DYNAMIC ANALYSIS OF TEMPERATURE AND HEAT GAINS IN CLASSROOMS WITH DIFFERENT TYPE OF WINDOWS

by

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Energy consumption in buildings, in schools as well, in Serbia and Montenegro is significantly higher than is defined in world's energy standards. Heating energy is the biggest part of total energy consumption in schools. Energy losses through the windows reach up to 40% of total energy for heating of building that points out the importance of economically usage and saving of energy. This paper presents one-week analysis of temperatures and heat gains for two classrooms with different type of windows. The analysis is performed by Design Builder software. Due to heat losses analyses continual measurements of ambient and outside temperatures with sampling time of one hour have been performed. The measurements were performed in two classrooms; in one classroom, there are old windows with wood frames, whereas in the other there are new PVC windows. The system for temperature measuring was realized based on microcontroller and a digital temperature sensor. Taking into account measured and simulation results, the relevant conclusions were performed regarding energy consumption efficiency for school buildings heating.

Key words: *school building, temperature measurement, microcontroller, design builder dynamics simulation, heat gains*

Introduction

Buildings are significant users of energy in a society and their energy consumption has important implications to social, economic, and environmental issues. A challenging task today is to design and promote energy efficient buildings in a cost effective and environmentally responsive way.

School buildings are most numerous typology objects whose importance should not be questioned. From the point of energy consumption, school buildings are big consumers, which should be supplied continually with energy of good quality. For the society, it is important that this consumption is rational as well. Good quality of energy together with rational consumption means energy efficiency of school buildings. Energy costs are also an enormous expense for public schools in Serbia [1]. On the territory of Čačak municipality there are 23 schools, 17 primary (7 in the town and 10 in the villages)

and 6 secondary schools. According to the data from 2004, 13,428 pupils attend these schools.

Most of these school buildings were built in the 70s or in the 50s of the last century, while some village buildings date back to the first half of the last century. Type of building of almost all schools is classical, without outside insulation. Heating of the schools on the territory of Čačak municipality is carried out by individual boilers (9 of them use coal and wood, 9 use fuel), while 5 town schools are connected to the remote heating system. The condition of windows in schools is not satisfactory, as in most schools it is either made of wood or metal. Few school buildings have newly changed windows made of PVC which have good thermal characteristics [2].

Overall coefficient of heat transfer for the older type of windows is bigger than 3 W/m^{2}K (for the windows of this coefficient average losses are 240-280 W/m^2). European regulations prescribe/demand value of overall coefficient of heat transfer of k = = 1.40-1.80 W/m^{2}K.

Change of old windows in school objects are one of the priority tasks for energy saving and increasing of energy efficiency which is being realized in Čačak municipality [3].

One of the schools in Čačak municipality where the reconstruction of windows has started is a city school which was built in 1963. That is the object of a classical type, without insulation, with the outside surface of 2700 m^2 which is heated by individual boiler on fuel. The window surface cover 487 m^2, where majority of the windows has wood frames whose overall coefficient of heat transfer is up to k = 3.49 W/m^{2}K. In a few classrooms windows have been changed with the PVC ones.

Measurements of inside and outside temperatures are well suited for precise predictions on heating energy demand and comfort of the buildings and modifications of them [4].

In order to analyze decrease of energy consumption and increase of the ambient comfort in the classrooms with new PVC windows compared to the classrooms with old wood windows, comparative measurements of temperature have been performed continually during one week as well as dynamic analyses by using software package Design Builder [5, 6].

Temperature measurements

Continual measurements of inside (ambient) and outside temperatures with sampling time of one hour have been performed. The measurements of ambient temperature were performed in two classrooms; in one classroom there are old windows with wood frames whose overall coefficient of heat transfer is k = 3.49 W/m^{2}K, whereas in the other there are new PVC windows with k = 1,49 W/m^{2}K. These two classrooms have equals dimensions of 59.40 m^2 and very similar position so that it can be assumed that other relevant thermal parameters are also almost the same. Surfaces of windows in both classrooms are 18.48 m^2. The position of these classrooms where the continual tempera-

ture measurement was performed has been marked on the created Design Builder model of a school object given in fig.1.

