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INTEGRATION OF DAYLIGHT IN SCHOOLS AND KINDERGARTENS

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Abstract

Daylight is an important topic for wellbeing and also for energy savings. In our paper we present results of a pilot study in a kindergarten, where two exactly the same bathrooms were illuminated with daylight in a different way. One bathroom was practically without any daylight and in the other one two large flat roof windows were installed. Illuminance in both bathrooms was monitored for a period of almost two years. Once in this period we also carried out more precise illuminance measurements on locations, where visual tasks are performed. At that time also luminance measurements with calibrated digital camera were carried out. In this paper we show illuminance levels achieved by daylight in different seasons and at different weather conditions.

Keywords: Daylighting, School, Kindergarten, Roof windows

1 Introduction

Integration of daylight is more and more important in all types of buildings. Quality and quantity of daylight is important in private (residential) buildings and also in public buildings. Daylight has three major advantages: it helps synchronising circadian rhythm, gives you visual contact with surroundings and saves energy. In our study we are analysing the influence of daylight on illuminance in public building – in kindergarten. Energy consumption, illuminance levels, use of artificial lighting and user perception of the room were taken into account.

In this study we were involved already in the design process. So it was possible to design two rooms of the same size, same purpose and equipped with the same furniture with different amount of daylight.

In a newly built kindergarten with more departments we analysed two bathrooms, equipped with different amount of daylight. Both bathrooms are located adjacent to two activity rooms. In this case, two groups (together about 30 kids) use one bathroom. In bathrooms, kids wash their hands before every meal, after the use of toilets (which are in the same bathroom) and many times during the active day. Room leaders or educators also use bathrooms to change the diapers. The bathrooms should be well illuminated because those premises or at least a part of them is used also for the child care. In our country, premises for care have to be illuminated with 500 lx (Official Journal of RS, 2000-2017) and in technical note it is also written that premises, which are not permanently occupied, have to be equipped with presence sensors to switch on lighting (Official Journal of RS, 2010-2017).

Bathrooms are usually designed as secondary premises in view of perceived daylight and because of that they are usually located inside the buildings without any daylight. This designs' mentality was also used initially in case of this kindergarten and so there was no direct daylight penetrating into the bathrooms. In the initial design only a small amount of daylight was penetrating to the bathrooms through glass door which lead from the activity room to the bathroom and through small window between activity room and the bathroom (Figure 1).

Figure 1 – View from activity room towards bathroom

Luckily this kindergarten has only ground floor and because of that was possible to install roof windows in practically all premises where there was not enough daylight. To investigate the influence of daylight penetrated through the roof, we analysed two bathrooms which were same in a view of floorplan and furniture. The first bathroom (Figure 2, A) was practically without any daylight and in the second one (Figure 2, B) daylight penetration was designed with appropriate software and two large fixed flat roof windows were installed.

