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Daylight Analysis in tle UNESCO Listed Building

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Abstract
The paper is aimed at a case study of daylighting in a residential hall of Villa Tugendhat in Brno. Illuminance measurements and monitoring of internal surface luminance were completed for overcast and partly cloudy sky conditions of winter season evaluations. The residential area insolation was simulated in software BSim for the time of daylight measurements. The daylight analysis shows convenient daylighting for indoor visual comfort.

Keywords - daylighting in buildings; indoor climate, illuminance; luminance; insolation.

1. Introduction

A case study focused on the daylighting in a building that is architecturally valuable premise of the UNESCO listed building. The Villa Tugendhat is located in city of Brno in the Czech Republic [1-4]. It was designed in 1928 by architect Ludwig Miese van der Rohe. The villa was constructed in 1928-1930. The reconstruction to the original state of the architect′s design was completed in 2010 – 2012.

A research focused on an analysis of indoor climate conditions has been carried out in the villa [5-7]. Temperature distribution and ventilation system as well as the building insolation study for direct sunlight were evaluated. A new task within the frame of the indoor climate evaluation is a study of daylighting in the main residential area of the villa.

The ground floor of the villa has fully glazed facade in the south-west orientation. The glazed conservatory is located in the south-east position. The main residential hall has an onyx wall located in the middle of the ground floor disposition, Figure 1.

The wall was studied with respect of its influence on the indoor thermal climate [5]. It was proven that the onyx wall is not only aesthetic interior partition but it plays important role as a heat accumulation construction [6,7]. There is a photograph and scheme of the onyx wall in elevation from the internal side of the glazed facade in Figure 2.

Fig. 1 Villa Tugendhat photograph [3] and plan of the ground floor [1,2,4]

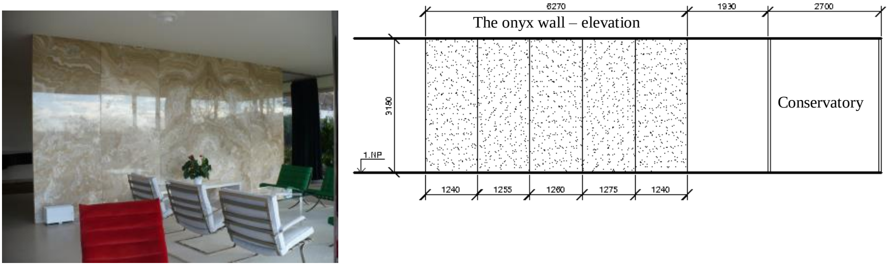

Fig. 2 The onyx wall in the residential hall, photograph (authors) and scheme [4]

2. Evaluations

Daylight measurements were carried out in the residential hall. Illuminance distribution was studied for winter season external conditions of overcast and partly cloudy sky (13th January 2016). The illuminance was measured in a grid on the working plane positioned 0.85 m over the floor level, Figure 3.

The second task was measurement of luminance on the interior surfaces in the visual view from the residential hall separated by the onyx wall, Figure 4. The above mentioned evaluations based on daylight measurements were completed for winter overcast and partly cloudy sky conditions. These conditions are characteristic for Brno climatic region. Clear sky with intensive sun shining is scarcely appeared in winter seasons.

The third task was an insolation evaluation. Transmission of solar radiation into the residential hall was simulated for in software BSim [9] for the time of the daylight evaluations. The hall isolation area was studied for time intervals from morning to afternoon.

