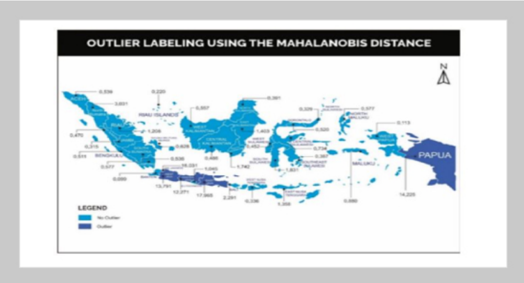
# Volume 25, Issue 1



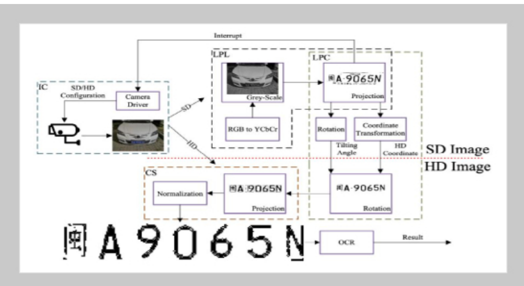

Outlier Labeling Using the Mahalanobis Distance

## Minimum Vector Variance Estimator in Outlier labeling of Multivariate Data: Application to HIV patient in Indonesia (/articles/jase-202202-25-1-0002)

(/articles/jase-202202-25-1-0002)

2022 - Volume 25 (/articles/25)

Volume 25, Issue 1 (/Articles/25/1) 05 July 2021 Reach: 1239



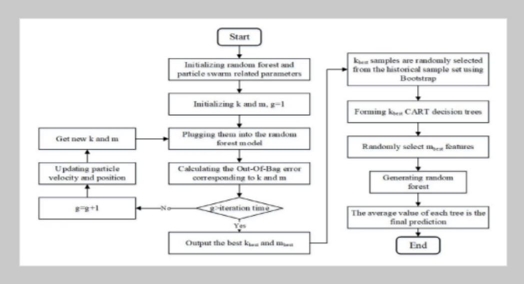

Hardware block diagram

## Real-Time High Definition License Plate Localization and Recognition Accelerator for IoT Endpoint System on Chip (/articles/jase-202202-25-1-0001)

(/articles/jase-202202-25-1-0001)

2022 - Volume 25 (/articles/25)

Volume 25, Issue 1 (/Articles/25/1) 05 July 2021 Reach: 1372



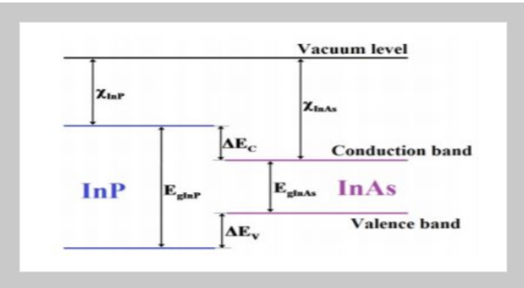

The structure of new RF

## Grey correlation-oriented Random Forest and Particle Swarm Optimization Algorithm for Power Load Forecasting (/articles/jase-202202-25-1-0003)

(/articles/jase-202202-25-1-0003)

2022 - Volume 25 (/articles/25)

Volume 25, Issue 1 (/Articles/25/1) 05 July 2021 Reach: 1178



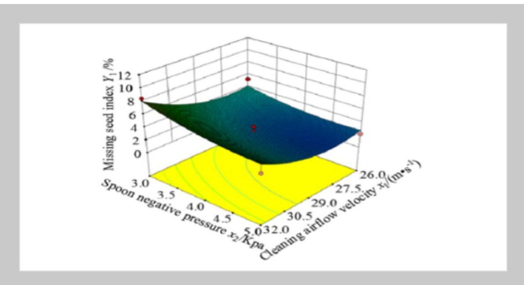

InP/InAs zone diogram

## Calculation of the energy levels and wave functions of electrons in nanowires by the shooting method (/articles/jase-202202-25-1-0004)

(/articles/jase-202202-25-1-0004)

2022 - Volume 25 (/articles/25)

Volume 25, Issue 1 (/Articles/25/1) 06 July 2021 Reach: 338



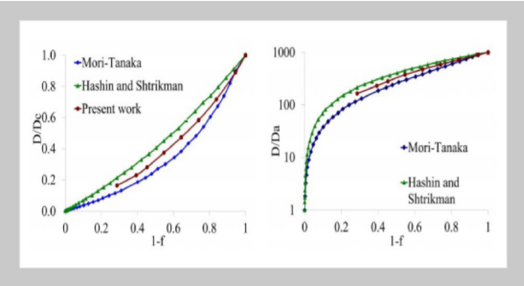

The interactive effect of cleaning airflow velocity x1 and spoon negative pressure x2 on the missing seed index Y1

## Design and Test of Pneumatic Cleaning System for Potato Micro-seed Seeding (/articles/jase-202202-25-1-0005)

(/articles/jase-202202-25-1-0005)

2022 - Volume 25 (/articles/25)

Volume 25, Issue 1 (/Articles/25/1) 07 July 2021 Reach: 1249



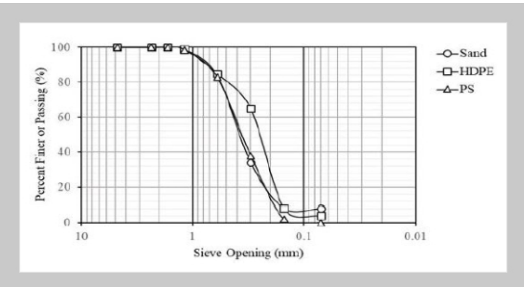

Diffusivity coefficient of concrete (D) versus aggregate volume fraction (1-f )

# Lattice Mesoscale modelling of Chloride Penetration in Concrete: Effect of aggregate volume fraction and fly ash (/articles/jase-202202-25-1-0006)

(/articles/jase-202202-25-1-0006)

2022 - Volume 25 (/articles/25)

Volume 25, Issue 1 (/Articles/25/1) 09 July 2021 Reach: 1228



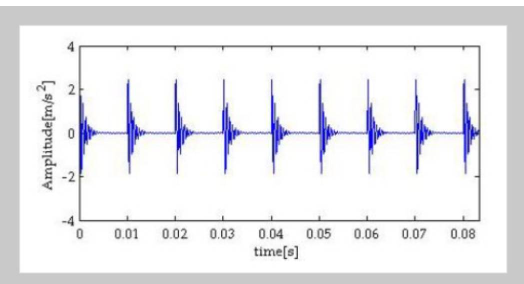

Size distribution of recycled plastic waste compared to sand

# Properties of Mortar Composites from Plastic Waste (/articles/jase-202202-25-1-0007)

(/articles/jase-202202-25-1-0007)

2022 - Volume 25 (/articles/25)

Volume 25, Issue 1 (/Articles/25/1) 12 July 2021 Reach: 1489



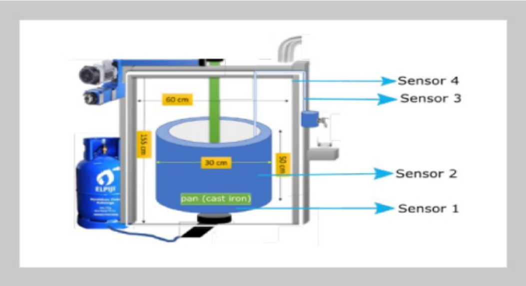

# A fault feature extraction algorithm based on CEEMD-TVD-MOMEDA (/articles/jase-202202-25-1-0008)

Original signal

(/articles/jase-202202-25-1-0008)

2022 - Volume 25 (/articles/25)

Volume 25, Issue 1 (/Articles/25/1) 12 July 2021 Reach: 1124



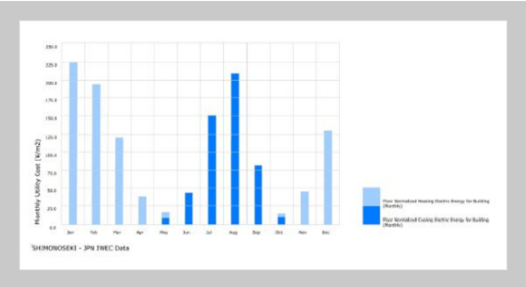

Sensor placement

# IoT Based Less-Contact System on Sauce Production for Small Enterprises (/articles/jase-202202-25-1-0009)

(/articles/jase-202202-25-1-0009)

2022 - Volume 25 (/articles/25)

Volume 25, Issue 1 (/Articles/25/1) 12 July 2021 Reach: 436



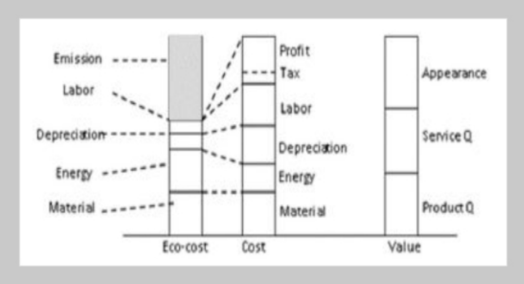
Monthly utility costs for minimum surface radiation model.

