INTERNATIONAL JOURNAL OF
ENERGY AND ENVIRONMENT

Volume 4, Issue 6, 2013 pp.1003-1012
Journal homepage: www.IJEE.IEEFoundation.org

Importance of thermal comfort for library building in Kuching, Sarawak

S.H. Ibrahim, A. Baharun, M.D. Abdul Mannan, D.A. Abang Adenan

Department of Civil Engineering, Faculty of Engineering, University Malaysia Sarawak (UNIMAS), 94300 Kota Samarahan, Sarawak, Malaysia.

Abstract
Malaysian Government takes an initiative to provide library in housing areas to improve the quality of human capital. However, the government has to evaluate every aspect of their provision to ensure the services provided meet the demands of the users, including the aspect of thermal comfort in the building. For this study, a library constructed using Industrialised Building System (IBS) are selected for thermal comfort evaluation. The data were analyzed using Corrected Effective Temperature (CET) index. From the data analysis, it shows that thermal comfort in the library could not be achieved most of the time unless when the mechanical cooling is used. A series of technical design improvements are then recommended to improve the thermal comfort inside the library by incorporating construction details without increasing the cost.

Keywords: Library building; Industrialised Building System (IBS); Thermal comfort; Corrected Effective Temperature (CET).

1. Introduction

Education plays an important role on human development and economic growth by providing people with the tools and knowledge they need to understand and participate in the modern world. Educational system becomes national agenda in order to produce a dynamic young generation in the international arena. This could be achieved through encouragement of success in education thus enabled the country to improve the quality of its human capital. Therefore, to achieve the target, the government has provided various infrastructures and public buildings such as library. Overall, for all the libraries in the country, including those in institutions of higher learning and rural areas, there was an increase of 14.35% in membership in 2009. In the same year, there was a significant increase in loans as well. Last year saw the highest number of new members (56,676) at the National Library, which has been seeing a steady increase in membership since 2007 [1].

A library is a place to gain knowledge and encourage the reading culture among the community where most of information and references are kept systematically. The government has a responsibility to improve the educational background among the community by providing at least a library in housing area. Besides, the provision of library will encourage the reading culture among the community. Therefore, the government has to evaluate every aspect of its provision to ensure that the services provided meet the demands of the library users. A library should be well-functioned and meet the human comfort criteria, as well as a good environment should be provided. According to Popoola [2], the library plays a central support role in the educational program and must be responsive to curriculum development, to group and individual learning needs. Boyden and Weiner [3] mentioned that the library must have highly visible and accessible spaces that open to all members of the community. As a focal point for the interface between participants in the community and the world of information, it should have a direct connection to education resources.

Sarja [4] stated that the main goal of construction in all societies is a good quality of the built environment in terms of aesthetics, health, economy and ecology throughout its lifespan. In order to speed up construction process, different methods of construction applied in the industries. Method of construction or building system is classified into two major categories which are conventional building system and Industrialised Building System (IBS). Badir *et al* [5] stated that IBS is an innovative approach of construction compared with the current local construction industry towards a systematically method of construction. The construction industry has continuously developed during the years for a technical change. Other researchers claim that this method of construction has numerous benefits compared to the conventional method. It will definitely reduced the construction time, minimize the involvement of workmanship, environmental friendly ways of building, increased site cleanliness and ultimately produce better products due to the quality control [6]. Thousands of similar buildings using IBS are being built each year in Malaysia. But there are some parameters of the design which are of some concern. A major concern which prompted this study is that despite the mass building using this method of construction, no technical evaluation has been done to establish that the technology provides a thermally comfortable environment for the occupants.

Nowadays, environmental awareness in construction field has increased. Thermal comfort becomes one of initial factors in providing acceptable environment for the occupants. In order for occupants to be comfortable in their living area, four environmental parameters; air temperature, air velocity, relative humidity and mean radiant temperature (MRT) need to be presented in adequate proportions [6,7].

Air temperature is often taken as the main design parameter for thermal comfort. Evan [8] reported that the range of air temperatures within which thermal conditions may be considered comfortable are between 16^{o}C to 28^{o}C. The higher value might be more appropriate to the hot climate. According to ASHRAE Standards [9], a recommended comfort temperature for people living under climatic condition such as those found in Malaysia is around 24^{o}C ± 1^{o}C. Humphrey [10] indicates a comfort temperature of 28.7^{o}C for a hot humid region. The actual requirement for a comfort temperature for people living in the South East Asian region was found to be higher by Karyono [11]. A study by Zain *et al* [12] to determine the comfort temperature in Malaysia found that the optimum comfort temperature was 26.3^{o}C. Nyuk [13] concluded from their field study conducted in Singapore for classrooms (mechanically ventilated by fans) that the acceptable temperature range is from 27.1ºC to 29.3ºC.

