THE BEHAVIOR OF INTERNAL HUMIDITY FROM FIBRE OPTIC DAYLIGHTING SYSTEM APPLICATION

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Abstract

Electrical lighting consumed 13% to 43% from overall energy which considered as second major usage of electrical energy in a building. Fibre optic daylighting is a potential approach for the remote source daylighting which is able to minimize the usage of electrical light if the minimum recommended standard of human comfort is achieved. Since the internal humidity also plays an important role in human comfort, the objectives of this research are to investigate the effects of the application inside building for humidity. This research assessed the potential of fibre optic daylighting for interior illumination using 4 m x 5 m x 2.8 (H-Ceiling) spaces through empirical data collection in an actual environment. The data were collected for every 5 minutes from 8:00 AM to 6:00 PM on the 17\textsuperscript{th} May 2013 until the 2\textsuperscript{nd} June 2013 using 4 computer-linked sensors to record humidity for both external and internal building. The comparison approach was selected in analyzing the data collected with the observation. It is shown that the fibre optic daylighting system has no significant effect in relative humidity even possibly increases the internal room temperature by 2\textdegree C.

Keywords: Remote-source daylighting, fibre optic daylighting, internal humidity

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1.0 INTRODUCTION

Natural light technology has made some notable strides recently, providing higher quality lighting at reduced cost. Daylighting is not expensive anymore to be implemented as compared to traditional lighting solutions. If an integrated design approach is used, daylighting quickly produces attractive paybacks. Energy studies in Malaysia conclude that electrical lighting represents up to 30% of building electricity consumption in a commercial office building [1, 2] meanwhile [3] concluded that lighting consumption in Malaysia’s residential buildings is 25.3%, shopping complexes 51.9% and offices 42.5% respectively.

Malaysia’s climate is blessed with a constant reliable sun rays and sources quite fairly distributed between day and night in twelve-hour alternation. This source has been ignored as a main source for lighting distribution in building until recent years where scholars and researchers implemented applied science and awareness in energy manner based on application that have been studied and established in the developed country. Optimizing the fibre optic daylighting configuration to integrate both available solar sources outside building by bringing it inside can minimize the usage of artificial light but the minimum recommended standard must be achieved.

Above statements however need to be proved by reliable empirical results that will be explicated in this research which consider overall investigation to assess the actual performance of the fibre optic daylighting system employing the optimum approach which is tested and evaluated under real tropical skies.

Therefore, a remote source fibre optic daylighting approach for interior illumination is significant to be explored by this research, expected to meet minimum standard of Green Building Index (GBI) and MS1525:2007 Code of Practice on Energy Efficiency and Use of Renewable Energy for Non-Residential Buildings (First Revision) under interior lighting’s subtopic.

The evaluation of the optimum approach in fibre optic daylighting system is to understand the overall potential and to investigate the effects on relative humidity from the system approach.

Next is to translate the optimization of experiment to a full-scale experiment conducted in a 5 m x 4 m x 2.8 m (H-Ceiling) test-bed. This test-bed is a typical standard working room constructed at the School of Housing, Building and Planning, Universiti Sains Malaysia Pulau Pinang.

Various parameters were recorded in support of the research objectives and research questions. The parameters involved are external and internal illuminance level, external and internal temperatures, external and internal humidity, external solar radiation and surface temperatures for lighting diffuser and ceiling board.

This full-scale field study however will only consider the installation of full range fibre optic daylighting system using solar receiver, fibre optic cable and light diffusing fitting system to meet the objectives of research. The selection for the optimum approach of fibre optic daylighting system is made based on the literature reading suggested by previous researchers. This research presents empirical findings on the assessment of daylighting system using fibre optic cable for interior illumination in Malaysia skies.

The optimum approach of fibre optic daylighting system was obtained from Parans Sweden consisting of latest 3rd generation set SP3 receiver, 6 numbers of 10 meters fibre optic cables and 6 numbers of L1 type diffusers. Parans was selected due to its patented technology since 2002 and their first product was commercialized in 2004 which was developed through extensive Research and Development in collaboration with Chalmers Technical University in Gothenburg, Sweden [4].

The research test bed was constructed using commonly found building materials at the School of Housing, Building and Planning, Universiti Sains Malaysia Pulau Pinang, Malaysia. The full scale field study data collected made by using a computer program linked with sensors to store the parameters in 5 minutes intervals for a period of 17 days starting from 17th May 2013 until 2nd June 2013.

