

# THE REFURBISHMENT OF TOP LIGHTING AND ITS IMPACT ON THE VISUAL ENVIRONMENT IN THE INDUSTRIAL HALL : A CASE STUDY

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## ABSTRACT

Natural daylight is a vital element in our daily life. Providing natural daylight into the working environment is of fundamental importance for the comfort, efficiency and safety for the people in that environment. This paper deals with visual comfort evaluation in selected hall. The aim of this study was to evaluate existing and reconstructed industrial hall lighting by measuring daylight. The measurement was carried out in the hall with two types of skylights and with the refurbishment of the side lighting.

## INTRODUCTION

About one – third of the electricity in most buildings is used for lighting. Daylighting is the use of natural sunlight or daylight for illumination in order to reduce or eliminate electric lighting [1].

One of the most important applications of lighting technology is undoubtedly the lighting of workplaces. Lighting quality has a major impact on quality of work output, productivity and efficiency. However, the quality of lighting is not only expressed by measurable parameters of lighting, it is also determined by hygienic, energetic or even aesthetic aspects [2]. In addition to increasing the interior light source and providing increased energy savings, daylighting solution also boosted employee morale in the manufacturing plant. The advantages and benefits of daylighting, including health improvement, cost and energy saving, should be verified by a number of previous studies [3], [4].

Top lighting is daylight that comes onto a room from above. Since skylights are located in the summer when the sun angle is high in the sky and can result in heat gain. Top lighting does not have the depth limitation that side lighting has. A building can be wide and still receive daylight, it does not provide a connection to the outdoors that has been shown to be important to human well-being [5], [6]. Top lighting is a daylight strategy to provide uniform distribution of daylight to the entire top floor plan through roof openings. It is often applied in large single story buildings and the top floor of multi-story buildings. Dynamically adjusted lighting levels help employees with their regular visual tasks. Active light helps reduce error rates and increase worker safety [7], [8].

Daylight factor (DF) is the ratio which represents the amount of illuminance available indoors relative to the illuminance present outdoors at the same time under overcast sky. DF is given as a percentage, and can be expressed as the following equation [9], [10]:

$$DF = \frac{E_i}{E_H} * 100 \% (\%), (1)$$

where

$E_i$  – the illuminance at a point in the room

$E_H$  – the illuminance of a horizontal surface outside under the overcast sky

Illuminance uniformity ( $U_0$ ) is defined as the quotient of minimum and average illuminance in the visual task area, keeping in mind that this minimum value must not be undercut at any time [10]:

$$U_0 = \frac{E_{min}}{\bar{E}} (-), (2)$$

Figure 1 shows a diagram that shows the factors that affect the appropriate lighting [11].

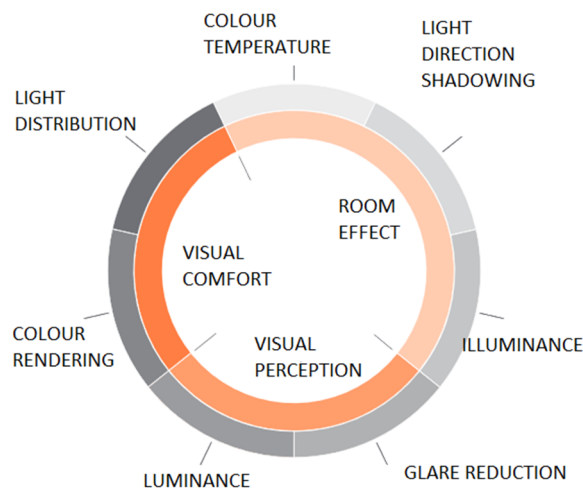


Figure 1 Factors affecting the appropriate lighting [11]

## EXPERIMENTAL SETTING

Measurements were performed in a single storey hall in Kosice, Slovakia. The hall is designed for work related to metal working and forming, production of semi-finished products from sheet metal and similar products. The interior dimensions of the hall are 15 m × 60 m × 8.5 m (see Figure 2).