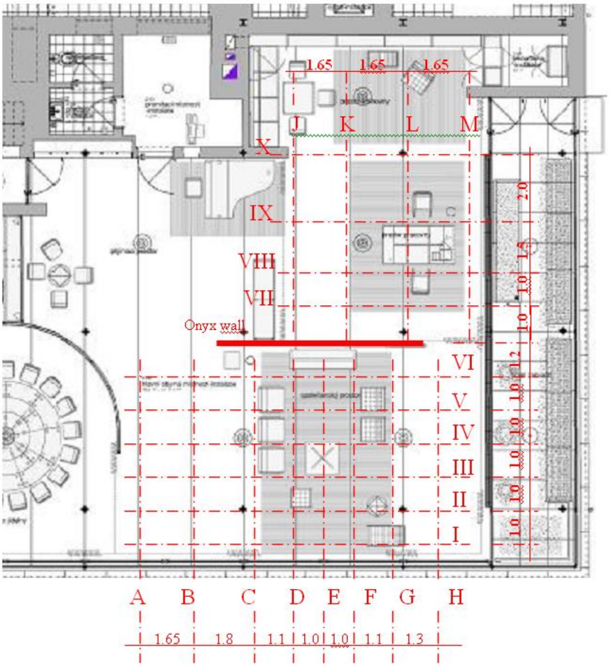

Fig. 3 Part of the ground floor residential area with the positions of illuminance measurements

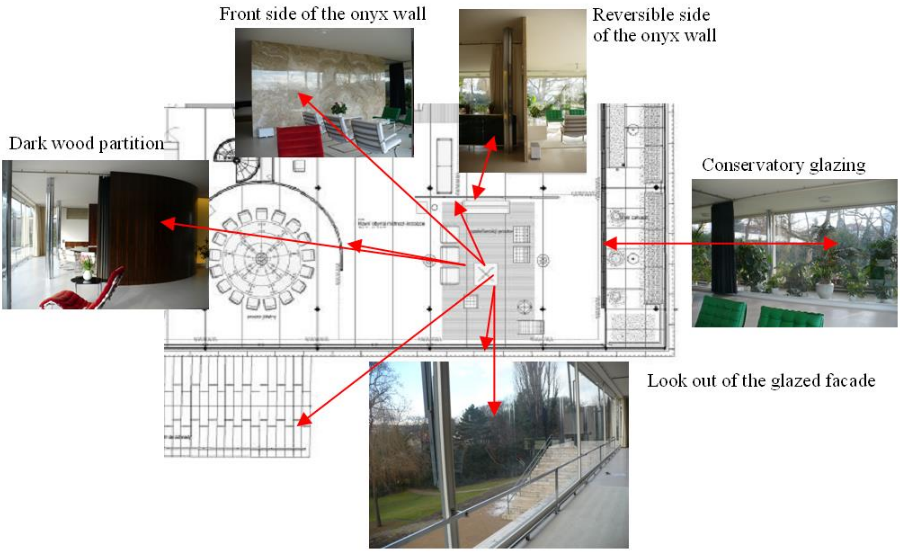

Fig. 4 Places of the luminance measurements

3. Results

3.1 Results of illuminance measurements

Results of illuminance measurements are presented in Figures 5 to 7. The measurement apparatus was illuminance meter T10 Konica Minolta. The measurements in points of the grid A to H and I to VI were completed three times and average values were calculated from the measured data. Comparison of the 1st, 2nd and 3rd measurements and the average values for part E – I to E – VI is in graph in Figure 5.

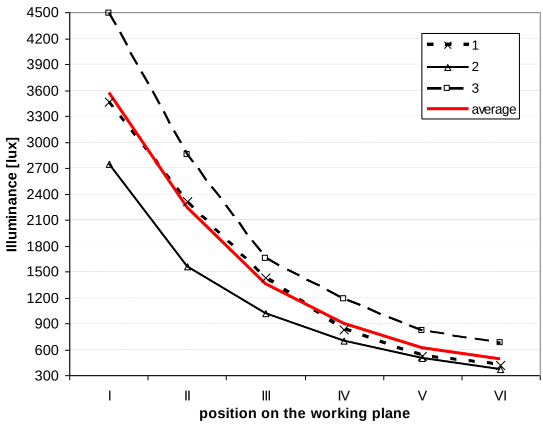

Fig. 5 Illuminance [lux] in the middle of the residential area between the glazed facade and the onyx wall (1 – 1st measurement, 2-2nd measurement, 3-3rd measurement, average – average value from 1,2 and 3)

