SURVEY OF INDOOR ENVIRONMENTAL CONDITIONS IN RESIDENTIAL BUILDINGS IN VIETNAM

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Abstract

As a result of the rapid economic development in Vietnam, lifestyles and the needs of residents have been changing in new building typologies. The increased demands for comfort lead to new indoor environmental conditions, while the outside climate is extremely warm and humid. This presents great challenges for the building materials used in construction projects. In order to develop climate-adapted materials, measurements and studies of indoor environmental conditions with corresponding outdoor climate conditions are essential. Therefore, a series of surveys are undertaken now in Vietnam. Protocols and measuring instruments used in the surveys are presented in this paper. The whole survey campaign consists of four main parts: preliminary household survey, building audit and long-term monitoring, detailed on-site survey and thermal comfort survey. The collected data will be analysed, processed and prepared for following research and development of climate-adapted buildings.

Keywords: IEQ, survey protocol, occupants' behaviour, building performance, hot and humid climate

1 Introduction

Vietnam is a country located in the mainland region of South-east Asia. With an estimated 96.2 million inhabitants as of 2019, it is the 15th most populous country in the world. Vietnam's unique climate creates distinctive building designs and occupant behaviour to adapt to the hot and humid climate conditions. In the study of Ly (2012), typical characteristics identified in traditional Vietnamese building are presented such as using local materials; applying a high roof pitch; employing semi-open spaces; optimising appropriate orientation; building dwellings on stilts and integrating with the natural landscape. According to the study of Schwede et al. (2016), adaptive occupant behaviours in dwellings can be captured as adjustment of posture, activity and clothing, using natural ventilation by opening the windows and doors or consuming cold drinks. Occupants can also change the location in- and outdoors in order to bring themselves into better comfort. For example, they might stay in the lower level living room during the day and on the roof terrace in the evening. These characteristics have remained unchanged until the economic reform in 1986 (Ly, 2012). Vietnam's dynamic development in the past decades went along with immense construction activities as a result of increasing demand for new residential and non-residential buildings as well as for new infrastructure (Schwede et al., 2016). Influenced by Western cultures, modern technologies, materials and construction methods are widely used in Vietnam. At the beginning of this development, building codes and regulations are borrowed from the West without adaptation to the regional climate and context (Hassan, 2002). Today localised building codes are available, but seldom used. The adaptation of buildings and occupants to the local climate is affected by heavyweight construction, high-rise buildings, increase of the building air-tightness, reduction of living area and change of lifestyle. The increased cooling demand and raised requirements on the indoor climate lead to the increased dependence on technical building equipment. A statistical report from JRAIA (2019) shows that the number of air conditioning units demanded by the Vietnamese market increased from 0.92 million units in 2012 to 2.04 million units in 2018. In Vietnam, air conditioning is the highest share of electricity consumption in private households (Hung,

2014) and drive electricity-demand growth. Consequently, these changes will contribute to global warming, which in turn will affect the cooling demand.

In this context, a series of surveys and studies are conducted in Vietnam within the CAMaRSEC research project (Schwede, 2019). Comprehensive indoor environmental data and occupant behaviour information will be collected, analysed and used as a basis for subsequent simulation studies in the CAMaRSEC project.

2 Representative cities and dwellings

Based on geographic and climatic conditions, there are seven different climatic regions in Vietnam. These seven different climatic regions are grouped into two main types, temperate in the north and tropical in the centre and south. Hanoi in the north and Ho Chi Minh City (HCMC) in the south were selected as representative cities according to population size and energy consumption. The research focuses on residential buildings because households cause a significant part in energy consumption and use more than one-third of the energy consumed in Vietnam (Schwede, 2016). High-rise apartment buildings have become more popular in the Vietnamese housing market due to their flexibility in providing spaces and floor areas for family life (Ly, 2012). Therefore, apartments in modern high-rise residential buildings under ten years of age are used as filter criteria for the selection of representative dwellings. In this highly dynamic segment, the most significant growth is expected for the future.

3 Survey protocols and procedures

3.1 Preliminary household survey

So far, there are no significant studies in Vietnam on the implementation of sustainability potential in the household sector with a focus on the currently fastest growing housing typology – apartments in modern high-rise buildings. The household survey has the objective to analyse the living context, living conditions and lifestyles in modern high-rise buildings. The survey includes demographic, social and economic data and housing characteristics (geometry, location, layout, building materials, window qualities, structural damage, mould formation), the perception of the life context (requirements, sensation of comfort), detailed behavioural data (use of space, frequency of ventilation, use of air conditioning) as well as the information on energy consumption and costs. Based on the results, it will be possible to make predictions on the development of comfort requirements and energy consumption in such apartments. The survey will be conducted among 500 households in Hanoi and 500 households in HCMC.

