JSACE 2/27

Survey Based Evaluation of Indoor Environment in an Administrative Military Facility

Received 2020/06/25

Accepted after revision 2020/08/24

Survey Based Evaluation of Indoor Environment in an Administrative Military Facility

Aleksejs Prozuments*, Anatolijs Borodinecs*, Jurgis Zemitis

Institute of Heat, Gas and Water technology, Riga Technical University, 6B/6A Kipsalas Str, Riga, Latvia.

*Corresponding authors: **aleksejs.prozuments@rtu.lv**, **anatolijs.borodinecs@rtu.lv**

http://dx.doi.org/10.5755/j01.sace.27.2.26079

Military facilities feature distinctive requirements with regards to building technical and structural design, material use and indoor environmental conditions, as these buildings serve specific purpose and the personnel occupying the premises may wear uniform or protective clothing (administrative staff, special forces, training personnel etc.), that can greatly affect their satisfaction level with thermal comfort and productivity.
In order to acquire data on the actual indoor environment conditions and obtain a feedback from the occupying personnel on their satisfaction level with the indoor environment in an administrative military building situated in a special purpose military compound, a series of indoor air quality measurements (temperature, humidity, CO2 level) and a survey on indoor air quality and thermal comfort was conducted in different premises of the administrative office building. A total of 73 respondents occupying the building participated in the survey.
The results of the conducted survey revealed that there is a high degree of dissatisfaction with the indoor environment in military buildings, that is attributed to inadequate ventilation and overtemperature. That matched the collected indoor environmental quality data, forming a relationship between poor energy management and poor energy efficiency, that can in turn lead to unsatisfactory indoor environmental conditions.
The study reiterates the need to address the poor current technical state of unclassified building stock, emphasizes the call for developing clear regulatory requirements for newly-constructed unclassified buildings and thorough feasibility assessment for renovation projects.

Keywords: thermal comfort, indoor air quality, occupant survey, military buildings.

Introduction

Unclassified buildings

Building sector is a major energy consumer, accounting for 40% of total energy use across the developed countries (Yüksek and Karadayi 2017), (Luo et al. 2019). The energy efficiency of the existing building stock may be substantially reduced through various deep retrofit and energy renovation programs (Eliopoulou and Mantziou 2017), (Borodinecs et al. 2017). However, majority of the energy efficiency incentive programs are focused on residential and public buildings, while the implementation of energy efficiency measures in the so-called unclassified buildings is not adequately addressed by the governmental and municipal support (Borodinecs, Geikins, and Prozuments 2020). Unclassified buildings encompass variety of military structures, prison facilities, security force, police and fire station buildings (Geikins et al. 2019), (Anon 2018).

Journal of Sustainable Architecture and Civil Engineering
Vol. 2 / No. 27 / 2020
pp. 96-107
DOI 10.5755/j01.sace.27.2.26079

Unclassified buildings feature distinctive requirements with regards to indoor environmental conditions (IEC), as these buildings serve specific purpose and the personnel occupying the premises may wear uniform or protective clothing (e.g., police officers, firefighters, military personnel etc.), that can greatly affect their satisfaction level with thermal comfort and productivity (Wang et al. 2019), (Casaru 2009).

The majority of unclassified buildings in Latvia were constructed during Soviet Union period between 1945 and 1990, when Latvia was part of Union of Soviet Socialist Republics (USSR). During that period building design and construction had little or no emphasis on energy efficiency efforts, as the energy prices were relatively low and cost optimization measures focused on short term rather than long term investments, putting fast construction time and use of rigid, durable materials ahead of sustainability strategies, such as building energy performance (Carlsmith et al. 1990). These buildings feature heavy brick external walls and unheated attics with poor thermal insulation. One-pipe heating system and natural ventilation are commonly used technical solutions, that is obsolete and inefficient in terms of energy consumption. In addition to initial poor technical conditions, the majority of unclassified buildings have not undergone proper energy management or energy audits due to enhanced security, data protection and limited access to these buildings (Borodinecs et al. 2020).

Energy performance of military buildings

According to the data provided by the Ministry of Economics of the Republic of Latvia the average annual energy consumption for heating (and ventilation where relevant) in military buildings (constructed before 1990) is 212 kWh/m^2, while in some military buildings this figure reaches 300 kWh/m^2 (Anon n.d.). This indicates the need to perform an energy audit to identify the major factors affecting high energy consumption. Fig. 1 shows that the average energy consumption in military buildings reduces in line with the building construction year, suggesting that certain design and construction approaches were implemented to enhance building energy performance over time.

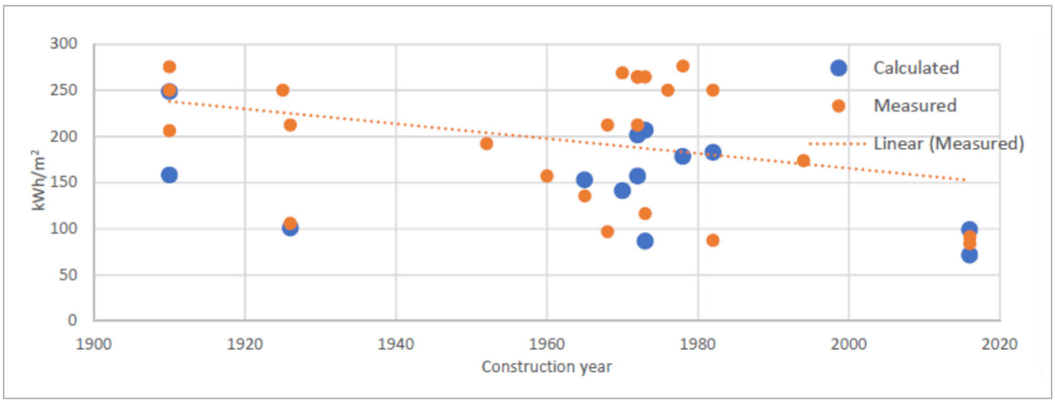


Fig. 1

Calculated and measured total annual energy consumption for heating (and ventilation) in the investigated military facilities

The energy performance requirements for military buildings is not defined by any local or regional EU norms, therefore, to perform calculations or set design criteria, energy auditors and engineers typically take into consideration simplified input data that is used for civil buildings (residential, public etc.) (Borodinecs et al. 2020). The measured energy consumption in military buildings significantly exceeds that of the residential buildings, that consume on average 180 kWh/m^2 per annum.

