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# The Green Building Index Rating Tool: Influence of Building Facade on Indoor Environmental Quality (IEQ) Performance

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**A B S T R A C T**

In a developed nation, buildings accounts for nearly half of overall energy consumption in both residential and commercial sectors. Green rating tools have become a key instrument to alleviate energy shortage, mitigate the effects of global warming and improve the indoor environmental conditions. This paper is based on a research on Green Building Index (GBI) as a pioneer rating tool used in Malaysia. The research investigates the effectiveness of the facade adopted in GBI rated office buildings as the interface of the ambient climate to the Indoor Environmental Quality (IEQ). Results of this study shows that most of the IEQ parameters fulfil the criteria stated in GBI Non Residential New Construction (NRNC) Tools standard although the envelop of the building consist of various types of facade. However, the performances on the Indoor Air Velocity parameter are slightly below the average requirement stipulated by the GBI Malaysia.



## 1. Introduction

The effect of global warming that the world is facing today has contributed to the increase in outdoor and indoor temperatures. Green buildings are meant to improve the design, construction, and landscaping practices so that it will last longer, cost less and contribute to healthy living. They are designed by conserving the natural resources and improving the built environment for humans, communities and ecosystems to strive in prosperity (John & Michael, 2007). Green buildings advocate environmental, economic and social benefits. The environmental benefits encompass conserving and restoring the biodiversity and natural resources. Whilst, the economic benefits include reducing the life-cycle cost, increase profit and rental value of buildings. As for the social

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benefits, it involves enhancing the occupants comfort and health, thus improving the overall quality of life. This entails the improvement of indoor environmental quality, indoor thermal comfort and occupants' productivity (Edwards, 2003), (Kats, 2003), (Ross et al., 2006). The crusade for sustainable and green approach in a country should integrate augmentation of the relevant energy policies and assessment tools.

## 2. Malaysian Green Initiatives

### 2.1 Energy Policies

Attempts at green initiatives in Malaysia, began since 1976, with the five-year development plan as well as the National Energy Policy in 1979 (Lau, 2009). The five years National Plans (7th, 8th, 9th and 10th) from 1996 to 2015 had given strong emphasis on sustainable development (Lau, 2009). In addition, the National Policy on Environment (2002), and National Green Technology Policy(NGTP) (2009) advocate further sustainable development towards energy independence and efficient utilization (Yong et al, 2017). The NGTP is envisioned to accelerate the national economy and promote sustainable development. It is placed under the auspices of the new restructured Ministry of Energy, Green Technology and Water (MEGTW) replacing the former Ministry of Energy, Water and Communications (MEWC). The strategic thrusts in the policy include: 1.Strengthen the Institutional Frameworks, 2.Provide a Conducive Environment for Green Technology Development 3.Intensify Human Capital Development In Green Technology 4.Intensify Green Technology Research And Innovations and 5.Promotion and Public Awareness. In the same year, the National Climate Change Policy was launched to ensure climate-resilient development, renewing its efforts to seriously work towards further reduction in carbon dioxide as pledged after the Kyoto Protocol 2005. Following the United Nations Framework Convention on Climate Change (UNFCCC) in Paris, 2015, Malaysia again joined the bandwagon on concerted effort to prevent average global temperatures rising above 2°C and declared the Intended Nationally Determined Contribution (INDC) (UNFCCC, 2017). Adequate plans and policies are formed to promote energy efficiency and provides a milieu for implementing schemes for selected sectors to attain the targeted end-use of energy and reducing overall energy intensity. Nonetheless, Malaysia’s electricity consumption continues on an upward curve towards unsustainable development (Yong et al, 2017, Shafie et al, 2011). Malaysian government has yet to define a short-term and long-term goals for reducing the energy consumption through energy efficiency holistic approach (Yong et al, 2017, Suhaida, 2013). In addition, swift actions are essential to reduce Malaysian's dependent on non renewable and shift towards renewable energy such as biomass, solar and also wind source (Shafie et al, 2011).