# Computational Approach in Investigating Surface and Site Radiation in the Early Phase of Designing Two-Story Wooden House in Orio District, Kitakyushu, Japan (/articles/jase-202202-25-1-0010)

(/articles/jase-202202-25-1-0010)

2022 - Volume 25 (/articles/25)

Volume 25, Issue 1 (/Articles/25/1) 18 July 2021 Reach: 429



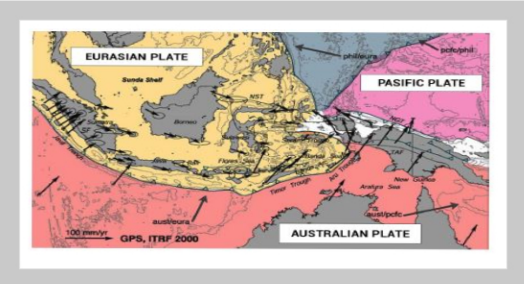

Eco-Cost Concept [19].

# A Calculation Approach of Embodied Energy, Carbon Emission and Eco-Costs on Waste Recycled Composite Materials (/articles/jase-202202-25-1-0011)

(/articles/jase-202202-25-1-0011)

2022 - Volume 25 (/articles/25)

Volume 25, Issue 1 (/Articles/25/1) 18 July 2021 Reach: 356



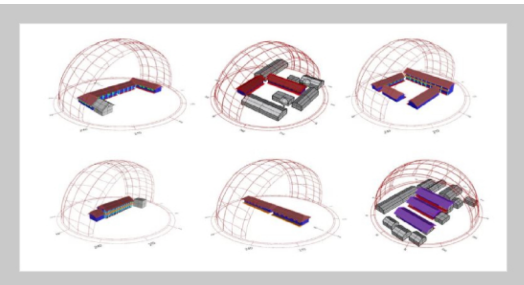

Tectonic Map of Indonesia Source: Meteorology Climatology and Geophysics Council, 2020

# Local Wisdom as a Sustainable Building Solution: Bamboo Incremental House Design Concept (/articles/jase-202202-25-1-0012)

(/articles/jase-202202-25-1-0012)

2022 - Volume 25 (/articles/25)

Volume 25, Issue 1 (/Articles/25/1) 19 July 2021 Reach: 390



Some digital modelling representation, for school objects in Rhinoceros with additional sun paths were added using Ladybug tools

# Daylight Annual Illuminance Investigation in Elementary School Classrooms for the Tropic of Lhokseumawe, Indonesia (/articles/jase-202202-25-1-0013)

(/articles/jase-202202-25-1-0013)

2022 - Volume 25 (/articles/25) Volume 25, Issue 1 (/Articles/25/1) 19 July 2021

Reach: 1707

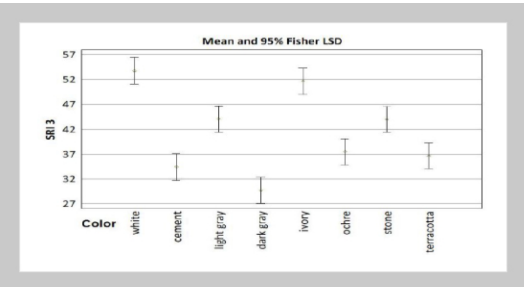

Condition for Simulation.

## Natural Ventilation Optimization Study in Mechanically Ventilated Studio Apartment Room in Surabaya (/articles/jase-202202-25-1-0014)

(/articles/jase-202202-25-1-0014)

2022 - Volume 25 (/articles/25)

Volume 25, Issue 1 (/Articles/25/1) 19 July 2021 Reach: 1278




SRI3 means graph of the color variable, according to Fisher's LSD method (95% IC). Sources: Author's own work.

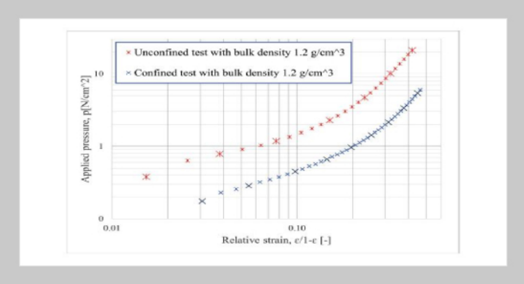
## Mathematical models to assessment the energy performance of textured cladding for facades (/articles/jase-202202-25-1-0015)

(/articles/jase-202202-25-1-0015)

2022 - Volume 25 (/articles/25)

Volume 25, Issue 1 (/Articles/25/1) 19 July 2021 Reach: 1121

## Soil behavior of shallow homogenous upper layer soil (/articles/jase-202202-25-1-001




Comparison of the pressure-strain curve of the confined and unconfined test at a water content of 8% and bulk density of 1.2 g/cm3

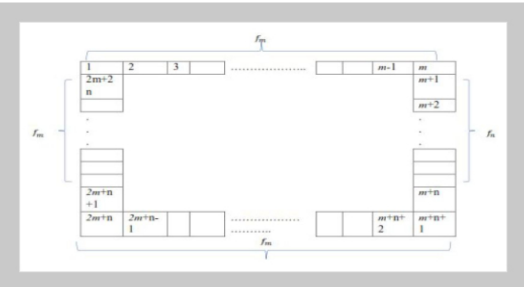
(/articles/jase-202202-25-1-0016)

2022 - Volume 25 (/articles/25)

Volume 25, Issue 1 (/Articles/25/1) 19 July 2021 Reach: 1010

---

# Formulated New Identities of Fibonacci Numbers with James Abacus Diagram (/articles/jase-202202-25-1-0017)



chain boards

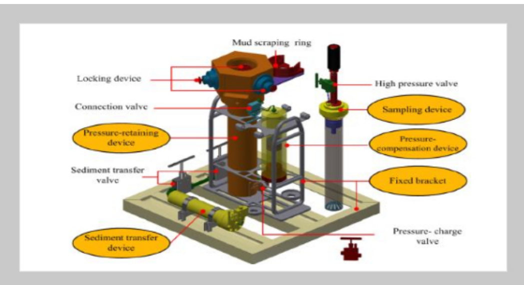
(/articles/jase-202202-25-1-0017)

2022 - Volume 25 (/articles/25)

Volume 25, Issue 1 (/Articles/25/1) 19 July 2021 Reach: 274

---

# Reliability Assessment of a Full-ocean-depth Pressure-retaining Sediment Sampler Using Fault Tree Analysis (/articles/jase-202202-25-1-0018)

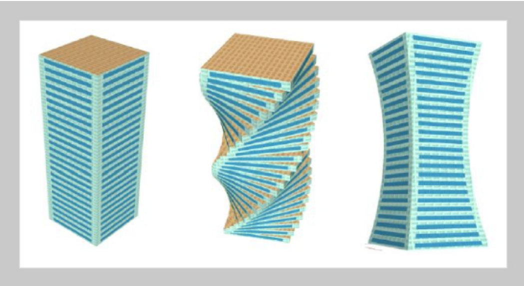



Structure of the pressure-retaining sampler

(/articles/jase-202202-25-1-0018)

2022 - Volume 25 (/articles/25)

Volume 25, Issue 1 (/Articles/25/1) 19 July 2021 Reach: 226



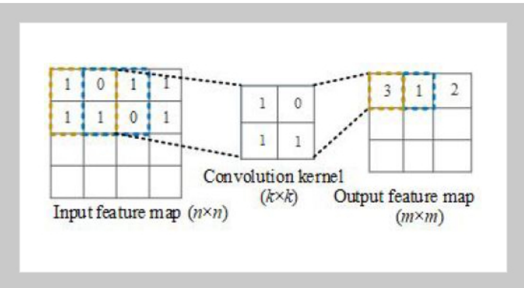
The selected models (extruder, twister, rotor)

