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Efficiency of Natural Ventilation in Central Greenhouse of Botanical Garden in Kosice

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Abstract. The object of paper is analysis of natural ventilation system in central greenhouse of Botanical garden in Kosice. The greenhouse was refurbished in 2015. The existing greenhouse covering from glass panels was replaced for polycarbonate panels. The ventilation system of central greenhouse is natural and there are used openings in covering (wall, roof). It is combination of thermally and wind driven ventilation. The main aim of contribution is to analyse different modes of natural ventilation during summer period mainly. The important factors that influence efficiency of natural ventilation in greenhouse are location and area of openings, temperature stratification in greenhouse, solar radiation level, wind speed and direction too. If the greenhouse is ventilated naturally only through external windows (roof windows are closed) the efficiency of ventilation is very poor. The defined modes of natural ventilation search the right location and size of opened windows in order to achieve the most efficiency ventilation of indoor environment. For this purpose the progressive dynamic simulation tool DesignBuilder is used where the geometrical and specific calculated model of whole central greenhouse was created.

Keywords: indoor air temperature, natural ventilation, greenhouse, DesignBuilder.

Conference topic: Energy for buildings.

Introduction

Exposition of tropical and subtropical flora in Botanical Garden Kosice was open in main greenhouse in 1958. The greenhouse was one of the biggest in Europe at this time (Cornakova, Fatolova 2014). The main greenhouse has three parts that were building during 1950–1957 (see Fig. 1).

This is steel supporting structure with single glazing system. The reason for greenhouse refurbishment was degradation of steel construction and glazing system and high operation cost of heating system too. The refurbishment was doing during years 2014 and 2015. Steel construction was purified from rust and original single glazing was replaced with multilayer polycarbonate panels. During the first heating period of greenhouse after refurbishment there was achieved the energy saving about 30%.

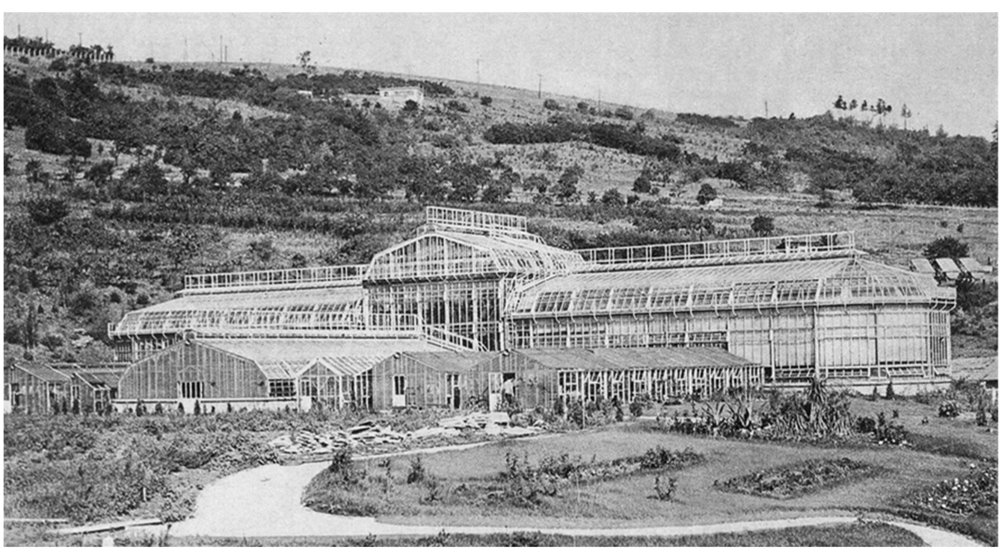

Fig. 1. The view on new built greenhouse of Botanical Garden Kosice in 1958 (Krajské architektonické stredisko Košice 2012)

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The present results of case study are gained by using dynamic energy tool DesignBuilder. This way was selected in order to get early picture about indoor air temperature trend during summer period after refurbishment of greenhouse. The greenhouse is ventilated natural; openings in external walls and roof are used. The area and location of openings is the same as before refurbishment (see Fig. 2, Fig. 3), the automatic control system of openings on base of indoor air temperature and humidity was completed.

The main aim of contribution is to analyse different modes of natural ventilation during summer period mainly. The important factors that influence efficiency of natural ventilation in greenhouse are location and area of openings, temperature stratification in greenhouse, solar radiation level, wind speed and direction too (Roy *et al.* 2002; Boulard *et al.* 2002, Shamshiri, Ismail 2013). The simulations were done without thinking with impact of flora, sink and indoor air humidizing.

