

FIELD ANALYSIS OF THERMAL COMFORT IN TWO ENERGY EFFICIENT OFFICE BUILDINGS IN MALAYSIA

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ABSTRACT

In recent years, there has been a growing interest to include passive concepts in buildings as a design strategy for achieving energy efficiency and optimum indoor thermal comfort in workspace as well. The paper attempts to evaluate the effectiveness of tropical passive solar control components in integrating thermal comfort with energy efficiency in office building. Field measurements are carried out in selected workspace of two office buildings that have been practiced the passive solar control. Solar radiation, air temperature, globe temperature, relative humidity and air velocity were measured for seven days including the non-working days, both indoors and outdoors for each building along with direct occupant's survey to compare the measurement and the votes of occupants under the same environment. The result shows that the thermal comfort parameters lie within the recommended comfort zone of Malaysian Standards with exception of an air movement in the workspace of both buildings. The result suggested workers' preferable condition.

Keywords: Building Energy Efficiency; Thermal comfort; and Occupant Satisfaction.

INTRODUCTION

In a tropical climate like in Malaysia, where the sun shines throughout the year and its radiation is considered as a serious problem affecting the building indoor environment, mainly the thermal comfort of workspace, that requires a mechanical controlling system for maintaining the indoor comfort, which in turn maximizing the demands of cooling energy. An energy efficient (EE) buildings that are designed properly might increase thermal comfort and highly appreciated by occupants with minimum energy use (Qahtan et al., 2010) (Hummelgaard et al., 2007) (Wagner et al., 2006). EE building in tropics is based on implementing passive building elements that improve building

envelop with less energy for cooling, lighting and other energy services (Chlela et al., 2009)

The study measures and evaluates the indoor environment of the two EE buildings and looks at their workspace; how energy efficiency buildings with the passive solar control elements, are in fact, performing from the thermal comforts' perspective. If they are performing well, this indicates that the goal is being achieved. With measuring their workspace environment in terms of: dry bulb temperature; glob bulb temperature; relative humidity and; air movement which are the main indoor parameters in tropics that influence the thermal comfort of workspace (Ariffin et al., 2002) (Zain-ahmed et al., 2002).

A number of studies of the description of the passive solar control elements and the definition of the thermal comfort parameters with respect to the energy efficiency have been reported in the literature (Bansal, 1994); (Hodder, 2007); (Nicol and Humphreys, 2007); (Nicol, 2004).

OBJECTIVES

Malaysia's Green Building Index GBI non-residential building was developed in 2009 based on six criteria, to promote design and construct green buildings, specifically for the Malaysian-tropical climate. Among the six criteria of GBI for indoor workspace, the emphasis is placed on energy efficiency and indoor environmental (GBI, 2009), mainly indoor thermal comfort that provides a high quality environment to the occupants. (ASHRAE, 2004a).

Two buildings in Malaysia have been named as a showcase to demonstrate energy efficient building designed with passive solar control elements which are Low Energy Office building LEO and Green Energy Office GEO building (Hong et al., 2007). The study aims to investigate the success of these two buildings in attaining the indoor comfort besides they

are Energy Efficient Buildings. To what extent the passive solar control elements, have contributed to integrating the main two criteria of GBI that mentioned earlier. The significance of this paper is that measuring the thermal comfort parameters supported by surveying the occupants' satisfaction in these two EE buildings would be as evaluation to upcoming EE buildings in tropical region.

MALAYSIA LOCAL CLIMATE CONDITIONS

As Malaysia is an equatorial country (Kuala-Lumpur 3.13°, 348 km north), therefore its climate characteristics are relatively uniform throughout the year. There are no large variations in temperature, relative humidity, and solar radiation during the daytime of the year, the variation significantly accure throughout the day. The average mean temperature in a day ranges from 31.6 °C during the daytime to 24.6 °C, during the night. Also the humidity is uniformly high all through the year. The mean monthly relative humidity is 82 % found in August and never falls below 75.79 % in November.

Solar Radiation

Malaysia has a characteristic of a hot-humid tropical climate, receiving annual total radiation above 4.31kwh/m², and approximately 10h of sunshine per a day causing a higher indoor temperature that is usually required an air conditioning in order to succeed in providing thermal comfort in the workspace. Global solar radiation in Malaysia varies significantly throughout the day. Fig.1 indicates the solar radiation and the average of dry bulb temperature along the day. Whereas monthly average of solar radiation according to the data from Subang station is varied from 4 to 4.6 kWh/m², with monthly sunshine duration ranging from 9 to 13 hours. The highest monthly average was recorded on February and September with 4.52 and 4.6 kWh/m² respectively, while the lower solar radiation occurs in December to January with 4 to 4.2kWh/m² respectively.