The recommended indoor air velocity is between 0.15 and 1.5m/s [14-16]. Published data is reasonably consistent and most researchers agreed that the temperature range for thermal comfort in a tropical climate should not exceed 28^{o}C and that air velocities should range between 0.15 and 1.5m/s.[17-19]. Olesen *et al* [20] suggested that an increased air velocity will balance the increased air temperature to maintain comfort condition. They also recommended ventilating the building during the unoccupied period with lower ventilation rate to maintain the internal heat that stored in the building.

Relative humidity is another important thermal comfort parameter. High levels of relative humidity will increase the discomfort levels in an overheated space. According to Ismail [21], in Malaysian hot and humid conditions, natural air flow will increase the evaporation process to achieve a certain level of comfort. ASHRAE [9] indicated that a relative humidity between 40% and 60% is considered healthy and comfortable in a comfort controlled environments. Based on Ibrahim [7], the increasing of air velocity will reduces the effect of high humidity and increases the evaporative capacity from human body. According to Seeley [22], in a hot and humid climate, the relative humidity prevails in equatorial lowland in the tropical near sea level. Thus, the buildings must be designed to minimize the effects of humidity in this climatic condition.

According to Hanafi [6], level of mean radiant temperature(MRT) which is 2ºC greater than temperature on environment is still considered as an acceptable comfort level. Kadulski [23] mentioned that the mean radiant temperature is dependent on the relationship of the surface to the person and the mean radiant temperature can vary from point to point. Kubba [24] stated that, if the surrounding area is colder than the surface temperature of the skin, which is around 29.4ºC, the body will lose heat through radiation. On the other hand, if the surrounding area is warmer, the body will heat as the mean radiant temperature reflects the value used to ascertain this aspect of comfort. According to Heerwagen [25], the mean radiant temperature(MRT) depends on the surface temperatures of the person and the object. The warmer surface radiates more energy to the cooler surface.

In order to combine the effect of physical parameters of thermal comfort, several thermal comfort indices had been proposed, developed and applied by previous researcher. These indices attempt to combine the effect of two or more variable into a single variable. Effective Temperature, Predicted Mean Vote (PMV), Predicted Percentage Dissatisfied (PPD) and Corrected Effective Temperature (CET) are among the common indices. Although PMV and PPD are commonly applied as thermal comfort's indicator, the indices are not suitable for the assessment in hot and humid climate. This also supported by Tanabe *et al* [26] in their study, where Fanger's thermal model was insufficient to predict thermal comfort for a building using fans in hot and humid climate. According to Olesen [20], PMV and PPD are only suitable for the evaluation within heated and air-conditioned building. In addition, the use of PMV encourages both unnecessary heating in cool conditions and unnecessary cooling in warm conditions. Meanwhile, CET is the most appropriate index compared to the others, in order to evaluate comfort temperature in hot and humid environment [6,7,9]. Therefore, the results will be investigated and analyzed by using Corrected Effective Temperature (CET) index to determine the significant of each experiment toward thermal comfort level for users in the specific library. Under the Malaysian climate, as suggested by most of the researchers, a reasonable thermal comfort temperature inside a building is between 25 to 28^{o}C [7, 9,10,12].

2. Experimental work set up

The main focus of this study was to investigate the factors affecting thermal comfort of users in the library, which is constructed by using IBS method. For the initial phase of the work described in this paper, a library located at Bandar Baru Semariang at latitudes 1^{0}38'4'' North and 110^{0}20'1'' was selected. Figure 1 shows the front view of the library. The building elongated at Northeast and Southwest axis. The roof is constructed at 30^{o} pitch using metal roofing sheet and using 50 mm Fibre Glass Wool with double sided aluminum foil as the insulation materials. The mini library layout plan shown in Figure 2 indicates the location of the door, windows, walls and the node points located at 1m and 1.5m. This level is crucial for the sedentary users in the library in order to catch prevailing breezes to flow through the body level [27]. Type-T thermocouples connected to a data logger were used to measure air and surface temperatures at selected node points inside the library. Air velocity and relative humidity were measured using a hot-wire anemometer and the mean radiant temperature (MRT) was measured using a globe thermometer. All data were measured and monitored within one hour interval from 9am to 4pm for five days. Corrected Effective Temperature (CET) is used to evaluate thermal comfort in this study.

