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Prescriptive- and performance-based approaches of the present and previous German DIN 4108-2. Hourly energy simulation for comparing the effectiveness of the methods

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Abstract

The study proposes a comparison between the thermal performances of a real building, built according to the German standard DIN 4108-2:2003, and a refurbished one (in a theoretical investigation), aimed at satisfying the more restrictive requirements of the new version (i.e., 2013) of the same standard. The analysed building, completed during the 2012, is located in Berlin. The building has good performances in terms of energy demand for heating. Diversely, during the first years of operations, some overheating problems have been verified in summer. Because of sustainability motivations, cooling devices are not installed. An energy-oriented retrofit is here proposed, aimed at verifying if the fulfillment of the new version of the DIN 4108-2:2013 will produce better microclimatic conditions in summer. The results show the necessity of an accurate approach to the topic of summer thermal protection.

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Keywords: Energy efficient buildings; non-residential edifices; thermal comfort in summer; overheating protection; weighted temperature hours

1. Introduction

In December 2008, the European Parliament enacted the 20-20-20 Package for contrasting the climate change. A significant improvement toward a low-carbon future cannot be achieved if the building activity is not taken into account, such as declared in the Recast of the European Energy Performance of Buildings Directive [1] and related documents. The current target of the European construction activity is to erect

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buildings with a nearly zero or very low energy demand. In Germany, the main focus is the reduction of energy demand for heating. Very often large fenestrations are installed to optimize the use of solar irradiation in wintertime. But, as already known, this can cause thermal discomfort in summertime due to the high solar gains. To balance the advantage of solar gains in wintertime and the disadvantage of solar gains in summertime, the German standard DIN 4108-2 should be taken into account in case of new erection or refurbishment of buildings. Notwithstanding a careful planning and construction process and a fulfillment of national requirements to a certain building quality, the thermal comfort in the rooms is not ensured automatically. About that, this paper investigates a real case study in Berlin, by means of a double approach, numerical and experimental.

2. Presentation of the case study building

The office building here analysed (Fig. 1) was built in Berlin and completed during the 2012. With the exceptions of some meeting rooms, the building is not equipped with mechanical cooling systems. For the space heating, hot water radiators, fuelled by a district heating system, are installed under the large windows. The building has six-floors, with a rectangular shape developed in the north-south direction, with the longest facades exposed on the east/west sides. Table 1 provides the main information and peculiarities.

Table 1. Building information and geometrical characteristics

Position and Dimension	Englische Str. 5, 10587 Berlin-Charlottenburg, Germany		
Latitude	52°30’54’’ North	Longitude	13°19’54’’ East
Length (South-North)	80.0 m	Width (East-West)	14.1 m
Height	24.5 m	Gross Volume	28748.67 m^3
Surface to volume ratio	0.26 m^{-1}	Building net floor Area	7585.42 m^2
Gross Wall Area	4727.97 m^2	Window-Wall Ratio	43.52 %

