DAYLIGHTING IN RENOVATED SCHOOL BUILDING

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ABSTRACT

The paper is presenting a simulation study focusing on school classrooms' daylighting and some retrofitting strategies to improve the existing conditions for better visual environment in the renovated building. The renovated school building's window retrofit was limited due to the historically valuable facade. Several solutions have been suggested for enhancing indoor daylight levels through computer simulations in daylight software WDLS under the CIE overcast sky conditions.

INTRODUCTION

Building renovations are in context of the EU priorities and sustainable development trends (Staniaszek, 2014). One of the main sustainable building criteria is indoor comfort (Sayigh, 2013). Visual performance is a key factor for the built environment (Boubekri, 2008). Daylighting is substantial for life because of the natural light spectrum of solar energy (Webb, 2006). The convenient daylight climate is important for health and productivity of the occupants (Leslie, 2003). School buildings are ones of the most important building design with high demands on indoor convenient daylight levels (Plympton, 2000). Daylight illuminance, full daylight light spectrum, correct direction, glare and overheating protection are very important for schools (Building Bulletin 90, 1999).

It was proven that daylight could positively influence study interest and concentration as well as social behaviour and attendance of school pupils (Barrett et al., 2013). In newly constructed buildings, window area and shading devices are designed to satisfy for visual comfort for whole year occupancy. Daylighting in existing buildings could be a problem in some cases. Window retrofit is influenced due to some legal obstructions for visual appearance of architecturally valuable facades (Wilkinson, 2014). In these cases, the window exchange is not possible and therefore, it is required to find alternative ways of daylight availability in these cases.

The paper presents a daylight simulation study of the existing state compared to the designed ones for completion of better visual standard recommendation compared to the old classrooms. Design recommendations for daylighting in schools are specified. The old school buildings are not properly daylit in many cases. A historical school building located in town Trebic, Czech Republic (CZ), altitude 406, latitude 49°13', longitude 15°53' is to be renovated. Window area is too small to supply daylight levels required for modern school study places. Hence, the window retrofit is not possible because of the architecturally valuable façade. Design concepts to improve classroom's daylighting in alternative ways were subject of the daylight simulation study.

DAYLIGHT SIMULATION

The simulations were run in daylight simulation software WDLS (Window Day-Light System), version 4.1 (Stanek, 2007). Several classrooms were simulated for indoor daylight levels on the working plane, 85 cm over the floor level. The simulations were completed for the CIE overcast sky (Standard ISO 15469) boundary conditions. The overcast and partly cloudy sky conditions are prevailing daylight conditions in the climatic locality of the studied school building. This means that insufficient daylight levels in classrooms are more significant risk than other issues such as glare effect and overheating problems.

The requirements for the school classrooms' daylighting are specified for the entire working area. The simulated illuminance were plotted in the daylight factor as D [%] isolines on the working plane. The daylight factor values were calculated as percentages of the horizontal diffuse illuminance in outdoors from an unobstructed sky hemisphere, which is received at a point indoors (Standard BS 8206-2). Daylight illuminance level of 150 lux is required for the school classroom visual activities. It is about 1.5 % of daylight factor (Standard CSN 730580-1) calculated for outdoor horizontal diffuse illuminance 10 klux.

The classrooms do not satisfy the required internal daylight levels. Integral lighting is not considered to be convenient to substitute the daylight levels. Additional windows or skylights should be applied in the building renovation. The architectural style of the building façade does not allow new bigger windows as shown in Figure 1.

Figure 1 The school building

Alternative ways of daylight systems were selected as daylighting though the corridor windows and roof lights. The daylight simulations were run for the third floor as shown in Figure 2. The floor clearance height is 3.4 m. Parameters for the simulations are: reflectance of indoor surfaces - 0.5 walls, 0.7 ceiling, 0.3 floor, 0.1 external ground. Window transmittance 0.8, frame factor 0.8, glass dirt factor 0.9.

