LUMINOUS ENVIRONMENT AND OCCUPANT'S SATISFACTION AT OPEN-PLAN OFFICE
(Case Study: Jawa Pos Office, Grha Pena 4th Floor, Surabaya)

Esti Asih Nurdiah[1], Asri Dinapradipta[2]
[1]Department of Architecture, Petra Christian University, Surabaya, Indonesia.
Email : estian@peter.petra.ac.id
[2]Department of Architecture, 10 Nopember Institutes of Technology, Surabaya, Indonesia.
Email: asridinapradipta@gmail.com

ABSTRACT

Open-plan office provides a spacious workspace for a wide range of work-related activities and a lot of chances to rearrange the workstation. In the workspace, a good lighting condition should be provided. Lighting is needed for work and it has a great impact on worker satisfaction, performance and productivity. For those purposes, light level must meet the minimum requirement for visual comfort. Luminous environment in office workspace will be assessed in different ways by the occupant. This research attempts to understand the effect of luminous environment at open-plan office on occupant satisfaction. The research was conducted through field study for measuring the ambient quantity of light and questionnaires for assessing occupant's satisfaction and room performance. The research found that although illuminance level at workspace was very low and not evenly distributed, most the occupants felt quite satisfied. Room design, lighting strategies and the level of occupant's perception may influence the results.

Keywords : Luminous environment, office workspace, occupant satisfaction, room quality.

INTRODUCTION

Lighting condition at office will be assessed in different ways by the occupant. It depends on the occupants' perception and human factors. Behavior, age, gender, etc. may affect the occupant's perception towards the lighting quality, thus affect worker performance and productivity. Good office lighting is a key element in assuring worker satisfaction and performance (Newsham et al, 2004).

Office building at high luminous climate, like Surabaya, can create undesirable lighting condition for the occupants due to glare, limitation of daylighting penetration, and high brightness/contrast between the room's perimeter and the room's depth. Users will react accordingly to provide themselves with devices such as blinds for avoiding this unfavorable situation. This situation commonly occurs particularly for fully-glazed office building (Capeluto et al, 2006).

For performing good daylight, especially for sidelit multi-storeys buildings, the plan depth is critical. As a rule of thumb, a room can be adequately daylit if it has a depth equal to twice of the room's ceiling height (Baker, et al, 2002). Architectural elements also play an important role in creating comfortable luminous environment. Design of openings determines the penetration of daylight, both quantitatively and qualitatively. Since light distribution is highly dependent on room reflectance, light reflected from the room's surfaces will be significant light sources, especially for deep and wide rooms, and a room with sidelit windows (Egan, et al., 2002).

Electrical lighting is needed when daylight cannot provide enough quantity of light. The satisfaction of the occupants is necessary for the acceptance of technical solution in combining daylight and electric light (Galasiu et al., 2006).

Based on IESNA recommendation, lighting level for office building, especially for typing on computer is 100-150-200 lux whereas for writing and reading is 200-300-500 lux (Robbins, 1986). Horizontal illuminance on the desk surface was the primary numerical design criterion for office lighting. With the shift in office work for paper to computer, the recommended horizontal level has been reduced. IRC found that average chosen illuminance on the desk surface were in the range of 400-500 Lux, even for those who are intensive computer users (Newsham et al, 2004). This quantity of light can be a basic parameter to determine the quality of light for office buildings.

The distribution of illuminance is a measure of how lighting varies from point to point across a plane or surface. For good visibility, some degree of uniformity across the task plane is desirable. Poor visibility and visual discomfort may result if the eye is forced to adapt too quickly to a wide range of light level (Ruck, 2000).

However, assessment on luminous environment couldn't be base only on quantity of light. The quantity of light is only one of many factors that determine how well we see and overall quality of luminous space. Each viewer and each space have

specific information needs, and each object and task have specific characteristic (Lam, 1986).

Lighting in office building is needed for fulfill the visual task. Luminous environment at office workspace needs to meet minimum intensity in order to enhance productivity and working activity and satisfy the workers. If luminous environment was poor, occupants became unsatisfied and this environment could distract working activity, decrease productivity and worker health.

