THE USE OF DAYLIGHT FOR SUSTAINABLE DEVELOPMENT

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ABSTRACT

Daylighting has always been natural thing for people inside buildings. It serves to create appropriate visual conditions without the financial and energy requirements, but also affects physiology and psychology of human needs and health. Meaningful use of daylighting keeps sustainable development. Currently, there is great emphasis on sufficient insulation of envelopes of buildings with reducing the glass surfaces. Despite the great development in the area of windows, windows are still weakening of the overall building façade. Often designed new windows have minimum dimensions, massive window frames and now triple glazing. These measures may minimize heat losses of the building, but also reduce the amount of daylight in interiors. Such approach has resulted in the lack of light inside the room, which has an adverse impact on human health. This paper shows how some reconstructions can affect daylight inside buildings – e.g. wall thickness, glazing, window frames. Most of reconstructions of building envelopes bring benefits from thermal viewpoint but reduction quality of indoor luminous environment. By contrast, some such reconstructions have beneficial effects both on thermal and optical properties of opaque and transparent elements.

Keywords: Daylighting, Daylight Factor, diffuse illuminance, glazing, measurement of daylighting, interior environment

1. INDOOR DAYLIGHT LUMINOUS ENVIRONMENT

The basic factor that describes the level of daylight in the interior and is required by Czech standards[1] is called Daylight Factor. It is ratio of the illuminance at a point on a given plane due to the light received directly and indirectly from a sky of assumed or known luminance distribution, to the illuminance on a horizontal plane due to an unobstructed hemisphere of this sky, where the contribution of direct sunlight to both illuminances is excluded. Daylight Factor consists of three basic parts.

$$D = D_s + D_e + D_i \, [\%] \tag{1}$$

where

- D_s is sky component,
- D_e is externally reflected component,
- D_i is internally reflected component.

Level of the Daylight Factor is influenced by: light transmittance of glazing, size and proportion of windows, shading obstacles (inside, outside) and reflectance of surrounding surfaces and exterior surfaces (façades, ground).

Currently, thermal technical properties of buildings envelopes are improved for saving of thermal energy – e.g. an additional insulation of the building envelope, exchange of windows with a greater proportion of the frames, and increasing the number of glazing. When people are satisfied with indoor luminous environment? How can reconstructions of envelope affect indoor daylight luminous environment? Next examples represent same buildings reconstructions and their impact on quality of indoor daylight luminous environment.

2. CONFIGURATIONS AND PARAMETERS OF ROOMS

2.1. Assessed building, selected rooms

To assess the effect of individual partial reconstruction options a unit room with a unit window was first chosen meeting by its minimum standard requirements for a residential room. The considered unit residential room has a floor area of $8m^2$, its dimensions are 2.8 x 2.8 m and its clearance 2.6 m. The window dimensions are 900 x 900 mm with the sill height of 900 mm and the wall thickness of 300 mm. Intended reconstruction of the building is the contact thermal insulation of walls, replacement of window with more thickness frame and multi-glazing. For this room, simulations of the effect of individual partial reconstructions were gradually made independently of each other. Boundary conditions were chosen for this model, including light loss factors corresponding with standard requirements in Czech Republic. Two most important check points were chosen on the reference plane in residential rooms. Points were situated at the distance of 1m from side walls at one half of the room depth for which standard requirements are defined.

The next assessed room is office in Czech Technical University in Prague, in building A, in 7^{th} floor. The office has a floor area of 25,8 m^2, its dimensions area 5,9 m x 4,4 m and its clearance is 3,3m. Strip window dimension is 5,5 x 2,0 m with the still height of 1,02 m. Furniture is located in the middle and at back of the room. The lightweight façade was replaced in this room. Previous windows had plastic film on the glazing for solar protection.

2.2. Basic input parameters

The Daylight Factor was evaluated on a working plane, at a height of 850 mm above the floor under the assumption of the CIE standard overcast sky with a continuous layer of clouds [2] and dark terrain. This distribution of D in selected rooms with various windows was calculated by Wdls 4.1. computer programme and the WAL 1.1 programme.