ROOM	FLOOR AREA [m²]	WINDOWS Dimension (m)
Classroom 1	6.70 x 8.10	3x 1.25/2.3 (sill 0.9)
Classroom 2	6.70 x 7.38	3x 1.25/2.3 (sill 0.9)
Classroom 3	7.50 x 6.75	3x 1.25/2.3 (sill 0.9)
Classroom 4	7.00 x 7.65	3x 1.05/2.0 (sill 0.9)
Classroom 5	7.65 x 6.50	4x 1.05/2.0 (sill 0.9)

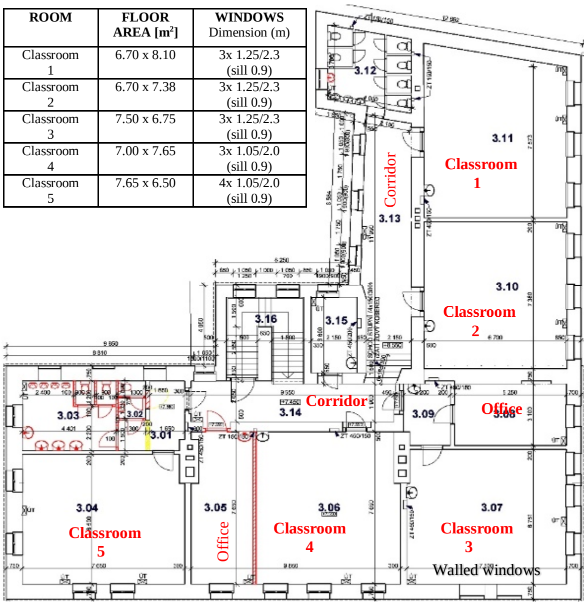

Figure 2 The third floor plan

The simulation graphical outputs are shown for the whole plan in Figure 3 for both the existing state and the renovated study. It is obvious that classrooms in the old school building are not properly daylit. Some improvements are designed for the renovation. New transparent areas are located in the central wall between classrooms and the corridor.

The first window with dimensions of length 3.5 m, height 0.9 m sill 2 m transmits daylight through the corridor into classroom 1. The second window with dimensions of length 6 m, height 0.9 m, sill 2 m is placed in the central wall of classroom 2. Classroom 3 daylight improvement is due to new façade windows. In this case, new windows are permitted. There is the place where original windows were applied to the facade. Two new roof lights were designed for classroom 4. Classroom 5 has convenient daylight levels on nearly the entire working plane. There is only a small area close to the room corner where daylight levels are lower than what is required. There is a door entrance area, and for this reason, no desk is located there.

Table 1
Simulation outputs – summary

BEFORE RENOVATION	D_{MAX} [%]	D_{AV} [%]	D_{MIN} [%]	U_1/U_2 [-]
Classroom 1	5.5	2.4	1.2	0.5/0.22
Classroom 2	6.9	2.6	1.4	0.54/0.20
Classroom 3	6.3	2.6	1.2	0.46/0.19
Classroom 4	5.6	1.7	0.8	0.47/0.14
Classroom 5	5.3	2.4	0.7	0.29/0.13
AFTER RENOVATION	**D_{MAX} [%]**	**D_{AV} [%]**	**D_{MIN} [%]**	**U1/U2 [-]**
Classroom 1	5.6	2.7	1.4	0.52/0.245
Classroom 2	7.2	3.2	1.9	0.59/0.26
Classroom 3	7.2	4.3	2.0	0.46/0.27
Classroom 4	5.9	2.9	1.6	0.55/0.27
Classroom 5	5.3	2.4	0.7	0.29/0.13