A "good" visual environment is one that satisfies the visual information needs of the occupants. Poor visual environments are dominated by visual information that is irrelevant to the interests or needs of the occupants (Lam, 1986).

METHODOLOGY

The research observed the *Jawa Pos'* office building (Grha Pena Building) which is located in Surabaya - the second biggest city in Indonesia as a case study. The office located at 4th floor of Grha Pena building, a multi-storey rental office building. The building located at Ahmad Yani Street. At the south side of the building is a privat university, the north side is car-showroom, and the west side is group of housing. All those building around Grha Pena are not more than two storeys and located far enough from it. For this reason, external reflection of daylight can be ignored because the office which observed is located higher than the surrounding.

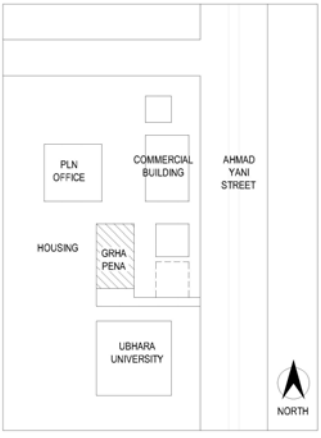

Figure 1 Location of Grha Pena Building

Jawa Pos' office was chosen because this office type is open-plan office with cubicle workstation. This office also has some specific lighting requirements. As an editorial national newspaper office, this office has a long period of working hours, almost 20 hours each day. Most working activities at this office is typing on computer, but writing and reading are principal, especially in editing the news. Also, it needs luminous environment with good color rendering to arrange the newspaper layout.

The office has a square plan. The room dimension is 36 m (width) x 32 m (depth) x 4.20 m (height). Above this floor level, there is a large void. This curve-shape void is placed at the center of the room (figure 2). The floor is creamy granite floor. The ceiling isn't covered with ceiling panel. It remains as exposed concrete slab and painted in dark blue. Some utility tools, such as fire pipes and sprinkles, ducting, etc. are installed on the ceiling (figure 4).

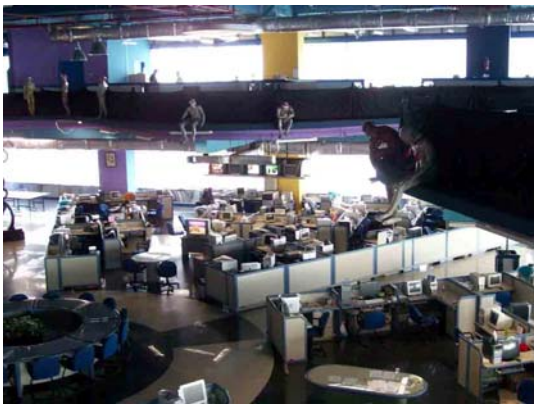

Figure 2 Room observed at Jawa Pos Office Building

Both natural light and artificial lighting are used as lighting strategy at daytime. Natural light enters the room through window at west and south sides. Glazing walls used blue tinted glass. The glasses were installed without shadings device. Window height is 2.15 m and the window sill is 0.80 cm above the floor (figure3).

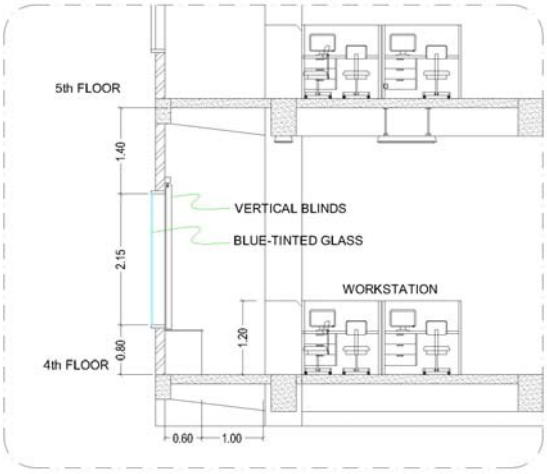

Figure 3 Window design

Artificial lighting is mostly provided by fluorescent lamps. At the center ceiling of 5th floor, a 1000 watt High Intensity Discharge (HID) lamp and 4 unit similar lamps with 250 watt of wattage are installed. At daytime, HID lamps are only used when the illumination level is low.