The Buildings and Passive Solar Control Elements

In Malaysia about 70% of energy consumption in building sector is used for cooling (Abdul Malik and Rodzi-Ismail, 2006), this is why passive solar control elements are so important to efficiently reduce energy use in office buildings (Voss et al., 2007).

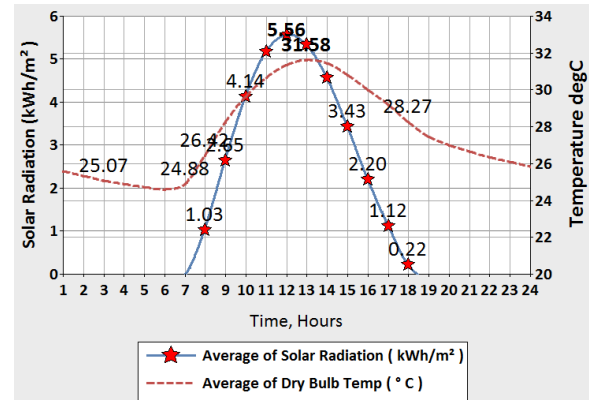


Fig. 1: Hourly solar radiation and temperature, average 3 years, 2004 to 2008 (source: author based on Subang j. Station)

The passive solar control strategies, mainly in both buildings, might be split into two groups. The first is preventing direct solar radiation through the glass area and heat gain through building envelop from penetrating to its workspaces (Ismail, 2002) (Abdullah et al., 2009), whereas the second is maximizing the heat lose from workspace by means of introducing an ample air movement and radiant system that are capable of reducing indoor air temperature (Vangtook and Chirarattananon, 2005).

The LEO building, Fig 2(a) was awarded the ASEAN Energy in 2006 (Hong et al., 2007). It was built with ambitious goal of energy saving more than 50%, with energy index of 114 kWh/m² year compared to typical conventional office building of 275 kWh/m² year (Lau et al., 2009a). It practices the passive concepts in addition to a centralized air-conditioning system, and was awarded the “ASEAN Energy Award” in 2006 (Hong et al., 2007). Whereas, the GEO building, Fig. 2(b) is stated in Malaysian’s GBI as a showcase to Green Energy Office with energy index of 65 kWh/m² year compared to typical conventional index of 250-300kWh/m²year (Lau et al., 2009a). In addition to passive concepts practiced in GEO building, it also uses a cooling system which is 75% of radiant cooling system and supplement by 25% air convection system. The details of the building is cited on GBI website (GBI, 2010).

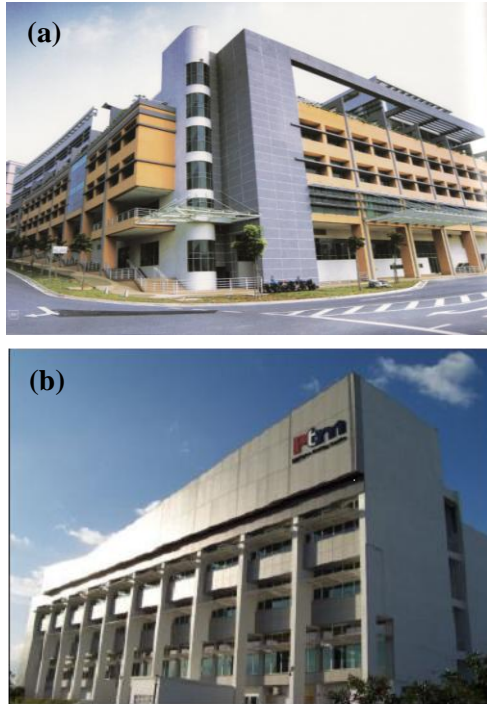


Fig.2. (a) Low Energy Office Building LEO, Putrajaya; (b) Green Energy Office Building GEO, Bandar Baru Bangi (Source: PTM)

RESEARCH METHODOLOGY

Two phases of methodology are adopted in this study. The first is based on physical measurement of the buildings environment to investigate the effectiveness of the passive solar elements in maintaining the thermal comfort in the workspace, in tropical climate. The results of the measurement were judged against the Malaysian thermal comfort Standard (MS 1525:2007). The second phase of the study relied on questionnaire survey to collect responses from building occupants and this constitutes a source of data to declare the occupants' perspective on their satisfaction at their workspace. The study was carried out between the months of August and September, where the sun is over the equator, and the building receives the largest amount of solar radiation.

Instrumentation and field measurement process

"Babuc /M" data logger for indoor and "Skye" data logger for outdoor logging with a number of sensors (outdoor/indoor temperature, air movement and R.H. sensors) were connected to the data logger. The outdoor temperature sensor was placed in a balcony of the LEO building (refer to Fig.3 (a)), at about 1.0 meter away from the building façade. Whereas placed on the roof of the GEO building. The

dry bulb temperature, globe temperature, air movement and RH sensors were stationed on a tripod located at about 1.0 m above the floor level, with about 2m away from the window in both buildings, (refer to Fig. 3). The readings of each sensor were recorded by the logger at 5 minutes interval for twenty-four hours duration. Manual readings were recorded from thermometer's readings, mini hygrometer to compare with initial readings of the sensors were recorded by the logger in order to minimize errors.