3.2 Building audit and long-term monitoring

A building audit will be undertaken for 50 apartments in Hanoi and 50 apartments in HCMC. Based on the preliminary household survey, a more detailed survey of the comfort demands of the occupants and their requirements to the indoor environment will be conducted during the building audit. The conditions of the building structure and technology (operating behaviour, retrofitting of units, damage and mould) will be photographed and documented in audit protocols. The protocol also includes specific information about building design (wall construction, ventilation options, orientation and fraction of transparent facade). The additional surveys will be supplemented at times of particular climatic conditions (e.g. rainy season, heating period and cooling period) via the web or mobile-based questionnaire. Basic indoor environmental parameters (temperature, humidity, CO_2-concentration and ambient pressure) in the living room and bedroom will be continuously monitored with wireless data loggers over 12 months. The measuring interval is set to 15 min, and the data will be sent to a cloud server in real-time. Also, two weather stations will be installed in Hanoi and HCMC. Outdoor climate data (temperature, humidity, wind speed and direction, solar radiation, rainfall and rain rate) will be

collected and sent to cloud-server every 15 min. The influences of outdoor climate will be considered in the data evaluation and on-site investigation.

3.3 Detailed on-site survey

A mobile test system will be designed for evaluating the physical and thermal building behaviour as well as the indoor air quality according to the relevant regulations and standards. Thermal comfort parameters (air temperature and humidity, radiant temperature and air velocity) and air quality parameters (CO_2, VOC, particulate matter) will be measured with this system. Structural damage (e.g. moisture damage) and faulty implementation (e.g. leaky window installation) will also be investigated using an infrared surface thermometer, moisture-measuring device, thermo-anemometer and smoke leak detector. The detailed on-site investigation will be undertaken for up to 10 apartments in Hanoi and up to 10 apartments in HCMC. Based on the building audit and 12-months monitoring, apartments with particular problems identified will be investigated with priority.

3.4 Thermal comfort survey

An additional series of thermal comfort surveys will be conducted in some of those apartments. During the measurements of thermal comfort parameters, on-the-spot surveys will be carried out at the same time. The subjects are asked to keep sedentary for at least 15 min before answering the questionnaire. The questionnaire consists of subjective ratings on a variety of scales (thermal sensation, thermal acceptability and preference, air movement acceptability and preference, thermal comfort), followed by a clothing checklist and concluded with adaptive occupant behaviours such as window openings and usage of the fan. The same apartment will not be visited more than once a week to avoid the effects of increased familiarity. The survey results will be compared with Vietnam Standards and other studies, such as the data from ASHRAE database II.

4 Instruments

***Table 1**: List of instruments*

No.	*Instrument*	*Physical quantity*	*Range*	*Accuracy*
1	Testo 160 IAQ WiFi data logger	Temperature	0 ~ 50 °C	±0.5 °C
		Relative Humidity	0 ~ 100 % (non-condensing)	±2.0 % at 20 ~ 80 %RH (±3.0% at remaining range)
		Ambient CO_2	0 ~ 5000 ppm	±(50 ppm + 3 % of mv)
		Atmospheric Pressure	600 ~ 1100 mbar	±3 mbar
2	Testo digital turbulence probe	Temperature	0 ~ 50 °C	±0.5 °C
		Atmospheric Pressure	700 ~ 1100 mbar	±3 mbar
		Velocity	0 ~ 5 m/s	±(0.03 m/s + 4 % of mv)
3	Globe probe (Ø 150 mm)	Globe Temperature	0 ~ 120 °C	±1.5 °C
4	Testo CO_2 digital probe	Temperature	0 ~ 50 °C	±0.5 °C
		Relative Humidity	5 ~ 95 %	±2.0 % at 35 ~ 65 %RH (±3.0% at remaining range)
		Atmospheric Pressure	700 ~ 1100 mbar	±3 mbar
		Ambient CO_2	0 ~ 10000 ppm	±(50 ppm+3 % of mv) at 0 ~ 5000 ppm
5	GLM 50 C Professional	Distance	0.05 ~ 50.00 m	± 1.5 mm
6	Vantage Pro2 GroWeather	Relative Humidity	1 ~ 100% (non-condensing)	±2%
		Temperature	-40 ~ 65 °C	±0.3°C
		Solar Radiation	0 ~ 1800 W/m²	±5% of full scale
		Wind Direction	0 ~ 360°	±3°
		Wind Speed	0.5 ~ 89 m/s	±1 m/s or ±5%
		Rainfall	0 ~ 999.8 mm	±4% of total or ± 0.2mm
		Rain Rate	0 ~ 2438 mm/hr	±5%
7	Testo 835-H1	Surface Temperature	-30 ~ 600 °C	±1.0 °C (0.0 ~ 99.9 °C)
		Relative Humidity	0 ~ 100 %	±2 %
8	Gann BL Compact B2	Material Moisture	0 ~ 199,9 digits	not specified
9	Aeroqual VOC PDL	Volatile Organic Compound	0 ~ 20 ppm	±(0.2 ppm + 10 % of mv)
10	Aeroqual PM	PM2.5 and PM10	0 ~ 1 mg/m³	±(0.002 mg/m³ + 15 % of mv)
11	Extech HD450	Illuminance	0 ~ 400 kLux	±5 % at 0 ~ 4000 lux
12	Testo 405i	Temperature	-20 ~ 60 °C	±0.5 °C
		Velocity	0 ~ 30 m/s	±(0.1 m/s + 5 % of mv) at 0 ~ 2 m/s