Figure 4 Lighting device and ceiling

The illuminance level was measured using Lutron Luxmeter LX-107 and positioned at 70 cm above floor level. The room was divided into 4 zones; each zone had 23-26 points of measurement which represents the perimeter area and the room depth. Measurement was conducted at daytime on actual lighting condition.

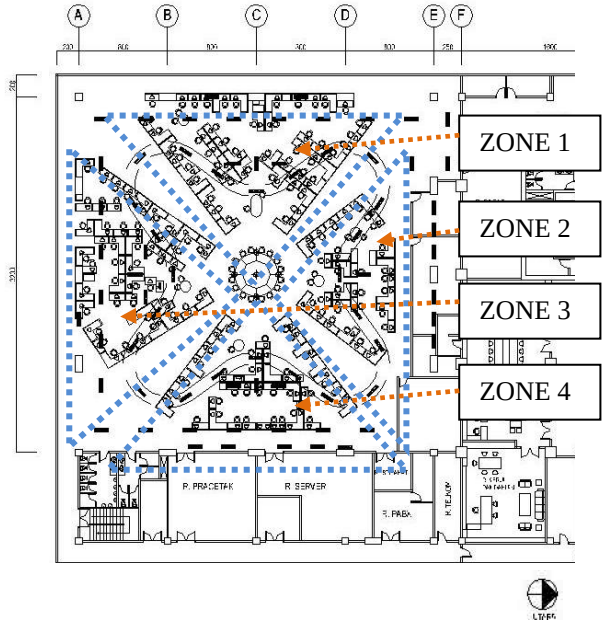

Figure 5 Lighting fixtures and cubicle workstation arrangement at Jawa Pos Office.

Questionnaires were used to assess the occupant's satisfaction. Visual need and visual comfort also taken as some factors that may influence the occupants' satisfaction. To assess visual need, occupants had been given some question about their response to the illuminance level. To assess visual comfort, the questions were designed to observe occupants response to the luminous environment. Did the occupant feel comfort with their environment or, on the contrary, they feel discomfort. Occupants were asked to record some visual discomfort, such as glare, eyes fatigue and color. Then, the occupants should make a final judgment to their luminous environment. They might be satisfied or unsatisfied.

As a newspaper office, some occupants should work outside, hunting the news and then back to the office for typing the news. Some others may stay at the office. They receive news from their correspondence or do editing job. As a result, the occupant didn't have same working period. Some occupants who usually work at morning till afternoon were chosen as research sample to evaluate the impact of natural light and the artificial light.

RESULT AND ANALYSIS

From measurement at 100 nodes, it was found that illuminance level at the office was quite low. The highest level was 290.5 Lux and it was found at zone 4. Meanwhile, the lowest level was only 13 Lux and it was found at zone 2. From measurements, the average value of illuminance level was 71.47 Lux.

Based on IESNA standard for lighting at office, the minimum illuminance level for reading was 200 Lux and for working with computer was 100 Lux. Compared to the standard, only a node at zone 4 had appropriate level for both type of working. Other 21 nodes had fulfilled only the minimum requirement for working with computer (Figure 6). Most illuminance level at measurement nodes was below 100 Lux.