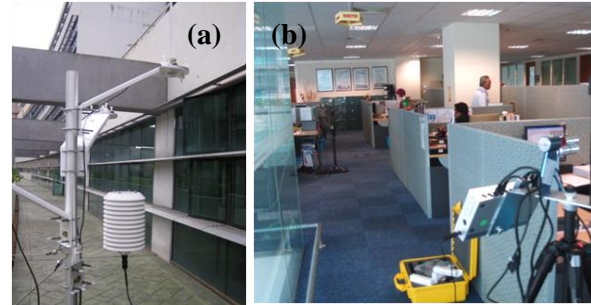


Fig.3. Setting up the data logger in LEO building: (a) Outdoor, SKYE data-logger, (b) indoor, BABUC/M data-logger

Questionnaire

Aiming to test the level of satisfaction of occupants in the two buildings, their satisfaction perceptions were obtained via a questionnaire that asked occupants to rate their workplace environment in terms of the most important ones influencing the thermal comfort; temperature, dampness, and air movement. The satisfaction level also is evaluated at two different locations of working space which is nearby a window within less than 3.0 meter distance and away from window which is more than 3.0 meter distance. The questionnaires were given to 50 staff of each building (an approximate number of employees that each building has). The number of responses received are 40 (80%) in the GEO office, and 30(60%) in the LEO office. A likerts 5-point scale was used to range the level of satisfaction with endpoints from (-2) "very dissatisfied" to (2) "very satisfied", level 0 of satisfaction is considered as positive or satisfied as the occupants who claim that were not complaining on any advantage or disadvantage. They can accept and are comfortable with the current indoor environment of their working space.

RESULTS

The result will be demonstrated in relation to the method implemented in the study, finding from

experimental work and, the questionnaire survey. The results of measuring the thermal comfort parameters were supported by the result of the questionnaire survey judging against the ideal indoor design conditions of thermal comfort in Malaysia (refer to Table1).

Measurements

As illustrated in Fig. 4 the average peak temperature (indoor dry-bulb) of the 5 working days in LEO building (14th to 18th of September) was 22.0°C at the 15:00h, when outdoor temperature was 30.2°C with a difference of 8.2°C. While in GEO (25th to 28th of August) the peak temperature was 23.8 °C (indoor dry-bulb) at 15:00h when outdoor temperature was 30.7°C, with difference of 6.9°C from indoor to outdoor. It was found that the difference of indoor air temperatures between the two buildings were approximately 1.0°C higher in GEO than in LEO during working hours of weekdays, this is compared with respect to the drop of temperature from outdoor to indoor in each building. Fig. 4 shows also that the indoor temperature in the two buildings during the weekdays were lower than outdoor temperature before the office core hours. At 08:00h the difference in LEO between indoor and outdoor was 21.4 °C and 25 °C respectively with 3.6 °C lower on indoor. In GEO indoor was lower with 1.0°C, as 23.5/24.6 °C indoor/outdoor. The globe-bulb temperature was shown, also, in Fig. 4 to be relatively equal with dry-bulb temperature.

On the other hand, as shown in Fig. 5 & table 1, the average peak temperature for the two non-working days. In LEO at the 15:00h was 26 °C (indoor dry-bulb temperature) when outdoor temperature was 31.40°C with a difference about 5°C. While in GEO the peak temperature was 25.64 °C (indoor dry-bulb temperature) at 15:00h when outdoor temperature was 31.16°C, with difference about 6°C from indoor to outdoor. However, during the non-working days, no significant difference between the two buildings was indicated.

Fig. 6 & 7 present relative humidity in LEO building that varies between 59.33 % at 08:00h to 57.70 % at midday during the weekdays, while on the non-working days the hourly average varies 64.23% at 08:00h and 66.15 at 13.00h due to its correlation with outdoor weather. Likewise in GEO building, during the weekdays, relative humidity varies with 57.17% at 08:00h to 49.70% at midday whereas, during the non-working days the hourly average varies from 65.17% at 08:00h to 63.58% at 14.00h.

Fig. 8 shows the distribution of air velocity in both building. The mean air velocity was recorded is 0.02m/s in both buildings. It was found that this air velocity is falling below the air speed limit of Malaysian standard of 0.15 m/s.