## Heat Transfer in the Universal Form of High-rise Buildings in Various Climate Zones (/articles/jase-202202-25-1-0019)

(/articles/jase-202202-25-1-0019)

2022 - Volume 25 (/articles/25)

Volume 25, Issue 1 (/Articles/25/1) 20 July 2021 Reach: 295



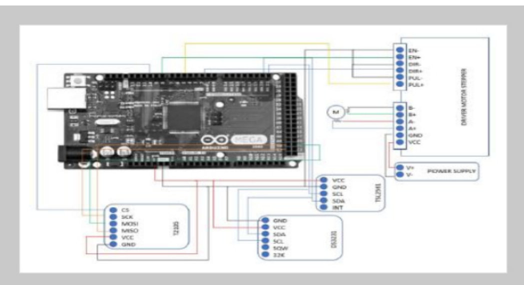

Principle diagram of convolution process

## Application of Convolutional Neural Network in Fault Line Selection of Distribution Network (/articles/jase-202202-25-1-0020)

(/articles/jase-202202-25-1-0020)

2022 - Volume 25 (/articles/25)

Volume 25, Issue 1 (/Articles/25/1) 23 July 2021 Reach: 1117



## Development of the Automated Shading Device: Its Effects on the Indoor Thermal Environments (/articles/jase-202202-25-1-0021)

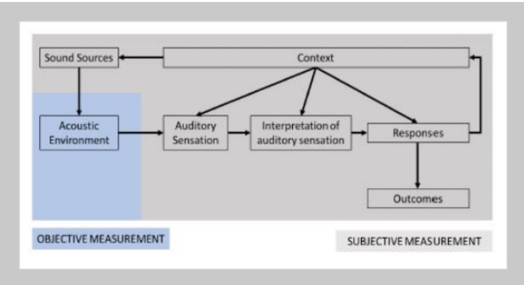
Configuration of sensors and acquisition datasystem.

(/articles/jase-202202-25-1-0021)

2022 - Volume 25 (/articles/25)

Volume 25, Issue 1 (/Articles/25/1) 10 August 2021 Reach: 218

---




Soundscape Framework. Adapted from ISO 12913- 1 [4].

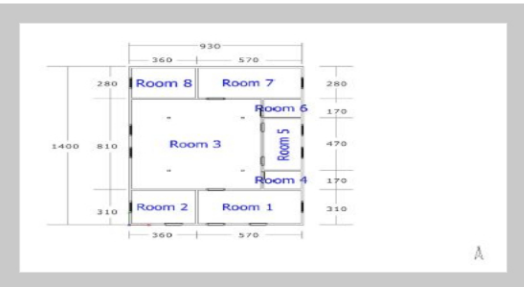
## The Development of Standard Perceptual Attributes in Indonesian for Soundscape Evaluation: Result from Initial Study (/articles/jase-202202-25-1-0022)

(/articles/jase-202202-25-1-0022)

2022 - Volume 25 (/articles/25)

Volume 25, Issue 1 (/Articles/25/1) 10 August 2021 Reach: 267

---



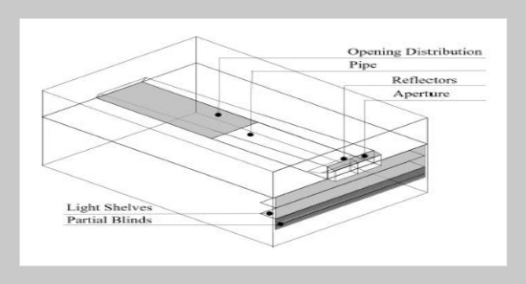

Stilt house plan.

## Natural Daylighting Performance at Stilt House in Jambi City (/articles/jase-202202-25-1-0023)

(/articles/jase-202202-25-1-0023)

2022 - Volume 25 (/articles/25)

Volume 25, Issue 1 (/Articles/25/1) 10 August 2021 Reach: 276



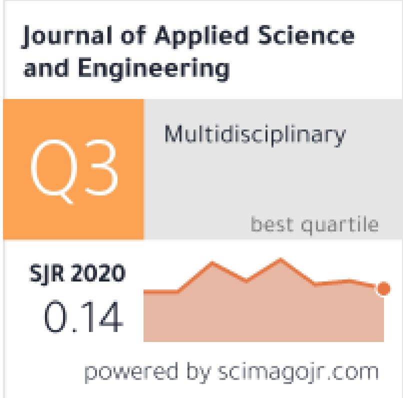

Integration of Horizontal Light Pipe and Shading Systems (Author’s own work, Lim et al., 2012 [8]).

# Integration of Horizontal Light Pipe and Shading Systems in Office Building in the Tropics (/articles/jase-202202-25-1-0024)

(/articles/jase-202202-25-1-0024)

2022 - Volume 25 (/articles/25)

Volume 25, Issue 1 (/Articles/25/1) 11 August 2021 Reach: 314




## Search keywords

## Most Popular Articles

Daylight Annual Illuminance Investigation in Elementary School Classrooms for the Tropic of Lhokseumawe, Indonesia (/articles/jase-202202-25-1-0013)
(Volume 25, Issue 1 (/articles/25/1))
Read More ... (/articles/jase-202202-25-1-0013)

Properties of Mortar Composites from Plastic Waste (/articles/jase-202202-25-1-0007)
(Volume 25, Issue 1 (/articles/25/1))
Read More ... (/articles/jase-202202-25-1-0007)

Real-Time High Definition License Plate Localization and Recognition Accelerator for IoT Endpoint System on Chip (/articles/jase-202202-25-1-0001)
(Volume 25, Issue 1 (/articles/25/1))
Read More ... (/articles/jase-202202-25-1-0001)

Natural Ventilation Optimization Study in Mechanically Ventilated Studio Apartment Room in Surabaya (/articles/jase-202202-25-1-0014)
(Volume 25, Issue 1 (/articles/25/1))
Read More ... (/articles/jase-202202-25-1-0014)

## Research Categories

Computer Science and Information Engineering (/articles/categories/computer-science)

Electrical Engineering (/articles/categories/electrical)

Mechanical Engineering (/articles/categories/mechanical) Civil Engineering (/articles/categories/civil)

Mathematics / Statistics (/articles/categories/mathematics)

Chemical Engineering (/articles/categories/chemical)

Material Engineering (/articles/categories/material)

Electro-Mechanical Engineering (/articles/categories/electro-mechanical)

Physics (/articles/categories/physics) Chemistry / Biochemistry (/articles/categories/chemistry)

Environmental Engineering (/articles/categories/environmental)

Aerospace Engineering (/articles/categories/aerospace)

Water Resources Engineering (/articles/categories/water-resources)

Enter your name and email below to receive latest published articles in Journal of Applied Science and Engineering.

Enter your name

Enter your email

Subscribe

*Journal of Applied Science and Engineering*

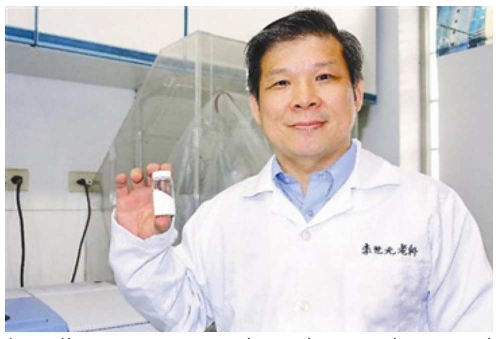
*Published by Tamkang University Press*

# Editorial Board


(https://scholar.google.com/citations?user=AAjx9vYAAAAJ&hl=en)

**Le Ngoc Chung (https://scholar.google.com/citations?user=AAjx9vYAAAAJ&hl=en)**

Dalat University, Vietnam


(http://www2.tku.edu.tw/~tscx/chinese/teachers/teacher_view.php?id=13)

**Adam Shih-Yuan Lee (http://www2.tku.edu.tw/~tscx/chinese/teachers/teacher_view.php?id=13)**

Tamkang University, Taiwan


(https://www.researchgate.net/profile/Cheng-Lan-Lin)