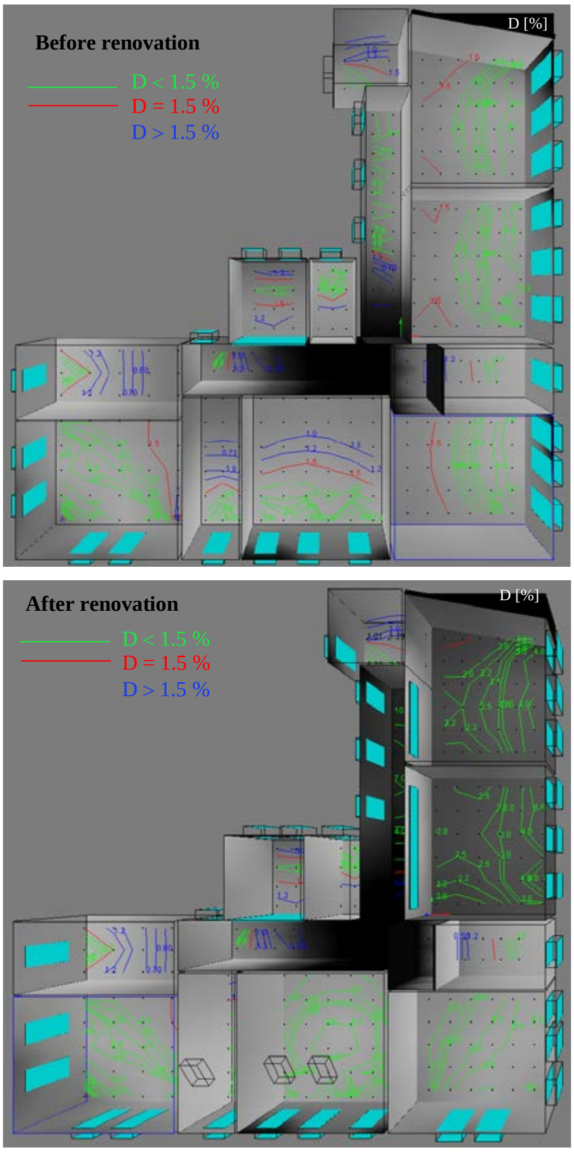

Figure 3 Daylight simulation outputs, D [%]

The daylight simulation main results of maximum D_{MAX}, minimum D_{MIN} and average D_{AV} daylight factors calculated on the working plane are summarised in Table 1. The daylight uniformity U [-] values are also included, where U_1 is a ratio of D_{MIN} to D_{AV} or U_2 as D_{MIN} to D_{MAX} respectively.

The simulation outputs show that the new windows and skylights would enhance daylight levels and uniformity in classrooms. Daylighting will satisfy the standard requirements for minimum daylight factor as D > 1.5 % on the working plane. The improvements due to internal windows of classrooms 1 and 2 are not so significant. However, it is not possible to suggest a new additional window or any skylight on the street facade of the historical building. Application of high light transmittance single glass panes for the internal windows in combinations of white surface finishings in classrooms and the corridor would increase daylight illuminance for more than third of the simulated values. Daylighting in classrooms 3 and 4 is improved so much due to vertical windows or skylights. These systems seem to be more convenient compared to the previous internal windows.

The simulation outputs are compared in details of daylight factor distribution as D [%] in points on the working plane 85 cm over the floor level. They are shown in Figure 4 for classrooms 1 and 2, and in Figures 5 and 6 for classrooms 3 to 5 for the study presenting the status before and after renovation.