The investigated administrative military building was constructed in 1963 when normative U-value requirements for different building elements were not specified. In fact, up until 1990s in Latvia and other post Soviet region countries there was not strict regulatory environment with regards to building energy efficiency. After gaining an independence from Soviet Union, the Ministry of Architecture and Construction of Latvia imposed local energy efficiency standard, that was later followed by a more stringent National Building Standard LBN 002 (Thonipara et al. 2019). A decade later, after becoming a member of the EU, the local building energy efficiency standards in Latvia were tightened further with the general aim to meet the common energy criteria requirements among the EU member countries (Anon 2007), however as of today unclassified building stock is still deemed obsolete in terms of energy performance, as only a handful of unclassified buildings were constructed (or renovated) after 1990s to comply with the updated regulatory environment. As such, majority of the military building stock lacks fundamental façade upgrades with added thermal insulation and moisture prevention as well as mechanical ventilation system to provide fresh and conditioned air into premises. According to simulation results conducted for fire stations, a typical façade retrofit of 50mm added external insulation layer to the building facades came out to 30% of total thermal energy savings used for space heating, while a deep retrofit that includes façade renovation, as well as HVAC system upgrade including the heat recovery generated 86% of thermal energy savings (Borodinecs et al. 2020).

Oftentimes, poor energy efficiency in the building goes in line with poor indoor comfort, as buildings featuring poor energy performance present considerably higher potential of overcooling/overheating, draft and other issues compromising indoor environment (Wells et al. 2015). For a successful design of healthy, energy efficient and satisfactory indoor environment conditions, it is critical to account for interdependencies in a human-built environment system (Šujanová et al. 2019). Therefore, this study aims to determine the occupant satisfaction level with the indoor environment in the investigated building and link the factors of the unsatisfactory indoor environment conditions (IEC) and the poor energy performance of a building via occupant survey.

Methods

IAQ measurements

In order to acquire data on the actual indoor environment conditions and obtain a feedback from the occupying personnel on their satisfaction level with the IEC in an administrative military facility, a series of IAQ measurements (temperature, humidity, CO_2 level) were carried out and a survey on the occupant satisfaction with the indoor air quality and thermal comfort was conducted in different premises of an investigated military building in Riga during the third decade of February 2019. The average recorded temperature in Riga during the 7 days of the continuous measurements was 0,4 °C, while the average daytime temperature (during the occupancy hours from 8.00 – 18.00) was 1,3 °C (Anon 2019b), (Anon 2019a). The Extech SD800 CO2, temperature and air humidity data logger was used to carry out the measurements.

Fig. 2

Extech SD800 data logger

Within the framework of this study an administrative military personnel facility was investigated, where a total of 73 respondents of different age and gender participated in the survey. As previously stated, the investigated building feature relatively poor thermal energy performance.

Occupant survey analysis

After the technical inspection relating to the building #11 energy profile, the personnel occupying or performing their duties in the building were asked to fill out a survey. Respondents were asked to fill in a questionnaire, consisting of the following questions (table 1). The questionnaire was designed to be brief and concise in order to increase reliability and validity of survey results, following the good survey practice guidelines (Anon 1995).

Table 1

Questionnaire

Question	Response options
Are you generally satisfied with the room temperature?	YES/NO
Evaluate your satisfaction/dissatisfaction level with the room temperature?	1 to 7
Is there any unwanted air movement in the room, drafts?	YES/NO
Are you satisfied with the indoor air quality?	YES/NO
Evaluate your satisfaction/dissatisfaction level with the humidity in the room?	1 to 7
Are there unpleasant odors in the room?	YES/NO
Are you satisfied with the acoustic condition of the room?	YES/NO
Additional questionnaire asking to specify sources of dissatisfactory comfort level.	N/A

Results and Discussion

Thermal energy consumption

The special purpose campus, where the administrative building is located contains a total of 15 buildings that serve different functions. The total area of the campus is 190 000 m^2 and half of that area is occupied by a series of unclassified and military buildings connected to a district heating system network (military dormitories, warehouses, training facilities etc.).

During the survey it was determined that the majority of the buildings have an uneven distribution of heat energy consumption, which is attributed to the fact that special purpose buildings have a rather unpredictable occupancy and occupant activity pattern. That activity pattern largely depends on various factors and is hard to align in a scheduled framework.

After an inspection of all 15 buildings situated in the compound, it was determined that only 5 of the buildings were equipped with thermal energy meters (labelled as #5, #11, #12, #13 and #15). Heat energy meters were installed mainly in those buildings with more or less regular energy consumption pattern.