Model geometric and boundary conditions of simulations

At first the geometric model of greenhouse was done in energy simulation tool DesignBuilder. Dimensions of greenhouse are 12.5×74 meters; the height is 9.0–12.0 meters (Cornakova, Fatolova 2014).

There were used the hourly simulation weather data (IWEC) for Kosice from EnergyPlus database. There were simulated the state after refurbishment with multilayer polycarbonate panels. The thermo-optical properties of used multilayer polycarbonate panels are following:

– Coefficient of thermal transmittance U = 1.55 W/(m^2·K),
– Thermal properties SHGC = 0.77,
– Optical properties τ = 0.65.

The floor area of greenhouse is 885.5 m^2. The area of external windows is 99.45 m^2 and the area of roof windows is 61 m^2. All openings are controlled by the automatic control system on base of indoor air temperature and humidity. If windows are open the free area for air supply and exhaust is about 30% from total windows area. The roof windows are protected by additional construction before rainfall (see Fig. 4). Nowadays there is'nt used any system of active shading. The simulations were done without thinking with impact of flora, sink and indoor air humidizing.

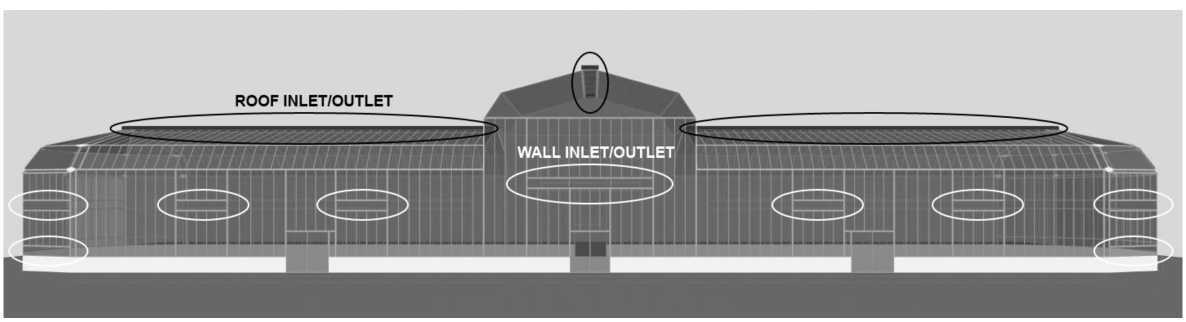

Fig. 2. Location of inlet/outlet openings, the view at the north side of greenhouse

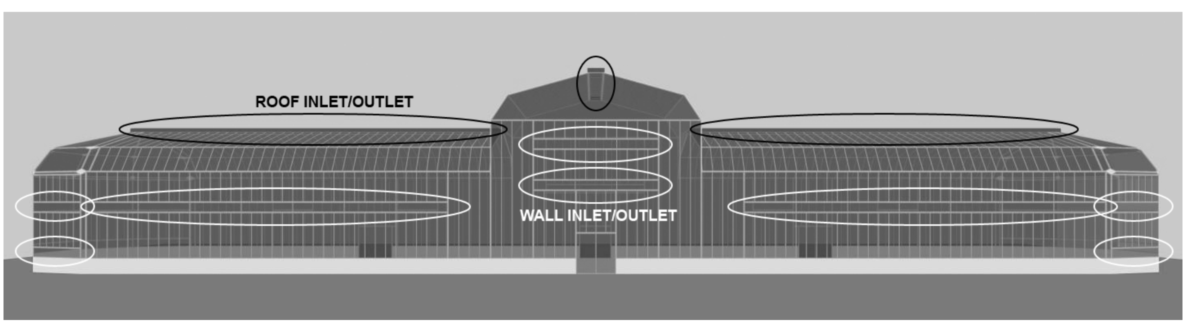

Fig. 3. Location of inlet/outlet openings, the view at the south side of greenhouse

Energy simulation results

There were created two variants in order to analyse the trend of indoor air temperature in greenhouse. The differences are in modes of natural ventilation system. Natural ventilation system operates windows opening if the air temperature in greenhouse is higher than outdoor air temperature and higher than defined value 24 °C together. The energy simulation of parameters of internal environment in greenhouse was done for summer monts July and August. The modelled variants are following:

- Variant A: state after refurbishment, natural ventilation with external windows only,
- Variant B: state after refurbishment, natural ventilation with external windows and roof windows.