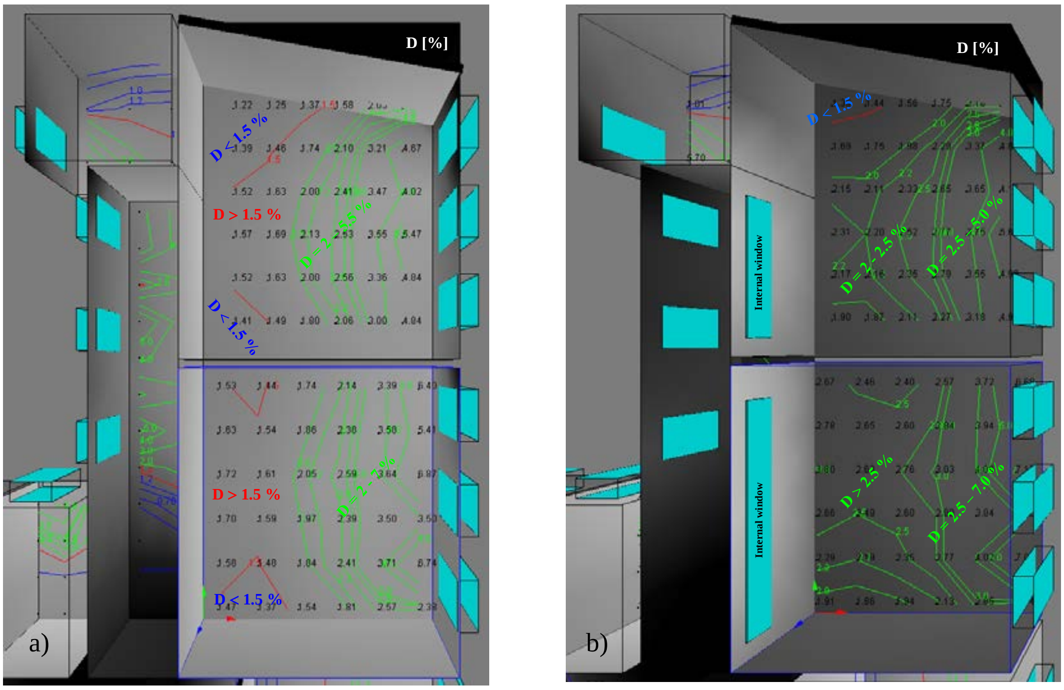

Figure 4 Daylight simulation in classrooms 1 and 2; a) before renovation and b) after renovation