The following basic input parameters were used in the general part of the calculation: the average reflectance of internal surfaces $\rho_m = 0.5$, the reflectance of the surrounding terrain $\rho = 0.1$ expressing dark surface. The pollution factor, or its value, chosen for internal glazing surface was $\tau_{zi} = 0.95$ (clear interior) and for external glazing surface $\tau_{ze} = 0.9$ corresponding to a zone with average pollution.

3. THE EFFECT OF CONSIDERED CHANGES ON THE DAYLIGHT LEVEL

3.1. Influence of thickness wall on the daylighting of residential room

The thermal insulation on the façade increases the width of the window jamb. To find out how much this parameter affects the quantity of daylight at assessed critical points, the façade wall thickness of 300 mm was considered in the calculations and the thickness of thermal insulation was gradually added to it from 50 to 250 mm. The achieved results of Daylight Factor calculations are presented in Tab.1.

Table 1: Calculated values of *D* [%] for different thermal insulation thicknesses

Wall thickness	Thermal insulation thicknesses	D_{min}	D_m	D_{max}	D 1m from the wall in 1/2 the depth of the room	Required value of *D*
[mm]	[mm]	[%]	[%]	[%]	[%]	[%]
300	+ 50	1,1	1,4	2,0	**1,2**	0,9
	+ 100	1,0	1,3	1,9	**1,0**	
	+ 150	0,9	1,1	1,7	**0,9**	
	+ 200	0,8	1,0	1,4	0,8	
	+ 250	0,7	0,9	1,2	0,8	

The values of *D* [%] is decreasing from 1,1% to 0,7%. The limit ($D \geq 0{,}9\%$, according with Czech standards) for a satisfactory interior environment when the thickness of thermal insulation up to 150 mm is applied.

3.2. Influence of window frame thickness on the daylighting of residential room

Older type of the window has thin window frames than new plastic windows. Therefore the influence of windows frame thickness on the Daylight Factor in critical points was investigated. For comparison, this factor was considered in a range of 15 – 50 % of the window area and, the corresponding frame thicknesses were additionally calculated for it. The found out Daylight Factors are documented in Tab.2 together with calculated D_{min}, D_m and D_{max}.

Table 2: Calculated values of *D* [%] for different window frame thicknesses

Proportion of the frame	Window frame thicknesses	D_{min}	D_m	D_{max}	D 1m from the wall in 1/2 the depth of the room	Required value of *D*
[%]	[mm]	[%]	[%]	[%]	[%]	[%]
15	35	1,2	1,5	2,2	**1,2**	0,9
20	48	1,1	1,4	2,0	**1,1**	
25	60	1,0	1,3	1,9	**1,0**	
30	74	1,0	1,2	1,8	**1,0**	
35	87	0,9	1,1	1,8	**0,9**	
40	102	0,8	1,0	1,6	0,8	
45	116	0,8	0,9	1,4	0,8	
50	132	0,7	0,9	1,3	0,7	

The effect of the window frame thickness on indoor daylighting, is evident from the results. The value of the Daylight Factor is decreasing from 1.2% to 0.7%. In the ratio of area the window frame to the net glazed area exceeds the 35% the assessed room becomes unsatisfactory in terms of Czech standard daylight requirements.

3.3. Influence of glazing on the daylighting of residential room

Daylight Factor value is also influenced by numbers of window glazing. The most common type of lighting was considered with a vertical window double-glazed with clear glass in front of where a loggia is situated. The first computation was without glazing of loggia, the second with clear glass glazing of loggia, the third computation was with double-glazing of loggia. The finally computation was with a vertical window triple-glazed with clear glass in the room and with double glazing of loggia. Furthermore, the window was also replaced, it was double-glazed with clear glass, and the loggia was first double-glazed and finally even triple-glazed. The results are documented in Tab.3.