Table 1 Studies of recommended design of thermal comfort zone in tropics, Malaysia

Study	Comfort zone		
	Air temperature □C	Relative humidity %	Air velocity m/s
Department of Standard Malaysia MS1525:2007 (Ministry of Science, 2007)	22°C to 26°C	55% to 70%	0.15 to 0.7 m/s
Abdul Rahman (Abdul Malik and Rodzi-Ismail, 2006)	24°C to 28°C	--	--
Zain-Ahmed (Zain-Ahmed, 1998)	24.5 °C to 28°C	72% to 74%	0.3
ASHRAE (ASHRAE, 2004b)	23 to 26	20 to 60	

Table 2 Summarizes the hourly average temperature during the non-working days in both buildings LEO (September, 12Sat. & 13Sun.), and GEO (August, 30Sun. & 31 public holiday)

Parameters/Hours		8	9	10	11	12	13	14	15	16	17	18	Average
Outdoor Temperature	LEO	25.7	26.8	28.5	29.4	29.8	28.3	29.9	31.4	30.8	30.6	30.4	29.2
	GEO	25.1	26.1	26.9	28.5	29.5	30.5	31.1	31.2	31.1	30.4	29.7	29.1
Ind. dry-bulb temperature	LEO	24.7	25.0	25.4	25.6	25.7	25.6	25.6	25.9	25.9	26.1	26.1	25.6
	GEO	24.6	24.7	24.9	25.1	25.3	25.4	25.6	25.6	25.7	25.6	25.5	25.3
Indoor glob Temperature	LEO	25.4	25.8	26.3	26.7	26.9	26.6	26.9	27.4	27.3	27.4	27.4	26.7
	GEO	24.8	24.9	25.1	25.4	25.6	25.6	25.9	25.9	25.8	25.7	25.6	25.5