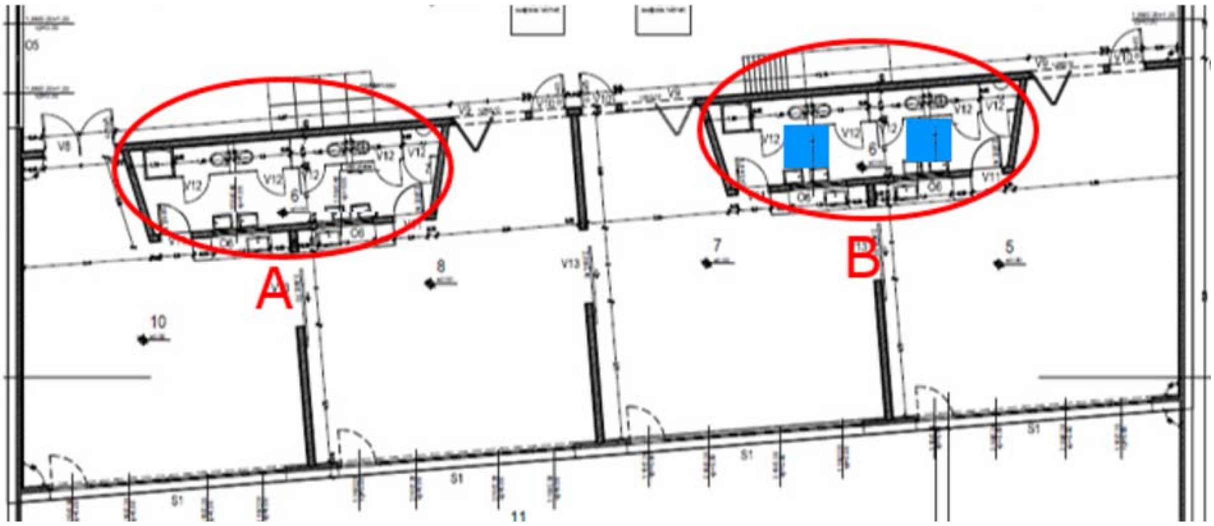


Figure 2 – Floorplan of activity rooms with two bathrooms (A-without roof windows, B-with two roof windows)

2 Simulations

With a help of daylight analyses we were able to predict dimension of daylight openings and lining construction to get a proper amount of daylight. A software Daylight Visualizer was used here.

We analyzed two possible dimensions of horizontal openings, 100 x 100 cm (Figure 3) and 120 x 120 cm (Figure 4), simulated with daylight factor (DF). In both cases we predicted open linings. The result shows a DF of 2,5% in most of the area for dimension 100 x 100 cm and 4,3% DF for dimension 120 x 120 cm.

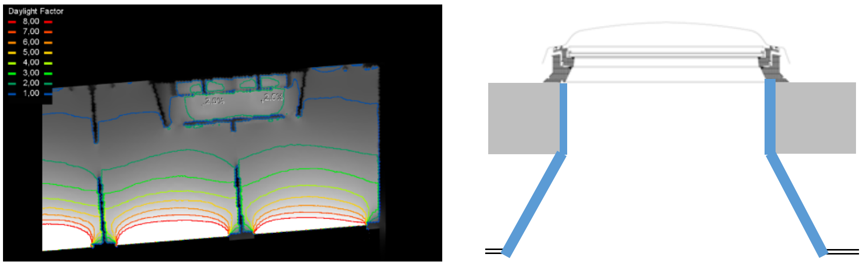


Figure 3 – DF analyses with daylight opening 100 x 100 cm with open linings in the height of the lowered ceiling

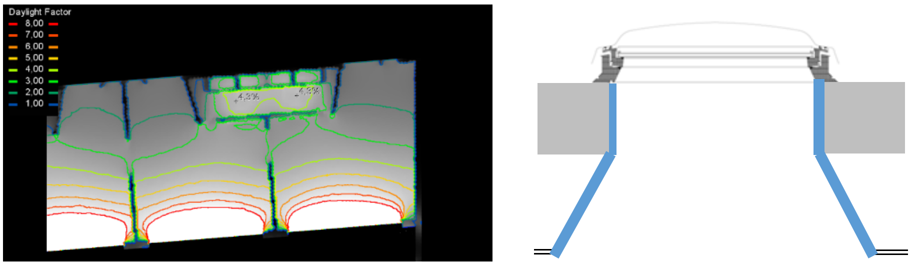


Figure 4 – DF analyses with daylight opening 120 x 120 cm with open linings in the height of the lowered ceiling

Design of lining construction has an impact on daylight conditions, what is seen from Figure 5. With vertical lining DF drops from 4,3 % to 3,8 %.

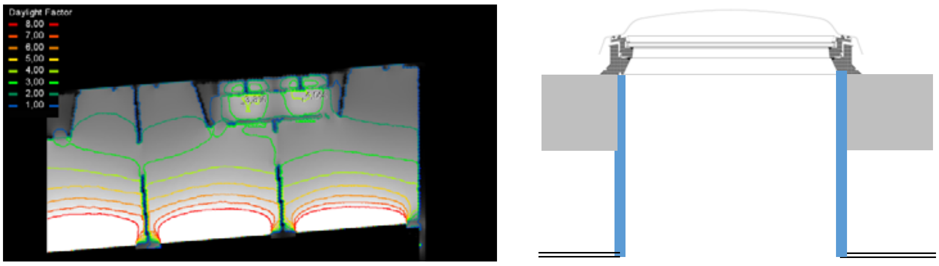


Figure 5 – DF analyses with daylight opening 120 x 120 cm with vertical linings in the height of the lowered ceiling

Differences in DF lead us to decision to choose daylight opening 120 x 120 cm. The goal was that daylight is the primary source of light during the daylit hours, without a need for artificial light to be switched on unless early in the mornings and late in the afternoons. A room with an average DF above 2% will assure that room will not look dull (CIBSE, 1999).