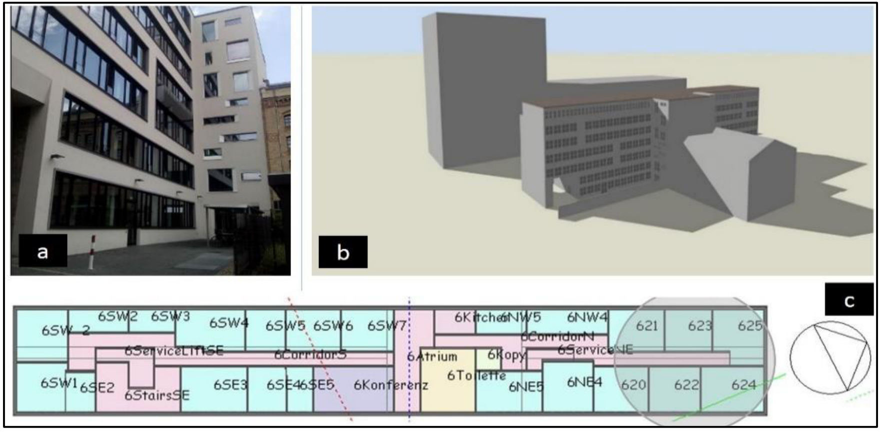

Fig. 1. The case study building: a) backside, b) model, c) plan of the 6th floor

The thermal-physical properties of the building envelope fulfil the requirements of the energy saving ordinance EnEV 2009 [2]. The thermal insulation is placed on the external face of the wall, so that the heated building mass, on the internal sides, becomes a thermal buffer. The large fenestrations - characterised by low values of thermal transmittance and provided with low-emissive coatings - reduce the heat losses and allow large solar gains. According to the occupants’ opinion, the building is comfortable during the heating season. On the other hand, starting from the spring/summer 2013 (the first warm season in which the building was used), overheating problems in summer have been recorded. About it, the indoor conditions are not fully comfortable, mainly because of the high solar radiation that enters into the offices.

In this regard, the present study will analyse possible strategies for improving the indoor microclimate in summer, by taking into account the tailored boundary conditions characterizing the building use. The first part of the study tries to investigate solutions for doing the building respectful of the new version of the DIN 4108-2 (release 2013) [3], developed for permitting better performance of the building envelope. Then, by applying the prescriptive (simplified) criterion of the cited standard, by means of hourly numerical simulations, once calibrated on real measurements, it has been verified if also the performance-based criterion was satisfied.

3. Calculations of thermal comfort in summer according to the German standard DIN 4108-2

3.1 Calculation of summer overheating protection

According to the present German regulations, in conformity with the European guidelines in matter of energy performances of buildings, during the planning phase, the thermal comfort in summertime must be verified. The modalities are inferred by the standard DIN 4108-2. Two calculation methods are possible:

- a simplified method with standardised boundary conditions (Criterion 1, in the following) (Chapter 8.3 DIN 4108-2:2013),
- the dynamic-thermal simulation (Criterion 2, in the following) (Chapter 8.4 DIN 4108-2:2013).

By adopting the simplified method, the summer overheating protection must be proven for the rooms with the highest criticalities in terms of sum of endogenous and solar energy gains. In particular, the calculated solar transmittance value "S_{vorh}" may not exceed a maximum value "S_{zul}" (eq. 1). The evaluated solar transmittance value S_{vorh} is a function of window size, room size, kind of glass of windows and solar shading devices. The maximum value S_{zul}, diversely, is evaluated by summing the so-called "S_x" (eq. 2). A deepening about the values of S_1, S_2 is reported in Tables 9 and 10 of the Appendix.

$$S_{vorh} \leq S_{zul} \qquad \text{(eq. 1)} \qquad\qquad S_{zul} = \sum S_x \qquad \text{(eq. 2)}$$

With reference to the case study here proposed, at the construction period, the building design had to respect the standard DIN 4108-2:2003-07 of the year 2003. Evidently, this is not enough in order to avoid the overheating phenomena registered during the first years of operation. Meanwhile, a modification of the aforementioned standard came into effect. In detail, the version 2013 of DIN 4108-2:2013-02 improves the calculation methods for the summer overheating protection, by changing the coefficients for calculating S_x (and thus S_{zul}). Moreover, the new version diversifies residential and non-residential buildings. Because of the modification of the standard, here the following investigation steps are proposed:

1. Calculation of the summer overheating protection regarding standard DIN 4108-2:2003-07,
2. Calculation of the summer overheating protection regarding standard DIN 4108-2:2013-02,
3. Comparison of the calculation results.

Then, based on the achieved results, some measures for improving the summer overheating protection will be proposed. Indeed, in order to verify if the new DIN 4108-2 was more effective than the previous version, we tried to solve the overheating problems of the building by satisfying the new prescriptions of the new version of the standard. In other words, the building is modified in order to satisfy the Criterion 1 of the DIN 4108-2:2013. Then, the summer heat protection will be calculated by means of dynamic simulations, under tailored conditions (DIN 4108-2:2013-02). In this way, it is possible to verify both if the new standard is better than the previous one, and if the simplified (Criterion 1) and the detailed (Criterion 2) approaches of the new DIN 4108-2:2013 are equivalent.