Four experimental work conditions as in Table 1 were implemented. All the experiments were carried out in order to identify and evaluate the effect of different conditions that will affect thermal comfort inside the mini library.

Figure 1. A library located at Bandar Baru Semariang Kuching, Sarawak

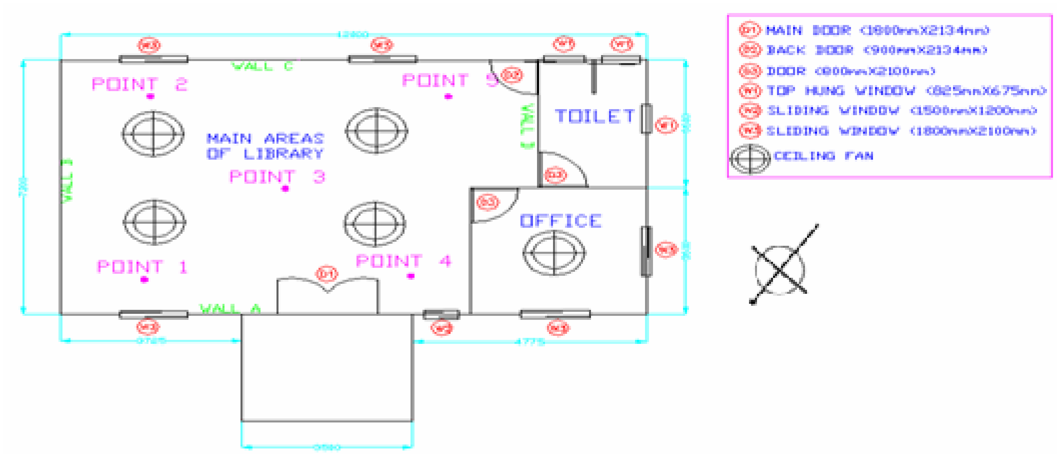

Figure 2. Building plan and the node points for instrumentation

Table 1. Experimental works conditions

Experiment	Condition	Description
Experiment 1	Building was fully closed and ceiling fans were switched off	To evaluate thermal comfort when there are no source of air movement
Experiment 2	Doors and windows were opened while ceiling fans were switched off	To evaluate thermal comfort under natural ventilation
Experiment 3	Doors and windows were closed while ceiling fans were switched on	To evaluate thermal while providing mechanical cooling
Experiment 4	All windows and doors were opened and the ceiling fans were switched on	To evaluate thermal comfort under both natural ventilation and mechanical cooling

3. Results and discussions

From the data obtained and shown in Figure 3, it can be seen that most of relative humidity values exceeded the standard for sedentary activity. The temperature specified by the standard should be between 25°C and 28°C and relative humidity should be between 30% to 60% [9].

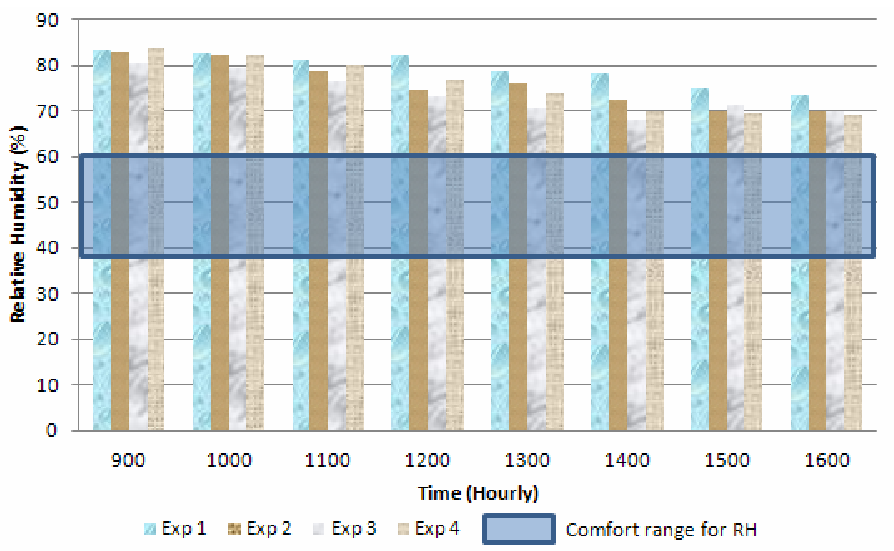

Figure 3. Relative Humidity (RH) in the library

The highest values for relative humidity were recorded in the mornings and the least in the afternoon. A rise in temperature results in a decrease in relative humidity. As the moisture holding capacity increases the relative humidity decrease. However, based on the above findings, the average relative humidity is 60% to 80%. This result confirms the study conducted by [28] on thermal comfort, saying that a high relative humidity has no significant psychological or physiological influence in human response. However this condition confirmed in their study that humidity has little or no effect on thermal comfort when within 60% to 90%.

