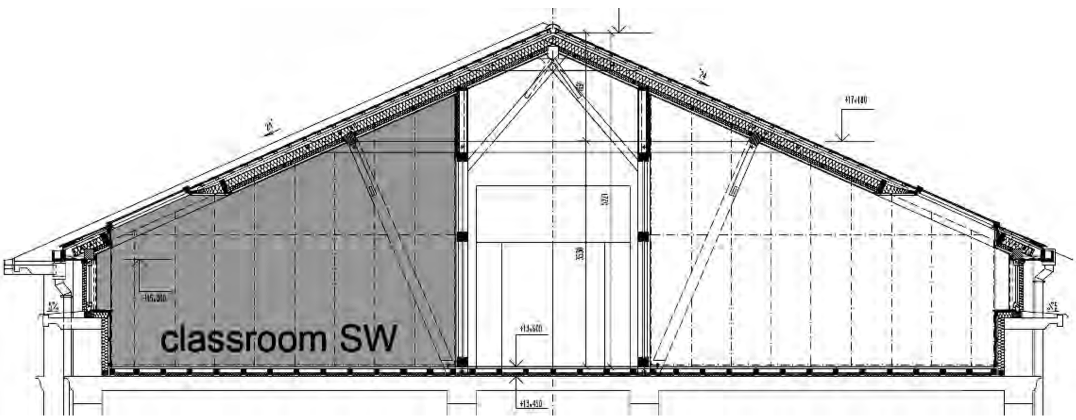


Fig. 1. Loft construction of CEF with highlighting of analysed classroom with south-west orientation

Creation of geometric model and definition of boundary conditions

There was modeled the object section of Civil Engineering Faculty (Fig. 3 left). In this section there was created block with defined boundaries of individual spaces like classrooms (SW, NE) and corridor. This way of modelling allows to define conditions of indoor environment (occupancy, activity, lighting, HVAC) and parameters of building construction (U-value, global heat gain coefficient) and their connections to adjacent building constructions for created block. The modelled block was located with real orientation to cardinal points and situated in the height 15 m above the level of surrounding ground what is the level of the 4-th floor. Further the block was divided to particular zones: classroom SW with windows orientation to south-west, classroom NE with orientation to north-east and corridor (Fig. 3 right). Floor area of one classroom is 66 m^2, volume of classroom is 210 m^3 and max capacity is 30 people per room. Full height by gradient of roof plain 23° is range from 1,9 to 4,5 m. The basic parameters of transparent and non-transparent building constructions are shown in next table (Table 1). The whole loft space is constructed like construction with poor accumulated effect (Fig. 1); there were used materials like plaster boards, mineral thermal insulation and wood-based panels on floors [1].

Real state — Classroom model in DesignBuilder

Fig. 2. View of analyzed classroom

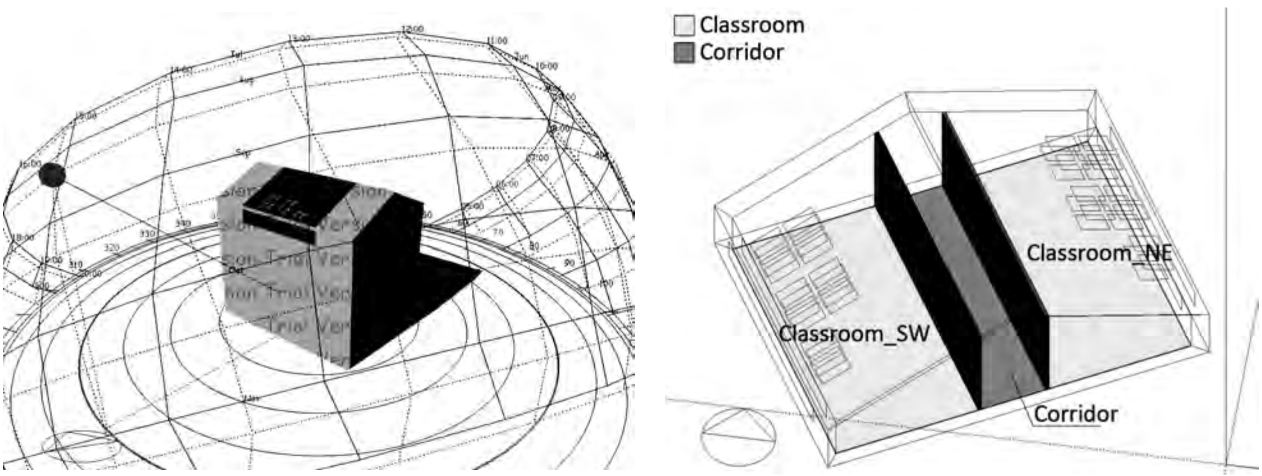
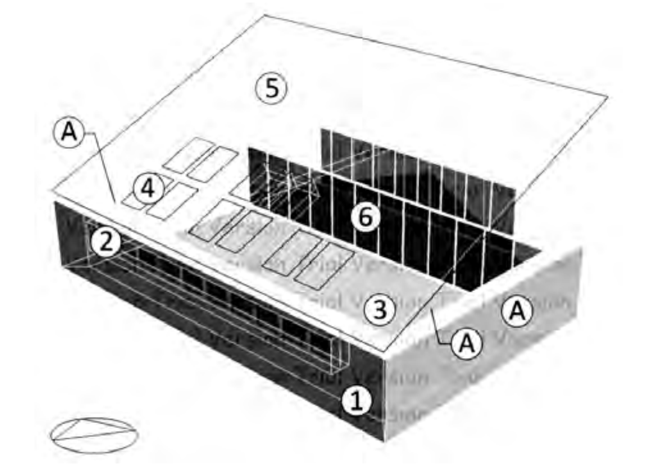