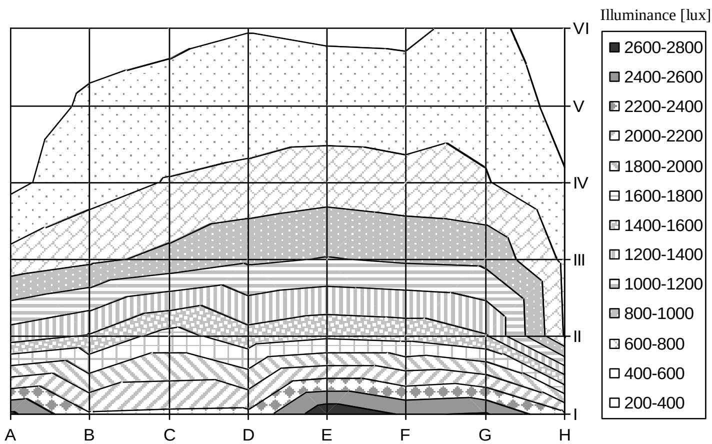

Fig. 6 Illuminance distribution on the working plane between the glazed facade and the onyx wall (the measurements for the mean external horizontal illuminance 7150 lux).

The illuminance distribution in Figure 6 shows slightly increased illuminance in the area F to H – IV to VI. It is caused because of the additional daylighting due to the glazed side wall of the neighbouring conservatory. The conservatory is equipped with many plants that are shading obstructions for daylight transmittance and for this reason the daylight level is not increased very much.

Fig. 7 Photographs of the part of the residential area in the corner between the glazed facade and the conservatory (photo authors)

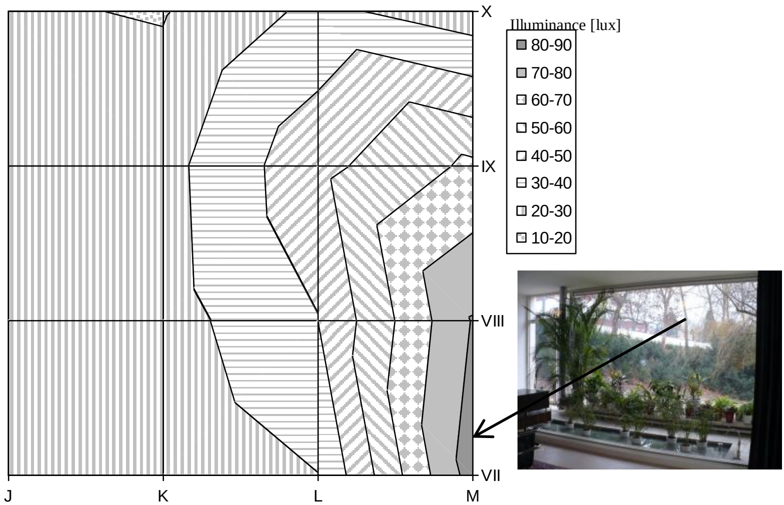

Fig. 8 Illuminance distribution on the working plane at the residential area outside of the onyx wall, J to M – VII to X (measurements for the mean external horizontal illuminance 7150 lux).

Continual measurements were completed by two illuminance meters Lutron 1128 SD. The first light sensor (S1) was located on the floor close to the glazed façade and the second one (S2) was placed on the glass table close to the onyx wall, Figure 9. Outputs of the one-minute interval measurements on 18th and 19th January 2016 are shown in Figure 10.