**Cheng-Lan Lin (https://www.researchgate.net/profile/Cheng-Lan-Lin)**

Tamkang University, Taiwan

(https://www.linkedin.com/in/cheng-lan-lin-61121897/) (https://orcid.org/0000-0002-5601-9064) (https://www.researchgate.net/profile/Cheng-Lan-Lin)

## Civil and Environmental Engineering


(http://www.ce.tku.edu.tw/main/?q=node/281)

**Zon-Yee Yang (http://www.ce.tku.edu.tw/main/?q=node/281)**

Tamkang University, Taiwan

(https://orcid.org/0000-0001-5699-7581)


(https://docenti.unisa.it/020364/en/curriculum)

**Vincenzo Naddeo (https://docenti.unisa.it/020364/en/curriculum)**

University of Salerno, Italy

(https://www.linkedin.com/in/vnaddeo/?originalSubdomain=it) (https://orcid.org/0000-0002-3395-3276) (https://www.researchgate.net/profile/Vincenzo_Naddeo)


(https://www.linkedin.com/in/noroozinejad/?originalSubdomain=ir)

**Ehsan Noroozinejad (https://www.linkedin.com/in/noroozinejad/?originalSubdomain=ir)**

Graduate University of Advanced Technology, Iran

(https://www.linkedin.com/in/noroozinejad/?originalSubdomain=ir) (https://orcid.org/0000-0002-2790-526X) (https://www.researchgate.net/profile/Ehsan_Farsang


(https://www.linkedin.com/in/chein-chi-chang-97638b5/)

**Chein-Chi Chang (https://www.linkedin.com/in/chein-chi-chang-97638b5/)**

D. C. Water and Sewer Authority, USA

(https://www.linkedin.com/in/chein-chi-chang-97638b5/)


(https://www.sc.edu/study/colleges_schools/engineering_and_computing/faculty-staff/bayat_mahmoud.php)


**Mahmoud Bayat (https://www.sc.edu/study/colleges_schools/engineering_and_computing/faculty-staff/bayat_mahmoud.php)**

University of South Carolina, USA

(https://www.linkedin.com/in/mahmoud-bayat-694b0a51/) (https://orcid.org/0000-0002-0990-7077) (https://scholar.google.com/citations?user=vnRTUhgAAAAJ&hl=en)



(https://orcid.org/0000-0002-8257-2779)


**Li-Chiu Chang (https://orcid.org/0000-0002-8257-2779)**

Tamkang University, Taiwan

(https://www.linkedin.com/in/li-chiu-chang-11680a36/?originalSubdomain=tw) (https://orcid.org/0000-0002-8257-2779) (https://www.researchgate.net/profile/Li-Chiu-Chang)


## Mechanical Engineering and Aerospace/Aeronautical Engineering


(https://scholar.google.com/citations?user=s7HndsYAAAAJ&hl=zh-TW)


**Yi-Ren Wang (https://scholar.google.com/citations?user=s7HndsYAAAAJ&hl=zh-TW)**

Tamkang University, Taiwan

(https://www.linkedin.com/in/yi-ren-wang-5a766b130/?originalSubdomain=tw) (https://www.researchgate.net/profile/Yi_Ren_Wang)



(https://sites.google.com/view/drweihecv/home)


**Wei He (https://sites.google.com/view/drweihecv/home)**

University of Science and Technology Beijing, China

(https://www.linkedin.com/in/wei-he-43a4a126/?originalSubdomain=cn) (https://www.researchgate.net/profile/Wei_He29)


## Electrical Engineering and Computer Engineering

(http://see.knu.ac.kr/mobile/english/content/profile_eng.html?id=182)

**Min Young Kim (http://see.knu.ac.kr/mobile/english/content/profile_eng.html?id=182)**

Kyungpook National University, Korea

(https://www.researchgate.net/profile/Min_Young_Kim3)

(https://sites.google.com/view/ycchen)

**Yi-Cheng Chen (https://sites.google.com/view/ycchen)**

National Central University, Taiwan

(https://wireless.csie.tku.edu.tw/~cychang/)

**Chih-Yung Chang (https://wireless.csie.tku.edu.tw/~cychang/)**

Tamkang University, Taiwan

(https://orcid.org/0000-0002-0672-5593)

(https://www.researchgate.net/profile/Chih-Yung_Chang)

(http://www.ee.tku.edu.tw/teachers/%E6%9D%8E%E7%B6%AD%E8%81%B0/)

**Wei-Tsong Lee (http://www.ee.tku.edu.tw/teachers/%E6%9D%8E%E7%B6%AD%E8%81%B0/)**

Tamkang University, Taiwan

(https://www.researchgate.net/profile/C_Bharatiraja)

**Bharatinaja Chokkalingam (https://www.researchgate.net/profile/C_Bharatiraja)**

SRM Institute of Science and Technology, India

(https://orcid.org/0000-0003-2517-2119)

(https://www.researchgate.net/profile/C-Bharatiraja)

(https://ieeexplore.ieee.org/author/37267411600)

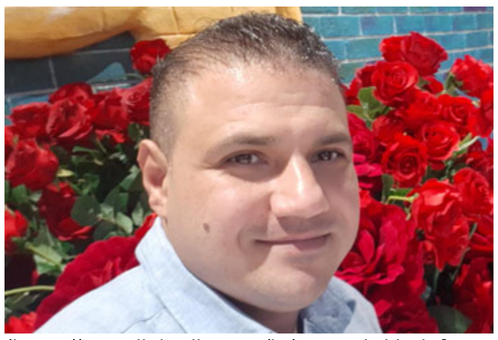
**Kuei-Ping Shih (https://ieeexplore.ieee.org/author/37267411**

Tamkang University, Taiwan

(https://www.linkedin.com/in/kuei-ping-shih-77835613/?originalSubdomain=tw)

(/ https://orcid.org/0000-0002-5060-9266)

(https://www.researchgate.net/profile/Kuei-Ping_Shih)



(https://www.linkedin.com/in/osamah-khalaf-63037758/)

**Osamah Ibrahim Khalaf (https://www.linkedin.com/in/osamah-khalaf-63037758/)**

Al-Nahrain University, Iraq

(https://www.linkedin.com/in/osamah-khalaf-63037758/)

# Editorial Advisory Board

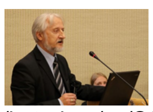
(https://www.vu.lt/en/scientific-report-2016/faculties-and-institutes/institute-of-mathematics-and-informatics)

**Adolfas Laimutis Telksnys**

(https://en.wikipedia.org/wiki/Akira_Fujishima)

**Akira Fujishima**

The University of Tokyo, Japan



(http://www.mif.vu.lt/katedros/cs/Staff/Mitasiunas.htm)

**Antanas Mitasiunas**

Vilnius University, Lithuania

(https://en.wikipedia.org/wiki/Bang-Yen_Chen)

**Bang-Yen Chen**

Michigan State University, USA.

(http://ww ... p=379&lang=en&fbclid=IwAR3 ... ECpXDkuLB-V2WJoi

**Duu-Jong Lee**

National Taiwan Univer

**Journal of Applied Science and Engineering** has published over 1,000 peer-reviewed articles. Enter your email address to receive latest updates and published articles.

First Name * Last Name *

Enter your email

Subscribe

**About JASE**

Organization (/about/organization)
Aims and Scope (/about/aims)
Editor's Letter (/about/editors-letter)
Editorial Board (/about/editors)
News (/news)
(https://www.linkedin.com/company/journal-of-applied-science-and-engineering/)
(https://www.facebook.com/JournalofAppliedScienceandEngineering/)

**Articles**

(/articles/just-accepted)

Latest Articles (/articles)
List of Issues (/articles/issues)
Research Categories (/articles/categories)
Submit Your Research (https://mc04.manuscriptcentral.com/jase)

### Publisher

Huan-Chao Keh (http://www.tku.edu.tw/about/leaders/President/index_eng.asp)
Tamkang University Press (http://www.tkupress.tku.edu.tw/index.html)ISSN: 2708-9975 (Online) (https://portal.issn.org/resource/ISSN/2708-9975)
ISSN: 2708-9967 (Print) (https://portal.issn.org/resource/ISSN/2708-9967)

E714, 151, Yingzhuan Rd., (https://goo.gl/maps/H9YF9j5JbBVoZiUc9)
Tamsui Dist., New Taipei City, 25137, Taiwan, R.O.C. (https://goo.gl/maps/H9YF9j5JbBVoZiUc9)
Tel: 886-2-2620-2947 (https://goo.gl/maps/H9YF9j5JbBVoZiUc9)