The hall is oriented longitudinally in the east – west direction. Production machines, tables and cabinets are deployed throughout the hall (Figure 3). A permanent supplementary artificial lighting system is designed in the lobby. The side lighting system consists windows with width of 5.6 m and height 1.8 m on the north and south perimeter walls in case original hall. In the case of a reconstructed hall, the windows on the north side are obscured. Windows with dimensions 3 × 1.8 m are orientated on the east and west sides. The top lighting system is a straddle skylight with a steel frame and a steel flange of 2.4 m × 48 m × 1.1 m (see Figure 4a). In case of original glazing the glazed elements consist of single – pane glazed walls reinforced with wires. In case of reconstructed hall the glazed elements consist of double plastic glass (side windows) and single – pane skylight transparent plastic sheets of poly (methyl-methacrylate) reinforced with wires (see Figure 4b). For calculations, the following coefficients of reflections were considered, see Table 1. The working plane was 0.75 m high. The neighboring objects at a distance did not shade the room.

Measurement of daylighting was carried out according to STN 360020. The instruments were two Data Logger “ALMEMO 2690 – 10A, and illuminance Sensor ALMEMO FLA 623 VL with production number 15061543, accuracy of 5%, and reflection of 0.847. Luminance meter LS – 110 was used to measure the luminance with

an accuracy of 2%. On the selected days, the value of the outside light ranged from 4.500-8000 lx in January (for original hall) and for reconstructed from 26.000-39.000 lx in March during sunny days.

Table 1. The coefficients of reflections ( $\rho$ ) of the light

Surface	Original glazing	Reconstructed glazing
Wall	0.7	0.9
Ceiling	0.7	0.8
Floor	0.1	0.4
Light transmission factor-side lighting	0.4	0.6
Light transmission factor-skylight	0.6	0.5
Terrain	0.15	0.15

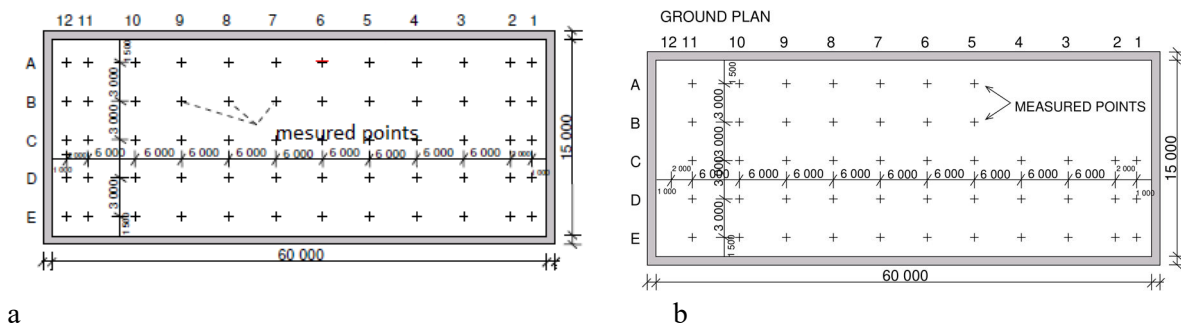


Figure 2 Plan of the hall; (a) – original hall, (b) – reconstructed hall.



Figure 3 Interior view of hall (a) original hall, (b) reconstructed hall.