Fig. 3. Geometric model of loft space created in simulation tool DesignBuilder

Table 1

Parametric characteristic of constructions



1	External wall: U = 0,29 W/(m^2.K)
2	External windows: U = 2,5 W/(m^2.K), g = 0,72, τ = 0,78
3	Roof: U = 0,2 W/(m^2.K)
4	Roof windows: U = 2,0 W/(m^2.K), g = 0,6, τ = 0,77
5	Internal wall (part over internal windows): U = 0,68 W/(m^2.K)
6	Internal windows: U = 2,9 W/(m^2.K), g = 0,75, τ = 0,82
A	Adiabatic constructions (walls and floor)

The object of analysis was to compare influence of natural and mechanical ventilation on profile of operative air temperature in selected classroom SW. Influence of natural ventilation for given model of classroom was analysed yet and the results were published on conference EnviBUILD 2012 [1]. In case of natural ventilation (Variant V1) there were under consideration these border conditions for analysed classroom SW:

- space occupancy (2,0 m^2/person, metabolic rate 108 W/person) during education process since 7.30 a.m. till 6.20 p.m.,
- 25 % area of windows in external wall opened in time since 6.00 a.m. till 6.20 p.m.,
- closed roof windows due to installed light internal shade roll (solar transmittance = 0,4) [1].

For these defined boundary conditions of natural ventilation there was achieved average air exchange intensity 3 1/h what represents ventilation rate for person on level 5,8 l/s per person. The operative temperature in classroom achieved values in interval from 18 °C in the morning hours till 32 °C in the afternoon (Fig. 4). The achieved ventilation rate per person fulfils the demand for suggests air exchange intensity that is given in II. category of indoor environment by standard STN EN 15251:2007 Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics [2]. On the other hand the values of operative temperature in classrooms don't fulfil the demands for suggest operative temperature in this II. category of indoor environment. And the next question is what the efficiency of classroom ventilation is by using only natural ventilation across the opened windows.

For comparison with natural ventilation of space there were proposed and analysed following 3 variants of mechanical ventilation:

- **Variant V2** – mechanical ventilation in time since 6.00 a.m. till 6.20 p.m., average air exchange intensity about 6,0 1/h, space occupancy 30 people/room (2,0 m^2/person, metabolic rate 108 W/person) during education process since 7.30 a.m. till 6.20 p.m., light internal shade roll (solar transmittance = 0,4) on roof windows,
- **Variant V3** – mechanical ventilation in time since 6.00 a.m. till 6.20 p.m., average air exchange intensity about 6,0 1/h, space occupancy 15 people/room (2,0 m^2/person, metabolic rate 108 W/person) during education process since 7.30 a.m. till 6.20 p.m., light internal shade roll (solar transmittance = 0,4) on roof windows,
- **Variant V4** – mechanical ventilation in time since 6.00 a.m. till 6.20 p.m., average air exchange intensity about 20,0 1/h, space occupancy 30 people/room (2,0 m^2/person, metabolic rate 108 W/person) during teaching from 7.30 a.m. till 6.20 p.m., light internal shade roll (solar transmittance = 0,4) on roof windows.