3.2 *Calculation with DIN 4108-2:2003 and DIN 4108-2:2013*

As critical rooms, the offices number 621, 623 and 624 have been chosen, located at the 6th floor, two on the west side and one on the east side. The two rooms on the west in the 6th floor have a higher window area compared to all other offices. For calculating the parameters established by the DIN 4108-2, the peculiarities reported in Table 2 have been considered. The calculation shows that all rooms fulfil the requirements for summer thermal protection inferred by the DIN 4108-2:2003 (Table 3, second to fourth columns). Diversely, in Table 3 it is evident that the two rooms on the west side, with a higher window area, do not respect the present DIN 4108-2 (came into force after the completion of the building).

Table 2. Constraints for the rooms 621, 623 and 624 (Heavy construction, German Climate Region B [3]

Room		Unit	621	623	624
Solar-control glass	double-glazed g =		0.40	0.40	0.40
Screens outside, dark colour awnings parallel to the windows	F_C		0.30	0.30	0.30
Window area (the shadings have the same area)	A_W	m²	8.80	11.77	10.84
Window area width		m	4.00	5.35	5.42
Window area height		m	2.20	2.20	2.00
Parapet height		m	0.25	0.25	0.50
Net floor space of the room	A_G	m²	24.15	24.61	34.64
External wall area	A_{AW}	m²	2.52	3.32	2.58
Heat transferring wall or ceiling area	A_D	m²	0.00	0.00	0.00

Table 3. Results for calculation regarding former and existing version of DIN 4108-2 for room 621, 623 and 624

DIN 4108-2:2003-07	621	623	624	DIN 4108-2:2013-02	621	623	624
existing solar transmittance value S_{vorh}:				existing solar transmittance value S_{vorh}:			
$g_{tot} = g \cdot F_C$	0.120	0.120	0.120	$g_{tot} = g \cdot F_C$	0.120	0.120	0.120
$S_{vorh} = (\sum A_{W,j} \cdot g_{tot,j}) / A_G$	0.044	0.057	0.038	$S_{vorh} = (\sum A_{W,j} \cdot g_{tot,j}) / A_G$	0.044	0.057	0.038
Valid solar transmittance value:				Valid solar transmittance value:			
S_1	0.015	0.015	0.015	S_1	0.018	0.018	0.018
$S_2 = 0{,}115 \cdot f_{gew}$ with $f_{gew} = (A_W + 0{,}3 \cdot A_{AW} + 0{,}1 \cdot A_D) / A_G$	0.046	0.060	0.039	$S_2 = a - (b \cdot f_{WG})$ with $f_{WG} = A_W / A_G$	-0.012	-0.025	-0.006
S_3	-	-	-	S_3	0.030	0.030	0.030
S_4	0.030	0.030	0.030	S_4	-	-	-
$S_{zul} = \sum S_x$	0.091	0.105	0.084	$S_{zul} = \sum S_x$	0.036	0.023	0.042
Fulfillment if: $S_{vorh} \leq S_{zul}$	*YES*	*YES*	*YES*	*Fulfillment if:* $S_{vorh} \leq S_{zul}$	*NO*	*NO*	*YES*

Starting from the above reported notes, and thus the indoor overheating problems that have been recorded in the first two summers, it can be derived that the version of the DIN 4108-2:2003 was not at all sufficient for guarantying optimal summer indoor conditions in non-residential buildings. In this regard, as briefly aforementioned, the present version of the DIN 4108-2:2013 differs between residential and non-residential buildings and the requirements for non-residential buildings are now more restrictive (Table 3).

Finally, the following section investigates for the present building some actions for fulfilling the new standard for room 621 and 623. The target is to apply some modifications to the building characteristics in order to be respectful of the new prescriptions, and then to verify if the renovated edifice guarantees better summer performances compared to the present one.

3.3 *Case 1: Changing of the solar shading systems*

If the blinds would be changed, by replacing the present dark colored awnings, parallel to the windows, with white external blinds (with 10° slat position), the FC-factor will be reduced from 0.3 to 0.2.