The research parameters are limited to external and internal humidity, external solar radiation and surface temperatures for lighting diffuser and ceiling board. Any other possible effects due to this exercise such as indoor air quality, acoustic comfort as also mentioned in MS1525:2007 will not be covered in this research. The perception estimating in cloud cover category is used. It is determined by using either Nebulosity Index, Oktas calculation or IESNA Classification is only a guideline but it has not been applied in this research.

2.0 DESIGN PARAMETER

The GBI is an environmental rating system for buildings developed by PAM (Pertubuhan Arkitek Malaysia) (http://www.pam.org.my) and The Association of Consulting Engineers Malaysia (http://www.acem.com.my) following Malaysian Standard 1525:2007 [5]. The GBI is Malaysia’s first comprehensive rating system for evaluating the environmental design and performance of Malaysian buildings based on six (6) main criteria. The GBI is developed specifically for the Malaysian tropical weather, environmental and developmental context, cultural and social needs. GBI Malaysia is currently promoted and recommended through research and experiments mainly in energy efficiency for buildings in Malaysia. Based on the studies made, we can conclude that the recommended values based on the parameter stated in GBI Malaysia are as mention in Table 1.
This research focus on the interior space daylighting by using fibre optic cable as a part of active daylighting to investigate the internal humidity effects.

### 2.3 Fibre Optic Daylighting

Fibre optic is a cylindrical dielectric waveguide that channelize light along its axis by the procedure of total interior reflection. The fibre comprises of a core bordered by a protective cover layer, both of which are made of dielectric materials [18].

Fibre optic typically consists of a crystal clear core bordered by reflective sheath material with a lower refractive index. Light is travelled in the core by total internal reflection with extremely low loss. In current application, fibre optic is possible to be used as the remote sunlight path from the external building to other parts of the building as a lighting system. [19, 18, 10].

Fibre optic daylighting system is a developing technology that will provide a resolution for daylighting designers. This systems use fibre optics with solar light collectors to transmit daylight to spaces previously difficult to daylight using side lighting or top lighting strategies. Fibre optic light transmission systems include a collector, reflectors, filters, lenses to direct light to the fibre optic cables, and a diffuser to distribute the light in the area to be illuminated. The term “remote source lighting” has been used to describe this type of system that conveys light to a destination not directly accessed by the light source [20]. Table 4 shows a list of studies that had been made by previous researchers in evaluating fibre optic cable for interior illumination lighting in various places.

### Table 1 Recommended internal parameters by GBI Malaysia

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>RECOMMENDED VALUES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Dry Bulb Temperature</td>
<td>22°C</td>
</tr>
<tr>
<td>Design Dry Bulb Temperature</td>
<td>23°C - 26°C</td>
</tr>
<tr>
<td>Humidity: Design Relative Humidity</td>
<td>55% - 70%</td>
</tr>
<tr>
<td>Air Movement</td>
<td>0.15m/s - 0.5m/s</td>
</tr>
<tr>
<td>Max Air Movement</td>
<td>0.7 m/s</td>
</tr>
</tbody>
</table>

Source: [6]

Malaysian Standard, in MS 1525:2007 earlier outlined the recommended value for internal parameters as shown in Table 2.

### Table 2 Recommended internal parameters by MS1525

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>RECOMMENDED VALUES</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEMPERATURE : Dry Bulb Temperature</td>
<td>23 °C – 26 °C</td>
</tr>
<tr>
<td>Relative Humidity</td>
<td>A space relative humidity below 70 % for comfort cooling purposes.</td>
</tr>
<tr>
<td>Height of Measurement Light Source</td>
<td>800 mm above the floor level</td>
</tr>
</tbody>
</table>

Source: [5]

Comfort temperature is 24°C and relative humidity is between 55% to 70%. The values become a design standard in Malaysia and will be a benchmark in summarizing the outcome from this research.

### 2.1 Relative Humidity

In most parts in Malaysia, the average of Relative Humidity (RH) level is almost uniformly high at about 70%-90% throughout the year, reaching the most critical values of 99% during the night and Monsoon seasons [7]. However, the lowest values of relative humidity during the day take place between 1:00 PM and 5.00 PM, which corresponds to the peaks of outdoor air temperature. This is due to the fact that the higher temperature, the higher the amount of moisture (humidity in steam form) that air can hold, which in turns makes the percentage values of relative humidity decrease at the same time that the air temperature increases.