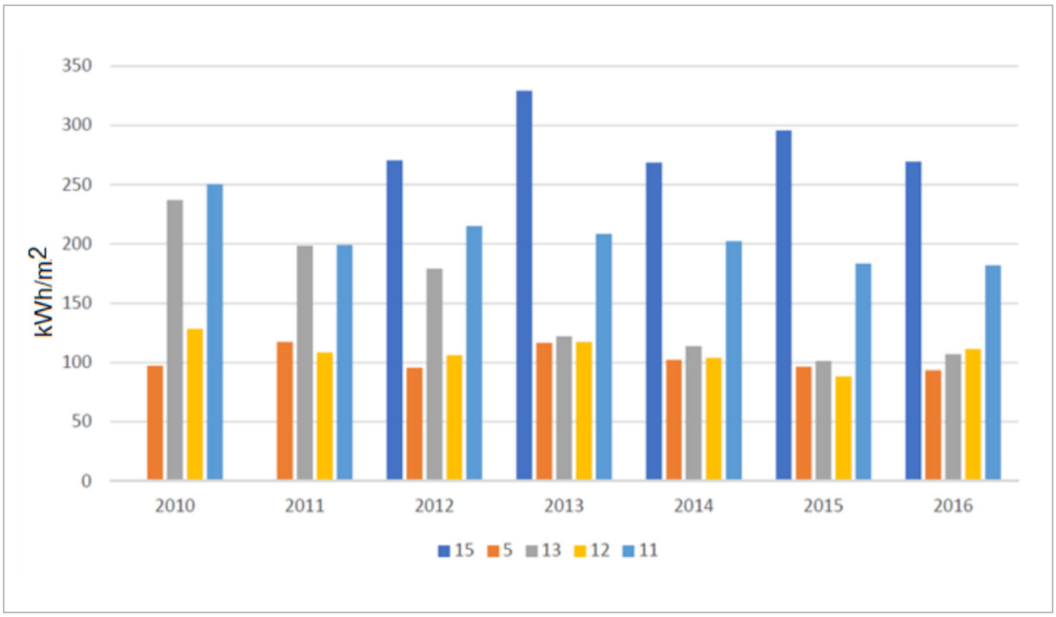


Fig. 3

Thermal energy consumption (Y axis: kWh/m^2) in the investigated special purpose compound buildings

Fig. 3 illustrates the thermal energy consumption (kWh/m^2) in 5 buildings of the military special purpose compound. Buildings are labeled by numbers #5, #11, #12, #13 and #15. As seen in Fig. 3 thermal energy consumption in building #13 drops down significantly after 2012, that is attributed to the renovation (building façade and HVAC system upgrade). As a result, the average thermal energy consumption reduced from 204 kWh/m^2 measured between 2010 and 2012 to 110 kWh/m^2 measured between 2013 and 2016.

Building #11 (fig. 3) corresponds to the administrative building investigated in this study more thoroughly, with comparatively higher energy consumption than other buildings. Another building that stands out is building #12 that serves as a dormitory for military personnel. The building features an increased energy consumption due to its age (constructed before 1970s) and is planned to be renovated soon.

In this study an administrative military building (#11 in Fig. 3) was investigated with regards to its annual energy performance (kWh/m^2) and indoor environmental comfort. The research team effortlessly tried to gain access to do thorough measurements in all of the 5 buildings, however, due to security and classified nature of the military compound, the team was only granted access to conduct measurements and occupant survey in building #11, i.e., administrative military building.

The investigated building was constructed in 1963 and its annual thermal energy consumption is in the ballpark of 180-220 kWh/m^2 annually on average. Since the building's construction, it has not undergone neither any façade retrofits, nor any major system retrofit measures, except for an introduction of mechanical ventilation system, that has been installed in 1980s, however, has not been upgraded since. We were not able to gain more information on the AHU and the frequency (if any) of technical inspection and maintenance of the AHU or the ventilation system, therefore it was difficult to assess the designed performance of the system.

The annual energy consumption calculation was carried out according to Latvian Cabinet of Ministers Regulation No. 348 "Methodology for Calculating the Energy Performance of a Building" (Minister of Economic Affairs and Communications 2014) (equation 1):

$$E_{annual} = (\Sigma U_i A_i + \Sigma \psi_j l_j + \Sigma \chi k + (V_{air} \cdot c) \cdot 24 \cdot D_{heat} \cdot (T_{in} - T_{out}))/(1000 \cdot A) - \eta \cdot (Q_{int} + Q_{sol}) \quad (1)$$

where:

U_i – heat transfer coefficient of the building construction element (W/(m^2·K));

A_i – the area of the respective construction element of the building prototype model (m^2);

Ψ_i – heat transfer coefficient of the linear thermal bridge (W/(m·K));

l_i – length of the linear thermal bridge (m);

χ_k – heat transfer coefficient of the point thermal bridge (W/·K);

V_{air} – ventilation air volumetric flowrate (m3/h);

c – air heat capacity per volume = 0.34 (Wh/(m3×K));

D_{heat} – number of heating days;

T_{in} – average set-point temperature in the assessment (heating or cooling) period (^{o}C);

T_{out} - average external temperature in the calculation period (^{o}C);

A – total floor area of the building (m^2);

η – gain use coefficient for heating in accordance with Paragraph 99 of this Regulation or Standard LVS EN ISO 13790:2009 L [85];

Q_{int} – interior gains of the whole building in the assessment period t (Wh);

Q_{sol} – solar heat gains of the whole building in the assessment period t (Wh).

The necessary building input data was acquired from building information system (BIS) database (Anon 2003). To compare the actual (measured) energy consumption vs theoretical (calculated) energy consumption, energy auditing and measurements were conducted in the same set of buildings throughout 2014-2016. As per the obtained results, the total average annual measured energy consumption for military buildings was 230 kWh/m^2, while the average calculated energy consumption for military buildings – 153 kWh/m^2 (33% lower than measured).

The high discrepancy between the calculated and measured data may have occurred due to deviation in the input values (hot water consumption, indoor temperature, supply air exchange rate, airtightness of building envelope etc.) against the actual values.