With reference to the room 621, the result of the calculation, by taking into consideration the new F_C-factor, is that the fulfillment of the new requirements of the DIN 4108-2:2013 is obtained. Oppositely, for the room 623, the existing solar transmittance value S_{vorh} is decreased by 33%, but the requirements for the summer thermal protection are not yet fulfilled. Finally, this is not the solution for all rooms. This result, together with the others concerning other building modifications, is reported in Table 5.

3.4 Case 2: Night ventilation with $n \geq 2\ h^{-1}$

A second investigated strategy concerns the achievable natural ventilation during the night. Indeed, the standard DIN 4108-2:2013 allows changing S_1 (and thus S_{zul}) if an air change during the night equal at least to 2 per hour is possible. In this case, the admitted limit of solar transmittance value S_{zul} would rise significantly and thus the requirements for summer thermal protection could be fulfilled for the office building here analysed. Therefore, starting from the present building (no change of blinds), the achievable nocturnal air change, aimed at discharging the building thermal mass, has been investigated. More in detail, by simulating the opening of the windows during the night, the airflow rate was calculated according to the set of equations (eq. 3-6, see appendix). The algorithm is based on the standard DIN EN 15242:2007 [4]. The calculation of the obtainable nocturnal ventilation gives the results reported in Table 4. We have verified that the windows geometry and openable areas cannot provide the achievement of the demanded double air change per hour. Indeed, if the windows will be opened through the night in tilt position, the airflow rate per hour will be $n = 0.4\ h^{-1}$ for room 621 and $n = 0.8\ h^{-1}$ for room 623. Finally, we are quite far to reach $n = 2\ h^{-1}$. It should be noted that the regulation of building use does not permit a complete opening of the windows during the night. Finally, Case 2 is not the solution for all rooms and thus for the building.

Table 4. Calculation of the airflow rate

Room	Room 621	Room 623
Volume of the room and number of windows	82.1 m^3 1	83.7 m^3 2
Window opening area A_{ow}, Width and Height (H_{window})	0.08 m^2 0.5 m 2.1 m	0.08 m^2 0.5 m 2.1 m
Opening angle (α) and Temperature difference Θ_i=20 °C Θ_e=15 °C	4.5° 5 K	4.5° 5 K
Wind speed (average for Berlin) (v_{met})	2.5 m/s	2.5 m/s
Airflow through 1 window (Q_v)	33.23 m^3/h	33.23 m^3/h
Airflow through 2 windows (Q_v)	-	66.46 m^3/h
Air change with 2 windows (n)	0.4 1/h	0.8 1/h

3.5 Case 3: Reduction of the window dimension by increasing the parapet height

The “window-wall ratio” of the office building is very high. Therefore, the Case 3 investigates how much the window area should be reduced to fulfil the DIN 4108-2:2013. By reducing the window area, S_2 and S_{zul} will be incremented in order to obtain an S_{vorh} lower than S_{zul}. As the result of the calculation, it is found that the parapet heights must be raised up to 0.95 m, in order to fulfil the standard for both rooms. The raise of the parapet (and thus the reduction of the window area) would have only a negligible impact on the indoor daylight at the workplaces. Regarding to the German workplace regulation ASR A3.4 [5] the indoor daylight quotient has to be more than 2% on the workplace or, alternatively, the relation between window area and net floor space of the room should be minimum 1:10. By applying the proposed modification at the “window-wall ratio”, the relation between window area and net floor space for both of the rooms would be 3:10. Therefore, the German workplace regulation is respected. As it can be seen in Table 5, this is the only one possible solution in order to fulfil the requirements of the DIN 4801-2:2013 for the entire building. In the next part of the paper, the variation in thermal performance of the building, before and after the Case 3 variation, will be investigated.