3.1 Experiment 1- Building was fully closed and ceiling fans were switched off

Data presented in Figure 4 shows that in the absence of air movement in the library, air temperatures exceeded 30°C at all the measurement points. Data presented in the same figure shows that the air velocity in the library is very low at less than 0.1m/s due to the doors and windows being closed. Although the air velocity in the library is within the desired range for tropical climates**,** due to the higher air temperatures, thermal comfort is not achieved. Corresponding CET temperatures are also shown on the figure from which it can be seen that the temperature exceeded the maximum comfort temperature throughout the building.

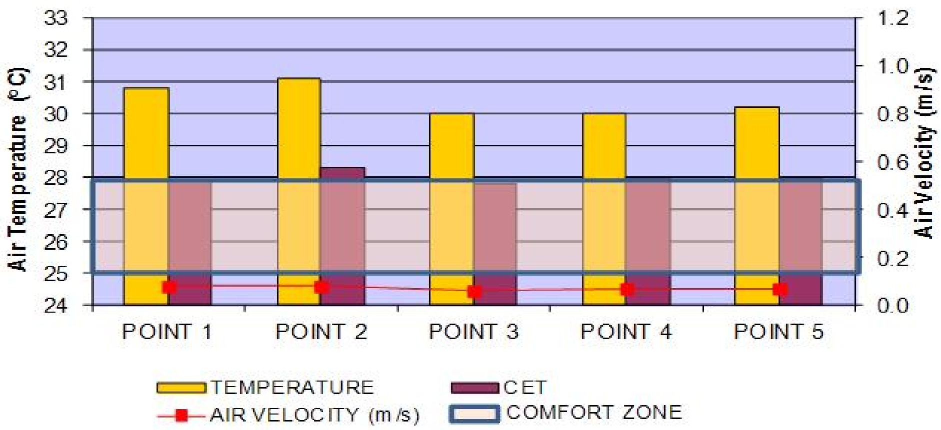

Figure 4. The relationship between air temperature, air velocity and CET value under Experiment 1

The surface temperature of the walls especially Wall B was 34°C and this was 3°C higher than the air temperature (Figure 5). Some of the radiation reflected from the surrounding surface caused this to happen. In addition, the car park beside Wall B contributed to the reflectance of the heat as shown in Figure 6. High thermal properties of the concrete driveway influenced the ground condition. Figure 7 indicated the comparison of surface temperatures between turfed surface and concrete driveway at the library. The surface temperature of concrete driveway (43ºC) was higher than the turfed surfaces (34ºC). The measurement was taken around 2 p.m, which is considered at critical hours in the afternoon.