# Source details

## Journal of Applied Science and Engineering (Taiwan)

Formerly known as: Journal of Applied Science and Engineering

Scopus coverage years: from 2021 to 2022

Publisher: Tamkang University
ISSN: 2708-9967 E-ISSN: 2708-9975

Subject area: Multidisciplinary Engineering: General Engineering

Source type: Journal

CiteScore 2020
0.7

SNIP

View all documents > Set document alert Save to source list Source Homepage

CiteScore CiteScore rank & trend Scopus content coverage

i Improved CiteScore methodology

CiteScore 2020 counts the citations received in 2017-2020 to articles, reviews, conference papers, book chapters and data papers published in 2017-2020, and divides this by the number of publications published in 2017-2020. Learn more >

### CiteScore 2020

$$0.7 = \frac{\text{187 Citations 2017 - 2020}}{\text{283 Documents 2017 - 2020}}$$

Calculated on 05 May, 2021

### CiteScoreTracker 2021

$$0.7 = \frac{\text{246 Citations to date}}{\text{333 Documents to date}}$$

Last updated on 04 November, 2021 • Updated monthly

### CiteScore rank 2020

| Category | Rank | Percentile |
|---|---|---|
| Multidisciplinary<br>└ Multidisciplinary | #74/110 | 33rd |
| Engineering<br>└ General Engineering | #237/297 | 20th |

View CiteScore methodology > CiteScore FAQ > Add CiteScore to your site

# Integration of Horizontal Light Pipe and Shading Systems in Office Building in the Tropics

Feny Elsiana[1,3], Sri Nastiti N. Ekasiwi[2*], and I Gusti Ngurah Antaryama[2]

[1] Doctoral Student, Department of Architecture, Institut Teknologi Sepuluh Nopember
[2] Department of Architecture, Institut Teknologi Sepuluh Nopember
[3] Department of Architecture, Petra Christian University
[*] Corresponding author. E-mail: nastiti@arch.its.ac.id

Received: Dec. 14, 2020; Accepted: Feb. 14, 2021

Many high-rise office buildings in the tropics have a full-glazed façade and a deep open-plan space. Without any external shading, the office space has a non-uniform daylight distribution and glare problem. A deep open-plan space design also causes insufficient daylight levels in the area distant from the building perimeter. Previous studies about Horizontal Light Pipe (HLP) mainly focused on system improvement in capturing, transporting, and distributing daylight into deep space. Integration of HLP as a light transport system that can deliver daylight deeper into building interiors and shading systems consist of Light Shelf (LS), blinds that can redirect and reduce the excessive daylight level near the side window are proposed and studied. The research objective is to explain the daylight performance of the integration of HLP and shading systems. The research method is experimental with Radiance-based simulation as a tool. Surabaya (latitude 7.38° S and longitude 112.79° E), a typical city in the Tropics, was chosen for the simulation. Daylight level, daylight distribution, and Daylight Glare Probability (DGP) of office room with East-facing window are compared with office room with HLP and shading systems. The results showed that the integration of HLP and shading systems increased the average illuminance level in the deep area reached 135 % and reduced the average illuminance level in the area near the side window reached 55 %. HLP and shading systems also increase the daylight distribution inside space and slightly improve the DGP but still in the range of imperceptible for building users.

**Keywords:** blinds; daylight performance; horizontal light pipe; light shelf; simulation

http://dx.doi.org/10.6180/jase.202202_25(1).0024

## 1. Introduction

Daylight use in buildings brings several benefits, including energy efficiency, the improvement of occupant's health, and productivity [1, 2]. Properly designed, daylighting can reduce building energy use for artificial lighting and overall energy use [3]. Daylight is also one of the most effective antidepressants available [4]. Daylight provides a full light spectrum that is important to make the human eye perform best [5]. Daylight is also the best light source for accurate color rendering [2]. Building occupants prefer daylight compared to artificial light [6]. Daylighting also improves occupant productivity in their workplaces [7].

The potential use of daylight in the Tropics is high. The tropical area receives high intensity of sunlight throughout the day [8] and has a long period of its illumination during daytime [9]. The illuminance in the Tropics can achieve more than 60,000 lx and 80,000 lx during the cloudy months and the brightest months, respectively [10]. The sky condition in the Tropics is also predominantly intermediate and dynamic, where the cloud formation changes in seconds [11].

Glazed buildings are predominant and built around the world at various climates and latitudes [12, 13]. Curtain wall construction with a full glazed or partially glazed is also commonly used in office buildings in Indonesia. Without any external shading devices, a large, glazed office building has a non-uniform daylight distribution and glare problem [11]. The daylight level at the area near the window perimeter is excessive and in contrast, is low at the area distant from the building perimeter and will require electric lighting [14]. A shading system is needed to block direct sunlight while admitting diffuse light and redirect sunlight into a deeper area of the building.

The deep-plan building design is popular among commercial buildings to maximize the rentable floor area [15]. Using a side window as the light source, a deep-plan building has an inadequate daylight level in the area distant from the building perimeter. The daylight level from a side window reduces as the distance from the building perimeter increases. Enlarging the window size to improve the daylight level at a deep area is ineffective [16]. A core daylighting system is needed to provide daylight in areas distances from the building perimeter [1].

Horizontal Light Pipe (HLP) is a core daylighting system that can deliver daylight to the area distant from the building perimeter. As a light transport system, HLP can collect, redirect daylight through an aperture at building façade, transport daylight using a pipe, and distribute daylight into a deep area using an opening distribution [17]. Previous research mainly focused on improving the daylight performance of HLP. The strategies including the use of mirror systems [18], trapezoidal form in plan and reflectors [19, 20], the use of Laser Cut Panels [21, 22]. Other strategies to improve the daylight performance are a flat capitation system and an active reflector [17], egg-crate reflector at the opening distribution [23]. Those previous research showed the reliability of HLP in improving daylight levels and uniformity in the area distant from the building perimeter. A previous study about the application of HLP in an office building in the Tropics also showed that a shading system is needed to reduce the excessive daylight level at the area near the perimeter window [24].

Two widely used shading systems to control glare are Venetian blinds and light shelves (LS) [2]. LS and blinds are categorized as shading systems that employ direct sunlight and can be applied in all climate [25]. A light shelf (LS) is a horizontal or tilted plane placed on an opening above the eye level [26]. LS may be external or internal one or both and can control and redirect daylight through its reflection using the upper surfaces [27]. In general, blinds can reduce luminance contrast [28]. LS can improve the daylight uniformity and reflect daylight deeper into space but also increased the luminance contrast [28]. The integration of LS and partial Venetian blinds can improve the work plane illuminance and luminance ratio [28].

Previous research about Horizontal Light Pipe mainly focused on the improvement of its performance in capturing, transporting, and distributing daylight. Considering that daylighting design in the Tropics should avoid excessive sunlight by restricting daylight levels transmitting the building [16], the HLP application as a complement to the side window in the Tropics should integrate a shading system to improve its daylight performance. Integration of HLP that can deliver daylight into deep space of the building and shading systems consist of Light Shelf (LS), blinds that can redirect and reduce the excessive daylight level near the side window are proposed and studied as an integrative daylight system in the Tropics.

The research purpose is to evaluate the daylight performance of HLP and shading systems integration. The research location is Surabaya (latitude 7.38° S and longitude 112.79°E), one of the cities in Indonesia that has a tropical climate. Experiment with Radiance based simulation, IES-VE (Integrated Environment Solution-Virtual Environment) as a tool is employed as a research method. Glare probability, daylight level, and daylight distribution of the system are studied.

## 2. Integration of Horizontal Light Pipe and Shading Systems

### 2.1. Horizontal Light Pipe

Horizontal Light Pipe (HLP) can collect, transfer, and distribute daylight to a deep floor plan building [29]. HLP has three main components: aperture, pipe, and opening distribution. Aperture can collect, redirect, in some cases concentrate or parallel the incoming light [17]. The pipe transport daylight into the building, while the opening distribution transmits the daylight inside the room. HLP can complement the daylight admitted by a side window and can be the main source of daylight at 4.6 to 9.1 m from the side window [19].