Table 5. Summary of the results for case 1 to case 3

		Case 1-change the blinds		Case 2-Night ventilation with n ≥ 2/h		Case 3-increasing the parapet height	
Room		621	623	621	623	621	623
Existing solar transmittance value S_{vorh}:	$g_{tot} = g \cdot F_C$	0.08	0.080	0.120	0.120	0.120	0.120
	$S_{vorh} = (\sum A_{W,j} \cdot g_{tot,j}) / A_G$	0.029	0.038	0.044	0.057	0.030	0.039
Permitted solar transmittance value S_{zul}:	S_1	0.018	0.018	0.092	0.092	0.018	0.018
	$S_2 = a - (b \cdot f_{WG})$ with $f_{WG} = A_W / A_G$	-0.012	-0.025	-0.012	-0.025	-0.001	-0.008
	S_3	0.030	0.030	0.030	0.030	0.030	0.030
	$S_{zul} = \sum S_x$	0.036	0.023	0.110	0.097	0.049	0.041
DIN 4108-2 Recast 2013	Verification of $S_{vorh} \leq S_{zul}$	*YES*	*NO*	*YES (Theoretical)*	*YES (Theoretical)*	*YES*	*YES*

4. Simulation of thermal comfort in summer

As aforementioned, in order to verify if the building could really have a better performance if the new standard DIN 4108-2:2013 is respected, we have defined a model for proper transient energy and thermal simulations. First of all, a validation of the model must be verified, for understanding the capability of the numerical study in predicting reliable indoor conditions. In order to do this, with reference to the indoor thermal levels, we compared the results of the hourly energy simulation (referred to the present building) to the temperature measurements performed in the building during the summer 2014.

4.1 Comparison between the results of simulation and monitoring

The comparisons between measurements and simulations are proposed for the room 621 (west exposure) and for the room 624 (east exposure). In this way, the entire behavior of the model (referred to the capability in representing the real situation) can be tested. The building model has been built by means of definition of the geometry in DesignBuilder [6] and then it was completed by the assignment of more precise information directly in EnergyPlus [7]. EnergyPlus has been recently and successfully used by several authors in order to evaluate energy performance of new [8] and hypothetical office buildings [9]. Other studies evaluate also the inter-building effect [10]. By comparison of the results of simulation and monitoring of the room air temperature, for the three months (i.e., June, July and August 2014), it was found that the simulation gives a good picture of the reality. Of course, the good correspondence concerns the whole months, while if single hours or days are considered, some gaps, more or less significant, can happen. This is mainly due to the different forcing phenomena. Indeed, for simulations, the authoritative and well-accredited IWEC (ASHRAE International Weather Data for Energy Calculation) file of Berlin has been used, while the measured temperatures are related to the real weather conditions of the summer 2014. The main outcomes of the comparisons are reported in Fig. 2, while Table 6 provides a monthly summary of the average gaps and the ones of the entire observation period.

The arithmetic average of the differences between ‘monitored’ and ‘simulated’ data for the room 624, with reference to each single month, is lower than 1 K. If the entire warm season is considered, the gap is about 0.40 K. Diversely, the seasonal gap for the room 621 is 1.46 K (errors ≈ 2 K in June and August).

As easily understandable, the comparisons give better outcomes for the room exposed on the east side (624). Indeed, on the west side, even if the main neighboring architectures have been modeled too (in order to consider also the indirect shadows), particular events, mainly related to local phenomena (first of all the occupants’ behavior) provided a less precise correspondence. However, the aim of this study is to compare, by simulations, the present building and the one refurbished for fulfilling the new DIN 4108-2. Thus, a relative error between monitoring and simulations would not affect the aim of the investigations.