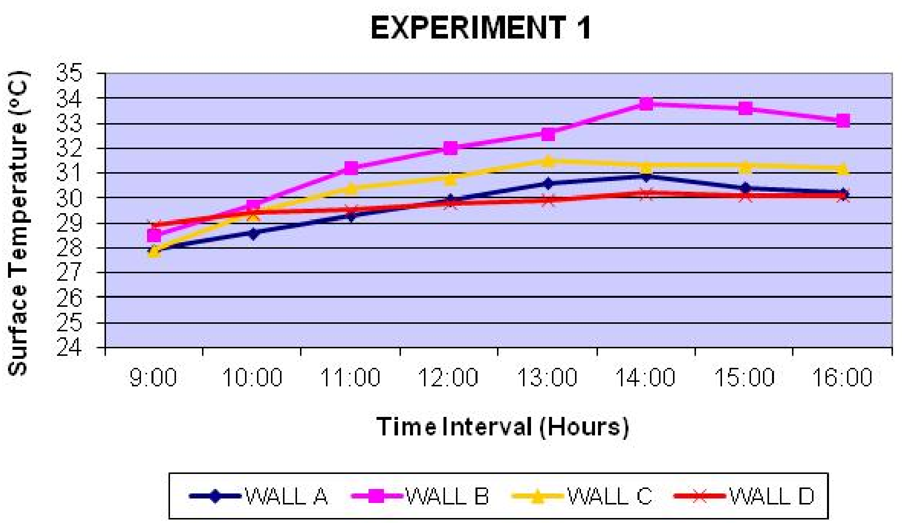

Figure 5. The comparison of surface temperature between walls under Experiment 1

Figure 6. The location of wall B at beside the concrete driveway surface

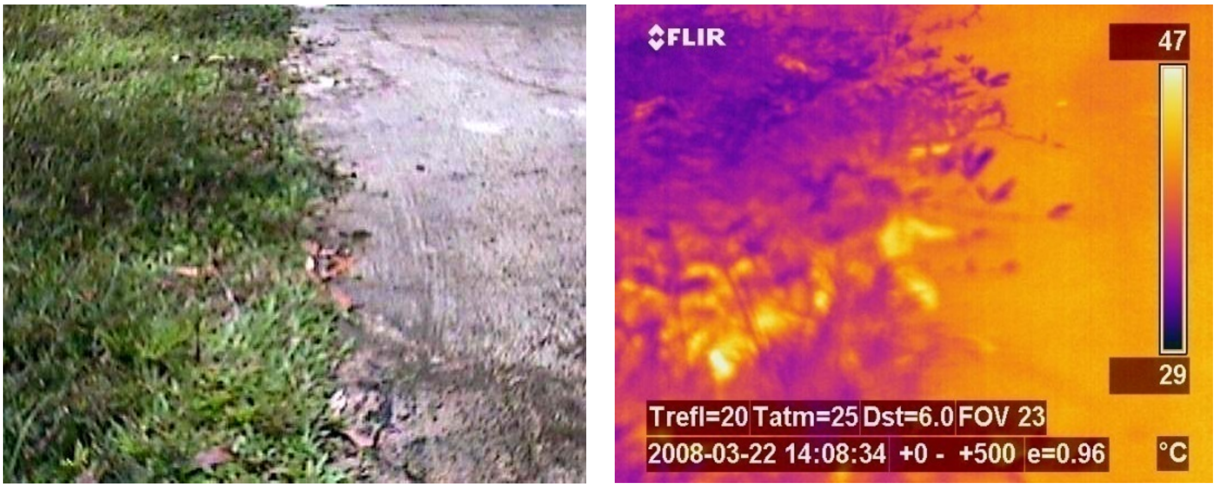

Figure 7. The comparison between surface temperatures of green turf surfaces and concrete driveway

Although Wall C (Figure 8) received almost the same exposure of the sun radiation as Wall B, the presence of green turf on surrounding ground at the backyard of the library has reduced the heat reflectance from the ground.

Figure 8. The location of wall C near the green turfed surrounding

3.2 Experiment 2-Door and windows were opened while ceiling fans were switched off

Data presented in Figure 9 shows the improvement of the air velocity inside the library when all the doors and windows were opened with increment between 0.24 m/s to 0.52 m/s. Air temperatures remain similar with outside air temperature but the improved air movement lowers the CET to within the comfort zone. Unfortunately the air speed remained low at node point 2 where the the shelves acted as a barrier to airflow (Figure 10).

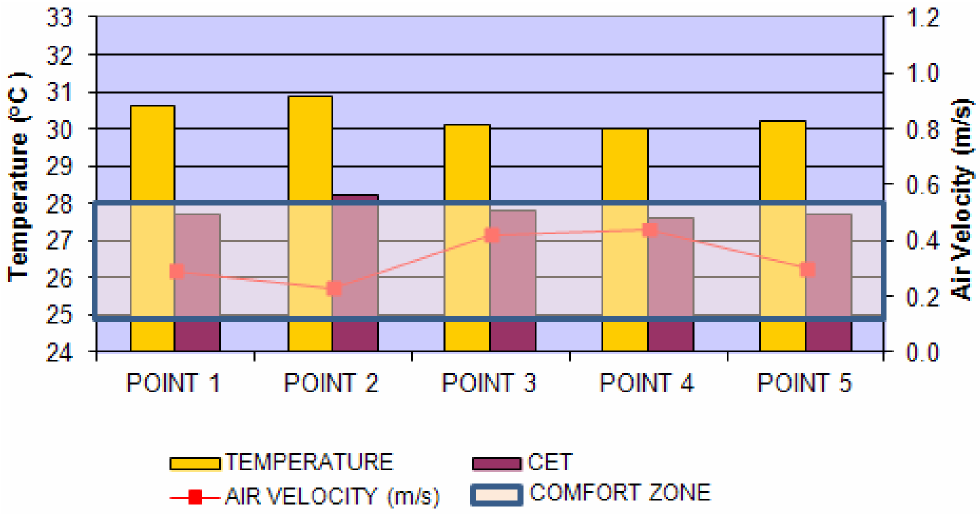

Figure 9. The relationship between air temperature, air velocity and CET value under Experiment 2