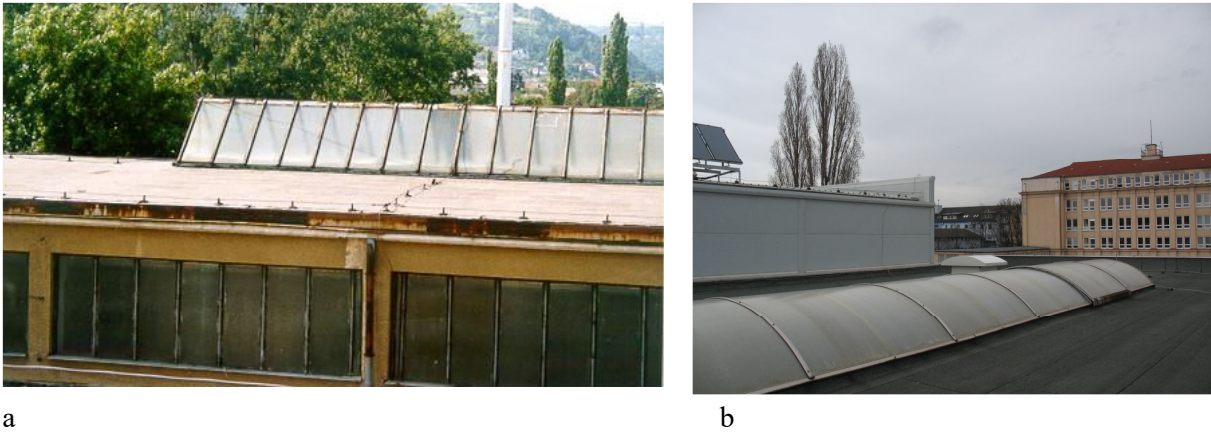


Figure 4 Skylight view (a) straddle skylight, (b) arc skylight.

RESULTS

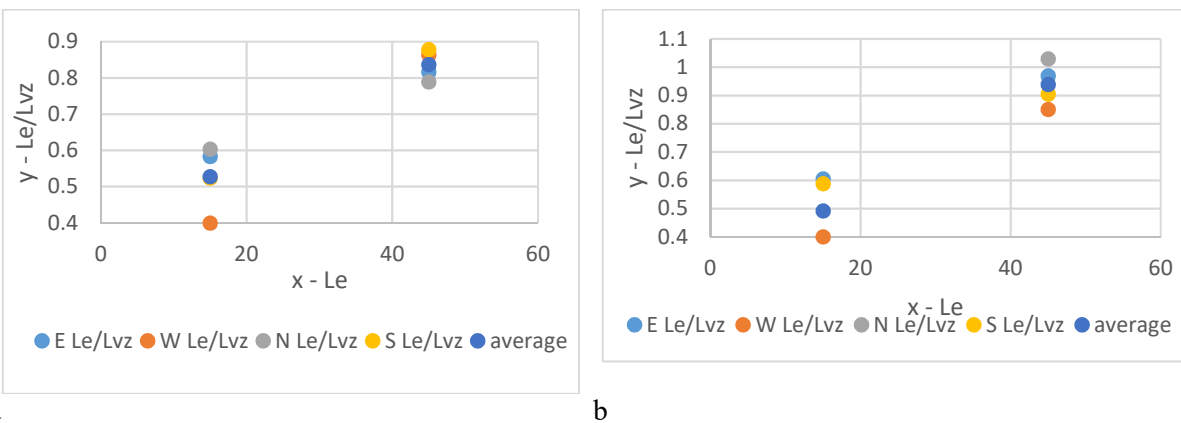


Figure 5 The measured sky conditions rating gradations of sky luminance, x—refers to the elevation angle, y—refers to the Le/Lvz ratio, Le refers to the external sky luminance, and Lvz refers to the sky luminance at an angle of Z 15° and 45°. January – straddle skylight (a) the beginning; and (b) the end of the measurement x—elevation angle, y—Le/Lvz ratio.

