Regulation of daylight and its effect on workplace illuminance

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Abstract: - The paper discuss inside illuminance of the workplace illuminance with daylight regulation by outside blinds. Daylight regulation is advantageous for more than inside illuminance regulation but also for reducing solar load from sunshine, due to this reduction it may not be necessary using cooling systems or its energy consumption is reduced to minimum. When outside blinds are used for regulation of the inside illuminance the standards requirements may not be fit. In this case, the artificial lighting is necessary to use. It is important to correctly regulate daylight and eventually supplement it with artificial lighting to set the system for minimum energy consumption to meet all standard requirements. The measurement was performed in laboratory of lighting systems for twelve inside points and one outside point, inside points represents workplaces. With outdoor illuminance daylight factor was calculated. Results indicated expected trend, reducing inside illuminance with increasing angles of blinds.

Key-Words: workplace illuminance, blinds, illumination measurement, simulation, daylight factor, tilt of blinds

1 Introduction

Nowadays, when electric energy is used almost in all areas, increased energy efficiency is required not only from electrical equipment but also from entire systems; for example, house automation.

For instance, to reduce solar load, it is necessary to regulate the glazing area. Hoffmann describes twelve different coplanar shade with different geometry. She presents a simulation of energy consumption in building with those different shades [1]. Daylight control can also be done with internal blinds. For example, Sanati divided the window into two parts, the upper part is equipped with fixed blind and the bottom part is equipped with blind, which can be controlled by the occupant [2]. Shen describes lighting and daylight control as one system; in other words, daylight control communicates with the lighting system and can communicate with HVAC system. His conclusion proves that less energy for lighting and cooling is needed when using integration [3]. The influence of shading control strategic describes Yun. He looked at the issue as a whole and include quantitative and qualitative criteria [4].

For optimal energy savings, it is also necessary to take into account the regulation of the light sources for the regulation of blinds. Roisin deals with lighting energy saving in office [5]. Similar approach presents Soori [6] with lighting strategy for a typical office building in Dubai, where he describes the impact of artificial lighting and natural lighting on the HVAC system. Caicedo demonstrates daylight-adaptive lighting control [7].

The purpose of this study is to describe blinds effect in the laboratory of lighting systems, also we compare simulated values of illumination levels for the laboratory. In this case, we consider only quantitative parameters of inside illuminance at measuring points. Quantitative requirements are described in Czech stands [8, 9]. Next phase of this research will contain artificial lighting and its automation with blinds to achieve optimal lighting conditions and energy consumption saving.

2 Methods

This article examines the effect of blinds on workplace illuminance in the laboratory that was built for the purpose of research on w orkplace lighting and home automation.

The laboratory is located at Tomas Bata University in Zlin, Faculty of Applied Informatics.

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GPS coordinates of the laboratory are 49°13’50” North latitude and 17°39’27” East longitude. The solar azimuth angle was set at 174°40’.

In the laboratory are six student workstations and one tutor workstation. The South wall is fitted with windows divided into smaller windows separated with inside pillars. These pillars are equipped with inside blinders for glazing regulation.

Outside the windows are equipped with outside blinders with electric motors for automatic functions.

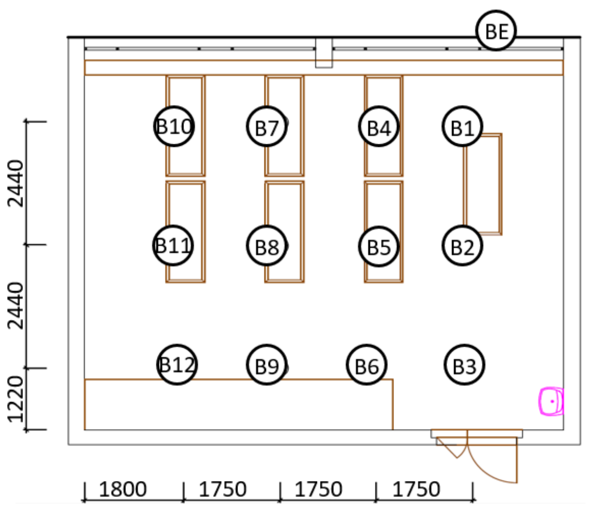

Fig. 1 The position of the measuring points in the room

In the laboratory were set twelve checking point, the positions are shown in fig. 1. Six checking points are at student’s workstation, two at tutor workstation and the rest of the inside checking point near the inner wall. Outside illuminance is measured in front of the window position BE.

