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THE QUALITY OF DAYLIGHT IN VARIOUS TYPES OF RESIDENTIAL BUILDINGS

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ABSTRACT

The residential building design must place an emphasis on daylight in interiors, in terms of quality as well as quantity. The legislative requirements are more or less unified across the spectrum of residential building types. The article compares the daylighting conditions in three different types of residential development in Prague: a tenement house from the 19th century, a neighbourhood of precast panel buildings from the second half of the 20th century and a contemporary housing complex. The urban situation, such as distances between the buildings and street profiles, majorly influences the daylight and insolation in the apartments. The apartment layout, the proportions of the room and the size and proportion of the windows are also important factors affecting the distribution of daylight in the rooms.

The case study is a part of a larger research project, which aims to create a supplementary teaching material for architecture students, who are learning to design the suitable interiors.

Keywords: daylight, insolation, tenement house, precast panel building, residential

INTRODUCTION

Daylight is an indispensable aspect of residential building design, especially nowadays when the developed world population spends over 90% of their time inside buildings, most of it at home [Brasche, 2005]. There is a number of studies pointing to the link between the daylight quality in buildings and the health of their inhabitants [Aries, 2013].

The interior lighting conditions are, besides climate, determined by the architectural and spatial properties of the building. This article compares the daylight quality in residential rooms of three common types of residential buildings in Prague and links them to some of the architectural features. It proceeds from the urban scale (especially street profiles, i.e. the height and distance of the opposite development and the associated shading angle), through shielding obstacles on the facade of the house itself (loggias, balconies) and spatial properties of the rooms (proportions of depth and width and positioning of window openings) up to the properties of window openings (especially window frame thickness and glazing properties).

The first example is a tenement house from the end of the 19th century in the house block urban structure, one of the most popular types of housing in Prague. Next, a typical apartment in a precast panel house neighbourhood built in the VVU ETA construction system was selected.

It is not possible to identify such a distinctive building type in the contemporary housing development. However, the selected housing complex appropriately illustrates some of the trends typical for contemporary housing construction.

This case study is part of a larger research project that aims to create additional teaching material for architects. The goal is to link the light characteristics (difficult to imagine for architects) to specific buildings

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and rooms known to architects. This should facilitate architectural design in accordance with daylighting requirements.

THE DEVELOPMENT OF DAYLIGHT REQUIREMENTS

The first requirements for the amount of daylight in residential buildings were already described by Marcus Vitruvius Pollio in the first century BC in his Ten books on architecture [Vitruvius, 15BC] and the modern daylighting requirements approximately match the notion recorded by Vitruvius [Kaňka, 2014]. The legislative requirements on the provision of daylight and on the sunlight duration were formed in most European countries after the second world war. In the Czech Republic, the first daylighting standard was drafted in 1949 and the requirements on residential room insolation were formulated in 1955.

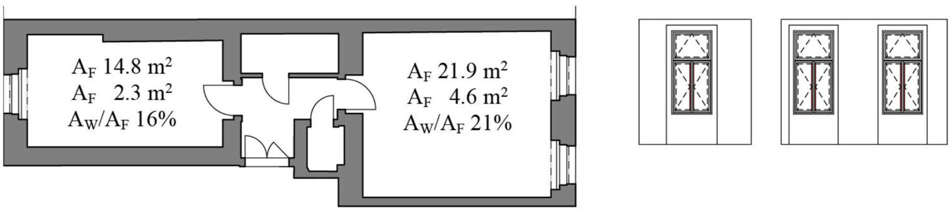
The currently valid standard ČSN 73 0580 – 2 Daylighting in buildings - Part 2: Daylighting in Residential Buildings specifies two calculation points on the working plane at a height of 0.85 m in the middle of the depth of the room at a distance of 1 m from the side walls. The minimum daylight factor at the two points shall be 0.7%, the minimum average of the two points shall be 0.9%. The requirements for sunlight duration (at least 90 minutes on 1.3.) are set out in ČSN 73 4301 Residential Buildings. Prague has its own set of building regulations, in which the requirements for daylighting refer to the applicable standard. In 2018, however, the insolation requirements were abolished in these regulations.