### 2.2 Methods of Directing External Illuminance to Building Interiors

Many studies on different methods of bringing external illuminance to building interiors were done by previous researchers and some of them can be listed below. Table 3 summarized the research related to the method in bringing daylighting into the building from 1997 to 2012.

### Table 3 Summary of previous researches related to methods of bringing external illuminance into the building

<table>
<thead>
<tr>
<th>No</th>
<th>Researchers/Area</th>
<th>Solar Tube</th>
<th>Light Shelf</th>
<th>Skylight</th>
<th>Light well</th>
<th>Atria</th>
<th>Fibre Optic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>O’Connor et al. (1997) U.S [8].</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Krarti et al. (2005) U.S [12].</td>
<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Han and Kim (2009) Korea [14].</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Chiras (2011), UK. [15].</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Seied et al. (2011), Sudan [16].</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Wong and Yang (2012), Hong Kong [17].</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
2.4 Optimized Fibre Optic Daylighting System

The final configuration for optimum approach of fibre optic daylighting system was made earlier based on the justification explained. Basically, the fibre optic daylighting system has 3 major components as highlighted by [10, 11, 22, 24, 26, 27] as summarized in Table 4. This research considers a Fresnel lenses type of solar receiver with sun tracking system as it was also selected by [29, 22, 23, 30] in their researches. Fresnel lens is widely used because it gives the good performance at a low cost [26].

Table 4 The selected optimum approach of fibre optic daylighting system

<table>
<thead>
<tr>
<th>Main Components and Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Receiver (Fresnel Lens):</strong></td>
</tr>
<tr>
<td>The receiver follows the sun over the day to collect its light. Optical design is using lenses to capture and concentrate the optimal amount of sunlight into the fibre optic cable for immediate transfer into the building. The receiver is powered up with a 10 W adapter for its motor and electronic sun tracking circuit inside the receiver.</td>
</tr>
<tr>
<td><strong>Fibre Optic Cable (10 meters):</strong></td>
</tr>
<tr>
<td>Six solar fibre optic cables are attached together at 10m length from the receiver to inside building. The cables have very good ability to transport light while retaining the full spectrum of the light. Cables are thin, flexible, and made of high pure silica which is common in fibre optic daylighting system.</td>
</tr>
<tr>
<td><strong>Diffusers:</strong></td>
</tr>
<tr>
<td>The diffusers are connected to the end of the fibre optic cables and will diffuse the light that had been concentrated earlier into the building spaces.</td>
</tr>
</tbody>
</table>

3.0 RESEARCH METHODOLOGY

3.1 External Data Collection

Since this research is aiming at the comparison study related to external and internal condition, the mini meteorological station was installed outside the building to record external parameters involving solar radiation, relative humidity and external air temperature. The station is located at the same level of fibre optic receiver to capture the most precise external reading to support research finding. The installation of mini meteorological station is shown in Figure 1. Outside temperature sensor and humidity sensor are shown in Figure 2.

![Figure 1 Mini meteorological station](image1)

![Figure 2 Outside temperature sensor and humidity sensor](image2)

3.2 Internal Data Collection

While the external data measurement was operating, the internal parameter data collection also was running concurrently and being stored. The internal parameter involves 1 (one) relative humidity sensor and 1 (one) internal temperature sensor in Figure 3.
All sensors (totalling 4 numbers for internal and external) were connected to a desktop computer located at external wall outside the building. The computer needs to be outside to avoid internal heat generated by the desktop computer that may influence the internal heat built-up by the equipment [31].

3.3 Data Analysis

In order to produce a comprehensive analysis from the data collected, a comparison analysis approach will be considered in this research. The analysis is expected to disclose the potential of the fibre optic daylighting system in Malaysia skies and at the same time will reveal how the human comfort parameter being affected by the system. This research investigated the effects of fibre optic daylighting in building interior using simplified comparative method as implemented by [31, 32] through the profile of heat and relative humidity (RH):

Humidity is simply a measure of amount of water vapour in the air. The more water vapour, the more humid it is. Heat and relative humidity are the parameters that are important in determining human comfort in a space. The higher the temperature of the air, the less water vapour the air can hold. That makes sense because air molecules and water vapour molecules are moving faster at higher temperature [33].