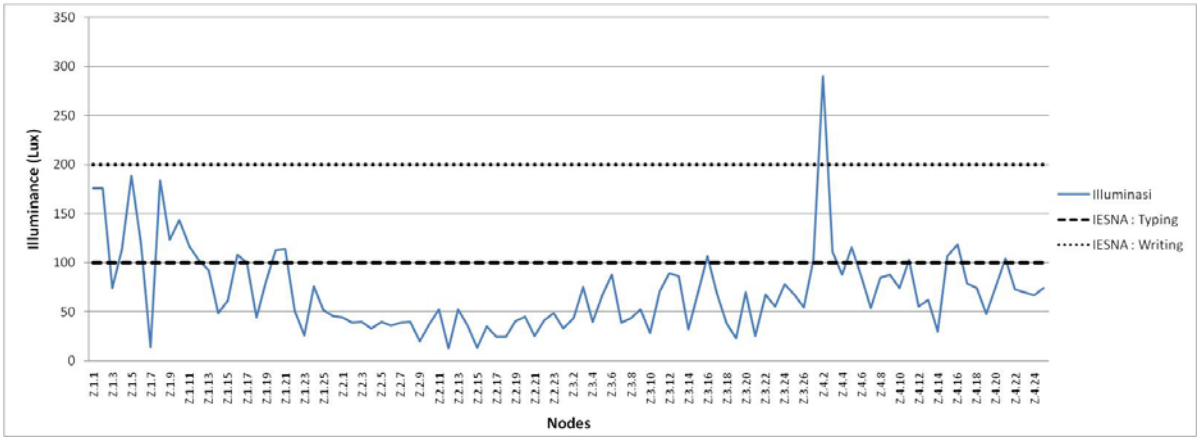

Figure 6 Illuminance level based on field measurement

Illuminance level at open plan office was also not evenly distributed. Figure 7 shows illuminance contour based on field measurement. Illuminance levels between 50-100 Lux were mostly found at the center areas of the office. However, at perimeter area, illuminance level did not always show high levels but it varies. Some area had high level, more than 200 Lux, whereas others had not more than 200 Lux. Conversely, the area at zone 2 had very poor lighting intensity, which is shown as the blue line.

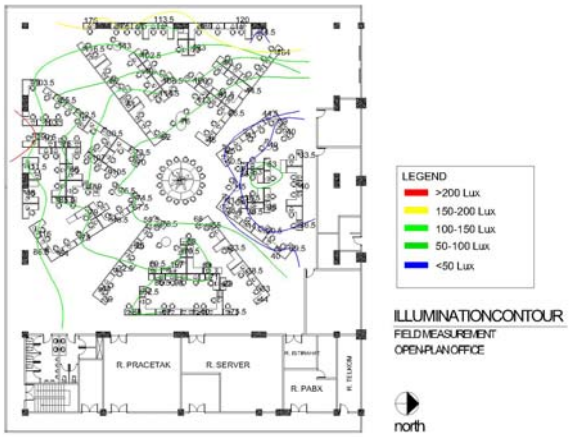

Figure 7 Illuminance contour based on field measurement

Measurement of Daylight Factor (DF) values was conducted by comparing indoor illuminance level and outdoor illuminance level. The measurement showed/indicated that the average value was only 0.21%. All nodes were under 1%, the highest level was 0.85% and the lowest was only 0.06% (Figure 8). From the data, illuminance level at indoor was much lower than outdoor illuminance. The highest outdoor illuminance could reach 52,600 Lux. On the other hand, indoor illuminance is mostly at the average of 100-200 Lux or even below that value.

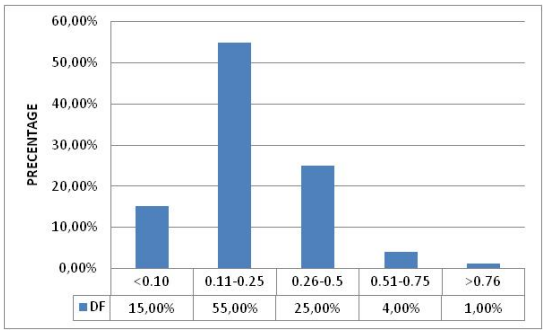

Figure 8 DF based on field measurement

All those phenomena could affect occupant's satisfaction and also produce visual discomfort, such as glare. Glare could happen because of high luminous intensity at window area and whereas lower luminous intensity at worker workstations.