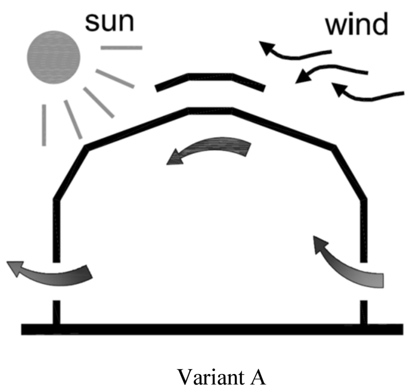

Fig. 4. Scheme of natural ventilation system of greenhouse

In both variants there were considered with new covering of greenhouse from multilayer polycarbonate panels. In Variant A the greenhouse is naturally ventilated with external windows only; the openings in roof are closed. The results from energy simulation for Variant A are shown in Figure 5 for time period 15th – 31st July. The total fresh air (air exchange) achieves values 2–8 ac/h during day (see Fig. 5). It is the impact of thermally and wind driven ventilation (Bailey 2000; Ganguly, Ghosh 2011). The efficiency of ventilation is poor and hot air cumulates under roof of greenhouse. Max value of indoor air temperature is 45 °C in this case.

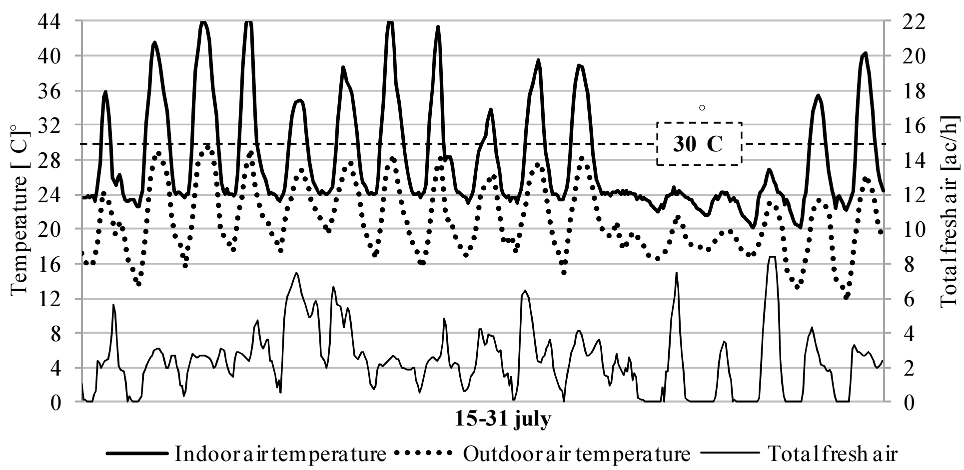

Fig. 5. The results from energy simulation for Variant "A"

Variant B is the modification of Variant A. In this case the greenhouse is naturally ventilated with external windows and roof windows are open too. The results from energy simulation for Variant A are shown in Figure 6 for time period 15th – 31st July. The total fresh air (air exchange) increased to value 4–16 ac/h during day (see Fig. 6). The efficiency of ventilation increased too. Max value of indoor air temperature is 37 °C in the case of Variant B. If we compare the results from energy simulation with Variant A, the hot air that is accumulated under roof is taken away through roof windows. There is using combination of thermally and wind driven ventilation with higher efficiency in compare with Variant A.

On the base of results from energy simulation the indoor air temperature dropped in average by 2–8 K in compare with Variant B (see Fig. 7).