Occupant survey analysis

Occupant survey analysis involved distributing the questionnaire (Table 1) to the building occupants. The majority of the personnel occupying the building are dressed in military uniform, that has a clothing factor (clo) of 1.4. This was assumed as the averaged clo value for all building occupants. The metabolic activity rate (met) was assessed as 2.0 which corresponds to medium activity environment, even though for different occupants, the metabolic rate might vary from 1.0 to 3.0 met.

It is also important to note that the research team were only granted a limited access to do necessary measurements in the premises of the administrative military building. The team was not authorized to contact the personnel and potential respondents neither in person nor via telephone or e-mail, and the questionnaires were distributed via the responsible administrative officer (team manager), so that the team had no control or any influence to receive as high and accurate response rate as possible or any additional feedback form the respondents. As a result, the number of completed and returned questionnaires was considerably lower than the number of personnel indicated on the administrative building registry. In overall, of presumed 145-150 regular occupants of the building (indicated on the registry), 73 responses came back for further analysis.

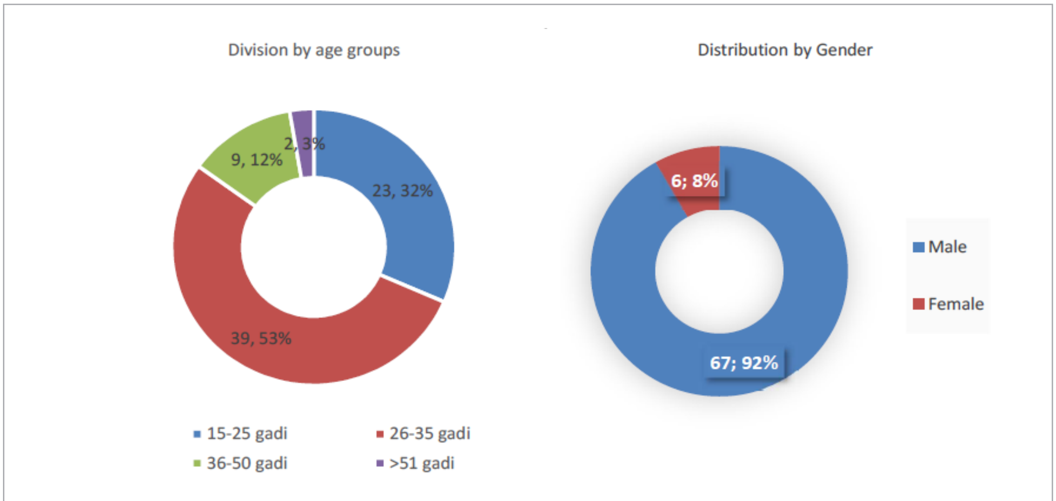


Fig. 4

Distribution of respondents by age and gender (quantitative values and percentages)

The occupant survey was distributed in March 2019. The results of the conducted survey distributed to the occupying personnel revealed that there is a high degree of dissatisfaction with the IEC in the investigated administrative military building. The majority of the respondents assessed the room temperature as dissatisfactory (43 out of 73). Also, most respondents assessed indoor air quality as neutral on the scale from 1 to 7. The low satisfaction rate is attributed to inadequate air exchange and overheating in the warm season, when the heat gains due to solar radiation intensify and the daytime temperature exceeds 20°C (primarily May – September). Reducing temperature in certain premises during the warm season would ensure higher IEC satisfaction level among the personnel, as well as offer energy savings (if the overheating period overlaps with the heating season). The results of the survey are outlined in Fig. 5 and 6.

Fig. 5

Respondents' satisfaction level with the room temperature (left) and indoor air quality (right)

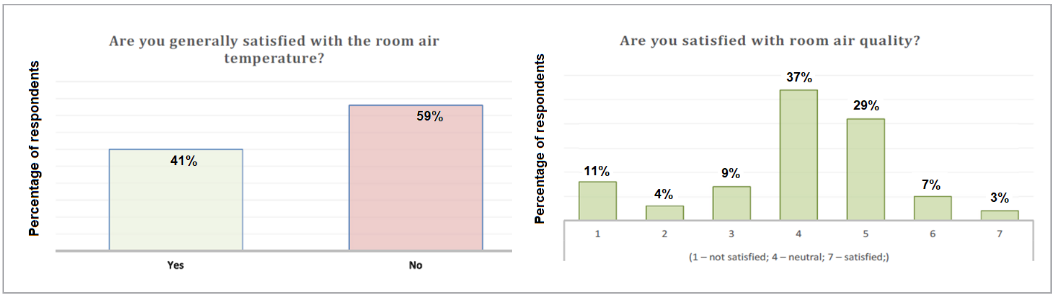
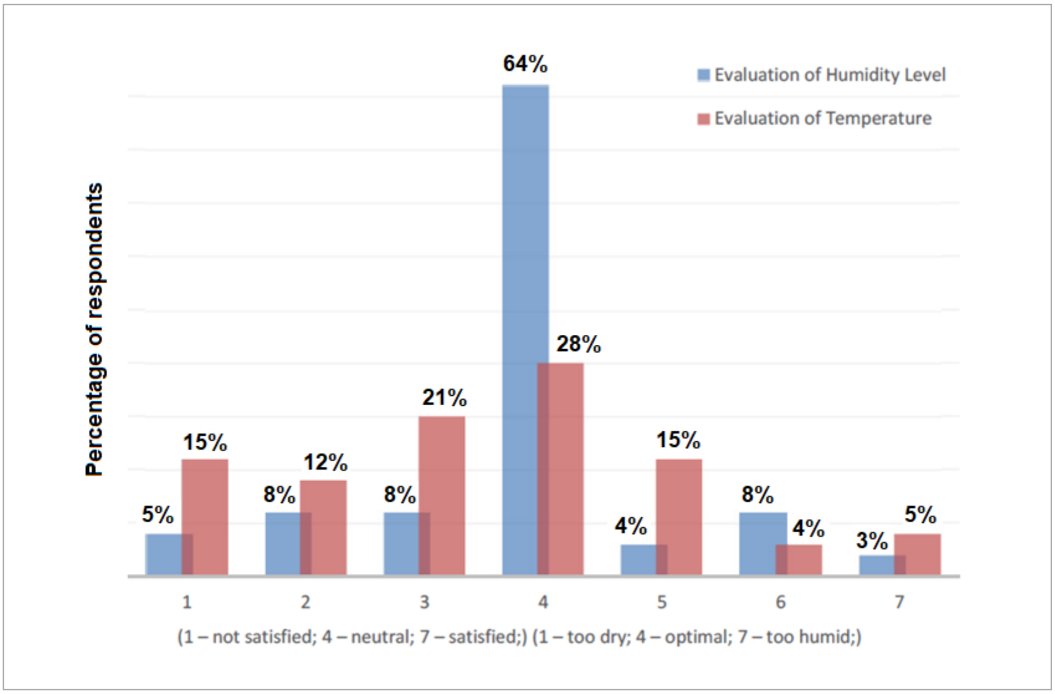