Fig. 9 Illuminnace sensors S1 and S2 location (photo [3])

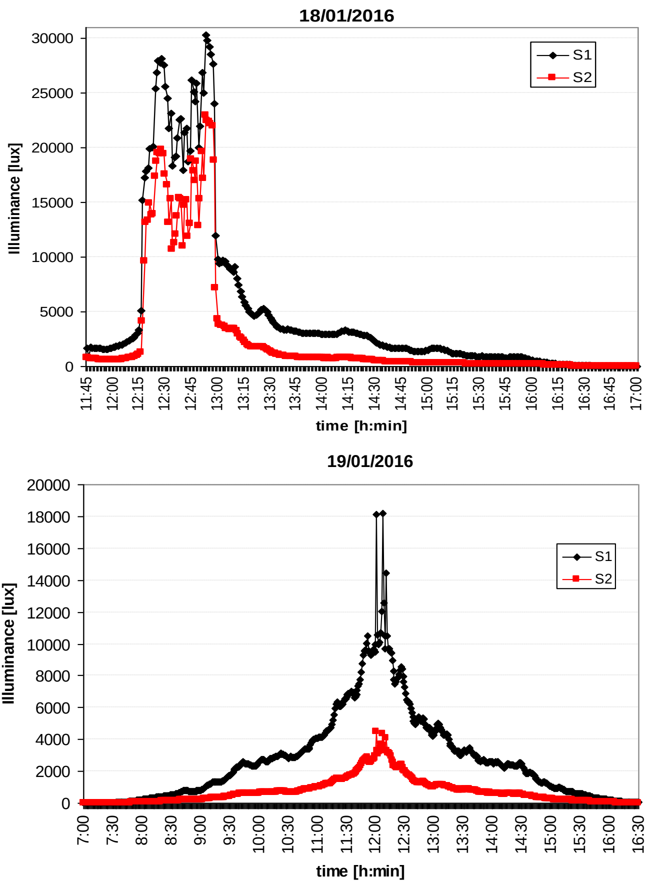

Fig. 10 The illuminance daily profiles on 18th and 19th January 2016

3.2 Results of the luminance measurements

The luminance measurements on surfaces in the residential hall were completed by luminance meter LS 100 Konica Minolta. The results are presented in Figures 11 and 12. The interior surfaces are in compliance to standard requirements for uniform luminance distribution in the visual field of the residential building occupants [8]. Only the dark wood partition is in contrast with the fully glazed façade area.

The luminance measurements give information about the luminance distribution for overcast sky and partly cloudy sky conditions. These skies are characteristic outdoor conditions for many days in winter and transitional periods in the given climatic locality. The direct sunlight impact on interior daylighting will be studied in the following research evaluations.