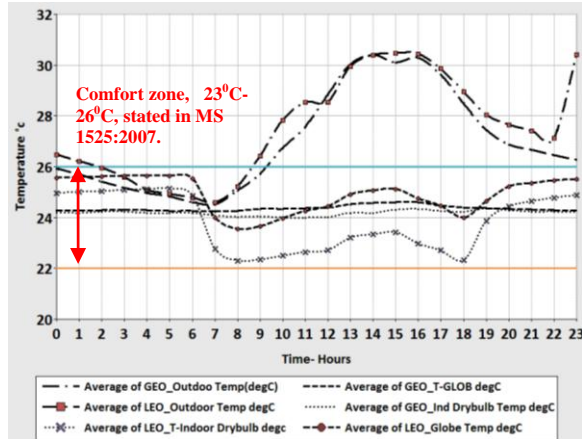


Fig. 4 The dry-bulb temperature in LEO and GEO building during weekdays

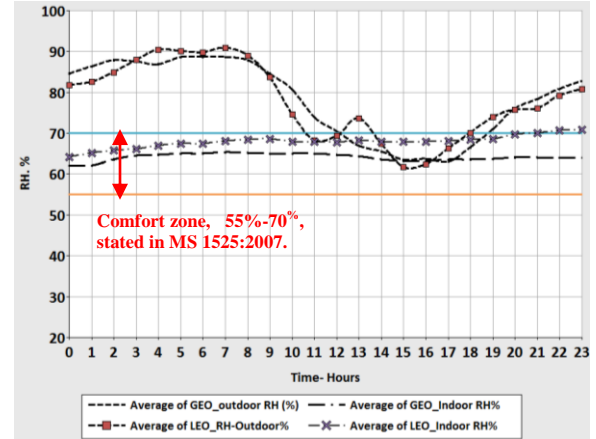


Fig. 7 The Relative humidity in both buildings during the off days

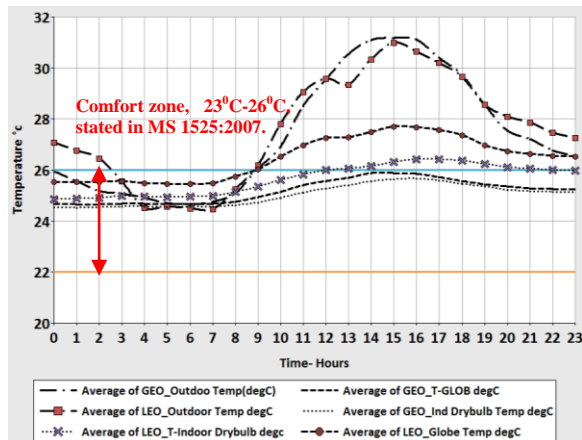


Fig. 5 The Dry-bulb temperature in both buildings, during the off-days

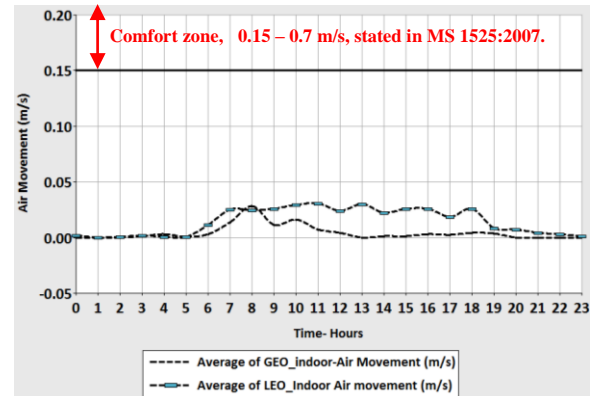


Fig. 8 The Air movement in both buildings during the weekdays

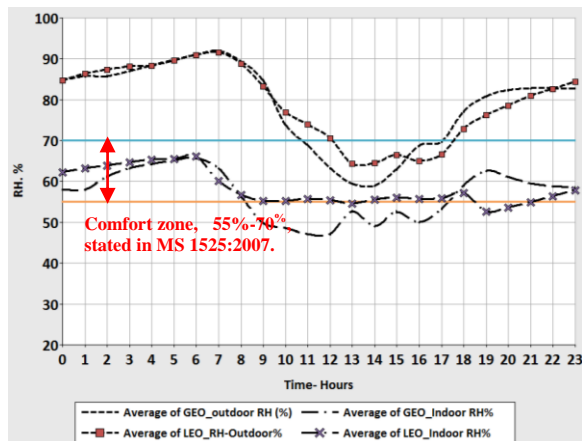


Fig.6 The Relative humidity of both buildings during the weekdays

Questionnaire

Comparing the results of surveys in the two EE buildings, the research found, as shown in Fig. 9, that on the average the occupants in LEO building are relatively more satisfied than in GEO buildings with thermal comfort parameters: Air movement; humidity; temperature and; overall satisfaction with workspace. In Fig. 10 (a) the study found that the occupants, in both buildings away to the windows are more satisfied with temperature than those near the windows. The occupants in both buildings, as illustrates in Fig. 10(b) showed preference to operate mechanical cooling system in their workspace. Fig.11 shows the votes in both EE buildings, within the category “_2 to 2” the survey found that the occupants in LEO are largely satisfied with their workspace, only less than 5% rating it as unsatisfied and 95% of them felt satisfied in their workspace with the thermal comfort aspects. Whereas in GEO

about 58% of occupants expressed satisfaction to the thermal parameters, and there are about 41% of the occupants are unsatisfied.

DISCUSSION

Based on field measurements, energy efficient buildings are perceived to be comfortable to their occupants. As indicated earlier in Table 1, the ideal conditions of thermal comfort in office workspace in Malaysian is found to fluctuate between 22°C to 28°C to indoor air temperature, 55% to 74% relative humidity, and air velocity of 0.15 to 0.3m/s. The analysis of the two buildings during the working hours, as refer to Fig. 4, an indoor temperature throughout a day for LEO building varied from GEO building. The indoor temperature fell below 22°C during working hour from 7.00a.m., until 8.00 p.m., when the cooling system inside the building is in operation. It starts to increase to above 25°C during the night when there is no cooling system provided. While for GEO building, the indoor air temperature is quite consistent and remains below 25°C throughout a day even during the night when the cooling system is off, and to be close to outdoor temperature. The differences of indoor air temperature for both building during the working hours are due to the different cooling system implemented in each building. As mentioned earlier the LEO building employs centralized air-conditioning system, and GEO building utilizes radiant cooling system and air convection system.

Nevertheless, it is hardly to determine the efficiency of passive building elements in controlling solar heat gain when the cooling system is imposed to the building during working days. Therefore, the effectiveness in controlling heat transfer in building only can be observed during non-working days. Although the indoor temperature throughout the non-working days is not maintaining with any of mechanical controlling for both LEO and GEO buildings, the indoor temperature during a day is still following the requirement set out in Malaysian Standard MS 1525:2007. The indoor air temperature measured for both buildings fall within the recommended comfort zone of 23°C to 26°C, with a slightly higher in LEO where the peak found to be 26.7°C at 15.00h (refer to Fig.5), and this still found within the comfort range according to other studies that have presented the variation of thermal comfort in Malaysia of about 24°C to 28°C (Abdul Malik and Rodzi-Ismail, 2006), (Lau et al., 2009b). Also Table2 shows variation between outdoor and indoor

temperature for 2 continuous non-working days in LEO and GEO buildings, it can be observed that the highest variation for LEO building is 5.32°C at 15.00h and for GEO building is approximately 6°C. The result shows that GEO building is a little more efficient in controlling solar heat transferring this is due to the high performance glazing has been implemented (for GEO double glazing consisted of two 7mm panes of glass with low emissivity coating and spectrally selective coating, separated with 16mm air space of inert gas)

Although the occupants in LEO building (refer to fig.8&9) were found to be more satisfied than in GEO building with the air movement, it was found during the building walkthrough a few occupants improving their satisfaction to the air movement utilizing the desk fans. This confirms the result from measurement that found the indoor air velocity in both buildings lower than the minimum recommended of air velocity in Malaysian standard (refer to table1). The maximum velocity of air has been recorded was 0.02m/s in both selected workspace of the buildings during the operating hours of the cooling system, which is lower than the recommended to air-conditioning office in tropics (Ministry of Science, 2007) not to mention the energy efficient buildings. However, this reveals that the future essential challenge to the architects is to get an ample air movement in the workspace of energy efficient buildings in addition to have the strategies have been successfully implemented. This also was concluded by another study that the ideal comfortable thermal environment in Malaysia is to have a sufficient air movement with a cool surrounding (Abdul Malik and Rodzi-Ismail, 2006).