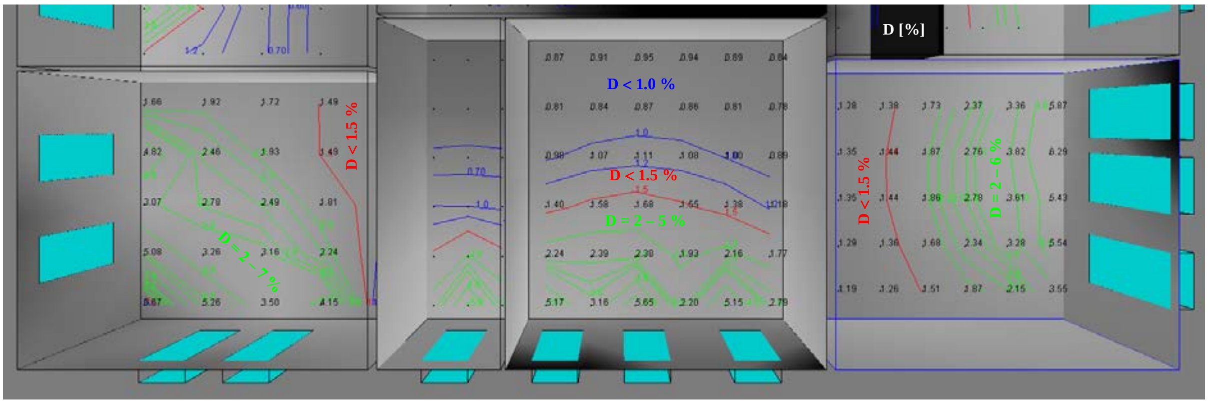

Figure 5 Daylighting in classrooms 3 to 5; before renovation

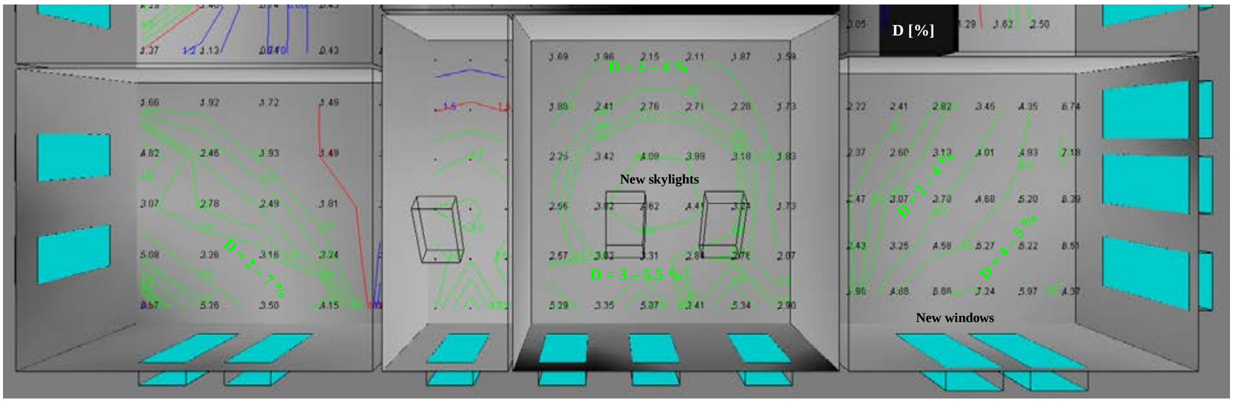

Figure 6 Daylighting in classrooms 3 to 5; after renovation

Moreover, DesignBuilder (version 3.4.0.041) simulations have been also carried out. The simulations compared for daylighting in Classroom 2 in the state before and after the renovation. The simulations were studied for the same parameters as were selected for the WDLS simulations for the overcast sky.

The clear sky conditions were selected for daylight simulations in summer solstice 21st June at 12:00 and 15:00. The simulation study outputs confirmed that the design improvements will be convenient for the renovation building daylighting.

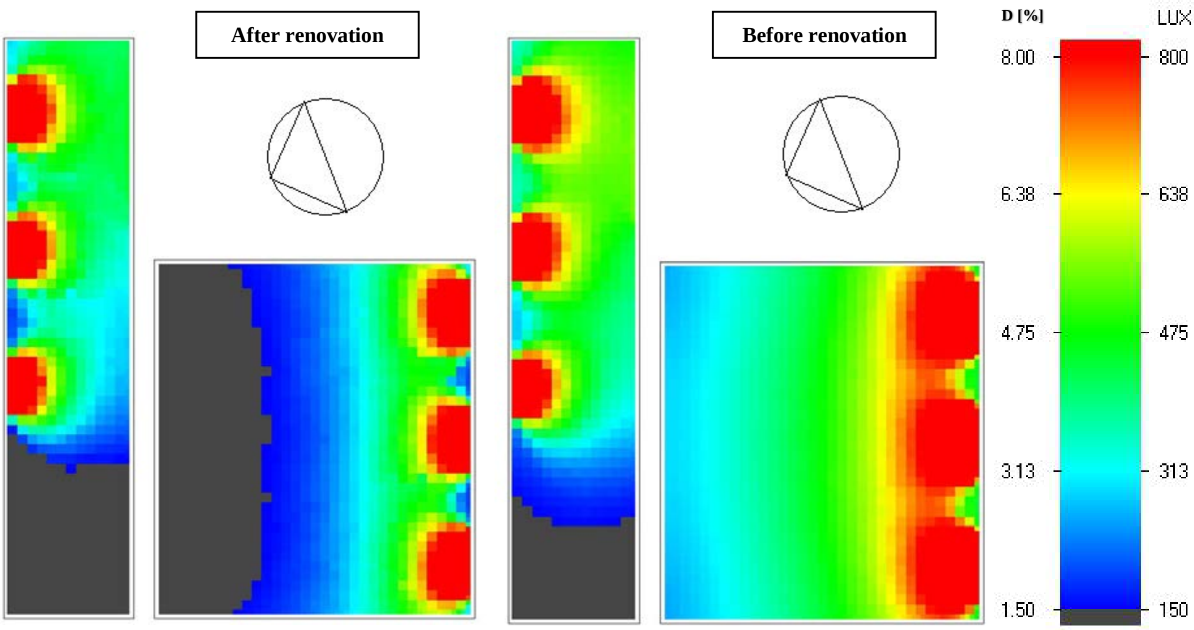

Figure 7 DesignBuilder simulations in classroom 2 and corridor (under overcast sky)