Assessment on luminous environment using questionnaires indicated different results with the field measurement. Almost 37.50% occupants said that those illuminance levels at their workplanes were sufficient, 59.38% felt average, and the rest (3.13%) said that the illuminance levels were low. The occupants' activity were mostly working with computer, but they were also doing reading and writing activities.

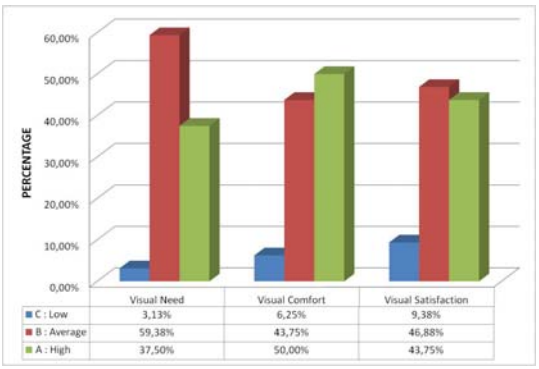

Figure 9 Percentage of occupant response to luminous environment

In terms of the occupants' satisfaction on luminous environment, it is revealed that 43.75% of the occupants felt satisfied, 46.88% felt average and only 9.38% of the occupants felt unsatisfied. Although most of the occupant felt satisfied, visual discomfort still occured frequently. Almost 62.50% occupants felt visual discomfort such as eyes fatigue, glare, and have difficulties to define color tones correctly.

Eventhough eyes fatigue can happen due to poor thermal environment and HVAC system, luminous environment also plays a role. It was shown from field observation that the occupants had made an adjustment with low illuminance level by increasing the desktop luminance. Consequently, their eyes should be adjusted to the fluctuated illuminance most of the time and they became exhausted.

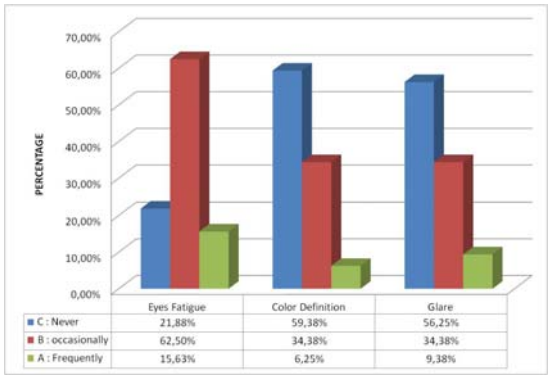

Figure 10 Percentage of visual discomfort

The occurence of glare was also measured from field measurement. The interesting phenomena of glare were the glare source. About 50% of the occupants, who noticed glare, asserted that the glare happened due to sun position. This condition always happens at afternoon because this room has a large window at the west side.

On the other hand, 31.25% of the occupants said that glare mostly happened due to high differences between illuminance level at window or perimeter area and at their work desk.

Vertical blinds were reasonable and easy means to solve that glare problem. As a consequence, almost the entire days, the room was covered with the blinds. Another visual discomfort was difficulties to define color tones. Those conditions were very annoying because the occupants were editorial staff of the national newspaper that had to arrange the newspaper layout and color tones. The difficulties to define color tones might happen due to inappropriate lighting fixtures types.

Architectural implication

Lighting, both daylight and electrical, will not perform well to provide a good luminous environment without a good room design. Office room, as a space for working, affects luminous environment in specific ways. Design elements, such as plan, property of surface and windows design, can both reduce and increase lighting quality in the office room.

Jawa Pos office room had the plan ratio of 9:8, and the room height of 4.20m. Window height is 2.15m and it is installed without shading device. Daylight from window decreases significantly at the perimeter area. Even though many electrical lighting fixtures had been installed, illuminance level could not be higher than 200 Lux (figure 11).

The room had properties of surfaces (table 1). The wall was painted in dark color such as dark blue, orange and violet. Meanwhile, the ceiling was not covered by ceiling panel and was painted dark blue.