Figure 10. The arrangement of shelves that blocked the air movement from nearby window at Point 2

3.3 Experiment 3-Door and windows were closed while ceiling fans were switched on.

Experiment 3 was conducted to investigate the effect of ceiling fans (mechanical cooling), without the natural ventilation. Thus, all the doors and windows were closed, while all the ceiling fans were switched on. Figure 11 showed that most of the points were below 30ºC except for Point 2. This was due to the improvement of air velocity within the library.

Obviously, the air movement from the ceiling fans showed the fluctuated readings with a quite high range, from 0.54 m/s until 1.04 m/s. Hyde [28] stated that higher air velocity will cause disturbance. Thus, high air velocity also gave problems to the readers although the air velocity was sufficient to reduce the air temperature. As shown in Figure 11, all the CET values were in range of comfort temperature although the entire maximum air temperature at all the points exceeded 29ºC.

3.4 Experiment 4 All windows and doors were opened and the ceiling fans were switched on

Experiment 4 was conducted to identify the effect from the combination of natural ventilation and mechanical cooling in this library. Hence, all the doors and windows were opened; meanwhile all the

ceiling fans were switched on. Same as previous experiments, Point 2 was still be the critical point with maximum air temperature of 30.5ºC at 2 p.m (Figure 12). In view of air velocity, the combination of ventilation indicated a moderate range, from 0.44 m/s until 0.89 m/s.
All the CET values were in range of comfort temperature at 2 p.m, which was considered as critical period in this experiment. From the case studies carried out at the library, Point 2 experienced the most critical condition as far as thermal comfort is concerned.

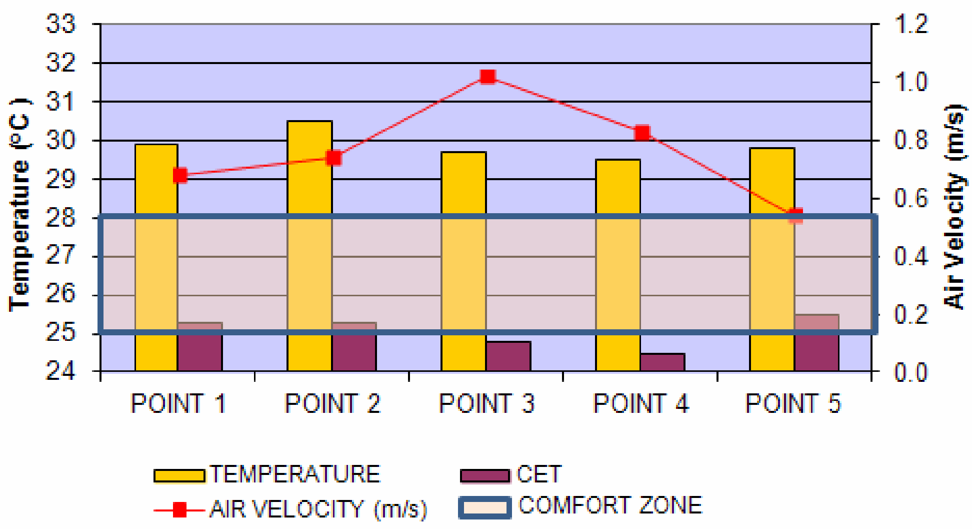

Figure 11. The relationship between air temperature, air velocity and CET value under Experiment 3