Recently, the European standard EN 17037 Daylight of Buildings, which summarizes the requirements for all aspects of natural lighting, came into force. In addition to daylight provision and exposure to sunlight, it also assesses the view out of the windows and glare protection.

This standard assesses the daylight provision on a grid of points located on a work plane 0.85 m from the floor. A target illuminance of at least 300 lux shall be achieved at half of the reference plane and at least 100 lux at 95% of the reference plane, at mid-daylight hours. The standard allows a simplified calculation using the daylight factor, where for Prague the minimum target illumination of 100 lux corresponds to D = 0.7% and the target illuminance of 300 lux corresponds to D = 2.0%. However, the minimum daylight factor values required by the Czech legislation is still assessed in the two points described above.

NINETEENTH CENTURY TENEMENT HOUSE

The house is located in a neighbourhood build in the second half of the 19th century, with four and five floor blocks of houses. The selected building has a layout typical for the 1890s: a three-tract, where the residential room location was based on the street and court orientation, regardless of the cardinal points. There are rooms in the street wing, staircase and kitchens in the courtyard wing. The middle section is reserved for corridors and sanitary facilities. Each floor typically has two apartments, both facing two facades. There are double casement windows with wooden frames and single glazing, with notably vertical proportions.



clear height = 3.2 m
windowsill height = 0.8 m
window height = 2.2 m
lintel height = 3.0 m

window frame 31 % τ_k = 0.69
window transmittance
(2 single glazed windows)
$\tau_{s,nor}$ = 0.846

Figure 1. 19th century tenement house typical floorplan and windows

Figure 2. 19th century tenement house street profile and urban situation

PRECAST PANEL HOUSE

The form of precast panel houses was largely influenced by the effort to increase the level of comfort, including the requirements for insolation and daylight. The street profile (distances and heights of the buildings) were set so that the houses do not obscure each other. The principles of prefabricated apartments are illustrated on a two-bedroom apartment built in the VVU ETA construction system, which is one of the last (and therefore the most developed) types in terms of layout. The apartments were mainly designed for families, i.e. two bedrooms, living room and kitchen. The kitchen with a surface area under 12 m^2 is not a residential room according to the Czech legislation and as such was not evaluated in this article.
In a vast majority of these apartments, the original wooden frame windows were replaced by thermal insulation windows of larger frame thickness, which are considered for the calculations in this article.