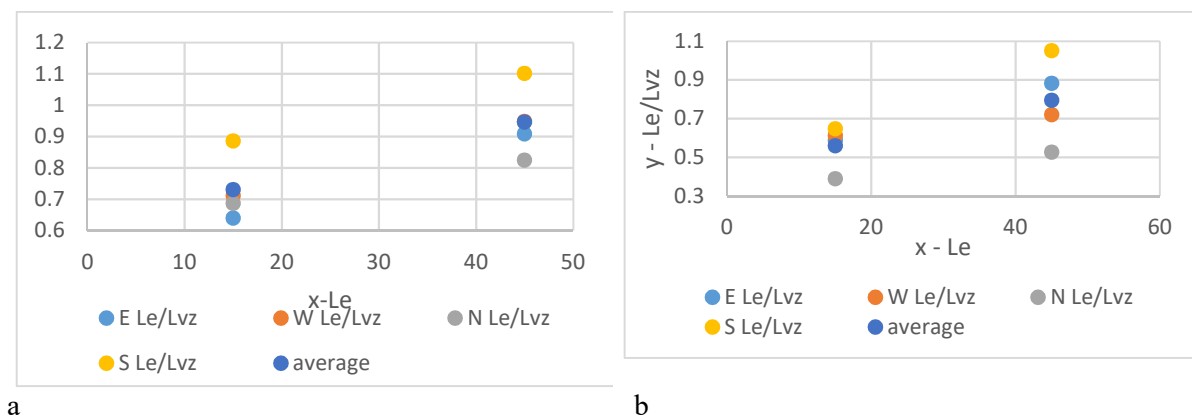


Figure 6 The measured sky conditions rating gradations of sky luminance, x—refers to the elevation angle, y—refers to the Le/Lvz ratio, Le refers to the external sky luminance, and Lvz refers to the sky luminance at an angle of Z 15° and 45°. March – arc skylight (a) the beginning; and (b) the end of the measurement x—elevation angle, y—Le/Lvz ratio.

Table 2. The measured sky conditions rating gradations of sky luminance.

January – original hall – straddle skylight					
(a) at the beginning of measurements			(b) at the end of measurements		
Z	Le/Lvz	Average value	Z	Le/Lvz	Average value
15°	0.42–0.62	0.50	15°	0.40–0.66	0.50
45°	0.78–0.90	0.85	45°	0.88–1.05	0.95
March – reconstructed hall – arc skylight					
(a) at the beginning of measurements			(b) at the end of measurements		
Z	Le/Lvz	Average value	Z	Le/Lvz	Average value
15°	0.62–0.90	0.72	15°	0.35–0.69	0.60
45°	0.80–0.90	0.95	45°	0.51–1.05	0.80

Table 3. Daylight factor

	DF <sub>min</sub> (%)	DF <sub>max</sub> (%)	DF <sub>average</sub> (%)	U <sub>0</sub>
Straddle skylight	0.44	7.69	4.96	0.06
Arc skylight	1.62	9.57	5.42	0.17