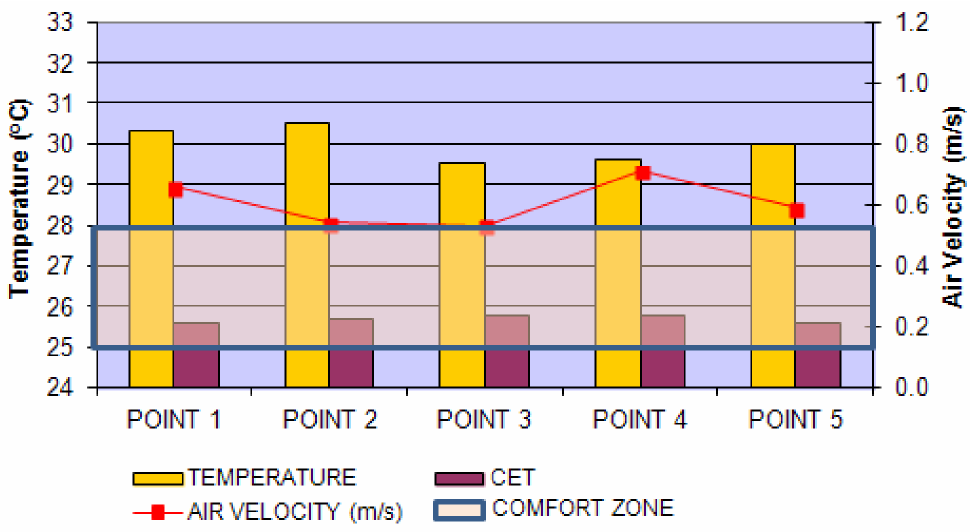

Figure 12. The relationship between air temperature, air velocity and CET value under Experiment 4

4. Conclusion

The results show that thermal comfort will never been achieved when all windows and doors are closed. Without the implementation of any mechanical cooling system, the excessive heat will be generated within the building. A comparative evaluation of thermal comfort achieved under different configurations in a library showed that good thermal comfort was achieved even when all the windows were opened. It is suggested to provide perforated panels as permanent ventilators at the specific areas instead of the design itself. The perforated panels on the wall and the arcade will promote continuous air movement in order to release the accumulation of heat in the attic. Most of the activities such as reading, writing as well as extra activities were done at approximately 1.0 m above the floor. As the cross ventilation must be passing through the body level, it is recommended to lower the position of all the sliding windows at the library from 0.9 m to 0.7 m above the floor level. It will be beneficial for sedentary users in the library in order to catch prevailing breezes to flow through the body level. It is possible to improve the comfort conditions inside a library by making changes to an existing design. By considering all the recommendations for the building design, thermal comfort will be achieved as the design encourages the maximum air movement as well as reduces the heat gain from solar radiation.

References

[1] Raslin, AB. Library Services and Trend in Malaysia. Asia Pacific Regional Council Conference 2012, National Library of Malaysia, 3-4 September 2012.
[2] Popoola,M.O. The role of librarians in the promotion of independent study. Developing Countries Research Strategies 1992, 10; 161-169.
[3] Boyden L. and Weiner J. Sustainable Libraries, The bottom line: Managing Mini library Finances 2000, 13(2); 74-82.
[4] Sarja A. Open and Industrialised Building 1998. London: E&FN Spon.
[5] Badir Y.F., Kadir M.R.A. and Ali A.A. Theory of classification on Badir-Razali building system classification. Bulletin of Institution of Engineers, Malaysia 1998.
[6] Hanafi Z. Rekabentuk Bangunan Dalam Iklim Panas dan Lembap di Malaysia, Kuala Lumpur : Dewan Bahasa dan Pustaka 1999.
[7] Ibrahim S.H. Thermal Comfort in Modern Low-Income Housing in Malaysia. Ph.D. Thesis, University of Leeds, UK, 2004.
[8] Evan M. Housing, climate and comfort, The Architectural Press London, Halsted Press Division, John Wiley and Son, New York, 1980.
[9] ASHRAE Standards. Thermal Environment conditions for human occupancy. ASHRAE 55-1992, Atlanta, U.S.A, 1992.
[10] Humphrey M.A. Fields Studies and Climate Chamber Experiments in Thermal Comfort Research. Building Research Establishment 1993, Paper 52/72; 52-69.
[11] Karyono T.H. Thermal Comfort in the Tropical South East Asia Region, Architectural Science Review 1996, Vol 39.
[12] Zain A., Sayigh A. and Othman M.Y. Field Study on the Thermal Comfort of Students in an Institution of Higher Learning. Proceeding of the First International Symposium of Alternative & Renewable Energy, ISSAE'97, 1997, Johor Bahru, Malaysia.
[13] Nyuk, H.W and Shan,S.K.,Energy and Buildings 35, 2003,Elsevier, http: www. Sciencedirect.com. Accessed September 7, 2011
[14] Olgyay V. Design with climate. Princeton University, New Jersey 1963, U.S.A., pp 14-23.
[15] Szokolay S. V. Design and research issues : passive control in the tropics. Porc. First World Renewable Energy Congress 1990. p 2337-2344, Reading U.K.
[16] Rajeh S. Wind Ventilation of of Terrace Housing in Malaysian. ISI-UTM International Convention and Exposition 1994, January 24-26. Kuala Lumpur, Malaysia.
[17] Cowan, H.J. and Smith, P.R. (1983) Environmental Systems. New York: Van Nostrand Reinhold Company.
[18] Arens E. A. and Watanabe N.S. A method for Designing Naturally Cooled Buildings Using Bin Climate Data. ASHRAE Transactions 1986, 92(2):773-791.
[19] Sapian, A.R. Evaluation of thermal comfort performance in Low-Cost Flats: Case study of Sri Perak Flats, Kuala Lumpur. Seminar on the Development of Passive Design and Technology in Tropical Climates: Proceedings of the Seminar for the Japanese Society for the Promotion of Science Vive- Chancellor Committee (JSPS-VCC), Pulau Pinang 2001, Malaysia.
[20] Olesen B.W., Steppanen O. and Boerstra A. Criteria for the indoor environment for energy performance of buildings. A New European Standard 2006, 40; 841-852.
[21] Ismail M.A. Wind Driven Natural Ventilation in High-Rise Office Building With Special Reference to the Hot-Humid Climate of Malaysia. PhD Thesis, University of Wales College 1996, Cardiff.
[22] Seeley I.H. Building Technology. 5th ed. New York 1995, Palgrave.
[23] Kadulski R. Greenbuilding Archieve 2002, http://www.buildinggreen.com/ Retrieved 5 August 2007
[24] Kubba S. Space Planning for Commercial and Residential Interiors. United States of America 2003, McGraw-Hill.
[25] Heerwagen D. Passive and Active Environmental Controls. New York 2004, McGraw-Hill.