We analysed also Illuminance levels to be able to confirm that illumination of the surfaces in the area of washbasins used during the day (washing hands after using toilets, before each meal, after art activities like painting with water colors etc.) exceeds at least 100 lx (Figure 4a). Because in practice construction of the linings is most often simplified due to the space needed for installations in the ceiling, we analyzed also the illuminance levels in case of vertical linings. In both cases washbasin surfaces exceeds 100 lx.

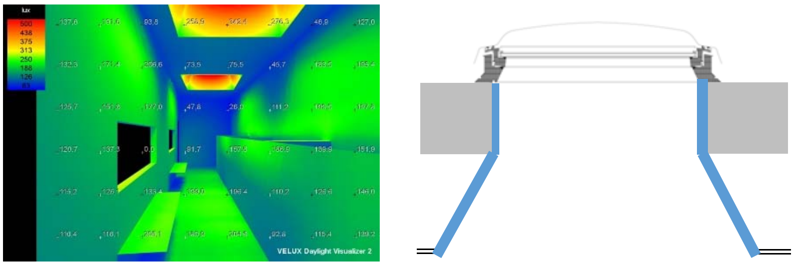


Figure 6 – Illuminance levels in range above 200 lx on the surfaces of washbasins.

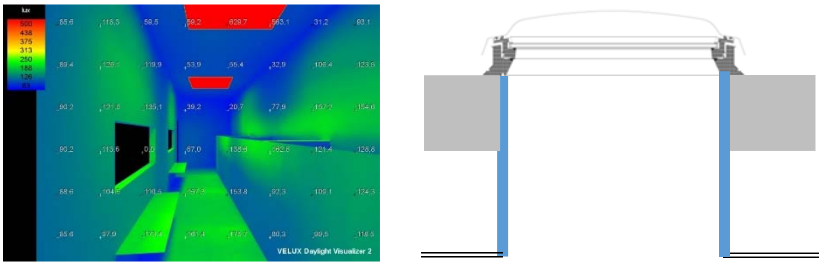


Figure 7 – Illuminance levels in range above 100 lx on the surfaces of washbasins.

When flat roof windows were installed, the linings were made in vertical shape as shown in Figure 7.

3 Data acquisition - monitoring

Energy monitoring in this kindergarten was installed to compare results from models with real measurements from a living building. All measurements were directly uploaded to a cloud server and web based interface was used to view data in real time (Figure 8). The user interface is possible to display hourly data for energy consumption for the whole kindergarten and for some consumers with higher powers, temperature of all playrooms, consumption of HVAC system. Beside energy as a pilot study, we were also monitoring illuminance values in two bathrooms. Each bathroom was equipped with an illuminance meter. Illuminance meters were mounted on the wall, facing activity room, at the height 1.8 m. Illuminance meters measured vertical illuminance and were connected to the measuring system. Since we were interested in more frequent measurements, illuminance values were collected every 4 minutes; all other values were collected every 60 minutes. All collected data are available at: http://www.energija-rr.si/view_locations_graphs/index.php?id_location=116&id_location_slide_site=923