Results analysis from simulation of natural and mechanical ventilation

In the first step, the simulation of the about variants (V1 to V4) was realised during since 1st till 15th May in order to gain operative temperature profiles in classroom SW. The gained results from analysed classroom SW for selected interval 12th and 15th May are shown below in the picture Fig. 4. From presented results it is possible to see clear growth of operative temperature on the level that overhangs recommended value 26 °C for internal environment of classrooms by standard STN EN 15251 [2] in the case of natural ventilation. Application of mechanical ventilation with raising air exchange intensity (6 1/h) brought drop of operative temperature in average about 2 K in analysed classroom (variant V2). The next option how to solve the drop of operative temperature in classroom is to reduce the heat gains from occupants namely by reduction of occupancy from initial 30 person on 15 person in classroom but at conservation of air exchange intensity 6 1/h (variant V3). The air exchange intensity in classroom in average 6 1/h represents ventilation rate for person on level 11,5 l/s per person at space occupancy with 30 persons and ventilation rate for person on level 23 l/s per person at space occupancy with 15 persons. It is possible to see that in the case of mechanical ventilation the operative temperature is above the level 26 °C in afternoon too. Only by application of variant V3 with raising air exchange intensity (in average 20 1/h) it is possible to keep operative temperature under level 26 °C [2] during education process with soft growth in some days (e.g. 15th May).

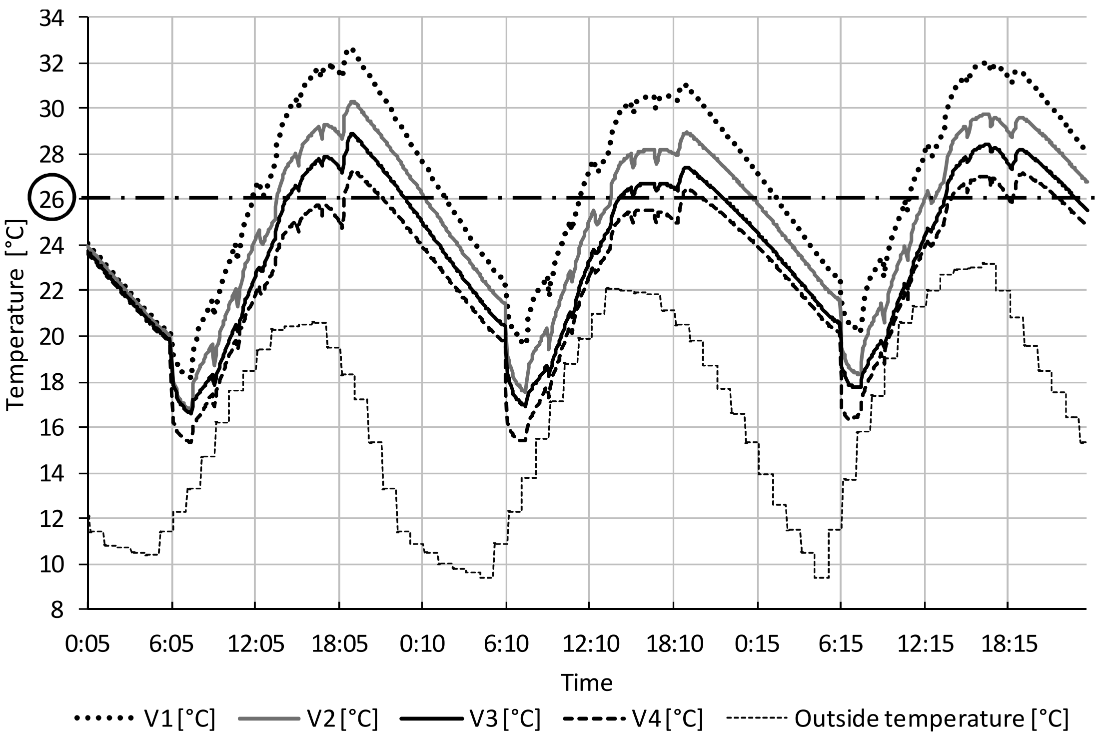


Fig. 4. Operative temperature profiles in the analyzed classroom for selected variants

The impact of internal and external factors on change of operative temperature in analysed classroom SW by mechanical ventilation (variant V2) is shown in the next picture (Fig. 5). The profile of passive solar gains classroom is given by actual availability of solar radiation and by thermo-optical parameters of transparent constructions (external and roof windows). The local drops of heat gains from people are caused by regular breaks for 10 minutes and lunch break for 70 minutes during education process since 7.30 a.m. till 6.20 p.m. The whole profile of heat gains from people has decreasing character because it was thought over dynamic simulation that makes provision for interaction between metabolic rate of people and parameters of surrounding environment. Negative heat load values of external air demonstrate heat load removal from classroom by natural ventilation (opened external windows) in time since 6.00 a.m. till 6.20 p.m. when external air temperature is lower than internal air temperature.