Table 6. Average monthly gap between simulation and monitoring

Room	June	July	August	Average summer value
621	2.08 K	-0.05 K	2.21 K	1.46 K
624	0.85 K	-0.15 K	0.51 K	0.40 K

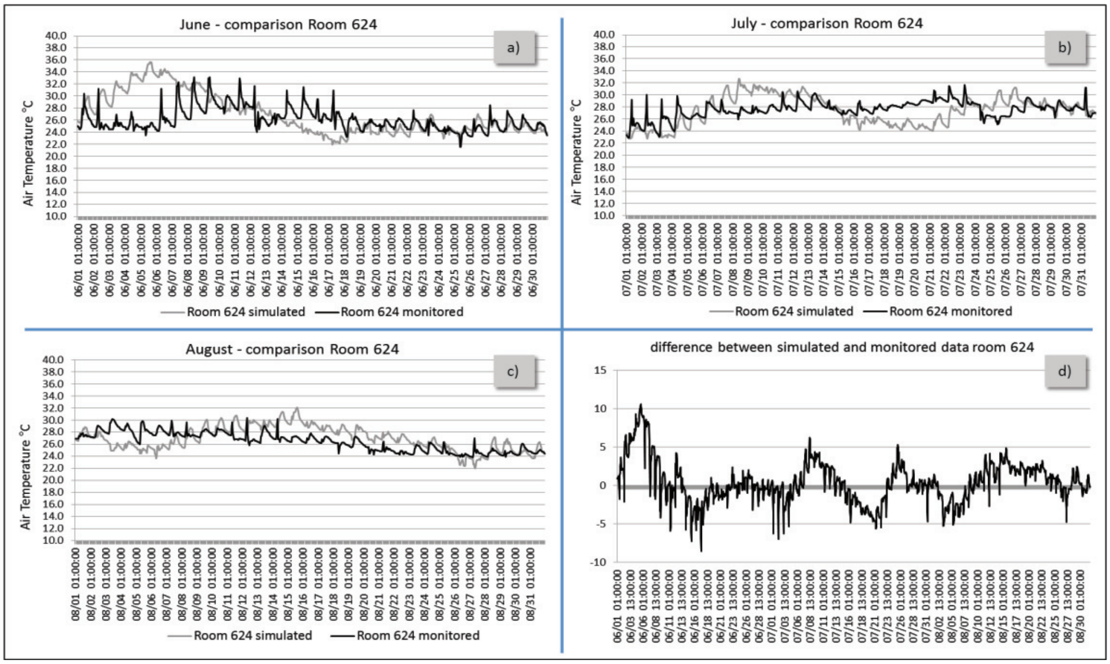

Fig. 2. Comparison between simulation and monitoring of the air temperature in room 624

4.2 *Comparison of the different methods to calculate the summer thermal protection*

Once verified a satisfactory reliability of the numerical model, the thermal performances and thus the indoor summer conditions of the buildings (i.e., present architecture and the modification of the Case 3) have been compared. This study is based on the numerical approach by means of energy simulations with EnergyPlus. In particular, one way to calculate the summer thermal protection according DIN 4108-2 is the easy method (i.e., Criterion 1). As said, the alternative is the dynamic-thermal simulation, by using well-accredited energy simulation engine. The next part of the paper will compare both methods.

For non-residential buildings, the dynamic-thermal simulation should be performed for a whole year, from Monday to Friday, from 7:00 am to 6:00 pm. The requirement for thermal comfort is that, for the indoor operative temperature, the annual sum of 'kelvin * hours' exceeding 26 °C (i.e, Berlin is in the area "B" of the standard) must be not higher than 500 Kh/a. This index is commonly known as 'weighted temperature hours'. About the limit of 26 °C, the entire Germany is divided in three climate summer zones, with limit operative temperatures from 25 °C to 27 °C. Over this maximum value, the summer thermal protection is not guaranteed. We want to verify if the respect of the simplified criterion ($S_{vor} \leq S_{zul}$) guarantees the fulfillment also of this simulative approach. We have adopted a double approach:

- "No corrections". It considers the indoor operative temperatures as simulated.

- “Applied corrections”. The indoor operative temperatures are corrected for taking into account the gap between simulations and monitoring (-1.46 K for the room 621, -0.40 K for the 624).