For occupants evaluation through the questionnaires of the two buildings, as shown in Fig. 11, LEO building shows more satisfaction to temperature (22°C, working hours) than GEO (23.75 °C working hours), this due to the air-conditioning system implement in LEO, whereas GEO employs air convection system to indoor environment. As mentioned earlier, judging from physical measurement found that the indoor temperature lies on comfort range of Malaysian standard, which is below 24 °C; the mean recommendation of MS1525:2007. However, the indoor temperature in the two buildings were found to be lower than outdoor temperature before the office core hours, 08:00h., leaving a positive impact on the staff. Nevertheless, the occupants show desire to implement additional mechanical controlling to

maintain their indoor environmental quality. Linked to this and more highlighting on occupant judgment the study as in Fig. 10 found that the occupants in both buildings away from the windows are more satisfied than those close to the windows. This suggests that the amount of heat gain and glare are still a problem close to the windows in these two energy efficient buildings, and the occupant confirm this result with recording their preference to work with an additional mechanical controlling to be employed in workspace.

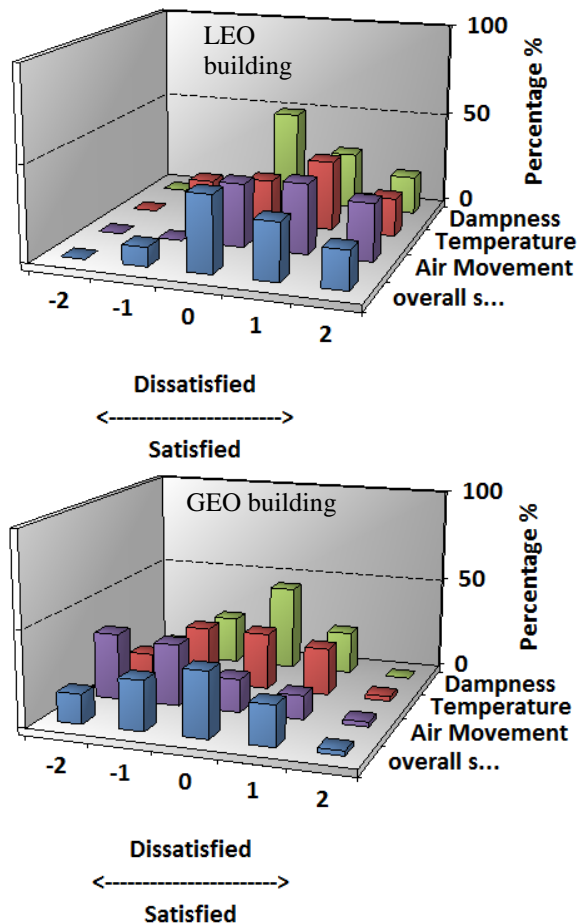


Fig. 9. The responses of occupants in the two buildings to thermal comfort parameters

Generally, according to ASHRAE (ASHRAE, 2004b) when 80% of occupants are satisfied, this indicates to be an acceptable environment for building. With respect to this concept, the survey found that the occupants in LEO are largely satisfied with their workspace, this due to the implementation of additional affective mechanical cooling and controllable interior blinds.

In GEO building about 58% of occupants stated a satisfaction level to the thermal comfort parameters. This is probably due to the orientation and the nearness to windows zones of their workspace. In GEO building about 58% of occupants stated a satisfaction level to the thermal comfort parameters. This is probably due to the orientation and the nearness to windows zones of their workspace. A study suggested that the occupant should be allowed to adjust the indoor comfort to their personal requirements by providing, for example, ceiling fans and open-able window (Nicol, 2007).