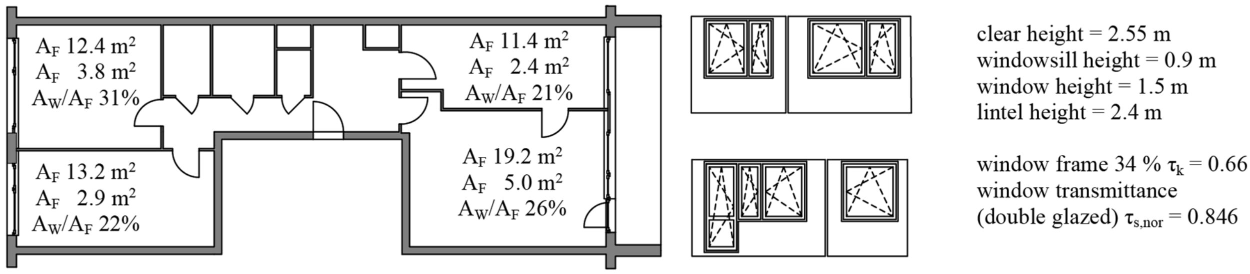


Figure 3. Precast panel house typical floorplan

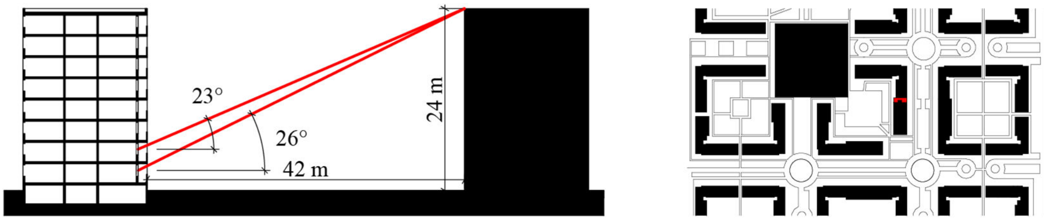


Figure 4. Precast panel house street profile and urban situation

CONTEMPORARY RESIDENTIAL BLOCK

The principles of contemporary housing construction are illustrated on the 4Blok residential complex built in 2015-2017. The residential complex forms an entire urban block. The most common layout is a one-bedroom apartment. Apartments (even larger layouts) are usually oriented to only one facade. Current housing construction must meet a number of technical requirements and standards, which are usually met to the minimum necessary extent. There are thermal insulation windows with double or triple glazing, often with a floor level windowsill. The calculations were performed for double glazed windows.

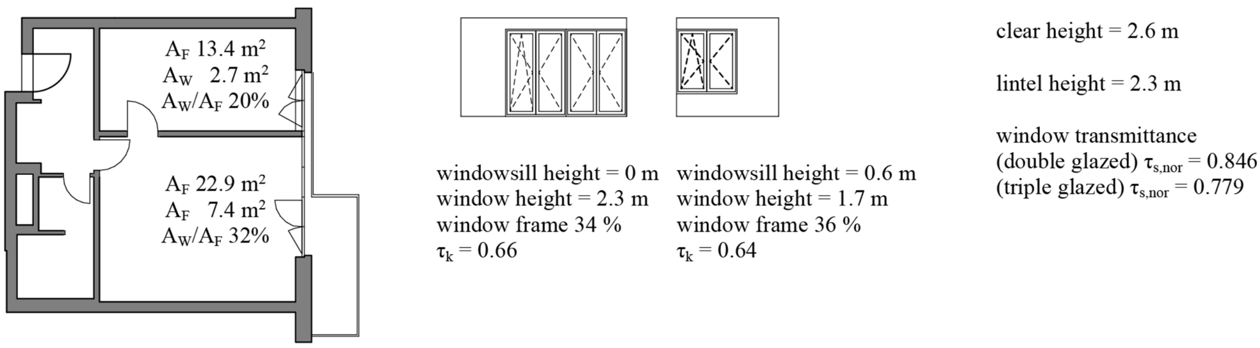


Figure 5. Contemporary housing complex typical apartment floorplan

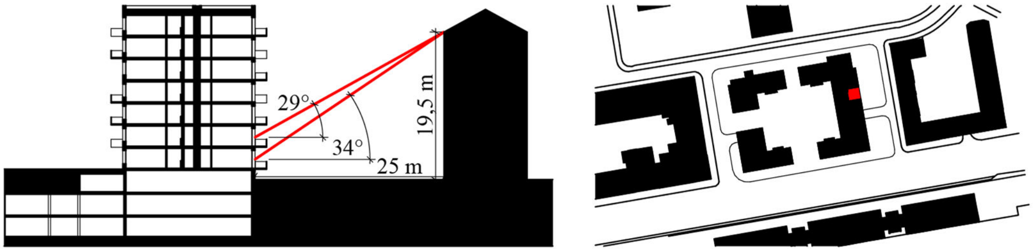


Figure 6. Contemporary housing complex street profile and urban situation

DAYLIGHT AND INSOLATION ASSESSMENT

The daylight provision in the rooms was assessed using the daylight factor. First, the residential rooms were considered separately, with no external shading, to determine the impact of their architectural properties on the interior daylight properties. The only shading element included was the loggia of the precast panel building, as it is an integral part of the apartment layout. Then, the urban situation was assessed the daylight factor on the surface of the windows was calculated and compared (discounting the shading obstacles of the buildings themselves, such as balconies and loggias). Finally, the daylight factor was calculated and assessed in the specific situation of each building in the apartments on the ground floor and on the first floor.

The daylight factor values were compared to the requirements of the currently valid standard (two points on the working plane) and also assessed according to the new European standard EN 17037 on the entire working plane. The uniformity of daylight was calculated as well.