### 2.2 Malaysian Green Rating Tools

The establishment of green building certification systems worldwide is one of the most prominent and systematic approach toward promoting environmental sustainability (Liang et al., 2014). In

Malaysia, the Green Building Index (GBI) was the pioneering tool launched in 2009. It is adapted and adopted from other rating systems such as the Leadership in Energy and Environmental Design Standard (LEED) and mainly GREENMARK of Singapore due to its climatic context. There are other rating tools developed by various agencies in the country as shown in Table 1, but GBI is currently the most established tool with the highest rate of certification. The highest score for GBI is on EE followed by IEQ.

**Table 1:** Green Rating Tools in Malaysia (Source: Abd. Hamid et al, 2014)

| **Criteria** | MyCREST | GreenRE | Green PASS | PH JKR | GBI |
|---|---|---|---|---|---|
| **Date of establishment** | 2016 | 2013 | 2012 | 2012 | 2009 |
| **Certification process** | Covers design, construction and operations and maintenance stages | Voluntary | Voluntary | Voluntary | Voluntary |
| **Developed by** | Construction Industry Development Board (CIDB) & Public Works Department (PWD) | REHDA | Construction Industry Development Board (CIDB) | Public Works Department (PWD)JKR | Board of Architects (PAM) and ACEM |
| **Nature of assessment** | To be made mandatory for public building RM50 million and above by 2020 | Voluntary | Voluntary | Voluntary | Voluntary |
| **Phase of assessment** | Design, construction and operations and maintenance stages | Design & Construction | Construction & Operation | Design & Construction | Design & Construction |
| **Mode of assessment** | Based on $CO_2$ emission | Criteria checklist | Based on CO2 emission | Criteria checklist | Criteria checklist |

The latest GBI data on certification of green buildings, as of May 2017 shows a total of 398 buildings had been certified in various categories, with 194 for Non-Residential New Construction (NRNC). Out of those certified, 16 buildings were awarded with Platinum, 90 buildings granted as Gold, 43 buildings achieved Silver and 249 buildings are certified category (GBI, 2017). Furthermore, the total number of buildings registered with GBI Malaysia totals to 768 for various categories. Out of the total, 314 were granted Provisional Certification after Design Assessment (DA) stage, 77 buildings successfully managed to obtained Final Certification after the Completion & Verification Assessment (CVA) stage while 7 building were recently awarded with Renewal Certification.

## 3. Literature Review

The Indoor environment quality is defined by Garnys, (2007) as "the measurement of the key parameters affects the comfort and well-being of occupants"- elements to provide an environment that is physically and psychologically healthy for its occupants". The National Institute of Occupational Safety and Health in the United States has established a definition of indoor environment quality which includes the integrated physiological and psychological influences of

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thermal, acoustic and luminous environments and air quality on occupants (Li, et al, 2013). According to (Sarbu and Sebarchievici, 2013), the most common and significant environmental factors that define the IEQ are thermal comfort, indoor air quality, acoustic and visual comfort. A few studies concluded the relationship between IEQ and occupants satisfaction; i.e. enhanced work performance, improved worker retention, reduced sick day and absenteeism (Clements-Croome and Baizhan, 2000, Fisk,2000, Loftness et al, 2005).

The building envelope, including the foundation, external wall, windows, and doors and also the roof systems are the interface between the interior with the outdoor environment (Straube & Burnett, 2005). It components serves as thermal barrier playing an important role in determining the amount of energy to maintain a comfortable indoor environment. Other popular terms used apart from building enclosure are building facade, building skin and building exterior. This research paper will use the terms facade in referring to the external wall of the building. Apart from the aesthetics quality, a green building should consider the energy properties of the entire wall and how the design and materials affect the indoor environment. It is mentioned that selecting the best facade is to ensure those that can reduce the radiation of the sun into the building and enhance indoor environment quality (Jin, 2017)