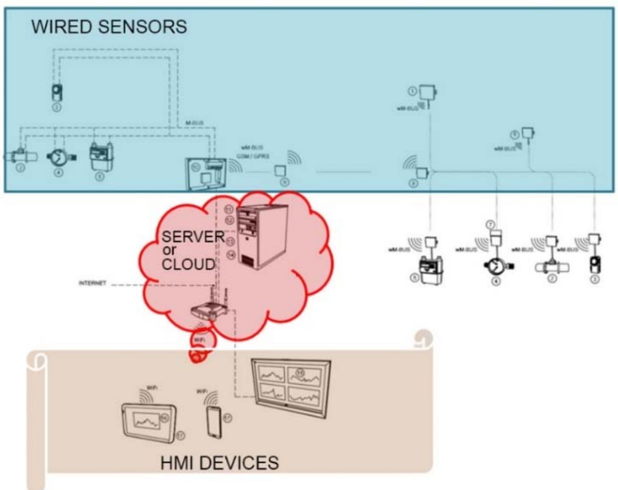


Figure 8 – Cloud based monitoring

4 Artificial lighting and electrical installations

In both bathrooms, LED luminaires (Schrack Lumo Round 24 W) with approximately 1500 lm and with correlated colour temperature 4000 K were installed. In a bathroom A (without roof windows), five luminaires were installed and in the bathroom B (with roof windows) only four luminaires were installed because there was a lack of space in the ceiling (Figure 9). In a bathroom A in accordance with technical note [2] a presence sensor was installed, in bathroom B beside a presence sensor also a secondary illuminance sensor was installed. Electrical installation was arranged in a way that luminaires in the bathroom B were switched on only if daylight illuminance dropped below 500 lx and there was a person in the bathroom.

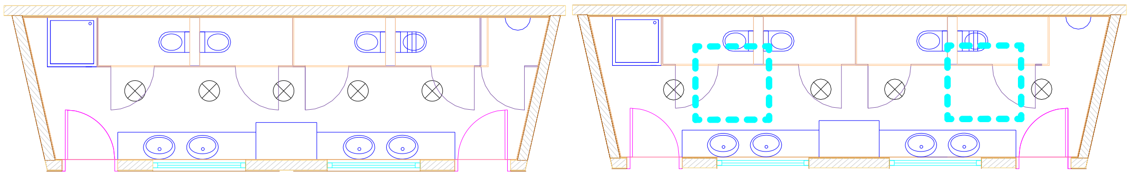


Figure 9 – Floorplan with luminaires of both bathrooms (A-without roof windows, B-with two roof windows)

5 Measurements and results

Measurements (illuminance, consumed power, temperature and other quantities) were collected for almost two years (January 2017 – December 2018) with a 4 minutes time interval between successive measurements. Beside long term measurements also one-time measurements of illuminance and luminance were carried out. From one-time measurements it was possible to evaluate illuminance levels at individual points for the whole period of two years from long term measurements.

5.1 One-time measurements

One-time measurements were carried out on January 29th 2018. In each bathroom, nine points were selected where horizontal illuminance measurements were performed (Figure 10). Additional point S was selected at the sensor to compare it with long-term measurements.

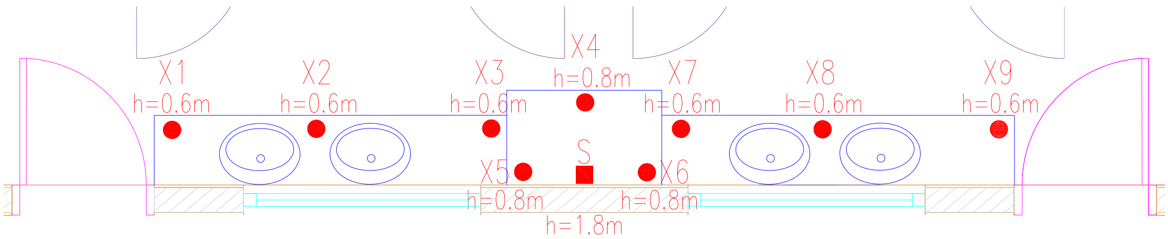


Figure 10 – Points with added height, where illuminance levels were carried out (circle – one-time measurements, square – long term measurement)

Points were selected on surfaces, where the most important visual tasks in bathroom are carried out: at height 0.6 m on the desk around basins and in the middle of the bathroom at 0,8 m on the table, where diapers are changed. Measurements are listed in table 1. A man can see that illuminance values in bathroom with roof windows are more than ten times higher when compared with the values in the bathroom without roof windows. The average factor is almost 13. In the last row of the Table 1 also illuminance values from SCADA (long term Figure 11) were added for comparison.