Table 3: Resultant values of *D* [%] for different types of window and loggia glazing

Number of clear glass panes	D_{min}	D_m	D_{max}	D 1m from the wall in 1/2 the depth of the room	Required value of *D*
[-]	[%]	[%]	[%]	[%]	[%]
2	1,0	1,3	1,9	**1,0**	0,90
3	0,9	1,2	1,8	**1,0**	
4	0,9	1,1	1,8	**0,9**	
5	0,8	1,0	1,5	0,8	

If was found the values of *D* [%] is decreasing from 1,0% to 0,8% after used number of glazing loggia. The Daylight Factor in check points on the reference plane complies standard requirements when 4 glazing (window + loggia) was tested. [3]

3.4. Influence of exchange of lightweight façade on the daylighting of office in Czech Technical University in Prague

Lightweight façade was replaced in the in 7th floor in 2013 in the headquarters of Civil Engineering Faculty of CTU in Prague in 2013. The previous windows had minimum transmittance of daylight, but new lightweight façade has better thermal transmittance of insulation and better transmittance of daylight. Indoor illuminance was measured in the office with both of type of lightweight façade. The calculated Daylight Factor distribution is documented in Fig. 1 and Fig. 2. Measured and calculated values of *D* (in check points) before and after reconstruction are compared in Tab.4.