HLP aperture collects and redirects daylight through a passive or active collector. There are two classifications of passive collectors: a light redirection or a light-concentrating [30]. Light redirection collectors including Laser Cut Panels [21], [22], mirror system [18], reflectors [19, 20] while light-concentrating collectors including anidolic collectors [9, 24]. In the Tropics, HLP orientation is East or West [22, 31]. HLP receives daylight only from half of the hemisphere in front of its aperture [18].

The pipe transports the daylight into the building, depending on the optical property of the material. The pipe can transport light through multiple specular reflections in mirror light pipe, total internal reflections in the hollow and solid pipe, or by convergences in the lens system [30]. The length of mirror HLP varies, from 5.75 m [18] to 20m [22]. The opening distribution provides uniform daylight in a room without any glare. To transmit daylight, opening distribution material can be a high visible transmittance such as transparent or translucent glazing [18], a Laser Cut Panels to deflect the sunlight into the room [21, 22] or diffused glass [17]. The light distribution system determines the light output nature and quality [30].

### 2.2. Light shelves and blinds

Light shelves and Venetian blinds are two widely used devices to control glare [2]. Light shelves are shading systems that primarily using direct sunlight [25]. Light shelves can provide shading and can redirect sunlight to the ceiling and improve daylight uniformity [26]. Venetian blinds are one of the shading systems that can block direct sunlight but admit the diffuse skylight [25]. Blinds are effective in decreasing luminance contrast [28].

Several criteria for the choice of blinds are its ability in glare protection, uniform illumination, and energy-saving potential for artificial lighting [25]. Several criteria for the selection of light shelves are its ability to provide a view outside, a light guiding into a deeper area of the building, uniform illumination, saving potential for artificial lighting [25]. Both light shelves and blinds are suitable for all climates [25] and can be applied in the Tropics [11], [28].

In the Tropics, the use of a shading system is essential since the emphasis of daylighting design is usually avoiding excessive sunlight by limiting the daylight amount entering the building [16]. The use of LS and partial blind is the most effective internal shading design for a high-rise office building in the Tropics [28]. The optimum LS depth to achieve a uniform daylight distribution in the Tropics is 600 mm [28]. A combination of LS (2 planes, at the distance of 0.6 between one another) and partial Venetian blinds that have slats 45° closed is an internal shading for optimum daylight performance for an East-facing side window in the Tropics [28].

### 2.3. Integration of Horizontal Light Pipe and Shading systems

The use of HLP improves daylight levels and uniformity in the area distant from the building perimeter. A previous study about the application of HLP in an office building in the Tropics showed that a shading system is needed to reduce the excessive daylight level at the area adjacent to the perimeter window [24]. In this research, the integration of light shelves and blinds as a shading system and HLP as the light-transport system in the East facing side window are studied.

Fig. 1 shows the integration of HLP and LS, blinds in an office room in the Tropics. A passive light redirection HLP is studied. The aperture is equipped with passive reflectors that have adjusted with the sun incident angle at the research location in the Tropics. The mirror light pipe transports light by multiple specular reflections and distributes daylight through an opening distribution 4.5 m to 10 m from the side window. Integration of LS (two planes, at the distance of 0.6 between one another) and partial Venetian blinds that have slats 45° closed [28] is used in combination with HLP.

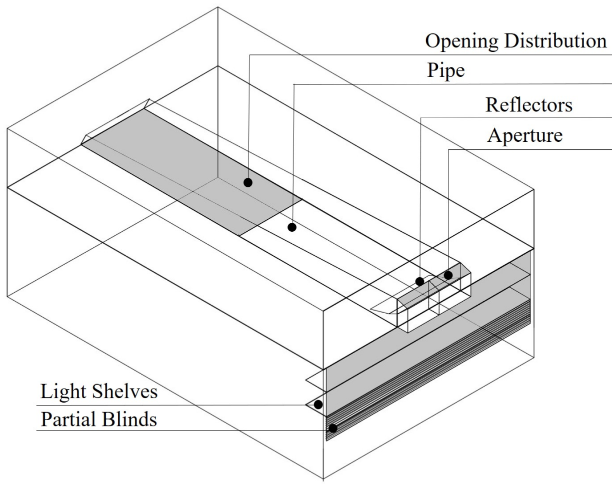



**Fig. 1.** Integration of Horizontal Light Pipe and Shading Systems (Author's own work, Lim et al., 2012 [8]).

## 3. Methodology

Previous studies about the daylight performance of HLP employed several methods, including experimental with a physical model, mathematical models, and simulation. The experiment with a physical model is used in several previous studies [20, 22] and with a full-scale model [31]. Mathematical modeling is employed by [15, 18]. The experimental method with simulation is employed in evaluating the daylight performance of HLP [9, 17, 21, 24]. Computer simulation programs have abilities involving lots of design parameters and complex models [29]. The simulation results also have a good match with measurement [32], showing the reliability of the computer software.

The method of the research is experimental with simulation as a tool. A radiance-based simulation software, IES-VE (Integrated Environment Solution-Virtual Environment), is employed in this study to simulate the daylight performance of HLP, LS, and blinds. IES-VE uses ray-tracing techniques and can include detailed complex geometry and material types. The reliability of IES-VE in simulating daylight performances for various sky conditions and design variables has been validated in several previous research [9, 11, 24, 33, 34].

The study location is Surabaya (latitude 7.38° S and longitude 112.79° E) that represents a typical city in the Tropics. Intermediate sky condition with sun is selected in simulation, corresponding to predominantly intermediate sky condition in the Tropics [10]. The climate data of Juanda International Airport, the closest area from the research location, are used in the simulation.

Daylight level, daylight distribution, and Daylight Glare Probability (DGP) of office room with East-facing window (base case) and office room with HLP and shading systems (the case) were compared. The width of the office space was 6 m, and the ceiling height is 2.70 m. The room depth is 10 m, represent a deep-plan office space. The office room has a side window with WWR (Window to Wall Ratio) 17.4 oriented to the East. The side window had 1.8 m in height and 5.8 m in width. The window glazing material was clear glass with a Visible Transmittance (VT) of 0.763. Table 1 shows the configuration of both cases, while Table 2 shows the material used in the simulation.

HLP and light shelves, partial blinds were installed at the same room geometry, represented the case. The width and length of HLP were 2 m and 10.4 m, respectively. Was in the plenum area, the HLP had 0.7 m in height. The light pipe had a trapezoidal section in elevation and had 0.4 m in rear part height. The HLP internal surfaces were covered by 90 % specular reflective film to redirect sunlight. The hollow mirrored HLP had a static reflector that had an inclination angle following the sun altitude in Surabaya (Table 1). HLP aperture was oriented to the East, corresponding to the best orientation of HLP with light redirection collector in the Tropics, to East or West [15, 31]. The aperture and opening distribution were covered with a clear glass that had a Visible Transmittance of 0.85 (Table 2).

The shading systems consist of two light shelves (LS) and partial blinds. The geometry of LS and partial blinds were adopted from previous research [28] as an effective internal shading in the Tropics for East-oriented window. LS was installed at 2.1 m and 1.5 m above the floor, respectively. The depth of both LS was 0.6 m and had a reflective material on its upper surface. Following previous research [28], the blind slats had an inclined angle of 45° to reduce the luminance from the side window and were placed at 0.9 m to 1.5 m above the office floor.

Fig. 2 shows the position of measurement points inside office space. In this experiment, measurement points were placed at 0.80 m above the floor in a grid of 1 m. Daylight Glare Probability analysis was then conducted with a camera view facing the side window from the center point of the office space. The camera height was 1.15 m above the floor, following the user's eye level height in sitting position. The simulation time is 21 March, 21 June, and 21 December at 09:00, 12:00, and 15:00.

The office room was divided into two zones: daylight area, at 0-4.5 m from East facing window, and partially daylight area, at 4.5-10 m from East facing window (Fig. 2). Measurement points at row 1 to 4 were located in the daylight area, while measurement points at row 5 to 9 were placed in a partial daylight area. The impact of HLP and shading systems integration was evaluated in both two zones.

## 4. Result and Discussions

The daylight performance of HLP and shading systems integration was evaluated using four daylighting metrics: Illuminance level, Daylight Factor (DF), uniformity ratio, and Daylight Glare Probability. The daylight level analysis involving illuminance level and daylight factor. Illuminance target for a workspace that performs a visual task of large size or high contrast is 300 lx [35] and less than 2000 lx to avoid visual discomfort [36]. DF was employed to determine the daylight performance of HLP, light shelf, and blinds under the overcast sky condition. A recommended average DF of 1.5-2.5 % for simple visual tasks such as easy office work, reading, and the filling was used [2].