Fig. 6

Respondents' satisfaction level with the indoor air humidity and indoor temperature



The analysis of the survey illustrates the issue of indoor comfort in the studied building. Many respondents gave negative ratings on indoor air temperature, relative humidity, and air quality; however, the largest percentage expressed that they are neither satisfied nor dissatisfied with the IAQ parameters, giving the score of 4. This may also be linked to some respondents being comfortable at the moment of filling out the questionnaire, or solely not paying full attention to the question subject and completing the survey negligently, which is being observed as a very common response behavior in filling out questionnaires (Questback 2019), (Stieger and Reips 2010). There are numerous factors for negligence in filling out the surveys, e.g., rush, inattentiveness, carelessness, and these factors can not be eliminated completely, however, the percentage of honest and credible responses can be substantially increased by certain mechanisms in the design and the content of the survey (Kelley et al. 2003). The survey generated by our team was prepared with full recognition of risks related to humans' response behavior and therefore it was carefully reviewed and adjusted before final dissemination to the personnel.

When asked to specify the source(-es) of dissatisfaction, most respondents indicated the lack of control over room temperature and excessive heat from direct sunlight (fig. 7) as the main flaws. These two factors can be linked together, suggesting that the building is not equipped neither with temperature sensors and automated ventilation control to account for overheating, nor with the manually adjustable thermostats, which leads to overtemperature if the direct sunlight penetration is not controlled by window blinds. Many respondents also pointed out the unpleasant odors and draft from windows as the cause of their dissatisfaction. These factors also indicate on poor tightness of the building envelope, as well as the lack or improper operation of ventilation system.