## 4. Problem Statement

Energy consumed in office buildings is 10 to 20 times higher than residential consumption (Yang et al, 2008). The total amount of energy used in building has risen to 20 to 40% in developed nations (Saidur, 2009). This high usage raised concern over demand versus supply, depleting of fossil fuel, global warming, ozone destruction, climate change, etc. People in the developed world spend most of their time; 75-90% inside building (Lebowitz et al., 1985). Chen et al., (1998) highlighted that the IEQ is important for people's health, welfare and productivity. He also pointed that occupants in internal environment that exposed to illuminations, acoustics, air quality, thermal comfort and social environment in the building, reflect the situation that surrounds them by their physiological and mental sensations (sight, hearing, smell, taste, touch and mentality). Most of assessment rating tools have apportioned the highest scores to EE followed by IEQ except for Japan’s CASBEE and France’s HQE, awarding a higher point to IEQ followed by EE (Kamaruzzaman et al, 2016). According to Kamaruzzaman et al (2016), this is linked to the increasing concern about sick building syndrome in Japan and France, IEQ is rapidly becoming a key concern in achieving a holistic sustainability. Elsewhere, research results revealed that green and low energy performance building do not always guarantee a better category of IEQ, especially during the summer (Fabbri and Tronchin, 2015, Yousef Al horr, 2016). It is crucial for the sustainable construction not only focused on environmental sustainability but also integrate parameters to improved health, satisfaction and wellbeing amongst building users (Yousef Al horr, 2016).

## 5. Research Methodology

Subsequently this study is purposely conducted to investigate the performance of various rated GBI Non Residential New Construction office buildings in Kuala Lumpur and Putrajaya as shown in Table 2 on Indoor Environmental Quality (IEQ) criteria. This study aims to evaluate these rated buildings in post occupancy period on the Indoor Environmental Quality (IEQ) performance based on different building facade. This paper focus only on Thermal Comfort measurement of IEQ parameters (consisting of the Air Temperature, Relative Humidity, Heat Transfer and Air Velocity), and also Outdoor Solar Radiation as shown in Table 3. The measurements were taken for five consecutive days for each building, from 8.30am to 4.30pm. The study also focuses on the measurement of heat flux of different building facade to the overall indoor performance in the building by using the various instruments. It also included the Post Occupancy Evaluation (POE) Questionnaire to gauge the occupants' perception and satisfaction of the indoor environmental as a triangulation with the actual measurement results but is omitted from the scope of this paper.

**Table 2:** Summary of case study buildings and photos showing exterior and interior views.

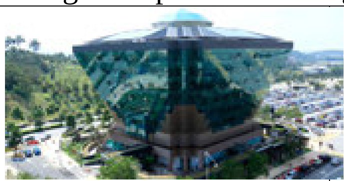
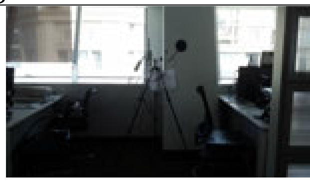
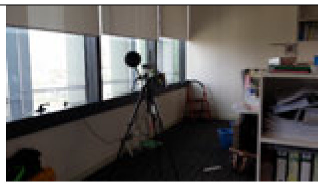
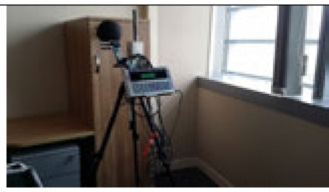
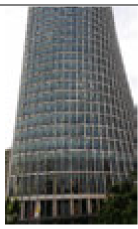
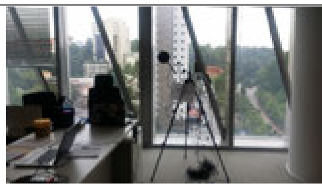
| | | |
|---|---|---|
| 1. Suruhanjaya Tenaga (ST - Energy Commissioning Malaysia ( Diamond Building))<br>Location: Putrajaya, Malaysia<br>GBI Rating: Platinum (Final Certification)<br>Measurement Location: 6th floor of the building (West Facing Façade)<br>Facade: Double Glazing/ Tilting Facade |  |  |
| 2. PJH Tower (Putrajaya Holding)<br><br>Location: Putrajaya, Malaysia<br>GBI Rating: Gold (Final Certification)<br>Measurement Location: 6th floor of the building (West Facing Façade)<br>Façade: Double Glazing with Vertical Fin |  |  |
| 3. MITI Tower (Ministry of International Trade and Industry)<br>Location: Kuala Lumpur, Malaysia<br>GBI Rating: Gold (Provisional Certification)<br>Measurement Location: 6th floor of the building (West Facing Façade)<br>Facade: Double Glazing with Horizontal Shading. |  |  |
| 4. KKR2 Tower (Ministry of Works)<br>Location: Kuala Lumpur, Malaysia<br>GBI Rating: Gold (Provisional Certification)<br>Measurement Location: 6th floor of the building (West Facing Façade)<br>Facade: Double Glazing with box |  |  |