The boundary parameters affecting daylight are: the average reflecting factor of the internal surfaces $\rho_m = 0.5$, the reflection factor of the surrounding terrain $\rho = 0.1$ for dark terrain. The window properties for each room are listed in Fig. 1, Fig. 3 and Fig. 5. The value of the pollution factor for internal pollution is $\tau_{zi} = 0.95$ for a clean interior and for external pollution it is $\tau_{ze} = 0.9$ for an area with average pollution. The daylight calculations were performed in the software Building Design [Astra SW,] using the computing module Wdls 5.0 – Daylight calculation and ČSN EN 17037 – Daylight of Buildings.

The insolation was evaluated using the duration of sunlight in the rooms on the first and second floor. The sunlight duration was calculated according to the EN 17037 – Daylight of Buildings. The duration of sunlight was evaluated on the 1st of March and the minimum requirement is 90 minutes.

DAYLIGHT PROVISION

Table 1. Daylight assessment with no external shading

	ČSN 73 0580 – 2 DF values [%]					**EN 17037** % of work plane area				uniformity of daylight
	point1	point2	>0.7	mean	>0.9	DF>2.0%	>50%	DF>0.7%	>95%	
19th century tenement house										
kitchen	0.9	0.9	yes	0.9	yes	16%	no	73%	no	0.200
room	1.2	1.4	yes	1.3	yes	33%	no	94%	no	0.075
Precast panel building										
bedroom1	1.2	1.2	yes	1.2	yes	33%	no	67%	no	0.054
bedroom2	2.6	2.6	yes	2.6	yes	60%	yes	100%	yes	0.110
living	0.8	0.9	yes	0.9	yes	19%	no	63%	no	0.092
Contemporary housing complex										
bedroom	0.8	0.9	yes	0.9	yes	17%	no	56%	no	0.050
living	1.6	1.2	yes	1.4	yes	27%	no	95%	yes	0.073

With no external shading, all the evaluated apartments meet the requirements of the valid daylighting standard, although some of the rooms are already at minimum values even without any external shading. However, with the exception of one of the precast panel house bedrooms, none of the rooms meet even the minimum requirements of the new European standard EN 17037 Daylight.

Table 2. Daylight factor DF_W [%] on the points in the middle of the window surface

	19th century tenement house			precast panel house			contemporary block	
	room (w2)	room (w2)	kitchen	bedroom1	bedrooom2	living	bedroom	living
ground floor	24.5	24.8	22.0	39.5	39.5	39.6	29.7	28.6
1st floor	29.7	29.9	28.5	39.5	39.5	39.6	32.7	32.1

According to the standard ČSN 73 0580 – 1, the minimum required DF_W values are 24% in areas with permanent residence of people in extremely cramped conditions of historical city centres (the tenement house) and 29% in areas with permanent residence of people in continuous development in city centres, therefore all of the evaluated building meet the requirements, with the exception of the ground floor kitchen of the tenement house, which is oriented into a rather small courtyard and the living room window on the contemporary building ground floor.

Table 3. Daylight assessment on ground floor

	ČSN 73 0580 – 2 DF values [%]					**EN 17037** % of work plane area				uniformity of daylight
	point1	point2	>0.7	mean	>0.9	DF>2.0%	>50%	DF>0.7%	>95%	
19th century tenement house										
kitchen	0.3	0.2	no	0.3	no	10%	no	28%	no	0.030
room	0.4	0.4	no	0.4	no	13%	no	32%	no	0.052
Precast panel house										
bedroom1	1.2	1.2	yes	1.2	yes	33%	no	67%	no	0.054
bedroom2	2.6	2.6	yes	2.6	yes	60%	yes	100%	yes	0.110
living	0.8	0.9	yes	0.9	yes	19%	no	63%	no	0.092
Contemporary housing complex										
bedroom	0.3	0.3	no	0.8	yes	8%	no	22%	no	0.034
living	0.4	0.4	no	0.4	no	6%	no	27%	no	0.100