Table 1 – Measured illuminances for one-time measurement

Point of measurement	Illuminance (lx)		Factor
	Bathroom without roof windows	Bathroom with roof windows	Illuminance in bathroom with roof windows/ Illuminance in bathroom without roof windows
X1	75	749	10,0
X2	60	847	14,1
X3	46	903	19,6
X4	56	680	12,1
X5	49	685	14,0
X6	46	620	13,5
X7	54	714	13,2
X8	62	804	13,0
X9	83	810	9,8
S	50	437	8,7
SCADA value	**30**	**520**	**17,3**

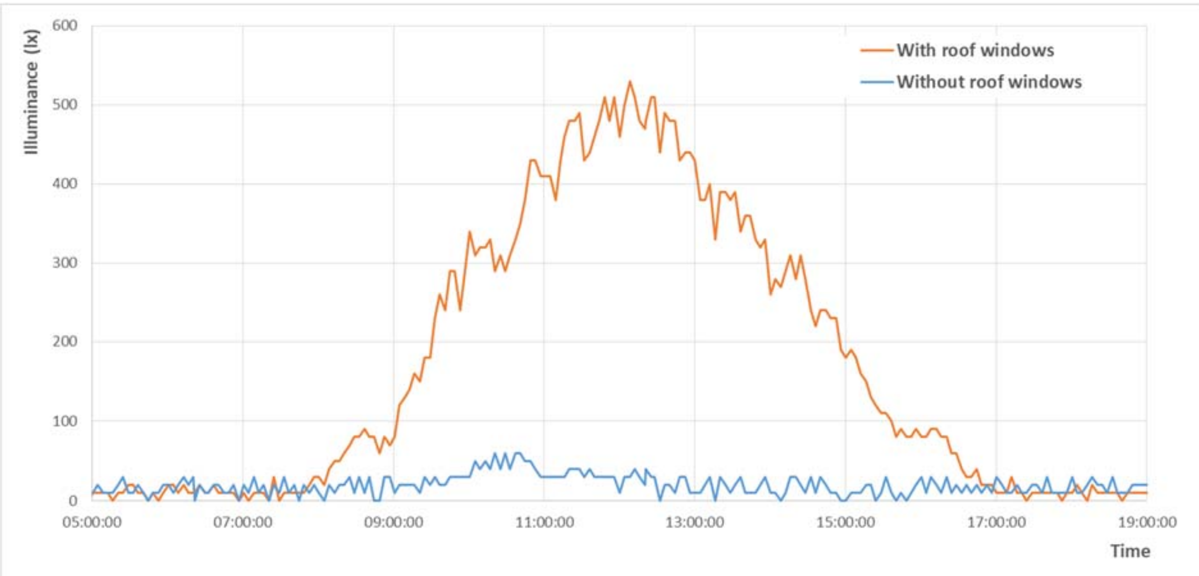


Figure 11 – Illuminance values for the bathroom with and without roof windows for the day (27.1.2018), when one-time measurements were carried out (SCADA values).

5.2 Long term measurements

From the long term measurements it is possible to evaluate difference in energy consumption between both bathrooms for artificial lighting. Energy consumption depends on the time in a year. The highest difference is during summer months when altitude of the sun is the highest. In June and July consumed energy in a bathroom without daylight could be 13 times higher than the energy consumed in a bathroom with skylights. During the winter days with the sun at low altitudes and clear skies the ratio is "only" 6!

Illuminance in the bathroom without skylights is maintained above 500 lx all the time when the luminaries are switched on. In the daylit bathroom the illuminance follows outdoor illuminance pattern.

During winter months and cloudy skies daylight is not sufficient during most of the day. In Figure 12 we show illuminance values for both bathrooms for the period from February 1st 2018 to February 4th 2018. Because also artificial lighting is switching on during working days, we should pay attention to Saturday, when kindergarten is closed and artificial lighting is off. A man can see that illuminance levels also in a bathroom with roof windows are below 50 lx all day long. Therefore, during winter months and overcast skies there are no energy savings.