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**Table 3:** Indoor Environmental Quality (IEQ) Parameters and Instruments

| PARAMETERS | INSTRUMENTS |
|---|---|
| Air Temperature | Temperature Sensor |
| Relative Humidity | Thermo Hygrometer |
| Air Velocity | Air Velocity Fan |
| Solar/Heat Radiation | Globe Thermometer |
| Data Storage | BABUC data logger |

The recommended parameters for IEQ in GBI refer to the Malaysia Standard, MS 1525: 2007 (Code of Practice on Energy Efficiency and Use of Renewable for Non Residential Building) which establish the conditions given in Table 4: (Department of Standards Malaysia, 2007).

**Table 4:** The Recommended Indoor Conditions Based on MS: 1525: 2007.

| | |
|---|---|
| **Recommended dry bulb temperature** | **23°C - 26°C** |
| **Recommended relative humidity ( RH)** | **55% - 70%** |
| **Recommended air movement** | **0.15 m/s to 0.5 m/s** |
| **Minimum dry bulb temperature** | **22°C** |
| **Maximum air movement** | **0.7 m/s** |

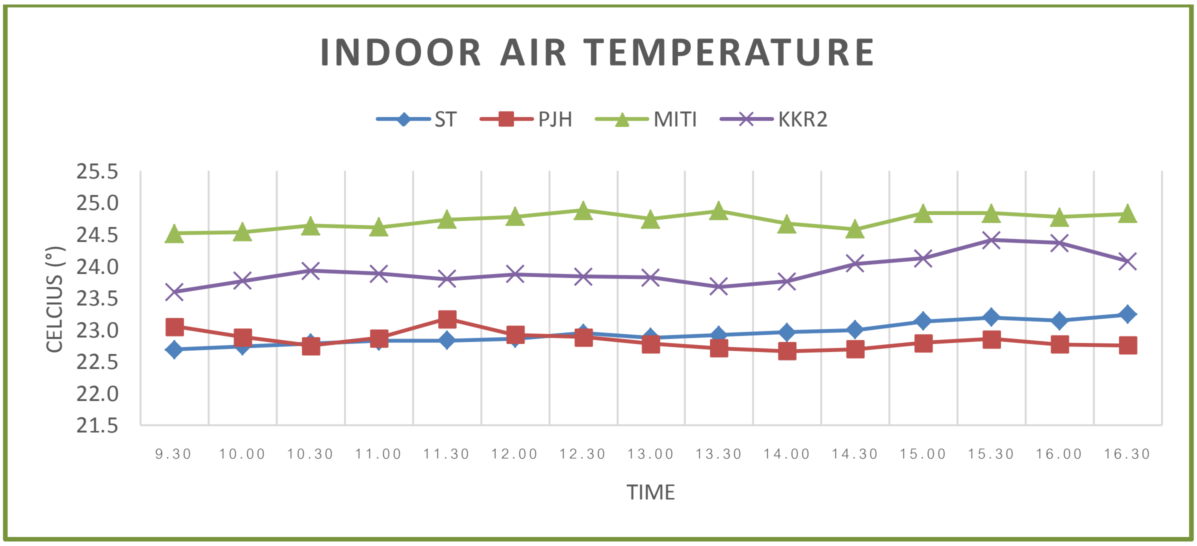


**Figure 1:** Mean Indoor Air Temperature of Four Case Study Buildings

## 6. Results and Discussion

### 6.1 Indoor Air Temperature

Figure 1 shows the mean indoor temperature of five days for all case studies. For ST building, a steady pattern of indoor air temperature was observed with exception of the 4th day of observation where the indoor temperature pattern differs from the rest of the observation days. The graph indicates that the average indoor temperature for the building ranged between 22°C and 25°C with highest indoor air temperature of 24.19°C was recorded at 4.30pm on the fourth day of observation. Subsequently, the indoor temperature of the PJH Tower shows quite a small difference in the five-day observation period. The indoor temperature of the building shows a consistent temperature value of not exceeding 24℃ except on the 2nd day of observation where the temperature rises above the value of 24℃. For MITI Building, the indoor air temperature ranged from 24℃ to roughly 26℃r. The indoor temperature increases drastically on the 3rd day of measurement to the value of 26℃ at 12.30 o'clock in the afternoon. This is likely due to the increase value of heat flux entering the building. Finally, from Figure 1, the five-day data measurement of the KKR2 Building indicates a regular pattern in which the indoor air temperature fluctuates contrastingly compared to the changes of the outdoor air temperature value.