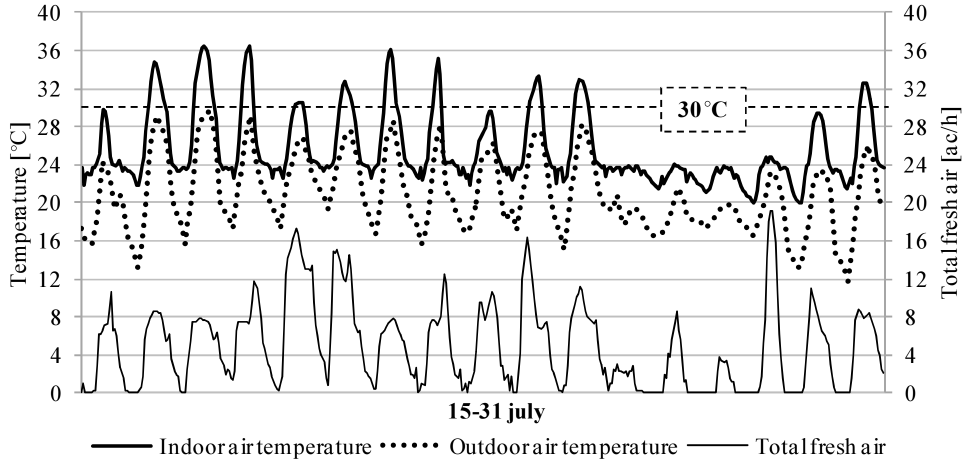

Fig. 6. The results from energy simulation for Variant „B“

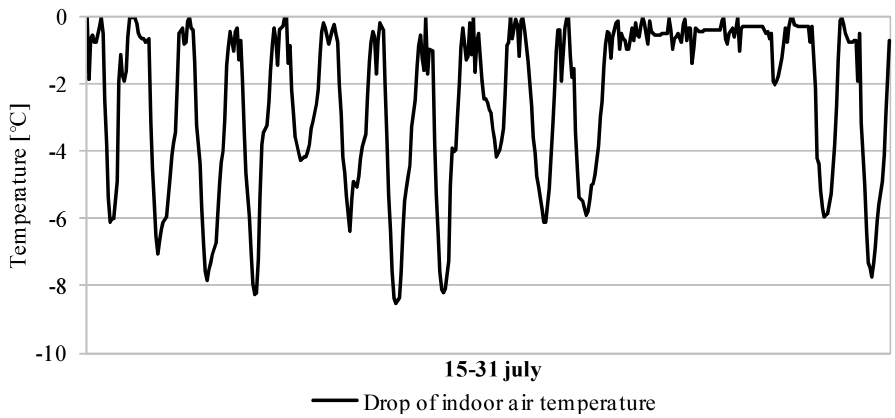

Fig. 7. Drop of indoor air temperature in Variant "B" compared with Variant "A"

Conclusions

The utilization of dynamic simulation tools make possible to analyse indoor environment of buildings. In this case study the indoor air temperature in greenhouse during summer period was analysed. The important is modes of natural ventilation system and location of openings.

Natural ventilation with external windows only (Variant A) is less effective than natural ventilation with external windows and roof windows too (Variant B). If we use only external windows for natural ventilation, the maximum indoor air temperature in greenhouse is at value 45 °C. If we use combination of external windows and roof windows for natural ventilation of greenhouse, the maximum indoor air temperature achieves the value 37 °C. On the base of results from energy simulation of greenhouse it is possible to achieve drop of indoor air temperature at value 2–8 K during day. If the roof windows are open too, the thermally driven ventilation is supported in time of windlessness too and together the wind driven ventilation is supported.

Extreme temperatures inside the greenhouse will limit the plant growth, as well as its quality (Dayioğlu, Silleli 2015). Greenhouse crops must not be kept for long time at temperatures higher than 30 °C in case of tropical and subtropical flora (Bailey 2006). The disadvantage of natural ventilation mode in case of Variang A is the high values of indoor air temperature and the high share of time when the indoor air temperature is over 30 °C. This share is about 36% time from monitored period July – August (without night time). Vice-versa in case of using effective mode of natural ventilation (Variant B) it is possible to shorten this time to value 18% what presents the following graph (see Fig. 8). The next possibility to keep the optimum indoor air temperature in greenhouse would be to use the active shading system.

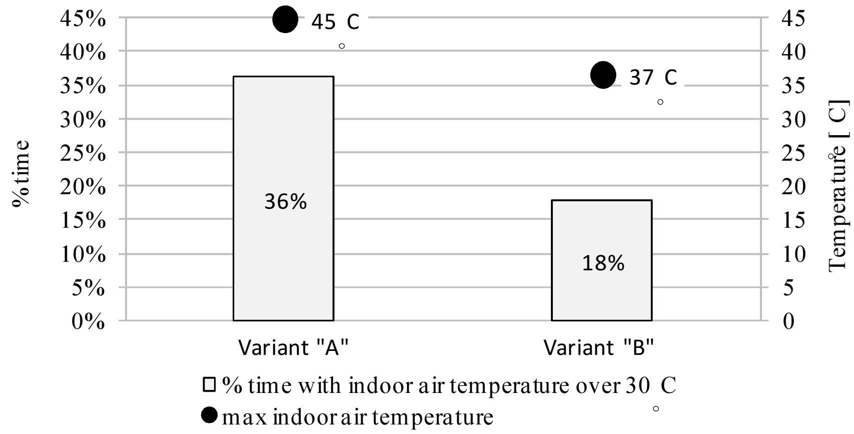

Fig. 8. The comparison of the effectiveness of natural ventilation modes in terms of indoor air temperature

The presented results for indoor air temperature trend are given by energy equations that take into account heat losses, gains and heat accumulation (Ganguly, Ghosh 2011; Raczek, Wachovicz 2014). In regard to greenhouse construction (height) and size of glass surface the important factor is so called temperature stratification too.

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Disclosure statement

Authors declare that have no competing financial, professional, or personal interests from other parties.

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