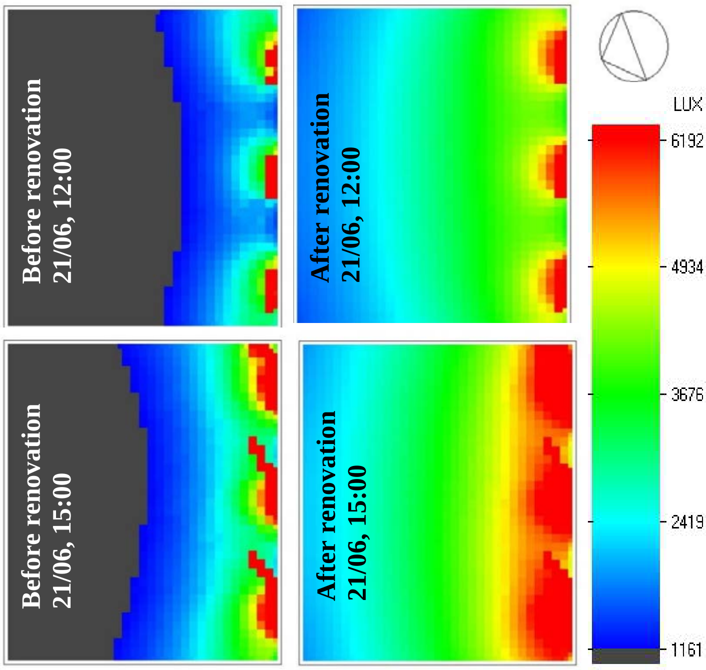

Figure 8 DesignBuilder simulations in classroom 2 and corridor (under clear sky)

CONCLUSION

The daylight simulation study was completed for the selected school building classrooms. Additional windows and skylights were selected to improve daylighting. Better daylight conditions will be positive for indoor visual environment in the renovated building.

The design study of the old school renovation has to be completed with respect to the building architectural style and in context of the surrounding municipal areas. Two classrooms have additional windows located into the internal walls to transmit daylight from neighbouring corridor into the distant parts of the rooms. In this way, the classrooms' daylighting is more uniform. Sufficient daylight illuminance and uniformity are very important for the school occupants' comfort. Daylight simulations in the examined classrooms with additional façade windows or skylights have given information about the indoor daylighting improvements.

The daylight simulations were run for the overcast sky conditions. The boundary condition is important for the renovated building evaluations. The classrooms with large floor area are not properly daylit due to the old and small windows. For this reason, the most inconvenient outdoor daylight conditions were selected for the simulations in the study for demonstrating possible design improvements.

The simulations provided information that the maximum daylight factor does not exceed 7 % in the existing rooms or 7.5 % in the renovated study case. This means that indoor horizontal illuminance on the working plane will not be greater than 700 lux or 750 lux respectively. The room maximum illuminance levels were estimated for outdoor diffusive horizontal illuminance as 10 klux.

The estimated daylight levels are sufficient for school visual activities for the major part of any year in climatic conditions of both the overcast and partly cloudy skies. Shading blinds in double glass window units would be sufficient for reduction of solar gains and elimination of glare risks during summer seasons and times of intensive sun shining.

NOMENCLATURE

D [%], daylight factor.
U [-], daylight uniformity.
D_{MAX} [%], maximum D [%].
D_{AV} [%], average D [%].
D_{MIN} [%], minimum D [%].
$U_1 = D_{MIN}/D_{MAX}$ [-].
$U_2 = D_{MIN}/D_{AV}$ [-].

ACKNOWLEDGEMENT

This paper / contribution / abstract has been worked out under the project No. LO1408 "AdMaS UP - Advanced Materials, Structures and Technologies", supported by Ministry of Education, Youth and Sports under the "National Sustainability Programme I" of Czech Republic.

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