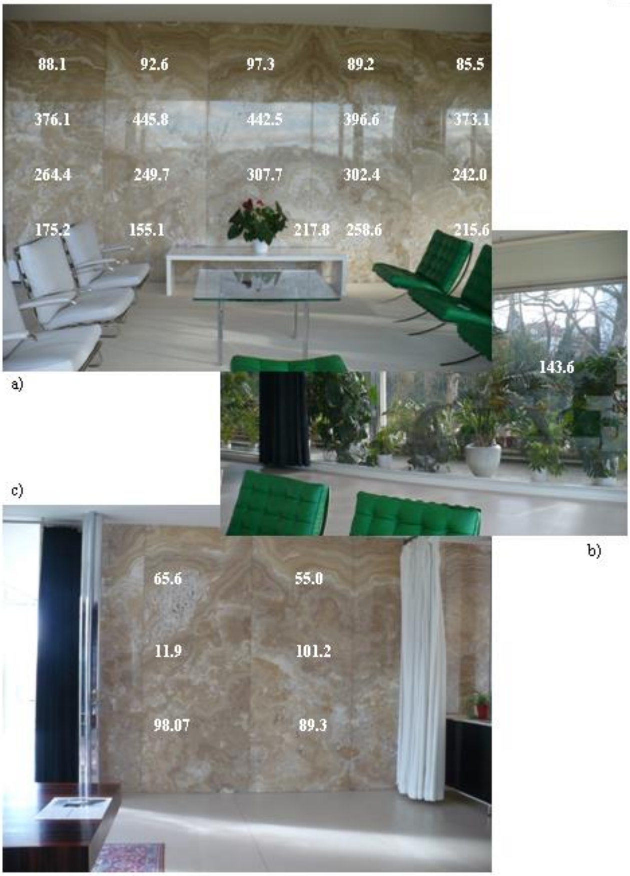

Fig. 11 Luminance [cd.m^{-2}] of the onyx wall and the conservatory glazing

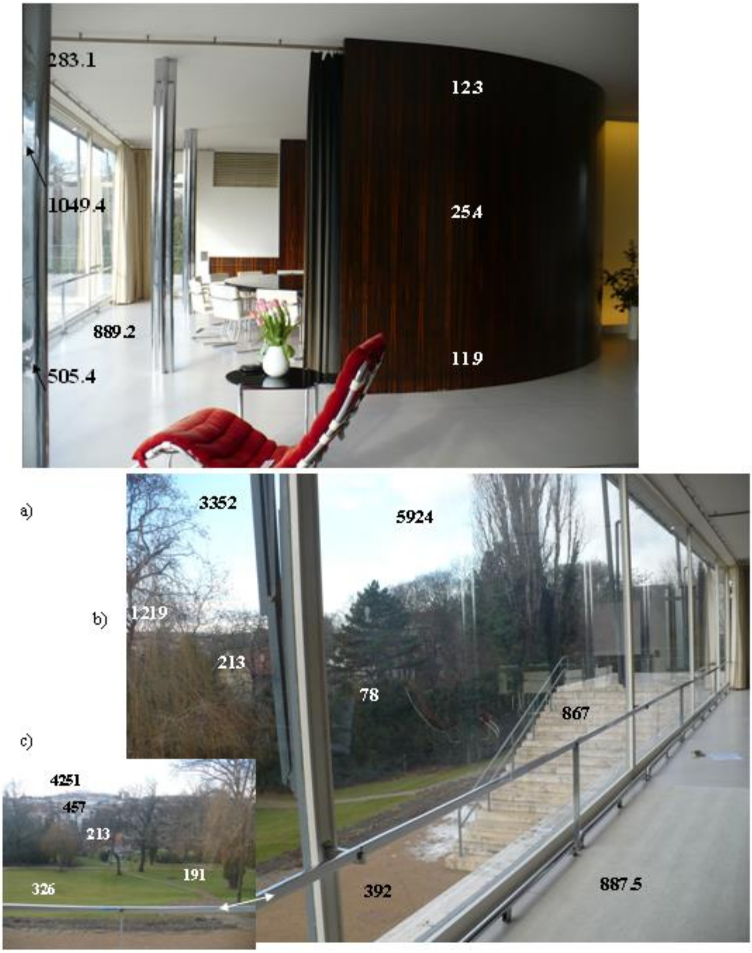

Fig. 12 Luminance [cd.m^{-2}] of surfaces in a view out of the onyx wall to the glazed area of the facade and the dark part of the internal wooden partition
a) look at the wooden partition, b) look at the external stairs through the glazed façade,
c) look to the garden through the glazed façade.

3.3 Insolation simulations

The BSim [9] simulation outputs show the residential hall insolated area (yellow parts) during the daytime between 10:00 and 14:00 on 13th January, Figure 13. It is obvious that the hall is fully insolated early in the morning and in the afternoon. The noon time solar radiation transmittance is reduced because of the south-west orientation of the glazed façade exposed to the high altitude solar radiation.