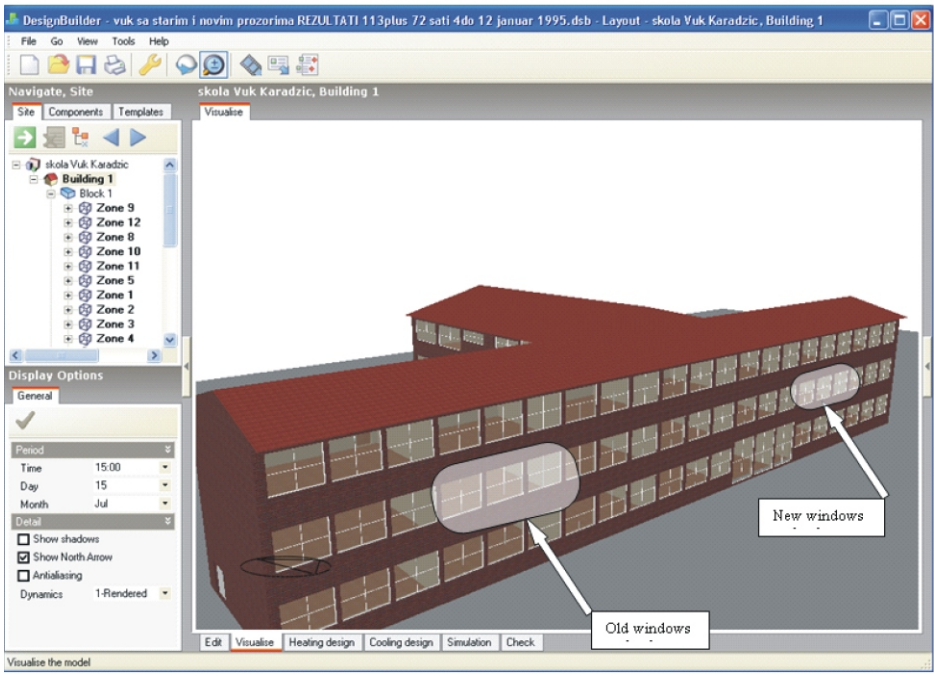

Figure 1. School building – Design Builder view

The system for measuring of temperature is given in fig. 2 was realized based on microcontroller Microchip PIC 18F452 and a digital temperature sensor Dalas 1820. On wire communication microcontroller – sensor was established. Digital temperature samples from the sensor are processed in microcontroller firmware and data are stored in MMC/SD memory card. Processing of the whole set of collected data are performed of line.

In fig. 3, the measured temperature changes are presented, as well as outside temperatures for these two classrooms. In the same picture, the results of hourly temperatures analysis in Design Builder are presented in order to compare results of simulations with measured data.

Results of measurements show that difference of inside temperatures for classroom with old windows in relation to classroom with new windows increase when outside temperature decreases. For outside temperature above 10 °C temperatures difference is insignificant.