The measurement was supplemented by the calculation of the daily illumination level

$$D = \frac{E}{E_h} \quad (1)$$

when D is daylight factor [%],
E inside illuminance [lx],
E_h outside illuminance [lx].

Two outdoor blinds can regulate daylight. Each blind can be controlled separately. Dimension and shape are shown in fig. 2. The blinder lamella angle can be set at an angle of 0 ° to 75 °.

For measurement were used data loggers Almemo and two measuring heads FLA 623VL with range 0 to 170k lx and FLA603VL2 with range 0,05 to 12k5 lx. Both measuring heads with an absolute error less than 5 %.

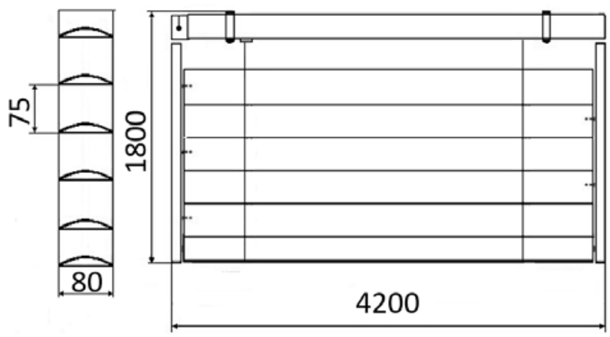

Fig. 2 Parameters of the blinds

3 Results

This article provides measurements of inside illuminance measured according to the checking points in the fig.1. Outside illuminance was measured at the same time as the measurement of inside illuminance.

The measurement was performed for cloudy sky without blinds and for clear sky without blinds and with blinds set on angles 90°, 120° and 165°. The angle is calculated from the horizontal plane.

3.1 Daylight with cloudy sky

Table 1 Measured values with cloudy sky

Window row	Inside illuminance [lx]	Outdoor illuminance [lx]	Daylight factor [%]
Point 1	2218	19489	11,38
Point 4	2006	19262	10,41
Point 7	1885	18545	10,16
Point 10	1999	18581	10,76
Middle row	Inside illuminance [lx]	Outdoor illuminance [lx]	Daylight factor [%]
Point 2	621	19381	3,20
Point 5	574	19187	2,99
Point 8	510	18565	2,75
Point 11	503	18386	2,73
Door row	Inside illuminance [lx]	Outdoor illuminance [lx]	Daylight factor [%]
Point 3	259	19346	1,34
Point 6	245	18525	1,32
Point 9	186	18861	0,99
Point 12	195	18485	1,06

The measurement was carried out 12. 4. 2017 between 11:15 and 11:30 with cloudy sky. With internal and external illumination were calculated daylight factor. Measured values and calculated daylight factor are in table 1. As can be seen outdoor illuminance during measurement is approximately nineteen thousands lux. When comparing daylight factor with standard values we can see that middle row meet minimal values for daylight factor and window row met average values for daylight factor. On the other hand, daylight factor at door row does not fit.

3.2 Daylight with clear sky

The measurement was carried out 11. 4. 2017 between 11:00 and 13:00 with a clear sky. To determine the effect of daylight regulation several angles of the blind lamella.

The first measurement was performed for clear sky and no blinds. Measured values and calculated daylight factor are in table 2. As can be seen outdoor illuminance during measurement is approximately eighty-nine thousand lux. When comparing daylight factor with standard values we can see that in this case window row is under average values for daylight factor. For middle row, the values meet minimal values for daylight factor. On the other hand, daylight factor at door row is not fit satisfied.