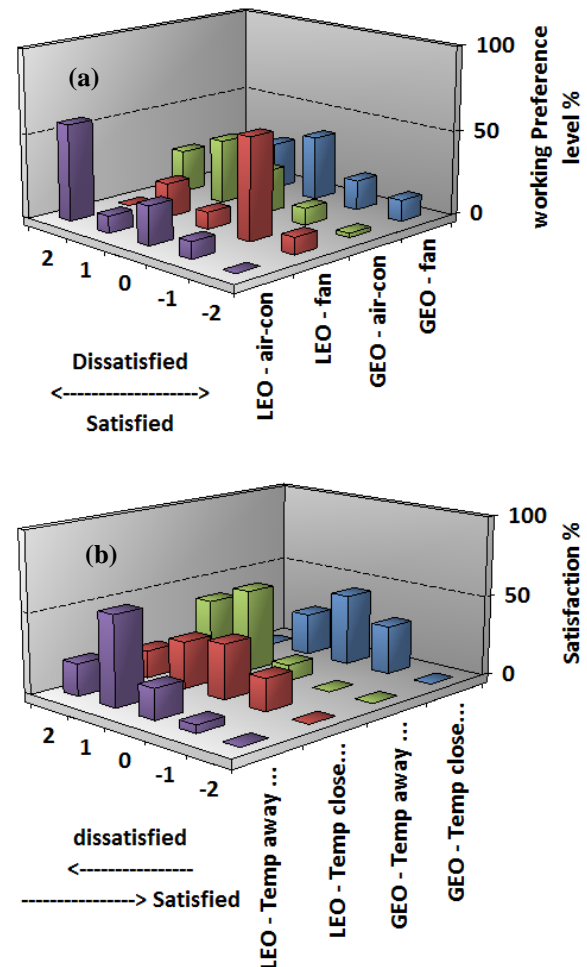


Fig. 10: (a) The votes of occupants in both LEO & GEO buildings to their preference with respect to mechanical solar heat control; (b) The occupants' preference to workspace location with respect to the distance from the window

For Malaysia it is proposed, to face this matter, that the reduction of thermal by passive design in tropical climate where the average air temperature is

about 33°C with relative humidity of about 80% is not enough to reach to the occupants comfort without the aid of active systems introducing the mechanical means to obtain the ample air movement (Abdul Malik and Rodzi-Ismail, 2006).

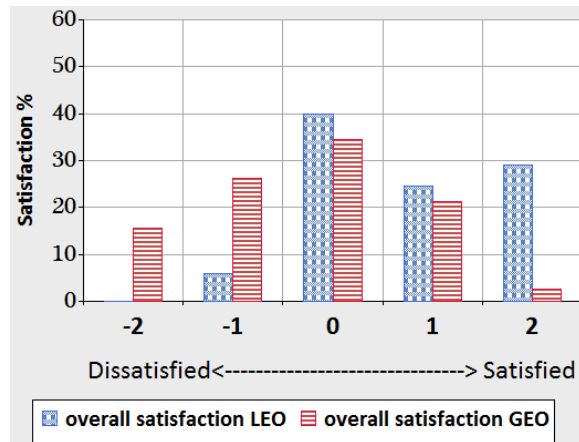


Fig. 11. Relationship between overall satisfaction in LEO and GEO building, as the “0” is considered positive the chart shows that the occupants are satisfied with their workspace in both buildings with “slightly more” satisfaction in LEO than in GEO

CONCLUSION

Designing energy efficient buildings in tropics can attain the occupant satisfaction provides a proof that the passive strategies that are energy efficient have succeed with their goal. They might not provide the exact indoor thermal comfort that is conducive to fully satisfy the occupants in their workspace, but it will absolutely reduce the energy consumption for sustaining it. The study examines the thermal comfort parameters compound with occupant’s satisfaction at the two EE buildings in Malaysia. The study concluded that the strategies were employed in the EE buildings have been, on the average, proven effective at improving indoor thermal comfort, which in turn lead to improving occupant satisfaction, with exclusion the air movement that was seen by not to their satisfaction. This position was confirmed from the measurement that was registered on both open workspaces. However, the air movement in the both building can be improved by adding some mechanical ventilation. In this context, the study supports the approach raised by Abdul Malik and Rodzi-Ismail (2006) that the passive design in tropical climate is not enough to reach to the occupants comfort satisfaction without the aid of active systems introducing the mechanical means to

obtain the ample air movement. Therefore, it is important to take occupant’s interactions with the indoor thermal comfort of EE buildings into account when designing the buildings, especially within tropical climate, like in Malaysia.