[26] Tanabe S., Kimura K. and Hara T. Thermal Comfort Requirements During the Summer Season in Japan. ASHRAE Transactions 1987, 93(1);564-577.
[27] CIBSE Guide Volume A, Design Data 1986, Watford.
[28] Hyde R. Climate Responsive Design: A study of building in moderate and hot humid climates 2000. London: E&FN Spon.

S.H. Ibrahim is a Senior Lecturer at Department of Civil Engineering, Faculty of Engineering, Universiti Malaysia Sarawak (UNIMAS), Sarawak. She received her B.Sc (HBP) majoring in Building Engineering,(1997) and MSc in Housing from Universiti Sains Malaysia(1998) and PhD in Building Services Engineering (University of Leeds, UK)(2004). Her main research interests are Housing Design, Thermal Comfort Study, Energy Efficiency Design and Green Technology.
E-mail address: ihalipah@feng.unimas.my

A. Baharun is an Associate Professor at Department of Civil Engineering, Faculty of Engineering, Universiti Malaysia Sarawak (UNIMAS), Sarawak. He graduated in the discipline of Civil Engineering from University of Hartford, CT, USA. He later pursued his PhD in Energy Efficient Buildings in University of Leeds and completed his study in 2002. His main research interests are in Energy Efficient Buildings and Green Technology. He is currently a member of Institution of Engineers Malaysia.
E-mail address: bazhaili@feng.unimas.my

M.D. Abdul Mannan is a Professor at Department of Civil Engineering, Faculty of Engineering, Universiti Malaysia Sarawak (UNIMAS), Sarawak. He received his BSc, Civil Engineering, Rajshahi University (Bangladesh)(1986), MSc, Civil Engineering, Universiti Kebangsaan Malaysia (UKM)(1994) and PhD, Civil Engineering, Universiti Malaysia Sabah (UMS)(2001). He is also a Fellow of the Institution of Engineers Bangladesh (IEB), an Associate Member of Malaysian Structural Steel Association (MSSA) and Member of The Concrete Society of Malaysia (CSM), Malaysia. His main research interests are Construction Materials and Structural Engineering, Industrialised Building System, Renewable Green-Construction Materials and Thermal Comfort in Housing.
E-mail address: mannan@feng.unimas.my

D.A. Abang Adenan currently is an engineer at Pasukan Projek Lebuhraya Pantai Timur Fasa 2, Kuala Terengganu, Terengganu Darul Iman. She received her B.Eng, Civil Engineering (2009) from Universiti Malaysia Sarawak (UNIMAS), Sarawak. Her main research interests are Industrial Building System and Highway Project.
E-mail address: DygAzwa@jkr.gov.my