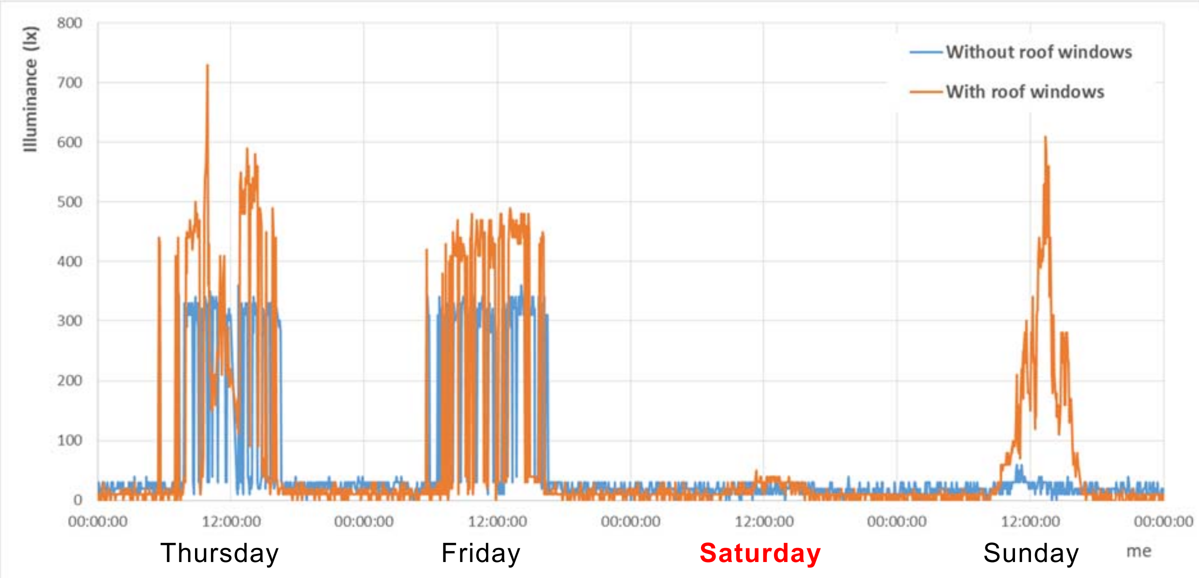


Figure 12 – Illuminance values for bathrooms with and without roof windows for four days with one totally overcast day in winter (Saturday, 3.2.2018)

On sunny days - also in winter - the illuminance in a daylit bathroom between 9 AM and 4 PM opening hours is maintained above 100 lx and above 300 lx between 10:30 AM and 2 PM. If the skies are sunny, than artificial lighting is needed in winter months only in the morning and in the afternoon (Figure 13).