## 6.2 Indoor Relative Humidity

Figure 2 indicates that the range of relative humidity for ST building is within the range of design relative humidity stated in MS 1525.. Overall, the indoor relative humidity rapidly drops until 4.30 pm during the five-day measurement observation in the building. The range of indoor humidity is from 50% to 59% for the whole period. As for the PJH Building, it shows that the range of relative humidity for the building is within the range of design relative humidity stated in MS 1525. On the whole, the indoor relative humidity rapidly drops at 10.30 to 11am on the second day of observation in the building. The range of indoor humidity is from 56% to 66% for the whole measurement period.

Subsequently, Figure 2 demonstrate the range of relative humidity for MITI Tower building which is within the range of design relative humidity stated in MS 1525. Overall, it shows a steady flow of indoor relative humidity throughout the five-day measurement. The range of indoor humidity is from 54% approximately up to 68% for the whole study period. Lastly, Figure 2 shows that the indoor relative humidity rapidly drops at 10 am in the morning during on the first-day of measurement in the KKR2 Building. The range of indoor humidity is from 57% up to 68% for the whole measurement period.

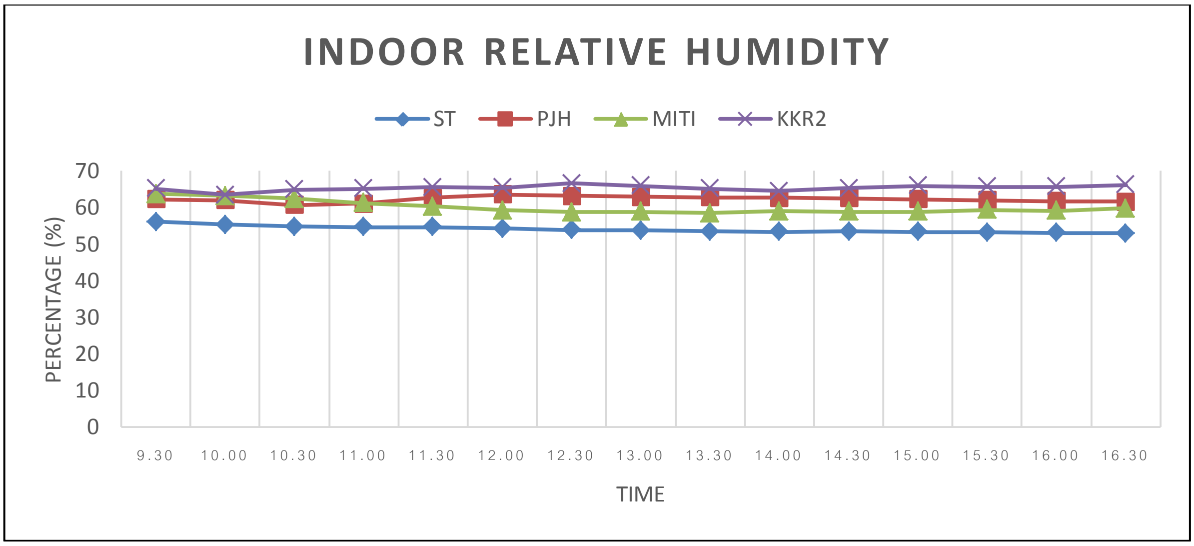


**Figure 2:** Mean Indoor Relative Humidity of Four Case Buildings

## 6.3 Mean Radiant Temperature

Figure 3 displays the five-day measurements of the heat transfer into the building monitored for ST Building. A fluctuated pattern of solar radiation was observed throughout the week with especially on the last two days of observation where the value of heat flux entered into the building raise above the value of 25 W/m2 recorded at 9.30 until 10.30 pm on the 4$^{th}$ day of heat flux measurement. Then, as for PJH Building, figure 3 displays the five-day measurements of the heat transfer into the building