REFERENCES

- ABDUL MALIK, A. R. & RODZI-ISMAIL, M. (2006) Future design in an energy efficient building as an identity of a Malaysian tropical architecture with emphasis on photovoltaic technology and passive solar building design elements IN MOKHLIS, H. (Ed. *4th international conference 2006 (MRG-AIC)*). United Kingdom.
- ABDULLAH, A. H., MENG, Q., ZHAO, L. & WANG, F. (2009) Field study on indoor thermal environment in an atrium in tropical climates. *Building and Environment*, 44, 431-436.
- ARIFFIN, A. R., RAO S.P. & INANGDA, N. (2002) Thermal comfort and evaporative cooling of external walls in an equatorial climate. IN RAHMAN, A. M. A. (Ed.) *Development of passive solar design and technology in tropical climate*. Pulau Pinang, Penerbit University Sains Malaysia.
- ASHRAE (2004a) Advanced Energy Design Guide for Small Office Buildings. IN AMERICAN SOCIETY OF HEATING, R. A. A.-C. E. (Ed. Atlanta, www.ashrae.org. ASHRAE (2004b) Thermal environmental conditions for human occupancy in AMERICAN SOCIETY of HEATING, R. A. A.-C. E. (Ed. Atlanta, www.ashrae.org
- BANSAL, N. K. H. (1994) concepts and elements of natural climatic control IN NAREND K. BANSAL, G. H., GERNOT MINKE (Ed.) *Passive building design* Netherlands, Elsevier Science B.V.
- CHLELA, F., HUSAUNNDEE, A., INARD, C. & RIEDERER, P. (2009) A new methodology for the design of low energy buildings *Energy and Buildings*, 41, 982-990.
- GBI, G. (2010) Green Building Index , rating system. Kula Lumpur, <http://www.greenbuildingindex.org/>.
- GBI, G. B. I. (2009) Green Building Index (GBI), rating system. Kula Lumpur,

- http://www.greenbuildingindex.org/rating_system.htm.
- HODDER, S. G., PARSONS, K. (2007) The effect of solar radiation on thermal comfort. *international journal of biometeorology*, 51, 233-250.
- HONG, W., CHIANG, M. S., SHAPIRO, R. A. & CLIFFORD, M. S. (2007) *Building Energy Efficiency: Why Green Buildings Are Key to Asia's Future*. , Hong Kong, Asia Business Council.
- HUMMELGAARD, J., JUHL, P., SAEBJORNSSON, K. O., CLAUSEN, G., TOFTUM, J. & LANGKILDE, G. (2007) Indoor air quality and occupant satisfaction in five mechanically and four naturally ventilated open-plan office buildings. *Building and Environment*, 42, 4051-4058.
- ISMAIL, M. R. (2002) Possible increase of air-conditioning temperature after application of passive solar design elements as retrofitting in a building. IN RAHMAN, A. M. A. (Ed.) *Development of passive solar design and technology in tropical climate*. Pulau Pinang, Penerbit University Sains Malaysia.
- LAU, L. C., TAN, K. T., LEE, K. T. & MOHAMED, A. (2009a) A comparative study on the energy policies in Japan and Malaysia in fulfilling their nations' obligations towards the Kyoto Protocol. *Energy Policy*.
- LAU, L. C., TAN, K. T., LEE, K. T. & MOHAMED, A. R. (2009b) A comparative study on the energy policies in Japan and Malaysia in fulfilling their nations' obligations towards the Kyoto Protocol. *Energy Policy*.
- MINISTRY OF SCIENCE, T. A. I. (2007) Code of practice on energy efficiency and use of renewable energy for non-residential buildings. IN DEPARTMENT OF STANDARDS MALAYSIA, M. (Ed. Putra Jaya.
- NICOL, F. (2004) Adaptive thermal comfort standards in the hot-humid tropics. *Energy and Buildings*, 36, 628-637.
- NICOL, F. & HUMPHREYS, M. (2007) Maximum temperatures in European office buildings to avoid heat discomfort. *Solar Energy* 81, 295-304.
- NICOL, F. A. R., SUSAN (2007) Progress on passive cooling: Adaptive thermal comfort and passive architecture IN SANTAMOURIS, M. (Ed.) *Advances in passive cooling* London Earthscan in the UK & USA.
- QAHTAN, A. M., KEUMALA, N. I. M. & RAO, S. P. (2010) Occupant satisfaction in respect to indoor environmental quality in energy efficient certified buildings in malaysia. *16th International Conference of the CIB W104 Open Building Implementation on "Open and Sustainable Building"*. Bilbao, Spain, CIB W104
- VANGTOOK, P. & CHIRARATTANANON, S. (2005) An experimental investigation of application of radiant cooling in hot humid climate
- VOSS, K., KUBN, T. E., NITZ, P., HERKEL, S., WALL, M. & HELLSTROM, B. (2007) Solar Control. IN SANTAMOURIS, M. (Ed.) *Advances in passive cooling* London Earthscan in the UK & USA.
- WAGNER, A., GOSSAUER, E., MOOSMANN, C., GROPP, T. & LEONHART, R. (2006) Thermal comfort and workplace occupant satisfaction - Results of field studies in German low energy office buildings. *Energy and Buildings*, 39, 758-769.
- ZAIN-AHMED, A. (1998) THE BIOCLIMATIC DESIGN APPROACH TO LOW-ENERGY BUILDINGS IN THE KLANG VALLEY. MALAYSIA. *Renewable Energy* 15, 437-7440.
- ZAIN-AHMED, A., SOPIAN, K., OTHMAN, M., SAYIGH, A. & SURENDRAN, P. (2002) Daylighting as a passive solar design strategy in tropical buildings: a case study of Malaysia. *Energy Conversion and Management*, 43 1725-1736.