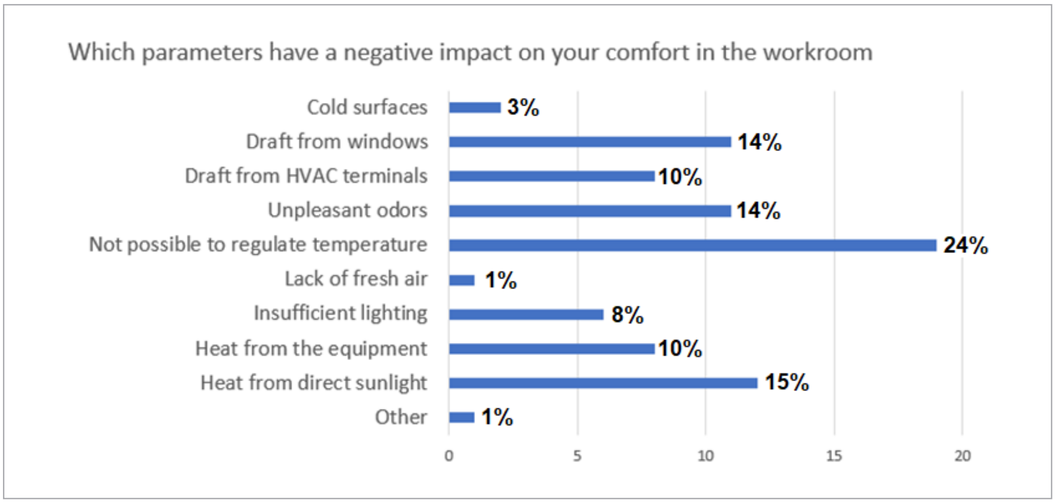


Fig. 7

Sources of dissatisfaction with the IEQ

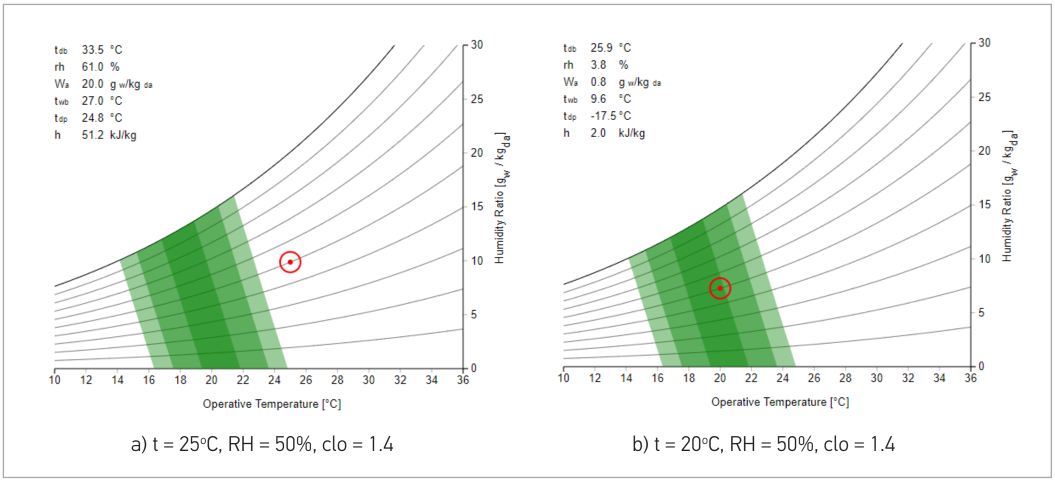
The technical inspection of the building showed that the mechanical ventilation system may not have been balanced properly, and the AHU equipment does not meet the capacity demand to cool down premised during intense sunlight hours and warm season. The existing ventilation system needs a series of upgrades, including the installation of a more powerful AHU, installation of room temperature sensors and VAV dampers, as well as proper system balancing. Also, installing manual or automated external blinds coupled with solar sensors would greatly reduce the risk of overheating and glare during intense sunlight hours.

Human comfort zone and IAQ measurements

Fig. 8 represents the IAQ measurements conducted in the building throughout the timeframe of the survey that was occurring during the 7 days period. As it is seen in the graph (Fig. 9), the indoor temperature fluctuated between 21 and 24 °C, which is slightly above the average human comfort temperature stipulated in CSA Z412-17 "Office Ergonomics – An application standard for workplace ergonomics" (Anon 2012). According to the standard, in the winter conditions the optimum temperature in offices is 22°C with an acceptable range of 20-23.5°C. Latvian Cab. Reg. No. 359 "Work safety requirements in workplaces" sets the optimum temperature range for category 2 workplaces (work related to medium activity, equivalent to metabolic activity of 2.0-3.0 met) between 16 and 23°C in wintertime (Anon 2009), which reiterates that temperature increase over 23°C is simply not justified to meet satisfactory indoor climate. Also, it is important to highlight, that the military personnel and trainees wear uniform when on their duties, therefore to assess the comfort perception of the military personnel in administrative buildings it is important to take into account clothing specifics with regards to their thermal insulation (clo) (Goldman and Kampmann 2007). National Armed Forces of the Republic of Latvia use standard military personnel uniforms with clo value of 1.4, which adds to the comfort temperature sensation and would require slightly lower temperature range than stipu-

Fig. 8

Human comfort zone diagram (Hoyt et al. 2013)

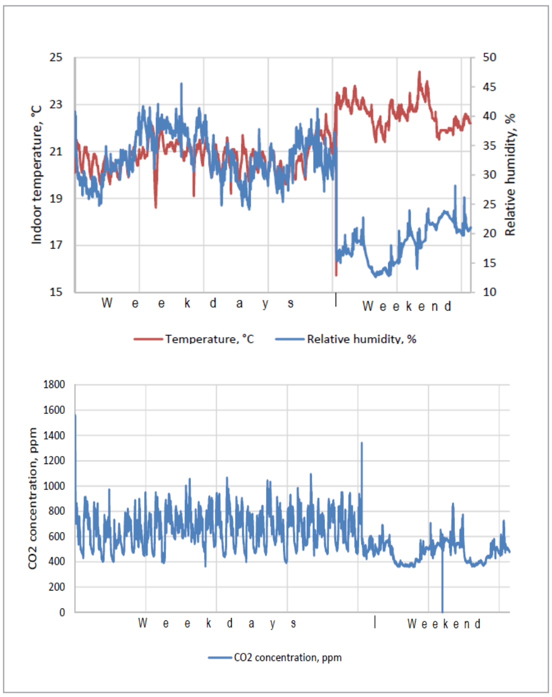


lated in the norms. Using the online calculator for assessing human thermal comfort based on indoor conditions, occupant metabolic rate and clothing level that was developed at UC Berkeley (Hoyt et al. 2013) (**Fig. 8**) it can be easily and quickly verified that personnel wearing thicker than normal clothing layers would require substantially lower indoor temperature (20°C instead of 25°C as per the example below) to fulfill their indoor comfort criteria.

According to the temperature and humidity graphs (**fig. 9**), throughout the weekdays the indoor temperature is maintained at 21°C, which given the personnel activity level (met) and thermal insulation (clo) may be perceived as 23-24°C, resulting in negative feedback with regards to not having control over room temperature. This discomfort only intensifies during sunny days when the heat from direct sunlight penetrates into the premises. The weekend temperature (during non-occupancy) is substantially higher (between 22.0 and 24.5°C), which may be related to the fact that the mechanical ventilation system have been turned off and/or that windows have been kept closed for the weekend. The relative humidity ranges over a quite wide span (from 13% to 41%), with the average humidity on the weekdays – 38.6%, and on the weekend – 20.6%. The recommended relative humidity according to the Cab. Reg. No. 359 in workspaces is 30-70% (Anon 2009). The relative humidity values on the weekend are below the recommended range, while during the weekdays it lies within the recommended range yet converging to the bottom threshold. The relative humidity between 20 and 30% does not cause any direct health issues, and although a long-term exposure to humidity below 25% may cause irritation and headache, there is little experimental evidence to indicate that the mucous membranes of healthy individuals are adversely affected by low relative humidity even after prolonged exposure (Arundel et al. 1986).