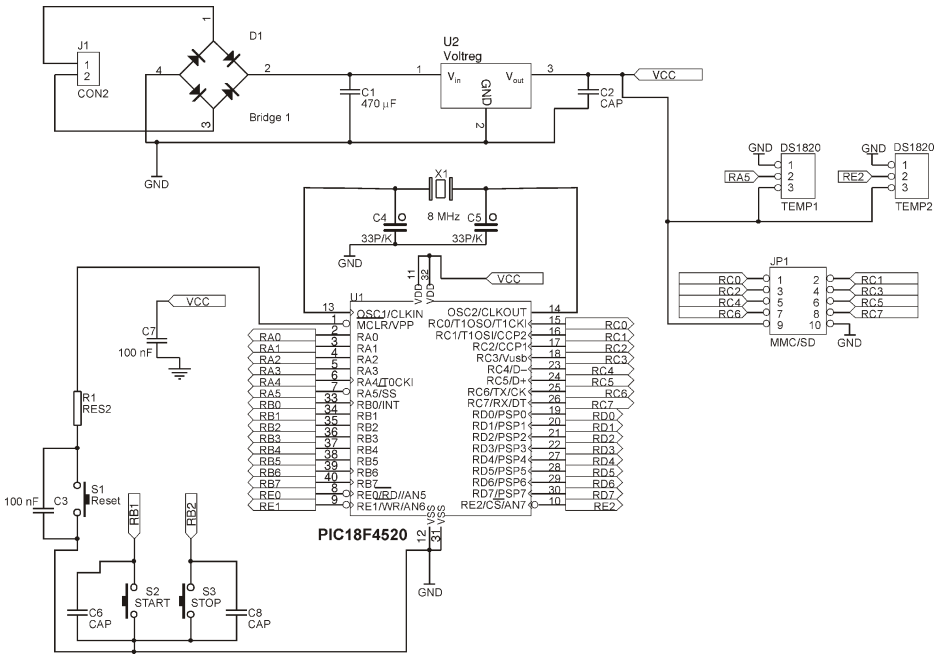

Figure 2. The system for measuring of inside and outside temperature

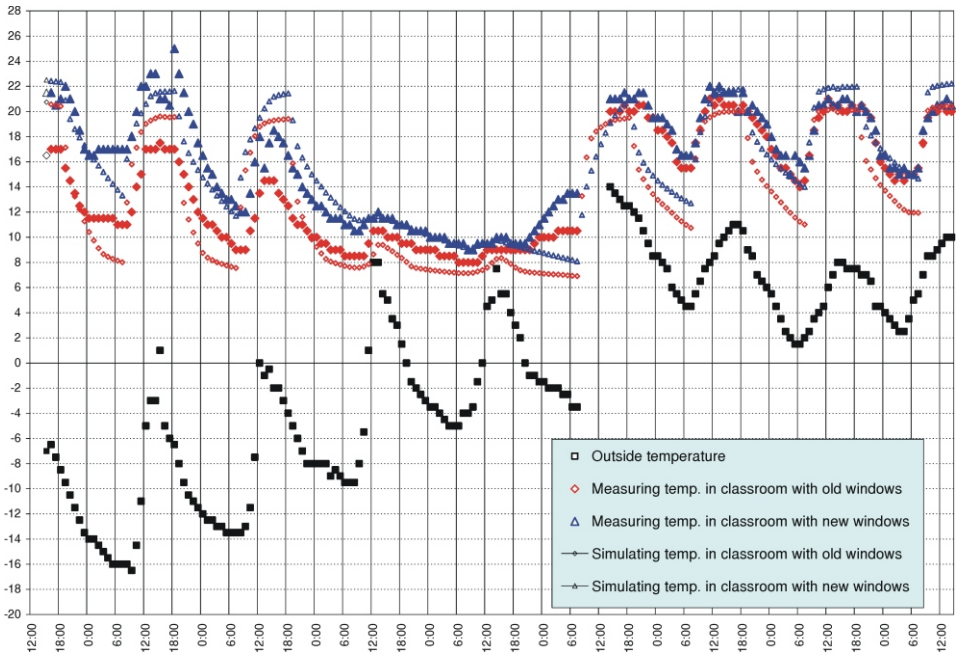

Figure 3. Hourly temperatures for two classrooms – measurements and simulations

Heat losses and gains analysis

Two-week dynamic simulations carried out on the created school building model by using of measured outside temperatures during one week. Design Builder dynamic simulation give hourly heat losses and gains trough windows (glazing), walls, ceilings, solid floors and partitions for classroom with old windows and for classroom with new windows, figs. 4 and 5. Heat losses trough the windows are especially concerned. Heat losses trough old windows reckons with external infiltration, fig. 4. It is obviously that heat losses trough old windows are bigger, especially during cold days. Simulation results shows that other heat losses are similar because analyzed classrooms have approximate same locations and thermal characteristic of walls, partitions, doors, ceilings, and floors.

There are not sizeable heat gains through the windows (transmitted solar gains) because simulation period was with poor sunshine, figs. 6 and 7.

Comparative preview of het gains simulation results for both type of windows and for different value of outside temperatures (0, –10, and –18 °C), is given in tab. 1. Simulation results also confirm adequacy of windows replacement from viewpoint of heating energy savings. For 0 °C HVAC heating for classroom with old windows is 2,02