Uniformity Ratio (UR) was employed for daylight distribution analysis, while the Daylight Glare Probability was employed for glare analysis. The uniformity ratio is related to the qualitative aspect of daylighting and represents the ratio of minimum illuminance and the average illuminance levels within a room [37]. The work plane illuminance should have a UR for a minimum of 0.8 [2]. DGP is a percentage of users disturbed by one or some sources of daylight glare [38]. DGP under 0.35 corresponds to an imperceptible glare by building users [38].

### 4.1. Daylight Level Analysis

Fig. 3 shows the average horizontal work plane illuminance levels for the daylight area (measurement points at row 1-4), partially daylight area (measurement points at row 5-9), and overall area (measurement points at row 1-9) obtained from simulation. Both cases provided an average illuminance level above 300 lx (for office room with paper-based and computer task [35]), only at 09:00, when the East-facing window receives direct illumination from

**Table 1.** The Configuration of the Base Case and Case

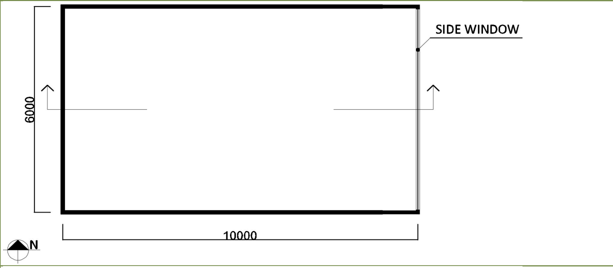
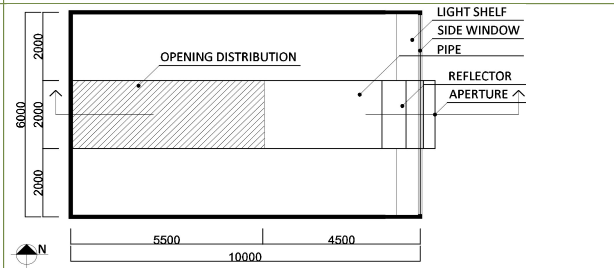
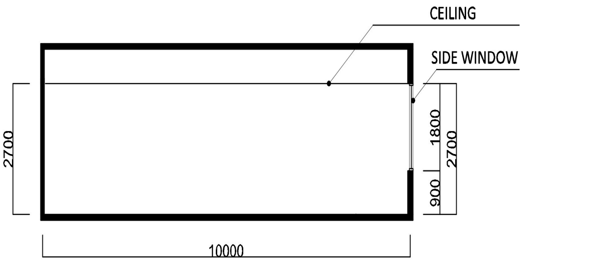
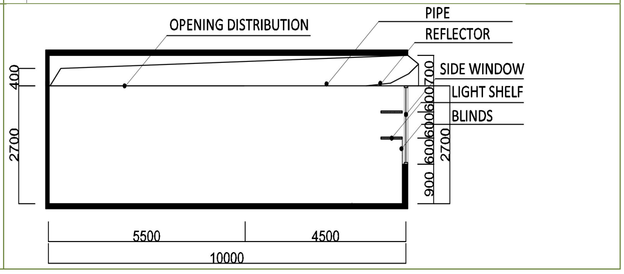
| | **Base Case**<br>Office room with East-facing window | **Case**<br>Office room with East-facing window, Horizontal Light Pipe, Light shelves, blinds |
|---|---|---|
| Plan |  |  |
| Section |  |  |









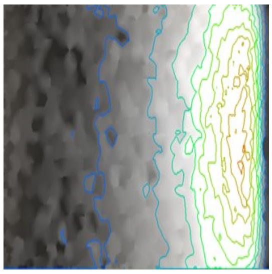
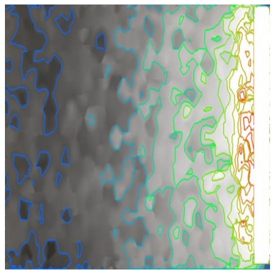
**Table 2.** Results of field measurement of illuminance values

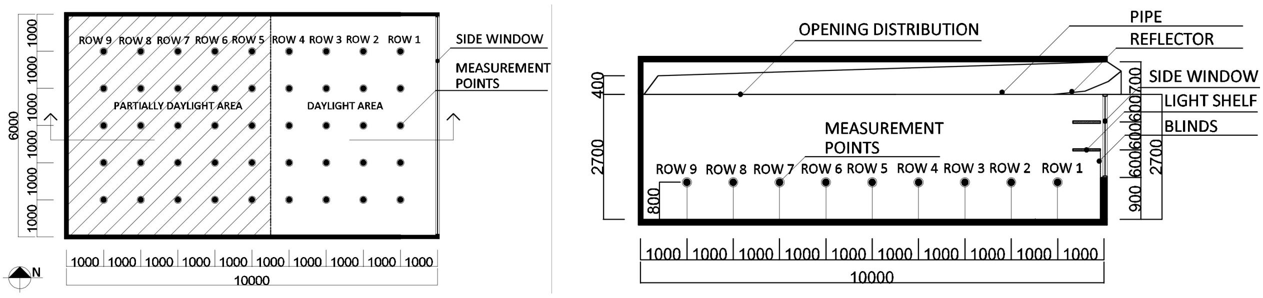
| **Building Component** | **Material** | **Properties** | | | |
|---|---|---|---|---|---|
| | | Specularity | Roughness | Reflectance | Visible Transmittance |
| **Office space** | | | | | |
| Glazing | Clear glazing | - | - | - | 0.763 |
| Floor | Tile Gray | 0.040 | 0.030 | 0.437 | - |
| Wall | | 0.030 | 0.020 | 0.630 | - |
| Ceiling | | 0.00 | 0.00 | 0.80 | - |
| **Light Pipe** | | | | | |
| Pipe internal surfaces | Sheet steel | 0.900 | 0.020 | 0.801 | - |
| Aperture | Clear glazing | - | - | - | 0.850 |
| Opening distribution | Clear glazing | - | - | - | 0.850 |
| **Blinds**<br>Shading coefficient 0.2 | | - | - | 0.40 | - |
| **Light shelf** | | | | | |
| Upper reflective surfaces | Sheet steel | 0.900 | 0.020 | 0.801 | - |
| surfaces | | 0.030 | 0.020 | 0.630 | - |

the sun. The mean illuminance level of the office room with an East-facing window was in the range of 349 lx-688 lx, while the mean illuminance level of the office room with HLP and shading systems was 305 lx-369 lx.

For the East-facing window, the average illuminance level at the overall area reached the highest at 09:00, lower at noon, and slightly increase at 15:00 (Fig. 3). The results also showed that on 21 March, both two cases had the highest average illuminance level in the overall office room. On 21 March 09:00, the mean illuminance level for an office room with the East-facing window was 688 lux, while for an office room with HLP and shading systems was 369 lux. Following the previous study of Djamila et al., 2011 [39], in the Tropics, the East facing window received the highest illuminance level on 21 March, and the diffused illuminance became the main daylighting source from noon

**Table 3.** Simulation results describes daylighting distribution

| Results | | Base Case<br>Office room with East-facing window | Case<br>Office room with East-facing window, Horizontal Light Pipe, Light shelves, blinds |
|---|---|---|---|
| Simulated Daylight Factor |   |  |  |
| Percentage of points achieving DF rnge (%) | <1.5 | 77.8 | 73.3 |
| | 1.5-2.5 | 22.2 | 26.7 |
| Daylight Factor (%) | Minimum | 0.1 | 0.2 |
| | Maximum | 4.1 | 3.5 |
| | Row 1-4 | 1.94 | 1.85 |
| | Row 5-9 | 0.20 | 0.44 |
| | Average | 0.97 | 1.74 |
| Percentage changes in DF level | Minimum | | 100 |
| | Maximum | | -15 |
| | Row 1-4 | | -5 |
| | Row 5-9 | | 120 |
| | Average | | 79 |




(a) (b)