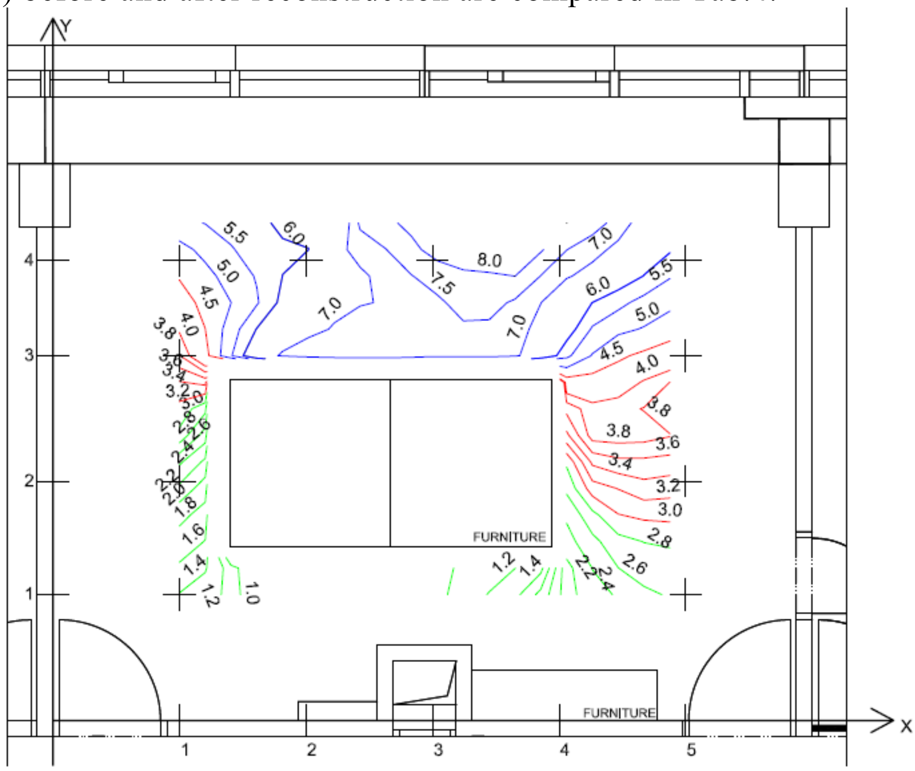

Figure 1 – Value of Daylight Factor situation with old façade

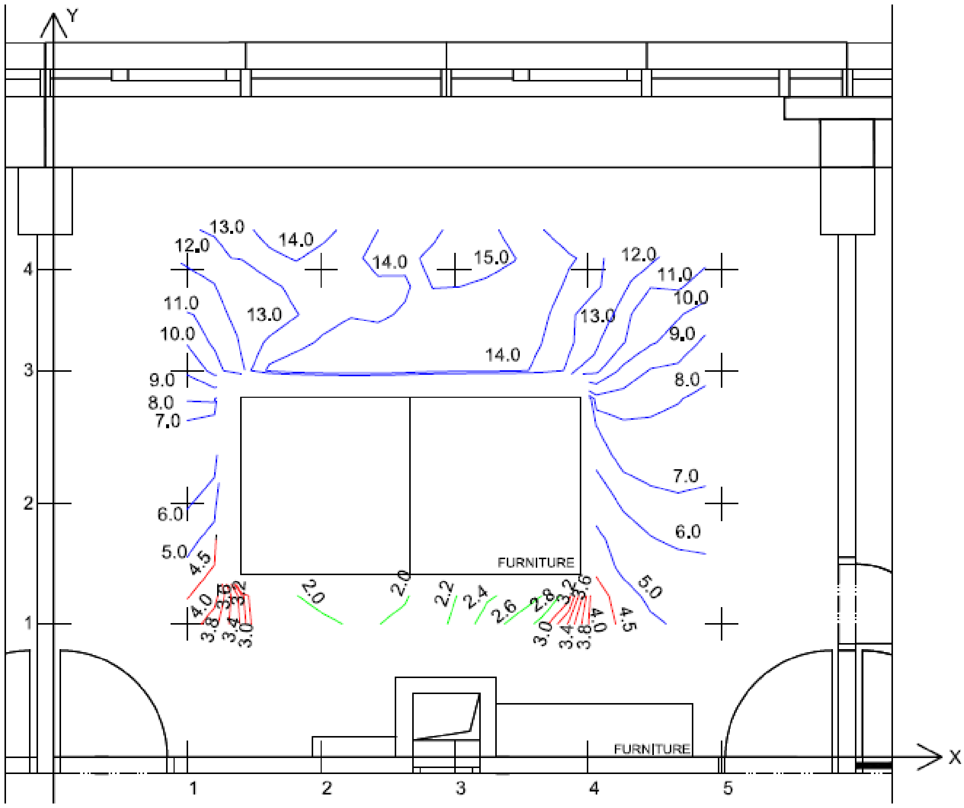

Figure 2 – Value of Daylight Factor situation with new façade

Table 4: Measured and calculated values in check points before and after reconstruction

Check points [x,y]	Measured *D* [%]		Calculated *D* [%]		Required value of *D* [%]
	Previous situation	Current situation	Previous situation	Current situation	
[1,4]	6,7	13,0	4,5	12,2	1,5
[2,4]	7,0	15,9	6,6	13,8	
[3,4]	6,6	16,8	7,6	15,6	
[4,4]	6,6	13,9	7,0	13,8	
[5,4]	6,6	12,6	5,3	10,8	
[1,3]	3,3	6,8	3,5	9,0	
[1,2]	1,7	3,4	2,0	6,0	
[1,1]	1,1	2,3	1,4	4,1	
[5,3]	3,7	5,8	4,0	8,0	
[5,2]	2,0	2,2	3,3	6,2	
[5,1]	1,2	1,5	2,6	5,0	

Results in Tab.4 show that there are a small differences which can be caused by inaccuracy of measuring. Daylight Factor was improved by about 100% after reconstruction. New windows with clear glazing and better thermal properties had better transmittance than previous windows. Previous windows were covered by plastic film with solar protection and lower high transmittance.

1. Conclusion

Daylighting inside interiors is affected by numerous external as well as internal factors. Thermal insulation on the façade, or the change of façade thickness can have substantial influence on daylighting. It was found that values of *D* [%] can decrease from 1.1% to 0.7%. The limit for a satisfactory interior environment is when thickness of thermal insulation up to 150 mm is applied. The reconstruction of the exterior envelope of a building represents multiple predominantly external changes which are reflected in the indoor luminous environment quality. The replacement of windows, or the effect of the window frame thickness on daylighting, is evident from the achieved results. The value of the Daylight Factor ranges from 0,7% to 1,2%. After exceeding the 35% limit value of the window frame area to the net glazed area ratio the assessed room becomes unsatisfactory in terms of standard daylight requirements. If we decide to design additional a glazing of loggia, we must expect also changing of the daylight level. Then, the Daylight Factor is decreasing from 1.0% to 0.7%.

It can occur that reconstruction of building façade can become both thermal and optical positive influences on indoor environment like it was changing of lightweight façade in the office building of Czech Technical University in Prague. The improvement thermal property whole building and indoor daylight luminous environment was achieved after this reconstruction. Daylight Factor was improved by 100%, because new windows with clear glazing and better thermal properties had better transmittance than previous windows, which were covered by plastic film with solar protection.

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