Fig. 9

Measured IAQ parameters in an administrative military personnel facility



CO_2 concentration in non-renovated post Soviet Union buildings (*refer to the intro-*

duction for detailed description) is usually lower than in recently constructed buildings, due to lower building envelope tightness (especially along window frames) which results in excessive outdoor air infiltration. As such, the CO_2 concentration in the investigated building did not present any concern and was in the range of 400-800 ppm on the weekdays, and in the range of 400-600 on the weekend, which is attributed to occupant presence and absence periods. ASHRAE Standard 62.1-2016 - Ventilation for Acceptable Indoor Air Quality recommendations define that indoor CO_2 concentration level should be kept below 1000 ppm (ANSI/ASHRAE Standard 62.1 2016). On the other hand, even CO_2 concentration as high as 5000 ppm Although CO_2 concentration is not a reliable indicator of overall building air quality, the excessive CO_2 concentration (>1200 ppm) clearly suggests that there is not enough fresh air supply and sufficient air exchange in the premise.

Conclusions

The energy efficiency requirements for unclassified buildings are not defined in the current regulatory building codes, as this building category accounts for less than 2% of total building stock. Unclassified buildings feature variety of structures with broad scope of energy performance criteria and stringent safety (and security) requirements. Moreover, according to the worldwide practice, energy efficiency upgrades in this building category has not been at the agenda for national governments and stakeholders. Nevertheless, the issue of poor energy conservation and management in those buildings should be addressed in future – by enhancing building envelope (proper thermal insulation, reducing thermal bridges, improving air tightness) and upgrading mechanical systems (energy saving lighting equipment, efficient mechanical ventilation, duct tightness, heat recovery). As a matter of fact, according to a recent study, a typical façade retrofitting package can generate 30% reduction in thermal energy consumption for space heating, while deep renovation measures (including mechanical ventilation system with heat recovery) could result in up to 86% savings.

The study results of the analyzed cold period show that humidity and CO_2 level in an administrative military building remain within the comfort zone, given the relatively high permeability and infiltration degree of an external envelope. Measured temperature during the occupancy days remains rather stable at 21°C, which lies within the comfort range. However, the survey results indicate on relatively high level of dissatisfaction with the indoor temperature in the building, that demonstrates a slight disagreement with the measured temperature values, suggesting the periodic and uncontrolled overheating in the premises. Provided that military staff occupying the building are wearing uniforms that have a higher clo level than the outfit of an average office individual (1.4 clo and 1.0 clo, respectively), the comfort temperature range for military personnel differs from that specified in the existing building codes for public buildings. As such, the measured actual temperature of 21°C in the administrative office premises might be perceived by the majority of the occupants (particularly those wearing military uniform and having clothing ratio of 1.4) as relatively high, and thus, causing a sense of overheating.

In line with the need for renovation of the majority of the existing unclassified buildings, a clear regulatory environment should be established with regards to the thermal comfort criteria in unclassified buildings to address the issue of inadequate temperature settings (for the majority of the occupants) and insufficient ventilation in such buildings. Moreover, currently applied practices of designing new construction unclassified buildings have to be thoroughly reviewed, and separate regulatory requirements have to be developed for various types of new construction unclassified buildings (military barracks, administrative offices, training facilities etc.).

This study contributes to the existing knowledge of the poor energy management and conservation in unclassified buildings by identifying gaps in IEC, while addressing the energy performance of those buildings via occupant survey and indoor air quality measurements.

Authors acknowledge, that the relatively low number of respondents completing the survey may compromise the credibility of the study results. On the other hand, for the study related to investigating military facilities that involved onsite technical inspection and occupant survey, such response figure is fairly reasonable. Given that military facilities are kept under enhanced security and the access to such buildings is only granted to authorized personnel, our team is proud to have managed pioneer a study that may eventually trigger continuous efforts in addressing the significance of energy performance not only in military facilities, but on a broader scale, in other unclassified buildings such as fire stations, police departments, prison and detention facilities etc.

Acknowledgment

This study was supported by the European Regional Development Fund project No.1.1.1.1/16/A/048 "Nearly Zero Energy Solutions for Unclassified Buildings". This publication was supported by Riga Technical University's Doctoral Grant program.

References

American Statistical Association Section on Survey Research Methods. 1995. "How to Plan A Survey. ASA: Section on Survey Research Methods."

Building Information System. 1-92. Retrieved (https://bis.gov.lv/bisp/). 2003.

Energy Efficiency Policies and Measures in Estonia. Evaluation and Monitoring of Energy Efficiency in the New EU Member Countries and the EU-25. Vol. 25. 2007.

Ministru Kabineta Noteikumi Nr.359 "Darba Aizsardzības Prasības Darba Vietās." 2009.

CSA Standard Z412-17 Office Ergonomics - An Application Standard for Workplace Ergonomics. 2012.

Cabinet of Ministers Regulations Nr. 326 Building Classification Regulations." 2018.

"Riga Historical Weather." Retrieved (https://www.worldweatheronline.com/riga-weather-history/riga/lv.aspx). 2019.

"Weather Data Overview, February 2019." Retrieved (https://www.meteo.lv/lapas/laiks/laika-apstaklu-raksturojums/2019/februaris-2019/februaris-2019-meteo?id=2396&nid=1190). 2019.

"Ministry of Economics." Retrieved (https://www.em.gov.lv/en/).

ANSI/ASHRAE Standard 62.1. 2016. Ventilation for Acceptable Indoor Air Quality. Vol. 2016.