Table 2 Measured values with clear sky and no blinds

Window row	Inside illuminance [lx]	Outdoor illuminance [lx]	Daylight factor [%]
Point 1	4268	88556	4,82
Point 4	3795,7	88590	4,28
Point 7	3910,9	88785	4,40
Point 10	4501,7	88918	5,06
Middle row	Inside illuminance [lx]	Outdoor illuminance [lx]	Daylight factor [%]
Point 2	1642,3	88619	1,85
Point 5	1638,6	88604	1,85
Point 8	1660,9	88534	1,88
Point 11	1543,6	88312	1,75
Door row	Inside illuminance [lx]	Outdoor illuminance [lx]	Daylight factor [%]
Point 3	766,24	88748	0,86
Point 6	772,41	88974	0,87
Point 9	835,55	88543	0,94
Point 12	713,72	87849	0,81

The second measurement was performed for clear sky and blinds set at 90°. Measured values and calculated daylight factor are in table 3. As can be seen outdoor illuminance during measurement is approximately eighty-nine thousand lux. When comparing daylight factor with standard values we can see that in this case window row is under minimal values for daylight factor. For middle and door row, the values do n ot meet minimal values for daylight factor.

Table 3 Measured values with clear sky and tilt of blinds 90°

Window row	Inside illuminance [lx]	Outdoor illuminance [lx]	Daylight factor [%]
Point 1	1158	89114	1,30
Point 4	1035	90020	1,15
Point 7	1000	89362	1,12
Point 10	1138	89302	1,27
Middle row	Inside illuminance [lx]	Outdoor illuminance [lx]	Daylight factor [%]
Point 2	643	89629	0,72
Point 5	617	89681	0,69
Point 8	617	89203	0,69
Point 11	568	89927	0,63
Door row	Inside illuminance [lx]	Outdoor illuminance [lx]	Daylight factor [%]
Point 3	323	89528	0,36
Point 6	320	89864	0,36
Point 9	355	89189	0,40
Point 12	238	89639	0,27

The third measurement was performed for clear sky and blinds set at 120°. Measured values and calculated daylight factor are in table 4. As can be seen outdoor illuminance during measurement is approximately eighty-seven thousand lux. When comparing daylight factor with standard values we can see that no values of daylight are fulfilled.

Table 4 Measured values with clear sky and tilt of blinds 120°

Window row	Inside illuminance [lx]	Outdoor illuminance [lx]	Daylight factor [%]
Point 1	678	86458	0,78
Point 4	639	87248	0,73
Point 7	552	87348	0,63
Point 10	586	87387	0,67
Middle row	Inside illuminance [lx]	Outdoor illuminance [lx]	Daylight factor [%]
Point 2	346	86807	0,40
Point 5	329	87288	0,38
Point 8	311	87106	0,36
Point 11	298	87095	0,34

Door row	Inside illuminance [lx]	Outdoor illuminance [lx]	Daylight factor [%]
Point 3	192	87300	0,22
Point 6	187	87567	0,21
Point 9	204	87217	0,23
Point 12	139	87266	0,16

The last measurement was performed for clear sky and blinds set at 165°, which is the maximum angle and represents the maximum shade blinds. Measured values and calculated daylight factor are in table 5. As can be seen outdoor illuminance during measurement is approximately ninety thousand lux. When comparing daylight factor with standard values we can see that in this case none of the measured points fulfils standard values.

Table 5 Measured values with clear sky and tilt of blinds 165°

Window row	Inside illuminance [lx]	Outdoor illuminance [lx]	Daylight factor [%]
Point 1	58	90424	0,06
Point 4	58	89958	0,06
Point 7	55	90062	0,06
Point 10	55	90098	0,06
Middle row	Inside illuminance [lx]	Outdoor illuminance [lx]	Daylight factor [%]
Point 2	26	89797	0,03
Point 5	25	90155	0,03
Point 8	24	90236	0,03
Point 11	23	89809	0,03
Door row	Inside illuminance [lx]	Outdoor illuminance [lx]	Daylight factor [%]
Point 3	13	90437	0,01
Point 6	12	90487	0,01
Point 9	12	90292	0,01
Point 12	9	90368	0,01

Fig. 4 show inside illuminance for blinds angle 90°, 120° and 165°. In this figure can be seen, that requirement for the illuminance of working place are fulfilled for angle 90° window row and middle row and for angle 120° is this requirement fulfilled for window row. The rest of values does not fit the standard requirements and they should be completed with artificial lighting.