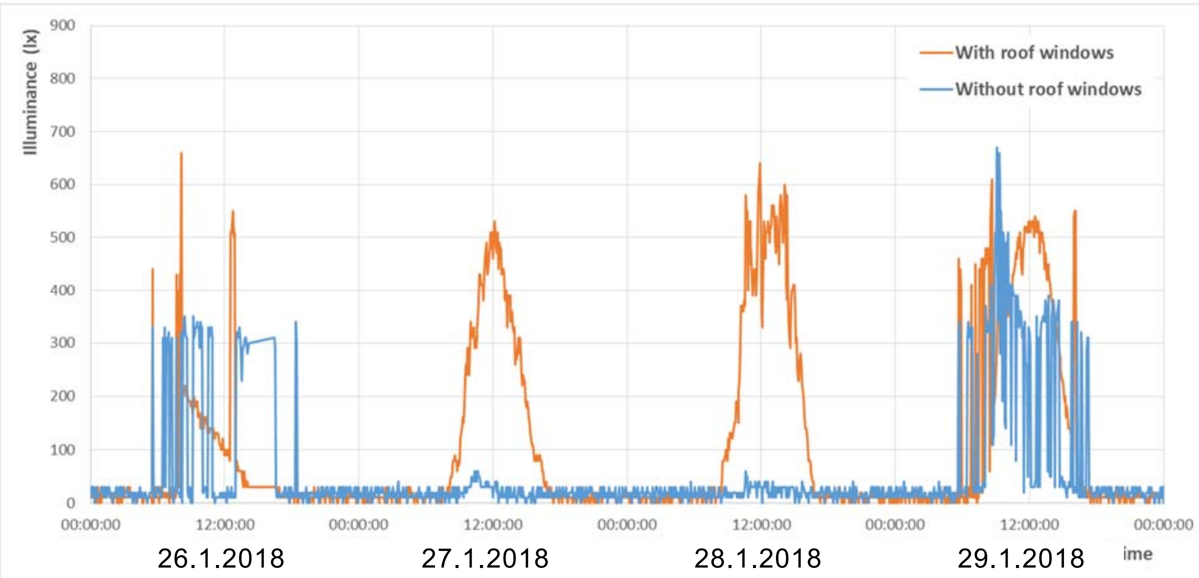


Figure 13 – Illuminance values for bathrooms with and without roof windows for four days with one more or less clear day in winter (Saturday, 27.1.2018)

In summer months, illuminance in daylit bathroom is much higher when compared with the bathroom without roof windows. With sunny skies, it reaches up to 2.500 lx (Figure 14). With extremely cloudy skies, which are rare in summer, illuminance is maintained above 150 lx between 8 AM and 6 PM.

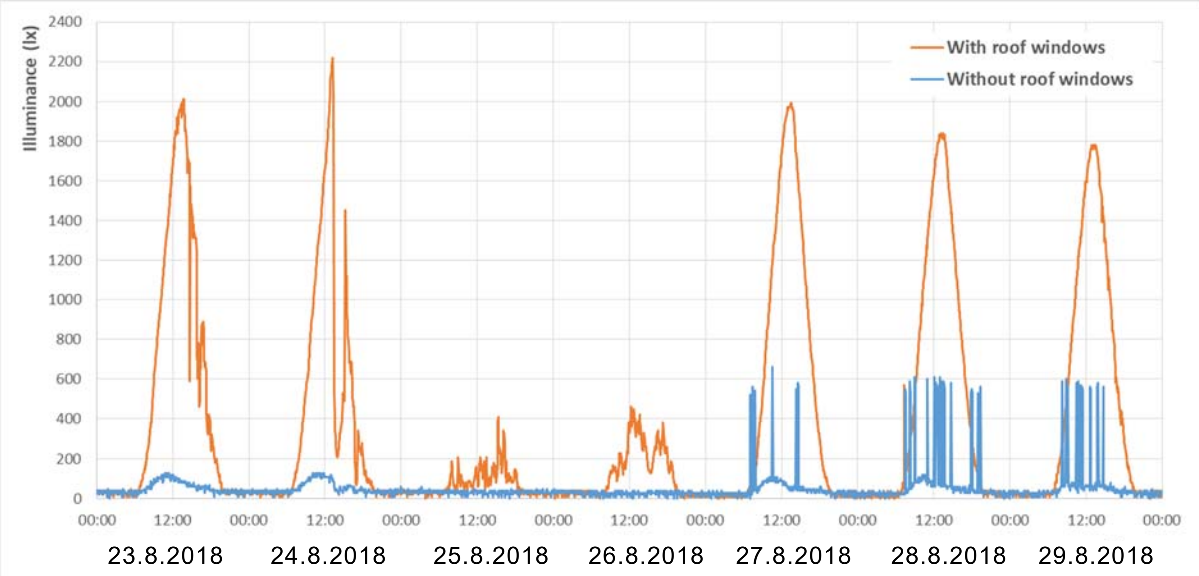
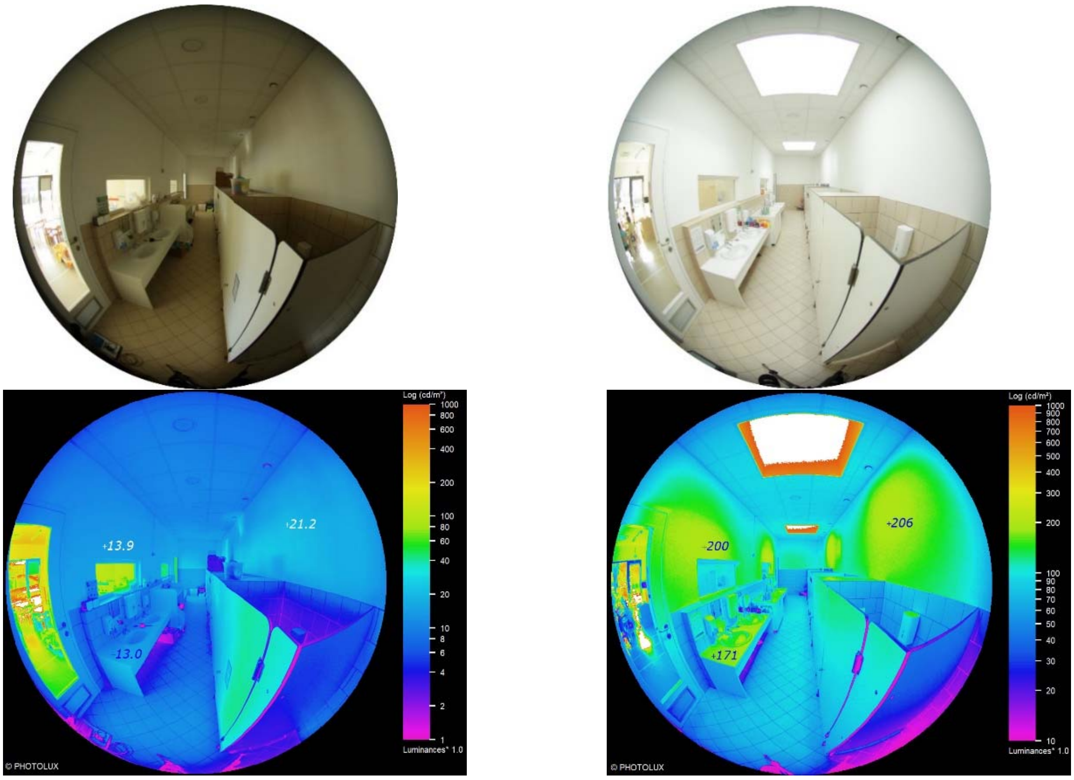