Table 4. Daylight assessment on the first floor

	ČSN 73 0580 – 2 DF values [%]					**EN 17037** % of work plane area				uniformity of daylight
	point1	point2	>0.7	mean	>0.9	DF>2.0%	>50%	DF>0.7%	>95%	
19th century tenement house										
kitchen	0.5	0.5	no	0.5	no	12%	no	44%	no	0.033
room	0.6	0.6	no	0.6	no	17%	no	38%	no	0.058
Precast panel building										
bedroom1	1.2	1.2	yes	1.2	yes	33%	no	67%	no	0.054
bedroom2	2.6	2.6	yes	2.6	yes	60%	yes	100%	yes	0.110
living	0.8	0.9	yes	0.9	yes	19%	no	63%	no	0.092
Contemporary housing complex										
bedroom	0.4	0.4	no	0.4	no	14%	no	22%	no	0.035
living	0.7	0.6	no	0.7	no	24%	no	27%	no	0.056

Due to the cramped urban situation, the rooms in the 19th century tenement house do not meet the current daylighting requirements. In the precast panel house, the daylight provision remains virtually unchanged from the ideal (unshaded) situation, as the neighbourhood was designed with emphasis on the lighting conditions. The contemporary housing complex fails to meet the daylight requirements, especially due to the shading by balconies. However, this evaluation took into account the entire room area and used the real window frame thickness, which was probably not the case for the building permit process.

INSOLATION

Table 5. Duration of sunlight in the best insolated rooms

	19th century tenement house	precast panel house	contemporary block
ground floor	0 minutes	224 minutes	76 minutes
1st floor	111 minutes	224 minutes	92 minutes

Due to unfavourable urban situation (Fig. 2 and Fig. 6), both the tenement house and the contemporary housing complex fail to meet the current legislative requirements on the ground floor.

SUMMARY

This article compared the daylighting conditions in three different types of residential development in Prague. Typical apartments were evaluated, first separately (with no external shading) and then in the context of the actual urban situation.

In the 19th century tenement house, the daylight provision on the work plane was acceptable in the ideal conditions. In the real conditions, the daylight factor values did not fit the contemporary requirements. There are no architectural features on the facades obscuring the windows (such as balconies), the urban situation of the neighbourhood is however rather cramped. There were no daylight requirements in the time of construction and the street profiles were limited by the fire safety requirements and construction options. Although this apartment has the smallest windows compared to the room area, it has the highest lintel, which improves the lighting conditions.

Of all the evaluated apartments, the one in the precast panel house neighbourhood had the best overall daylighting properties, both in terms of daylight and insolation. The neighbourhood was designed with the daylighting requirements in mind and there was virtually no difference between the ideal unshaded conditions and the actual urban situation. The most prominent shading obstacle is the loggia of the living room.

The apartment in contemporary housing block did meet the legislative requirements in the ideal conditions. In the real urban situation, the daylight factor values were far below the required limits. Beside the shading from the opposite building, the windows are mostly obscured by the balconies, which are the largest of all the evaluated buildings. This apartment had the lowest lintel height and the thickest window frames.

Of the architectural features of the rooms themselves, the windows influence the daylighting conditions in the room the most. The total area of the window has much lesser impact on the daylight provision on the work plane than the window position, especially the lintel height, and the frame thickness.

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REFERENCES

[1] BRASCHE, Sabine a Wolfgang BISCHOF. (2005): Daily time spent indoors in German homes – Baseline data for the assessment of indoor exposure of German occupants. *International Journal of Hygiene and Environmental Health.* **208**(4), 247-253

[2] ARIES, MBC, MPJ AARTS a J VAN HOOF. (2013): Daylight and health: A review of the evidence and consequences for the built environment: A review of the evidence and consequences for the built environment. *Lighting Research & Technology*. SAGE Publications Ltd STM, **47**(1), 6-27.

[4] KAŇKA, Jan. (2014): Vitruvius o denním osvětlení a dnešní stavební předpisy = Vitruvius on daylight and contemporary building regulations. *Tepelná ochrana budov*. **17**, 14-17.

[5] Autodesk and Astra MS software . Building design, module Wdls 5.0 (daylighting) and ČSN EN 17037 (Daylight of Buildings), [software], accessible from http://www.astrasw.cz/cs/node/3.