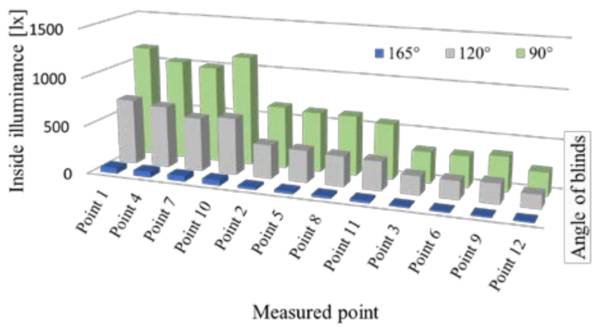

Fig. 3 Inside illuminance for blinds angle 90°, 120° and 165°

3.3 Simulation of inside illumination

Today's computing technology enables simulation of daylight and thus optimization of energy systems in buildings.

The question is whether these simulations are sufficiently precise and not time-consuming to calculate.

Table 6 presents simulated values of inside illuminance with clear sky. Values from table 6 can be compared with measured values from table 2, 3, 4 and 5.

Table 6 Simulated values for inside illumination with clear sky

	no blinds	tilt of blinds 90°	tilt of blinds 120°	tilt of blinds 165°
Window row	Inside illuminance [lx]			
Point 1	2686	1271	903	85
Point 4	2385	1111	834	79
Point 7	2506	1090	816	81
Point 10	2660	1184	867	85
Middle row	Inside illuminance [lx]			
Point 2	853	510	365	35
Point 5	910	514	368	36
Point 8	860	490	362	35
Point 11	868	443	346	33
Door row	Inside illuminance [lx]			
Point 3	418	276	196	19
Point 6	454	267	203	20
Point 9	439	240	362	18
Point 12	394	207	168	16

This comparison is shown in the fig 4. From this figure, it is clear that measured and simulated values are different. This difference is probably caused by the problem of entering input data into the simulation. It is possible to select a few fixed sky scenes and these scenes may not exactly match the real parameters at the measurement point.

As can be seen, the highest difference is in case with no blinds.

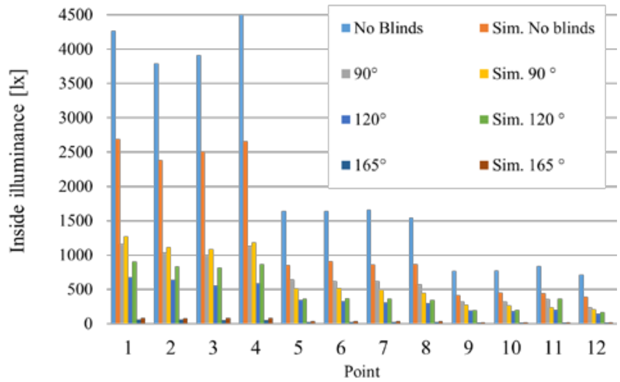

Fig. 4 Comparison of measured and simulated values

4 Conclusion

This paper describing the effect of blinds on workplace illuminance. Table 1 presents illuminance levels at 12 checking point in the laboratory without the blinders with cloudy sky. Both requirements, illuminance of workspace and daylight factor are fulfilled.

Table 2 shows illuminance levels for clear sky and no blinders. As can be seen, the illuminance of the workspace is meet for all measured points, but daylight requirement is fulfilled only for window and middle row. The disadvantage of this solution is that solar load will enormously burden inside temperature and direct sunlight will cause glare.

To eliminate solar load and glare the blinders could be used. This article provides basic measurement of blinds angle on internal illuminance. The angle was set at 90°, 120° and 165°, which present maximal shading.

Measured values of those angles are in tables 3, 4 and 5. As can be seen, daylight factor is not fulfilled except for angle 90° window row, when values meet with minimal daylight factor. On the other hand, workplace illuminance is fulfilled for angle 90° window and middle row and for angle 120°window row. This fact is also evident from the figure 3.

Next part of this paper is comparison of the measured and simulated values. Simulated values are in table 6. And figure 4 present us graphical comparison of this measured and simulated values. As can be seen, in case of no blinds the difference between measured and simulated values is significant. This fact is probably caused by problems with input data when only few sky scenes can be selected. If measurement in done repeatedly this difference could be minimalized.

This study deals only with internal illuminance and it does not adequately reflect solar load savings. The main goal was to map the effect on the internal illuminance. The next step in this research is measured artificial lighting and program optimal control for combination of daylight and artificial lighting because when optimal daylight and artificial lighting is set the solar load is reduced at the minimum and inner illuminance is completed with artificial lighting.

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