Table 1 shows the detailed information of the instruments that will be used for the survey. The WiFi data logger (1) with integrated sensors for temperature, humidity, CO_2 and atmospheric pressure will be used for long-term monitoring in apartments. Batteries supply the power but alternatively can be connected with power cable to avoid interruption. The data transfer over wireless network ensures that data can be processed promptly and avoids disturbing occupants. The automatic error warning reduces the risk of missing data and the workload of operating status monitoring during the measurement campaign. The measuring probes (2-4) will be connected through a universal measuring instrument with data logger and mounted in a measuring tripod. The airflows will be measured simultaneously at three different heights (0.1 m; 0.6 m; 1.1 m). With a laser measuring device (5) the mobile test system will be located precisely in the room. By that, human errors during measurements can be minimised. A weather station (6) has already been installed in Hanoi, and the other one will be installed soon in HCMC. The instruments (7-12) will be used in the detailed on-site survey. Besides the thermal comfort, indoor air quality, visual comfort, building structure and natural ventilation will also be investigated.

5 Conclusion

This paper presents a detailed description of protocols and measuring instruments for surveying indoor environmental conditions in residential buildings in Vietnam. Apartments in modern high-rise residential buildings were selected as representative dwellings due to their fastest growth rates. Following the method described in this paper, the essential and necessary indoor environmental data can be collected for investigating the impact of changes in living conditions on the local thermal comfort requirements. The measuring instruments and their specifications used for the survey were introduced in detail. The human errors during measurements can be minimised by using the mobile test system. The long-term monitoring data can be transferred over a wireless network in real-time. By that, the indoor environmental data can be comprehensively analysed with consideration of outdoor climate conditions in a timely manner.

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7 References

P.T. Ly, 2012, *A critical regionalist approach to housing design in Vietnam: socio-environmental organisation of living spaces in pre- and post-reform houses*, dissertation.

D. Schwede, M. Waibel, C. Hesse, T.T.N. Nhien, 2016, *Promoting Climate Adapted Housing and Energy Efficient Buildings in Vietnam: Chances and Challenges*, Sustainable Ho Chi Minh City: Climate Policies for Emerging Mega Cities, pp 239-258, ISBN 978-3-319-04615-0

A.S. Hassan, 2001, *Towards sustainable housing construction in Southeast Asia*, Agenda 21 for Sustainable Construction in Developing Countries, http://www.irbnet.de/daten/iconda/CIB668.pdf

JRAIA, 2019, *World Air Conditioner Demand by Region*, The Japan Refrigeration and Air Conditioning Industry Association, https://www.jraia.or.jp/english/World_AC_Demand.pdf

N.N. Hung, 2014, Examination of energy supply-demand balance and measures for energy efficiency and conservation in the household sector of Ho Chi Minh City - impact on spatial development, dissertation.

D. Schwede, *Climate-adapted material research for the socio-economic context of Vietnam (CAMaRSEC)*, International Conference on Building Materials, pp 134-141, Hanoi, Vietnam, 31 October -2 November 2019.