Arundel, Anthony V., Elia M. Sterling, Judith H. Biggin, and Theodor D. Sterling. „Indirect Health Effects of Relative Humidity in Indoor Environments." Environmental Health Perspectives 65:351. 1986. https://doi.org/10.2307/3430203

Borodinecs, Anatolijs, Aleksandrs Geikins, and Aleksejs Prozuments. „Energy Consumption and Retrofitting Potential of Latvian Unclassified Buildings." Pp. 319-26 in Smart Innovation, Systems and Technologies. Vol. 163. 2020.https://doi.org/10.1007/978-981-32-9868-2_27

Borodinecs, Anatolijs, Jurgis Zemitis, Modris Dobelis, Maris Kalinka, Aleksejs Prozuments, and Kristīne Šteinerte. „Modular Retrofitting Solution of Buildings Based on 3D Scanning." Pp. 160-66 in Procedia Engineering. Vol. 205. 2017.https://doi.org/10.1016/j.proeng.2017.09.948

Carlsmith, Roger S., William U. Chandler, James E. McMahon, and Danilo J. Santini. "Energy Efficiency: How Far Can We Go?" Proceedings of the Intersociety Energy Conversion Engineering Conference 4:74-77. 1990.

Casaru, Catalina. "Energy Cost and Thermal Contribution of Components of Protective Firefighter Gear." 2009.

Eliopoulou, Eftychia and Eleni Mantziou. „Architectural Energy Retrofit (AER): An Alternative Building's Deep Energy Retrofit Strategy." Energy and Buildings 150:239-52. 2017.https://doi.org/10.1016/j.enbuild.2017.05.001

Geikins, A., A. Borodinecs, G. Daksa, R. Bogdanovics, and D. Zajecs. „Typology of Unclassified Buildings and Specifics of Input Parameters for Energy Audits in Latvia." in IOP Conference Series: Earth and Environmental Science. Vol. 290. 2019.https://doi.org/10.1088/1755-1315/290/1/012131

Goldman, Ralph F. and Bernhard Kampmann. Handbook on Clothing - Biomedical Effects of Military Clothing and Equipment Systems. 2007.

Hoyt, Tyler, Stefano Schiavon, Alberto Piccioli, Dustin Moon, and Kyle Steinfeld. "CBE Thermal Comfort Tool." Center for the Built Environment, University of California Berkeley 2013. Retrieved (http://cbe.berkeley.edu/comforttool). 2013.

Kelley, Kate, Belinda Clark, Vivienne Brown, and John Sitzia. „Good Practice in the Conduct and Reporting of Survey Research." International Journal for Quality in Health Care 15(3):261-66. 2003.https://doi.org/10.1093/intqhc/mzg031

Luo, Yongqiang, Ling Zhang, Michael Bozlar, Zhongbing Liu, Hongshan Guo, and Forrest Meggers. „Active Building Envelope Systems toward Renewable and Sustainable Energy." Renewable and Sustainable Energy Reviews 104(November 2018):470-91. 2019.https://doi.org/10.1016/j.rser.2019.01.005

Minister of Economic Affairs and Communications. Methodology for Calculating the Energy Performance of Buildings. 2014

"Honesty in Survey Responses - What Can We Do to Ensure Respondents Are Able to Be Honest with Us When We Ask for Feedback?" Questback. 2019.

Stieger, Stefan and Ulf Dietrich Reips. „What Are Participants Doing While Filling in an Online Questionnaire: A Paradata Collection Tool and an Empirical Study." Computers in Human Behavior 26(6):1488-95. 2010.https://doi.org/10.1016/j.chb.2010.05.013

Šujanová, Paulína, Monika Rychtáriková, Tiago Sotto Mayor, and Affan Hyder. „A Healthy, Energy-Efficient and Comfortable Indoor Environment, a Review." Energies 12(8). 2019.https://doi.org/10.3390/en12081414

Thonipara, Anita, Petrik Runst, Christian Ochsner, and Kilian Bizer. „Energy Efficiency of Residential Buildings in the European Union - An Exploratory Analysis of Cross-Country Consumption Patterns." Energy Policy 129:1156-67. 2019.https://doi.org/10.1016/j.enpol.2019.03.003

Wang, Lijuan, Jungsoo Kim, Jing Xiong, and Haiguo Yin. „Optimal Clothing Insulation in Naturally Ventilated Buildings." Building and Environment 154:200-210. 2019.https://doi.org/10.1016/j.buildenv.2019.03.029

Wells, Ellen M., Matt Berges, Mandy Metcalf, Audrey Kinsella, Kimberly Foreman, Dorr G. Dearborn, and Stuart Greenberg. „Indoor Air Quality and Occupant Comfort in Homes with Deep versus Conventional Energy Efficiency Renovations." Building and Environment 93(P2):331-38. 2015.https://doi.org/10.1016/j.buildenv.2015.06.021

Yüksek, Izzet and Tülay Tikansak Karadayi. „Energy-Efficient Building Design in the Context of Building Life Cycle." in Energy Efficient Buildings. 2017. https://doi.org/10.5772/66670

About the Authors

ALEKSEJS PROZUMENTS

PhD researcher, Mg. Sc. Ing.

Riga Technical University, Faculty of Civil Engineering, Institute of Heat, Gas and Water technology

Main research area

Energy efficiency in buildings, healthy buildings.

Address

6B/6A Kipsalas Str, Riga, Latvia.
Tel. +371 2919 0871
E-mail: aleksejs.prozuments@rtu.lv

ANATOLIJS BORODINECS

Professor, Dr Sc. Ing.

Riga Technical University, Faculty of Civil Engineering, Institute of Heat, Gas and Water technology

Main research area

Energy efficiency in buildings, renewable energy sources.

Address

6B/6A Kipsalas Str, Riga, Latvia.
Tel.+371 2607 9655
E-mail: anatolijs.borodinecs@rtu.lv

JURGIS ZEMITIS

Postdoctoral researcher, Dr. Sc. Ing.

Riga Technical University, Faculty of Civil Engineering, Institute of Heat, Gas and Water technology

Main research area

Indoor air quality, heating & ventilation.

Address

6B/6A Kipsalas Str, Riga, Latvia.
Tel.+371 2836 9940
E-mail: jurgis.zemitis@rtu.lv