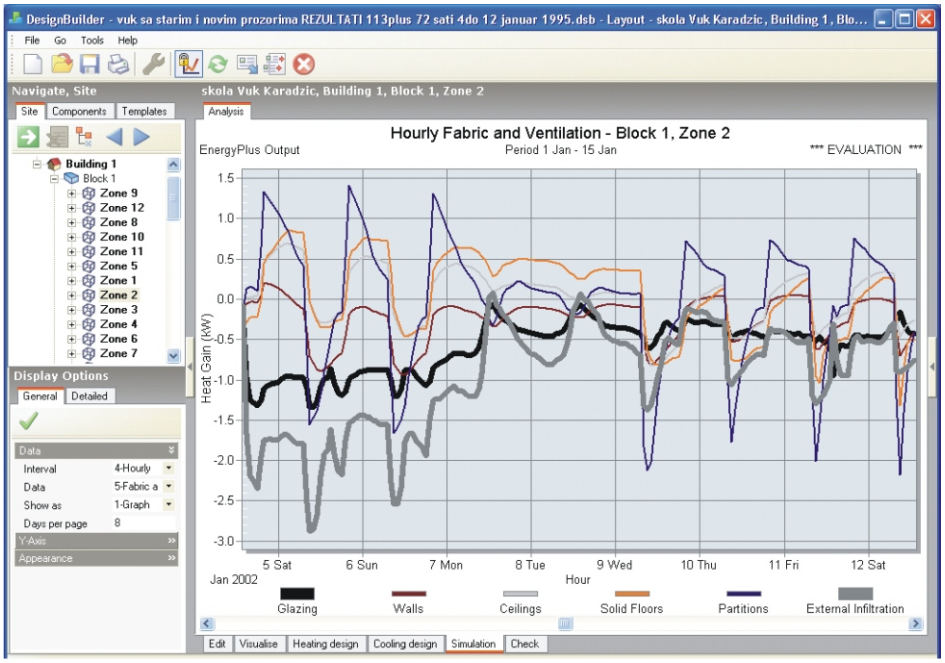

Figure 4. Heat losses – Classroom with old windows

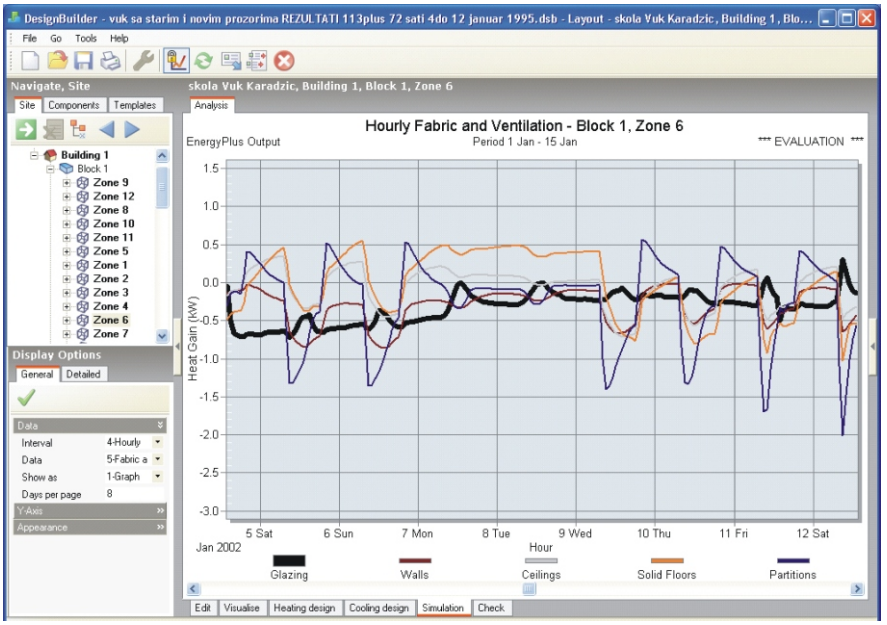

Figure 5. Heat losses – Classroom with new windows

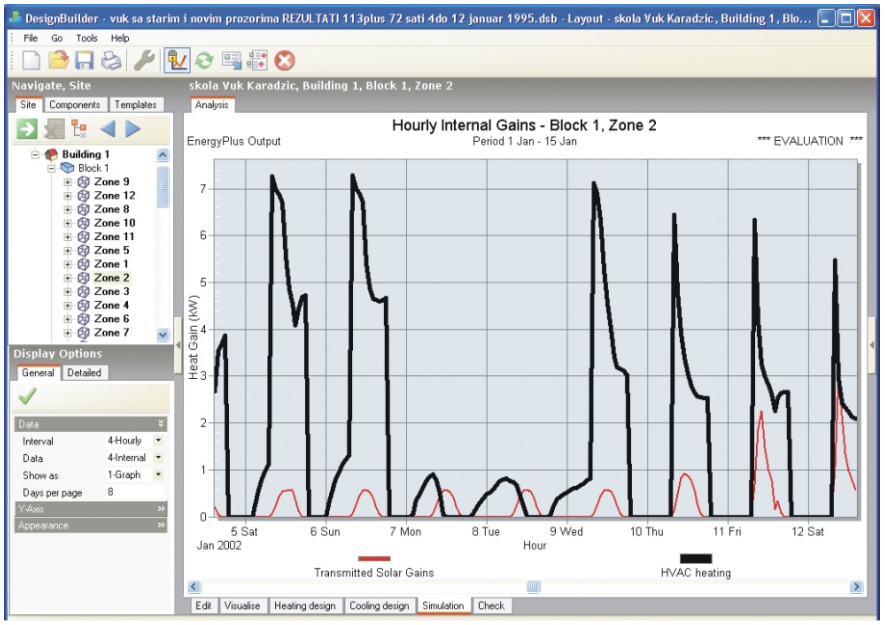

Figure 6. HVAC heating and solar gains – Classroom with old windows

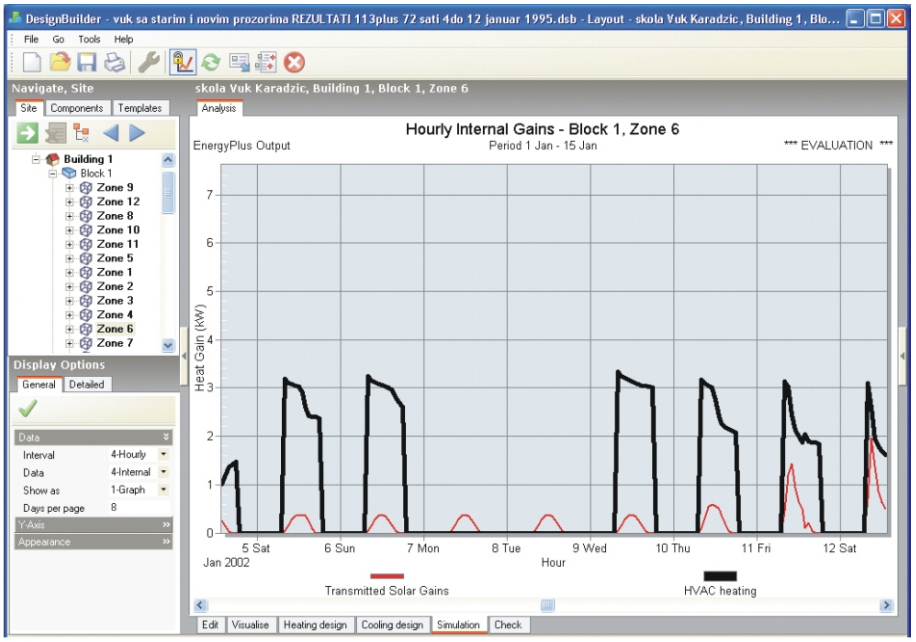

Figure 7. HVAC heating and solar gains – Classroom with new windows

times bigger than for classroom with new windows so as for –18 °C HVAC heating for classroom with old windows is 2,41 times bigger (tab. 1).

Table 1. Results of simulation for different value of outside temperatures

Classroom	Old windows $k = 3{,}49$ W/m^{2}K			New windows $k = 1{,}49$ W/m^{2}K		
	Temperatures [°C]					
Outside	0	–10	–18	0	–10	–18
Ambient air	20	20	20	20	20	20
	Heat losses (kW)					
Glazing	1.0	1.48	1.86	0.55	0.81	1.05
Walls	0.45	0.68	0.86	0.50	0.72	0.91
Ceilings	0.01	0.02	0.02	0.1	0.12	0.13
Solid floors	0.15	0.14	0.12	0.20	0.18	0.17
Partitions	0.09	0.1	0.11	0.31	0.34	0.36
HVAC heating [kW]	3.26	4.82	6.14	1.61	2.11	2.54

Conclusions

Comparative measurements of temperature performed continually during one week as well as dynamic analyses by using software package Design Builder in classroom with old wood windows and in classroom with new PVC window gave expected results. Results show that temperature differences are greater as outside temperatures are lower, so heat losses through new windows are reduced. Simulation results present that heating energy for classroom with old windows is twice bigger than for classroom with new windows. The proximity of simulation results with measured results also validates the accuracy of Design Builder simulation procedures and applicability of this software for prediction of energy consumption efficiency.

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