4.3 Dynamic-thermal simulation for the existing and improved building (Case 3)

For the present building, it has been calculated that the annual sum of kelvin * hours exceeding 26 °C in both rooms would be more than three times higher than 500 Kh/a. The Case 3 reduces greatly this number (≈ -20%), but this is not enough for fulfilling the maximum limit. Finally, the prescription of the DIN 4108-2:2013 is not met. Given the not satisfactory results (Table 7), the same parameters have been calculated by correcting the simulation results, by applying a coefficient of corrections, diversified for exposure (see Table 6), on the basis of what evidenced by the comparisons among simulations and monitoring. The new results are reported in Table 8. Also in this case (that combines the most favourable conditions and thus is not conservative) the requirements of the standard DIN 4108-2:2013 are not satisfied, for to both the present building and the one hypothetically refurbished according to the Case 3.

Table 7. NO CORRECTIONS: Comparisons of the annual sum of kelvin * hours exceeding 26 °C (existing and changed building)

Rooms		Existing Building	Changed Building (Case 3)	Δ (more comfortable hours)
621	Kh/a	1701	1323	378
624	Kh/a	1682	1244	438

Table 8. APPLIED CORRECTIONS: Comparisons of the annual sum of kelvin * hours exceeding 26 °C (existing and changed building)

Rooms		Existing Building	Changed Building (Case 3)	Δ (more comfortable hours)
621	Kh/a	959	664	295
624	Kh/a	1456	1033	423

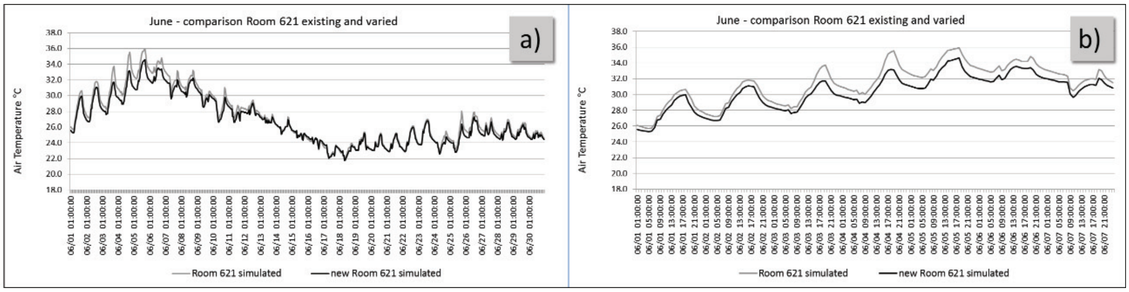

Fig. 3. Comparison of the trends of air temperature in existing and changed building

All told, even if the simplified criterion for fulfilling the DIN 4108-2:2013 (i.e., $S_{vorh} \leq S_{zul}$) does not allow indoor thermal comfort, the changing of the building according to the Case 3 induces a sure and significant improvement of the summer performance. More in detail, for the room 621 and with reference to the month of June, in Fig. 3 it can be seen that the building that fulfils the new version of the standard ($S_{vorh} \leq S_{zul}$) is characterised by indoor temperature lower compared to the present one (built according to the previous version). In particular, significant lower indoor temperatures are those at the daily peaks. To stress this fact, Fig. 3b) shows, without corrections, the indoor air temperature in some days of June.

Conclusions

For a new office building in Berlin (Germany), indoor overheating problems have been recorded in the first two summers of operation. The building fulfils the regulations of the German standard DIN 4108-2:2003-07, that, evidently, was not enough to guarantee summer thermal comfort for non-residential buildings. About it, the present version of DIN 4108-2:2013-02 differs between residential and non-residential buildings and the requirements are now more restrictive. This paper proposed modifications to the building in order to respect the new version and the most proper solution is the reduction of the transparent area. Energy simulations revealed that the new DIN 4108-2:2013, even if provides a real improvement, however does not guarantee that the thermal performance of the building will be completely comfortable if the fulfillment is proven by adopting the admitted simplified criterion. On the other hand, in order to avoid the use of cooling devices in the cold climates of Europe, it is very important to be as precise as possible during the building planning phase. In this regard, beyond the fulfillment of mere prescriptions, well-reliable hourly energy simulations can evidence criticalities and permit the test of various building technologies and alternatives for successful projects.