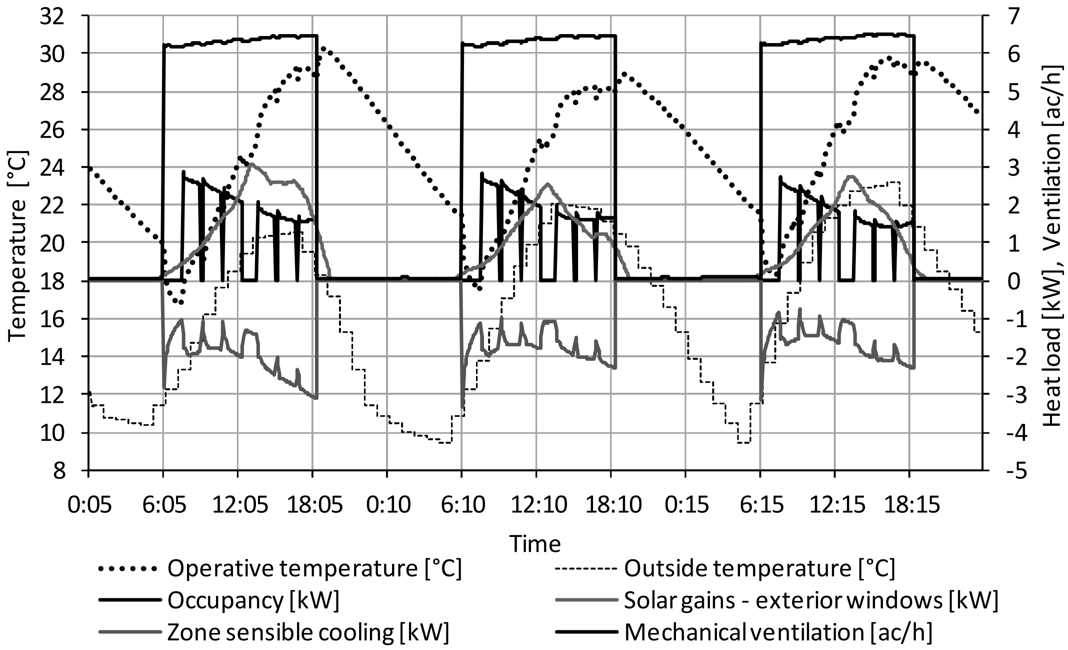


Fig. 5. Data profiles of indoor environment changes determined by internal and external factors (variant V2)

Possibilities for application of mechanical ventilation in analyzed classroom

From the results of operative temperature profiles in classroom (Fig. 4) is clear that natural ventilation is not effective in the case of heat load dissipation, operative temperature exceeds the value 26 °C. It is possible to achieve the required operative temperature only by application of mechanical ventilation with the high air exchange intensity in average 20 1/h what represents the total volume airflow of outdoor air 4 200 m^3/h by given parameters of analysed classroom. If we will think over the supply of air through large area inlets in number 4 pieces what represents airflow 1050 m^3/h through one inlet then the velocity 0,3 m/s will be achieved in distance 4,5 m from inlet. That solution of mechanical ventilation is not realised in this classroom.

It is realised the variant of mechanical ventilation with air exchange intensity in average 6 1/h what represents the total volume airflow of outdoor air 1260 m^3/h. If in this case too we will thing over the supply of air through large area inlets in number 4 pieces what represents airflow 315 m^3/h through one inlet then the velocity 0,3 m/s will be achieved in distance 1,5 m from inlet. In the case of that mechanical ventilation by using only outdoor air it is needed to suck outdoor air from just non dazzle (colder) side of building façade (Fig. 6, Fig. 7).