Colors always have a great impact on visual perception and give specific meaning to the room. Colors and surface reflectances also affect the illuminance level and lighting distribution in the room. Higher surface reflectance can distribute light better. Due to low surface reflectance particularly the color of ceiling, the illuminance level at Jawa Pos office was in average very low.

Moreover, the void which is placed at the center of the room can cause poor lighting condition for the workstations below. Although at the 5th floor ceiling had been installed several HID lamps, illuminance level at 4th floor was low because the distance between lamps and workplane was too far. It was worsened since the lamps were only turned on when light condition was very low, such as when there is overcast condition, and at night. As a result, the workstation still experienced insufficient illumination.

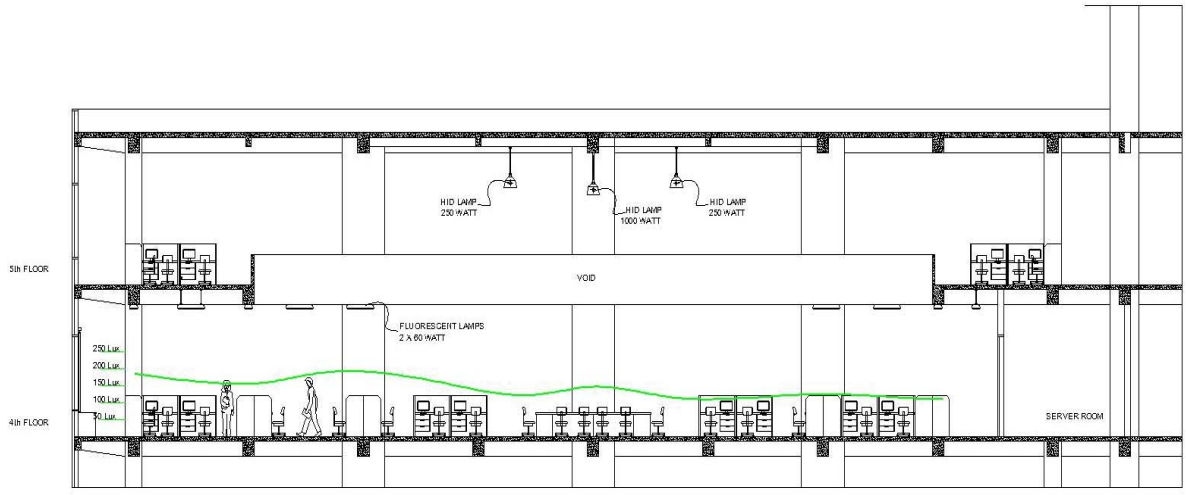

Figure 11 Room elevation and vertical illumination contour

Table 1
Property of Surfaces

Elements	Material	Color	Reflectance (%)	Specularity (%)	Roughness (%)	Transmittance (%)
Wall	Gypsum/Plastered	Dark Blue	4.11	-	-	-
		Yellow	58.24	-	-	-
		Violet	39.17	-	-	-
Ceiling	Plastered	Dark Blue	4.11	-	-	-
Floor	Marble	Creamy brown	25.9	3	2	-
Vertical blinds	Fabrics	Light blue	45	-	-	13.8

Windows, as daylight access, ware laminated glass. The glass color was blue and had visible transmittance value of 64.7%. The windows without shading were installed at north and west side of the room. The windows were mostly shut with vertical blinds. Vertical blinds were opened only at overcast condition. When outdoor was too bright, vertical blinds should be shut in order to avoid glare. The window area was too bright whereas the working area was too dim (Figure 12). That condition could trigger visual discomfort like glare.

Figure 12 Luminous environment at Jawa Pos office.

Lighting strategy

Generally, lighting strategy at Jawa Pos office could be classified as general or ambient lighting because there was an attempt to provide uniform lighting condition using uniform lamps type. Meanwhile, HID lamps at the center of the room provided local lighting below the void area. The effect of this lighting strategy produced various illuminance levels. Some workstations could receive good lighting condition but the others could not.