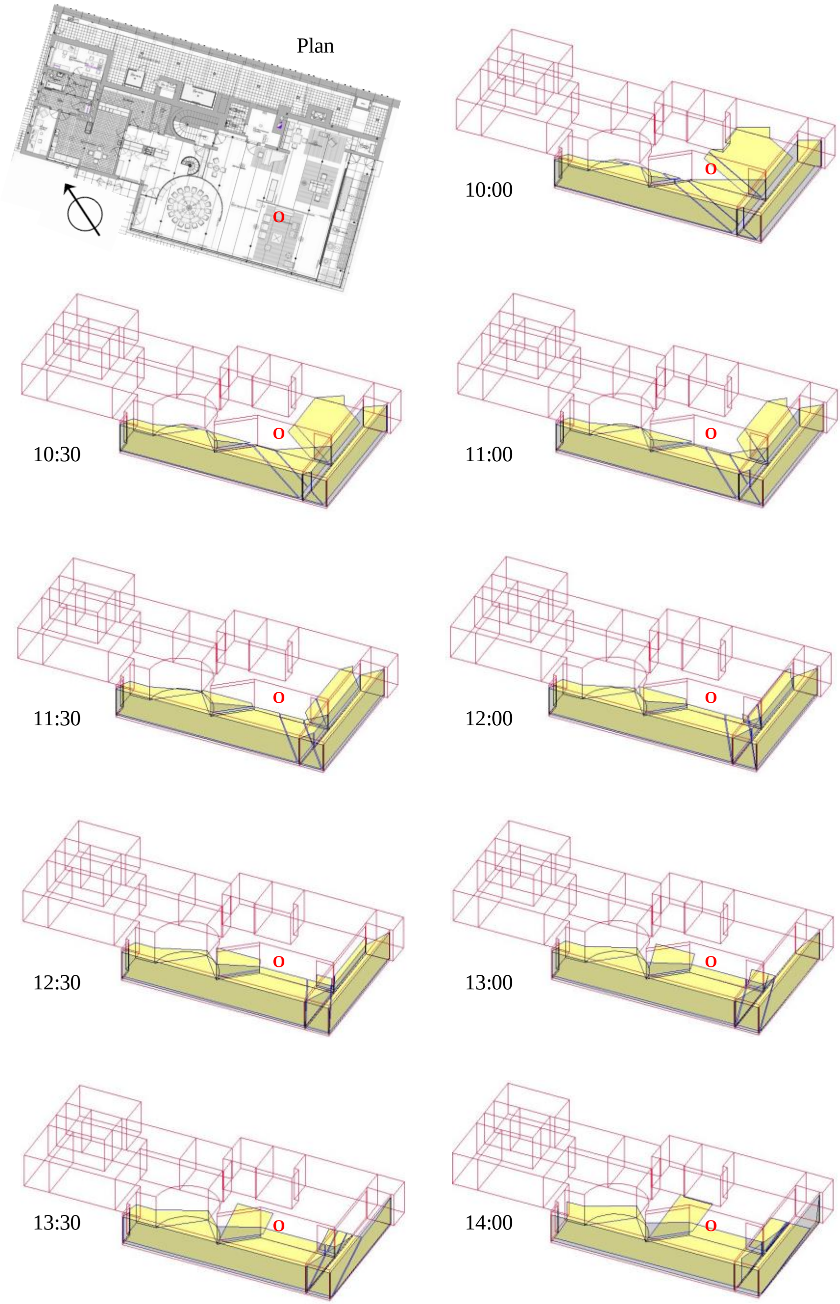

Fig. 13 Insolated area (yellow parts), 13th January from 10:00 to 14:00, (O – onyx wall)

4. Conclusion

Daylighting on the ground floor residential area of the UNESCO architectural monument of Villa Tugendhat was evaluated. The measurements and insolation simulations show that the ground floor of the villa is properly illuminated with plenty of daylight even in case of dark overcast sky conditions in the winter season. Also the luminance distribution is convenient with respect to the occupants′ visual comfort.

The insolation charts give information about the suitable orientation of the residential area to the cardinal points. The south-east glazing of the conservatory transmits solar radiation in the morning time. This façade has influence of insolation of the residential area behind the onyx wall. The south-west glazed façade transmits solar radiation into the residential hall during afternoon while the room behind the onyx wall serves shaded places.

The sophisticated architectural concept gives possibility of indoor visual comfort in the entire open plan disposition of the main living area in the villa. The study will continue in the annual daylight measurements profile for analysis of daylight conditions in summer season and for times with intensive solar radiation.

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