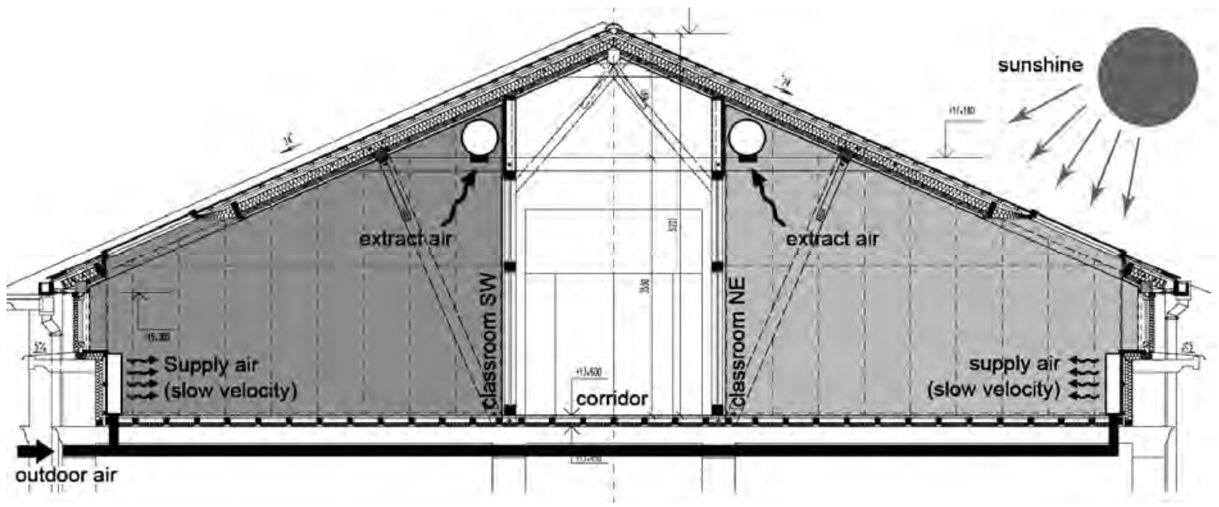


Fig. 6. The mechanical ventilation through large area inlets
(the sun in the east, the supply from west side of facade)

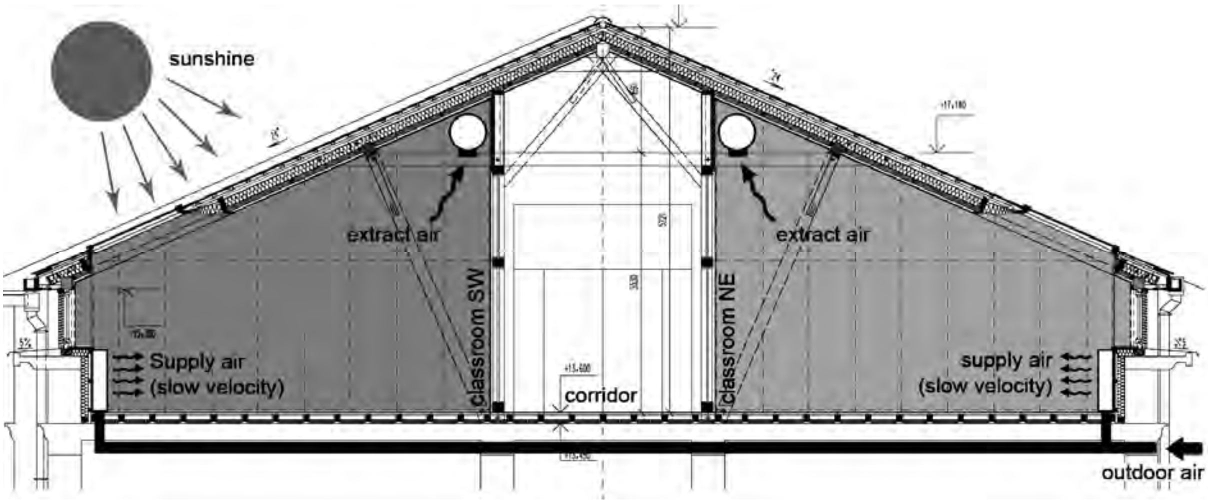


Fig. 7. The mechanical ventilation through large area inlets
(the sun in the west, the supply from east side of facade)

Conclusions

Our goal was to gain image about changes in indoor environment in consequence of internal and external factors and to consider the using of mechanical ventilation without additional air treatment in order to removal of heat load in classroom. On the base of presented results it is possible to state that application of mechanical ventilation brought some drop of operative temperature. In order to achieve the required value of operative temperature by standard STN EN 15251 it is needed to install cooling system in these spaces.

Acknowledgement

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