Daylighting has a complete color spectrum, thus gives better color rendering than electrical lighting. At Jawa Pos office, lighting was provided by electrical lighting fixtures. Then, luminous environment depended on the lighting quality, such as color rendering index (CRI) and also color temperature (CT) of the lamps.

Fluorescent lamps, as dominant lighting, failed to give good luminous environment. Based on the factory specification, Fluorescent lamps had CRI 95 and CT 3000K. CRI value was quite good and gave a good color rendering to the room. CT value was quite good but it was too low. 3000K was minimum level of CT and the color could be yellowish. Besides, the arrangement on the ceiling was disturbed by utility pipes. Some utility pipes, like ducting, fire sprinkler pipes and also electricity cables, were also installed on the ceiling. As a consequence, some lighting fixtures were laid among the utility pipes. As a result, lighting brightness was reduced.

HID lamps also could not give better luminous environment. Based on factory specification, HID lamps type HPL-N mercury had CRI 36 and CT 3900K. CRI value was too low, that was why some occupants felt some difficulties in defining color tones. This type of lamp does not have a complete color spectrum (figure 13). There is some missing colors at the color band.

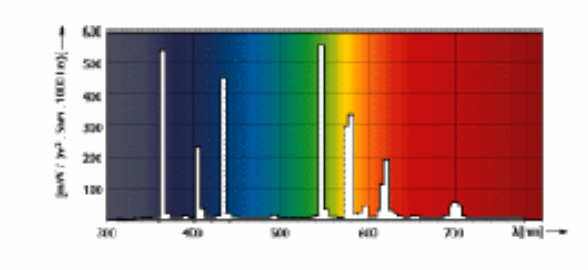

Figure 13 Color spectrum of HID Lamps, HPL-N Mercury. (http://www.prismaecat.lighting.philips.com).

Human perception

Even though the field measurement indicated that illuminance level was very low and did not meet the minimum standard for office task, most of the occupants felt satisfied. Furthermore, even though questionnaires revealed the occupants experienced visual discomfort, they still felt satisfied. These conditions might happen due to the differences in human perception, such as habits, age, gender, etc.(Lam, 1977)

Based on questionnaires' results, some occupants who had been working less than 1 year and more than 10 years could objectively assess the luminous environment. They complained about the poor lighting condition and some visual discomforts. However, some occupants who had been working between 1 until 10 years just felt satisfied. Although they had adapted to the lighting condition in the beginning, after long period of time, their eyes became fatigue and they could assess their luminous environment more clearly.

Occupants' age also affected the assessment. Young workers could tolerate poor lighting condition than old workers. Most occupants were between 20 – 30 years old. So, most occupants still had a good visual adaptation. That was why questionnaires showed that these occupants mostly did not bother with the poor lighting conditions.

CONCLUSION

Luminous environment at Jawa Pos office, generally and quantitatively can be categorized as a bad environment. The illuminance level mostly did not meet the minimum requirement for office working tasks and it was not evenly distributed. However, most of the occupants felt quite satisfied with the luminous environment, even though some visual discomfort might occurred.

The questionnaires revealed that the occupant didn't response luminous environment similar to the quantitative assessment. Habit and adaptation ability might affect the occupant's perception to the luminuos environment. However, a good luminous environment should give satisfaction to all the occupants and minimize ambiguity and visual discomfort. From this point of view, the authors conclude that luminous environment at Jawa Pos office have not provided a good environment.

We would also like to emphasize that architect's decision to the design of the room can affect the luminous environment and the occupants' satisfaction. For example, the color of room's surface can reduce the surfaces ability to reflect light and also produce uncomfortable condition, such as glare, due to the high differences between illuminance level at perimeter area and room depth. That was why the illuminance levels at Jawa Pos office were very low. Furthermore, window design, in this case is one without shading devices, failed to provide optimal daylighting since the window were always covered by vertical blinds due to glare from outside.

Finally, awareness of room design, lighting strategy, and also the occupants' habit should be considered in designing a good luminous environment. The quality of luminous environment cannot only be assessed quantitatively because value judgment of the occupants' perception on their luminuos environment is also important in determining good luminuos environment.

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