monitored for PJH Tower. A regular pattern of solar radiation was observed throughout the week with exception on the 2$^{nd}$ day of observation where the value of heat flux entered into the building raise almost to the value of 25 W/m2 recorded at 11.30 pm. From figure 3, a regular pattern of indoor heat transfer was observed during the week for MITI Building. The heat flux ranged between 24 W/m2 to approximately 27 W/m2. The maximum heat flux entering the building for the five days was recorded at 12.30 p.m. on the 3rd day of observation with the value of 26.61 W/m2.

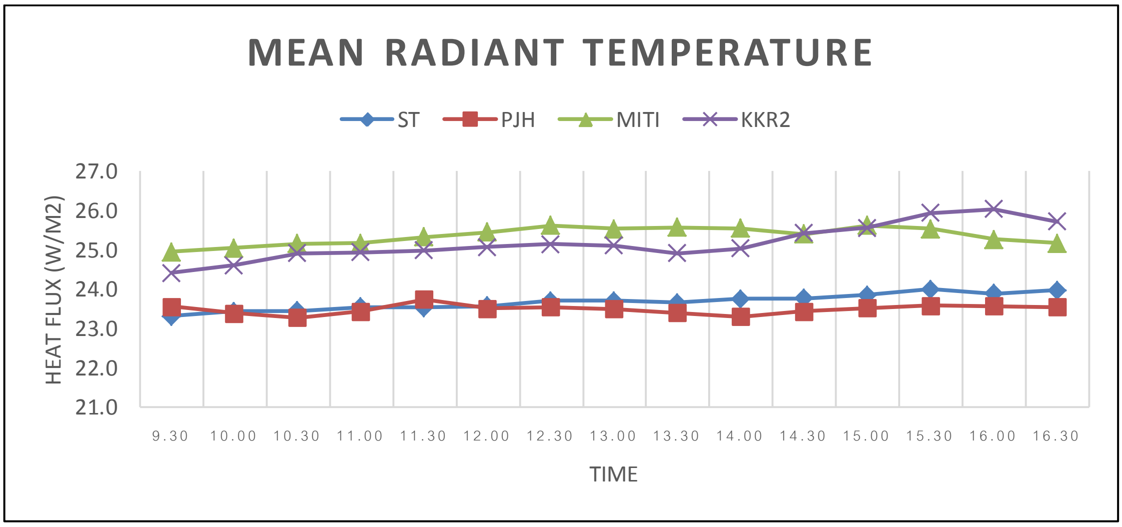


**Figure 3:** Mean Radiant Temperature of Four Case Buildings

Finally, Figure 3 shows the five-day measurements of the indoor heat transfer monitored for KKR2 Tower. A varying pattern of heat flux was observed throughout the week. The heat flux intensity entering the building through its facade fluctuated during the day due to the variation of cloud cover. The heat flux ranged from 24 to nearly 28 W/m2 between 9.30 a.m. to 4.30 p.m. each day. The highest indoor heat transfer intensity of 27.72 W/m2 was recorded on the 3rd day of observation at 4.30 p.m.

## 6.4 Indoor Air Velocity

Figure 4 indicates the average air movement that ranged from 0.00m/s and 0.25m/s for ST Building, 0.00m/s and 0.05 m/s for PJH Building, 0.00m/s to 0.27m/s for MITI Building and lastly 0.00 m/s for KKR2 Building. Subsequently, these results are quite low compared to ASHREA's minimum limit of 0.25m/s of air movement and also low as compared to requirement by MS 1525 with range of good air velocity at 0.15 to 0.50 m/s. This may be due to the low air exchange from the air conditioning system in the building. However, based on the overall observation of building thermal comfort, it is concluded that the thermal comfort condition is found acceptable to the indoor occupants of the observed building with slightly improvement made to enhance its air movement.