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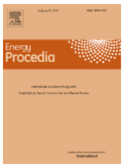

Biography
Uta Krone, M.Sc. Engineer for building services (Technical University of Berlin, Germany, 2005), is pursuing a German federal technical legal clerkship in matter of mechanical and electrical engineering in administration at the Federal Office for Building and Regional Planning (BBR). Previously she worked in the Heat Pumps industry.

Appendix

Here some information, mentioned in the manuscript, are specified. In the next two tables, you find the factors for the evaluation of the solar transmittance values. Table 9 shows the values from the present DIN 4108-2:2013-02 and Table 10 the values from DIN 4108-2:2003-07. After the tables, the equations to quantify the airflow through the windows, with the method of the standard DIN EN 15242:2007, are listed.

Table 9**.** Proportionate solar transmittance value S_x from DIN 4108-2:2013-02

			Proportionate solar transmittance value S_x					
		Using	Residential			Non-residential		
		Climate region	A	B	C	A	B	C
S_1	Night ventilation	Type of construction						
	Without	Light	0.071	0.056	0.041	0.013	0.007	0.000
		Medium	0.080	0.067	0.054	0.020	0.013	0.006
		Heavy	0.087	0.074	0.061	0.025	0.018	0.011
	With $n \geq 2h^{-1}$	Light	0.098	0.088	0.078	0.071	0.060	0.048
		Medium	0.114	0.103	0.092	0.089	0.081	0.072
		Heavy	0.125	0.113	0.101	0.101	0.092	0.083
	With $n \geq 5h^{-1}$	Light	0.128	0.117	0.105	0.090	0.082	0.074
		Medium	0.160	0.152	0.143	0.135	0.124	0.113
		Heavy	0.181	0.171	0.160	0.170	0.158	0.145
S_2	Window area per net floor space. $S_2 = a - (b \cdot f_{WG})$. $f_{WG} = A_W/A_G$	a	0.060			0.030		
		b	0.231			0.115		
S_3	Solar-control glass		0.03					
S_4	Passive cooling. Type of construction		Light = 0.02		Medium = 0.04		Heavy = 0.06	

Table 10. Proportionate solar transmittance value S_x from DIN 4108-2:2003-07

			Proportionate solar transmittance value S_x	
S_1	Climate region	A = 0.04	B = 0.03	C = 0.014
S_2	Type of construction	Light	$0.06 \cdot f_{gew}$ with $f_{gew} = (A_W + 0.3 \cdot A_{AW} + 0.1 \cdot A_D)/A_C$	
		Medium	$0.10 \cdot f_{gew}$	
		Heavy	$0.115 \cdot f_{gew}$	
S_3	Night ventilation with $n \geq 1.5h^{-1}$	Light and medium construction	+ 0.02	
		Heavy construction	+ 0.03	
S_4	Solar-control glass		+ 0.03	

Equations of the numerical algorithm to quantified the airflow via the window with the method of standard DIN EN 15242:2007:

$$Q_V = 3.6 \cdot 500 \cdot A_{ow} \cdot V^{0.5} \qquad \text{(eq. 3)}$$
$$V = C_t + C_w \cdot v_{met}^2 + C_{st} \cdot H_{window} \cdot abs\,(\Theta_i - \Theta_e) \qquad \text{(eq. 4)}$$
$$A_{ow} = C_k(\alpha) \cdot A_w \qquad \text{(eq. 5)}$$
$$C_k(\propto) = 2.6 \cdot 10^{-7} \cdot \alpha^3 - 1.19 \cdot 10^{-4} \cdot \alpha^2 + 1.86 \cdot 10^{-2} \cdot \alpha \qquad \text{(eq. 6)}$$

Where (nomenclature)

Q_v	airflow in m³/h	Θ_i	room temperature	$C_t = 0.01$	coefficient for wind turbulence
A_{ow}	window opening area	Θ_e	outdoor temperature	$C_w = 0.001$	coefficient for wind speed
A_w	total window opening area	α	opening angle	$C_{st} = 0.0035$	coefficient for thermal buoyancy
H_{window}	height of window opening area	v_{met}	meteorological wind speed	C_K	coefficient for opening angle