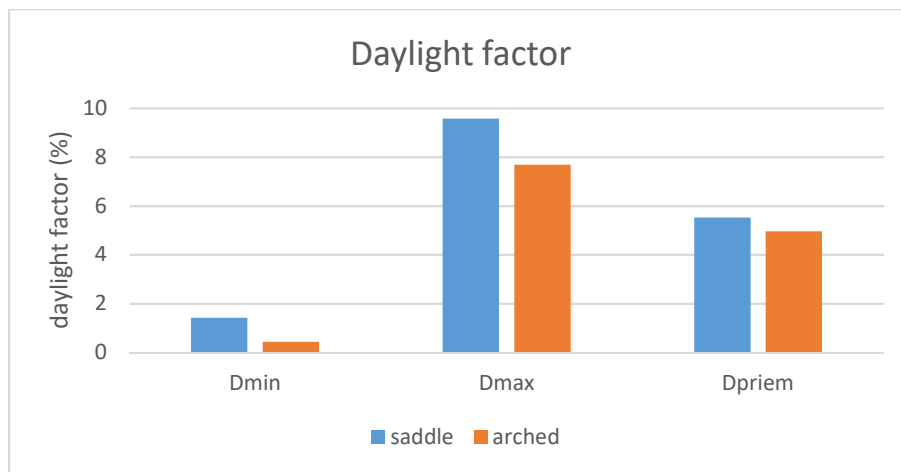


Figure 7 Daylight factor

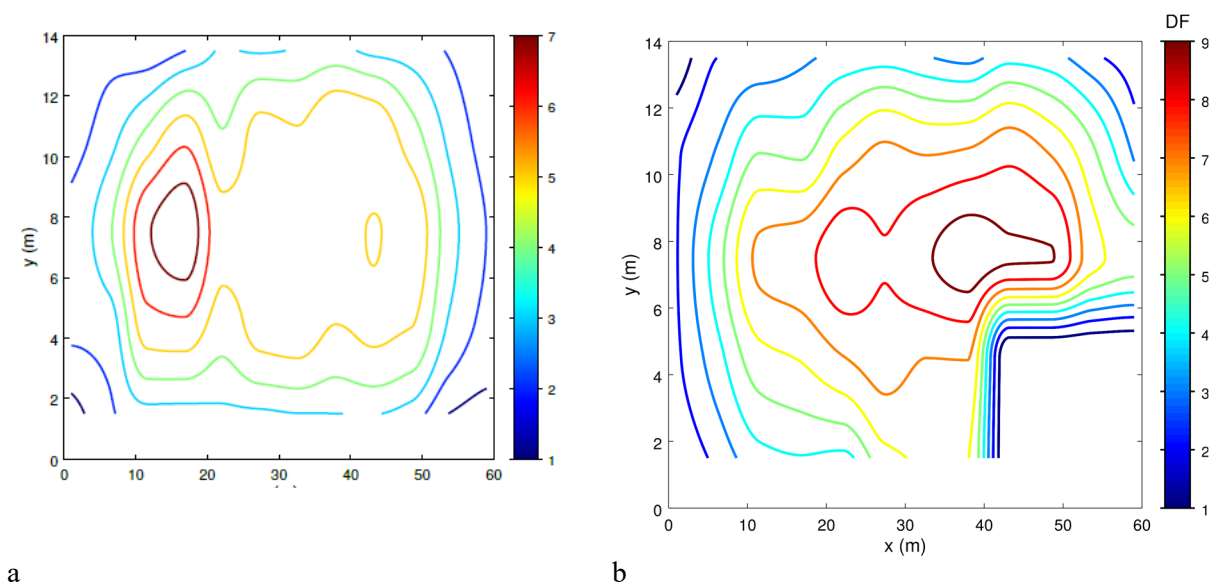


Figure 8 The results of the daylight factor (%), (a) straddle skylight, (b) arc skylight

## CONCLUSIONS

According to the STN 360020, the distribution of the sky brightness at a given elevation height to the sky brightness at zenith for 15° 0.3-0.6 and for 45° 0.7-0.85 is acceptable. It follows from the above graphs that the sky brightness values before and after the measurement are almost within the permissible range.

$DF_{\min} = 1.5-2\%$ ,  $DF_{\text{average}} = 5-6\%$ , illuminance uniformity  $U_0$  is greater than 0.2-0.3 for a given light technical class is required for the permanent supplementary artificial lighting system in accordance with the valid STN standard.

The results show that  $DF_{\min}$  is suitable for the reconstructed hall ( $0.62 < 1.5-2\%$ ) and not suitable for the original hall ( $0.44 < 1.5-2\%$ ).  $DF_{\text{average}}$  is suitable for both halls. Illuminance uniformity  $U_0$  is not met even for one hall. In the case of reconstruction, however, illuminance uniformity is better ( $U_0 = 0.17$ ).

Due to the fact that the measurements were carried out under different external conditions (the reconstruction took place after several years) it is not possible to adequately compare the results (see Figure 5-6, Table 2). But it can be stated that light well-being has improved, although the windows in the northern facade have a considerable impact.

DF values have increased as well as illuminance uniformity is improved. However, there is still a problem of overheating, especially in places under the skylight (confirmed by the workers in the hall).

### Acknowledgement

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