[34] discovered that an optimum relative humidity based on the research made in Shah Alam, Selangor was 73%. The baseline value is important as a comparison of humidity value will be recorded in this research in relation to the analysis at later stage.

4.0 RESULTS AND FINDINGS

As discussing the monitoring results in this section, daily data collected from 17th May 2013 until 2nd June 2013 is cropped and analyzed between 8:00 AM to 6:00 PM daily since this is considered as normal daytime working hours for offices. Although the data was collected continuously during that duration, this actual cropped time was selected to constitute the typical usage time of an office room and the purpose of simplified on analysis approach.

The following analysis will consider three major weather conditions in tropical climate on representing overall climatic condition available in determining the potential of fibre optic daylighting system for interior illumination which are:

i) Hot Sunny Day with Intermediate Blue Sky
   (Date selected 22nd May 2013, 28th May 2013 and 1st June 2013)
ii) Moderate Sunny Day with Intermediate Mean Sky
   (Date selected 18th May 2013, 29th May 2013 and 30th May 2013)
iii) Overcast and Intermediate Overcast Sky

On 22nd May 2013, the external average illuminance recorded is 72,251 lux where solar radiation averaged at 654 W/m² meanwhile on 7th June 2013, the average external illuminance recorded is 77,615 lux with solar radiation averaged at 690 W/m². Both dates are selected to compare the effect on relative humidity in intermediate blue sky from the operation of fibre optic daylighting system.

On the other hand, during intermediate mean sky, the data collected showed almost similar reading for both 18th May 2013 and 3rd June 2013 where the external illuminance averaged at about 57,500 lux for both days and the average solar radiation recorded is about 510 W/m².

Comparing the days, it is suggested that the overall form of graphs as shown in Figure 4 and Figure 5 for both selected days where overall patterns showing a close similarity during both system ON or OFF and no peculiar formation can be noticed.
It is notable that the external relative humidity starts at almost the same figure ranging from 90% RH to 100% RH for all selected days. During intermediate blue sky (22nd May 2013 and 7th June 2013) which was considered as highly temperature with sunny days, the external humidity recorded a decrease with a different of 36% to 38% RH representing about 25% when comparing the humidity on early morning and late evening. However during intermediate mean sky (18th May 2013 and 3rd June 2013), the different is detected mostly due to weather condition on 2nd June 2013 where having all day rain, even though the external parameters showing a close similarity for both days. It is obvious that even the data collected showing great resemblance in external parameters for selected days, the actual parameter recorded is identical and unique for every single day that can be concluded here as uncontrolled and involving complex parameters that are always different daily.

Figure 4 External solar radiation and humidity recorded for 22nd May 2013

Figure 5 External solar radiation and humidity recorded for 7th June 2013

Figure 6 External solar radiation and humidity recorded for 18th May 2013

Figure 7 External solar radiation and humidity recorded for 3rd June 2013

Figure 6 and Figure 7 shows the results obtained for intermediate mean sky (18th May 2013 and 3rd June 2013) in comparing the humidity effects due to the application of fibre optic daylighting system. The internal humidity recorded a decrease on 18th May 2013 and 3rd June 2013 which the different of humidity is about 5% in late evening compared to early morning. The experimental building is windowless and completely dark for internal light measurement that can be speculated here that during intermediate mean sky, due to moderate temperature outside and enclosed spaces using for humidity recording with no wind exchange and movement, the internal humidity can be sustained in longer period where the results shown that there is no major changes in humidity inside the building as shown in Figure 3 and Figure 4.
5.0 CONCLUSION

It can be concluded here that the fibre optic daylighting system does not significantly influence the internal relative humidity parameter since the building is totally dark and enclosed and yet no notable change were detected for internal humidity during data analysis even the external relative humidity is fluctuate.

For internal relative humidity, the research found that no notable effect from the application of fibre optic daylighting system by comparing two set of date representing Hot Sunny Day with Intermediate Blue Sky and Moderate Sunny Day with Intermediate Mean Sky through experimenting the system ON and OFF during the whole data collection process. Both heat and humidity are the parameters that influenced the human comfort in a space.

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References