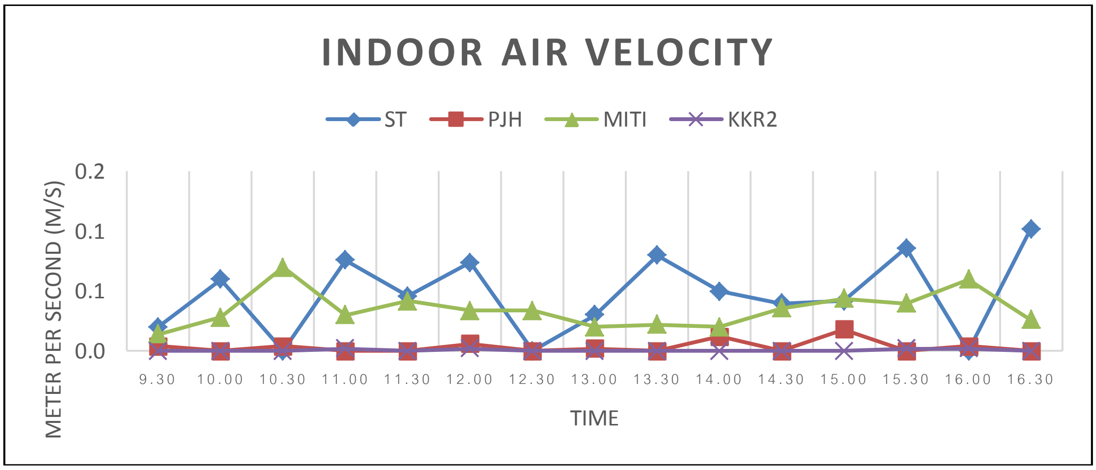


Figure 4: Mean Indoor Air Velocity

Table 5: Summary of Measurements

| Parameter | Reference | ST | PJH | MITI | KKR2 | Findings Summary |
|---|---|---|---|---|---|---|
| Temperature | 23°C to 26°C | 22°C to 25°C | 21 to 25°C | 24 to 25°C | 23 to 25°C | Within Range (Good) |
| Relative Humidity | 55% to 70% | 50% to 59% | 56 to 66% | 54-68 % | 57 to 68% | Within Range (Good) |
| Air Velocity | 0.15-0.50m/s | 0.00m/s to 0.25m/s | 0.00-0.05 m/s | 0.00-0.27 | 0.00-0.00 m/s | Slightly below range |
| Heat Flux | Not Exceeding 50W/m2 | 22 W/m2 to 26 W/m2 | 22-25 W/m2 | 24-27 W/m2 | 24-25 W/m2 | Within Range (Good) |

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## 7. Conclusion

Outcomes of this study as summarised in Table 5, demonstrate that most of the Indoor Environmental Quality (IEQ) parameters fulfill the criteria stated in GBI Non Residential New Construction (NRNC) Tools standard except for the Indoor Air Velocity which are slightly below the average standard stipulated by the GBI Malaysia (as mentioned in MS 1525). A presumption can be made that with very low air velocity, the occupants in those areas would suffer a slight stuffiness although the temperature are within range which should be verified with POE questionnaires. The varying wall facade of mainly double glazing with either horizontal or vertical fins/shading devices and unitised curtain wall of KKR2 did not show drastic effects on indoor temperature. All the buildings indoor reached a maximum of $25^{o}C$ even though the lowest temperature for MITI building starts with $24^{o}C$. Therefore, as a summary, it can be concluded that, this research is useful for the future planning of green office building development in Malaysia under the category of Non Residential New Construction (NRNC) regarding the aspect of Indoor Environmental Quality (IEQ). The results provide a valuable benchmark for office buildings in obtaining an expected mark for its indoor environmental quality that will qualify it to be certified by the Green Building Index (GBI) Malaysia.

However, on a more general note, overviews from various literature highlight that there should be a more holistic approach to not only implementation of policies amongst various agencies but also specifically on green rating of buildings. The rating tools are currently overlapping, focusing more on design and construction stage, There is a dire need for synchronisation of various tools to cover more on operational and maintenance as well as life cycle analysis from cradle to the grave of the building cycle. The varied tools would confuse stakeholders on the appropriate application best suited to cater for their needs and to gain green incentives. Again, any assessment tool should always priorities not only to protect mother earth but equally important to safeguard the wellbeing and comfort of dwellers in the buildings.

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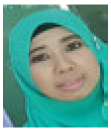

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