Figure 14 – Illuminance values for bathrooms with and without roof windows for one week with clear and overcast skies in summer

Working hours of artificial lighting in bathroom without roof windows is on average 7 hours per day and the kindergarten is opened from 6 AM to 4:30 PM (10,5 hours). As it can be seen, it is possible to save approximately 30 % of energy with presence sensors. We assume that without presence sensors light would be on all the time. In the bathroom with roof windows duration of time, when the lights are on, depends on the available daylight. In summer months and clear skies, lights are on only in the morning for less than half an hour, and on cloudy days between one and two hours. In winter months and totally overcast skies lights are on practically the same time in both bathrooms because daylight is not sufficient. In winter months with sunny skies, the lights are on for approximately 2 hours.

6 Luminance measurements

Luminance measurements were carried out at the same time as one-time illuminance measurements; on January 29th 2018 at 1 PM. Sky was clear. We used calibrated digital camera Canon EOS 50D and Sigma Fish-eye lens for taking several images with different exposure values and software Photolux for creating luminance maps. Luminance maps are shown in Figure 15. As a man can see from the luminance maps in Figure 15, the values of luminances in bathroom with roof windows are approximately 10 times higher than the ones in a bathroom without roof windows. The ratio is the same as for illuminance values.



without roof windows | with roof windows

Figure 15 – Luminance maps for bathrooms without and with roof windows

7 Conclusion

The measurements show that flat roof windows are the right way to get daylight into indoor premises without any vertical windows. This fact was also confirmed in interviews with people who work in this kindergarten and who use both bathrooms. They were all in favour of the one with large roof windows. Nevertheless, we should also mention drawbacks and possible problems with roof windows.

Roof windows are a critical place where water can penetrate into the house. We need to be aware of this concern and choose only tested materials and tested elements. Installation should be done by a specialist.

The windows in the roof can overheat the room. This concern is justified in certain areas where it is necessary to use motorized shading devices. For washbasins that are ventilated, overheating in summer times is not a problem. Large amount of air is being extracted from these premises all the time. In other premises, it is possible to install shading devices also as protection against the heat.

Unfortunately, we cannot foresee the amount of daylight. Design of daylight penetration can be analysed to ensure an appropriate size of window surfaces and position. Relevant experts in this field should be found.

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