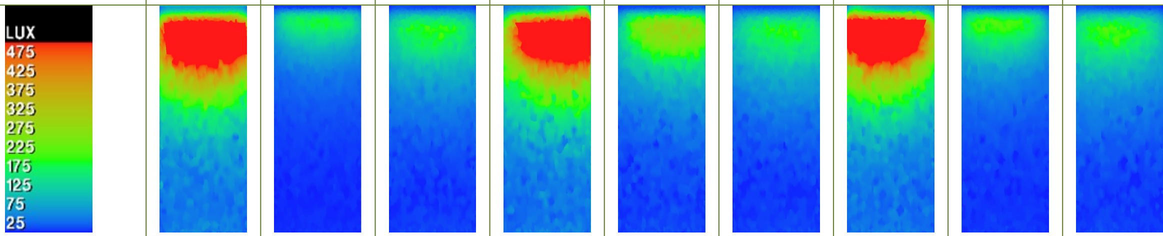
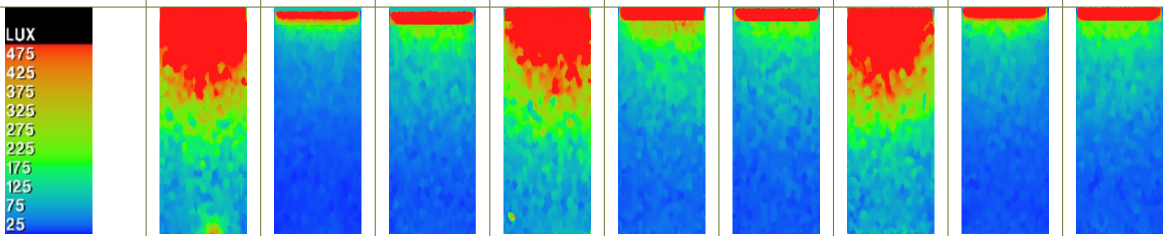
**Fig. 2.** Measurement points on (a) plan (b) section.

until the afternoon.

The results also showed that the average illuminance level in partially daylight area (measurement points at row 5-9) reached the highest at 09:00, lower at noon, and slightly increase in 15:00. In this area, HLP is the main daylight source [19]. Oriented to the East, the highest average illuminance level reached 131 lux on 21 March 09:00. These trends are following the study of Chirarattananon et al., 2009 [18] about East facing HLP with static reflector.

HLP and shading systems integration decreased the average illuminance level at the overall area (measurement points at row 1-9) of office space. FFig. 4 shows the percentage of average illuminance level decrement in overall office area after the integration of HLP and shading sys-

**Table 4.** Daylight Distribution Analysis

| Results | | Simulation Time | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 21 March 0900 | 21 March 1200 | 21 March 1500 | 21 June 0900 | 21 June 1200 | 21 June 1500 | 21 Dec 0900 | 21 Dec 1200 | 21 Dec 1500 |
| Base case |   | | | | | | | | | |
| Base case | Average Illuminance (lx) | 688 | 34 | 57 | 349 | 72 | 52 | 420 | 43 | 55 |
| Base case | Uniformity Ratio | 0.04 | 0.06 | 0.05 | 0.01 | 0.06 | 0.06 | 0.05 | 0.07 | 0.07 |
| Case |   | | | | | | | | | |
| Case | Average Illuminance (lx) | 369 | 38 | 70 | 311 | 81 | 64 | 305 | 50 | 63 |
| Case | Uniformity Ratio | 0.16 | 0.16 | 0.13 | 0.13 | 0.26 | 0.26 | 0.15 | 0.20 | 0.22 |

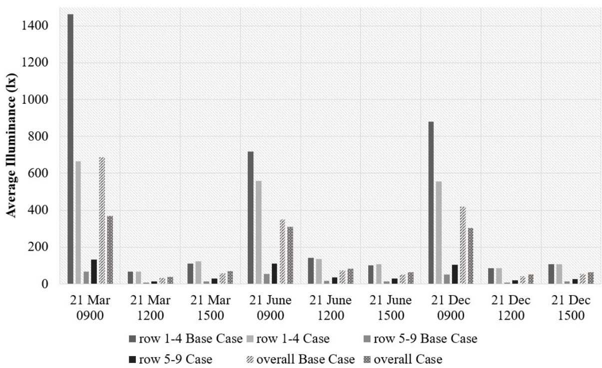


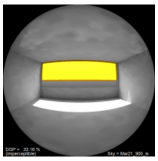
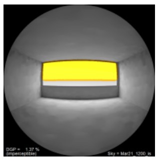
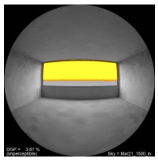
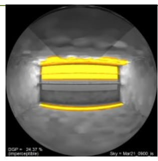
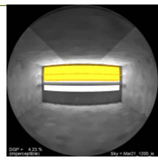
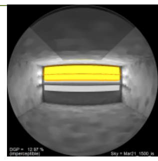
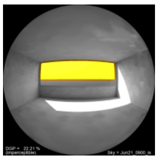
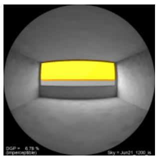
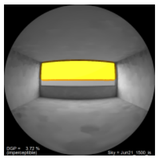
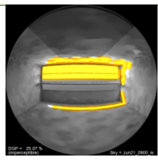
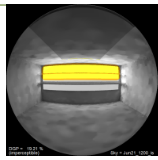
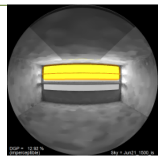
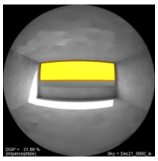
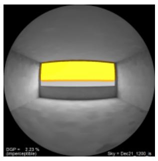
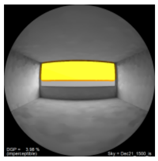
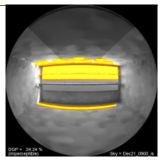
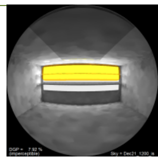
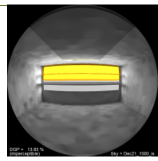

**Fig. 3.** Average Illuminance Level of Base Case and Case.

tems. The highest decrement reached 46% occurred on 21 March 09:00. When the East-facing side window receives direct sunlight, the role of the shading systems in decreasing the excessive illuminance level at the area near the side window is significant.

The integration of HLP, LS, and blinds decreased the average illuminance level in the daylight area when the East-oriented side window was facing the sun. The average illuminance level at daylight area decreased 55%, 22%, and 37% on 21 March 09:00, 21 June 09:00, and 21 December 09:00, respectively. At 12:00 and 15:00 when the side window was not received direct sunlight, integration of HLP and shading systems slightly increased the average illuminance level at daylight area in the range of 0.45% to 11%. In the daylight area, the role of the shading systems in decreasing the average illuminance level is significant, especially when the sun position is in front of the East-facing window (at 09:00).

HLP and shading systems integration increased the average illuminance level at partially daylight area at all measurement times. The average illuminance level improvement was in the range of 79% to 135%. Fig. 4 shows that the highest average illuminance level improvement occurred on 21 June 15:00, while the lowest improvement occurred on 21 December 15:00. In the partially daylight area, the role of HLP in increasing the average illuminance level was significant in all simulation time. Although the HLP received daylight only from half of the hemisphere in front of

**Table 5.** Daylight Distribution Analysis

| **Date** | **Results** | **Simulation Time** | | |
|---|---|---|---|---|
| | | 0900 | 1200 | 1500 |
| **21 March** | **Base case**<br>Office room with East-facing window |  |  |  |
| | Daylight Glare Probability | 22.16% | 1.37% | 3.67% |
| | **Case**<br>Office room with East-facing window Horizontal Light Pipe, Light shelves, blinds |  |  |  |
| | Daylight Glare Probability | 24.37% | 4.23% | 12.97% |
| **21 June** | **Base case**<br>Office room with East-facing window |  |  |  |
| | Daylight Glare Probability | 22.21% | 6.78% | 3.72% |
| | **Case**<br>Office room with East-facing window Horizontal Light Pipe, Light shelves, blinds |  |  |  |
| | Daylight Glare Probability | 25.07% | 19.21% | 12.92% |
| **21 December** | **Base case**<br>Office room with East-facing window |  |  |  |
| | Daylight Glare Probability | 21.89% | 2.23% | 3.98% |
| | **Case**<br>Office room with East-facing window Horizontal Light Pipe, Light shelves, blinds |  |  |  |
| | Daylight Glare Probability | 24.24% | 7.92% | 13.83% |

its aperture [18], the enhancement of average illuminance level at partially daylight area when the sun position was not in front of the side window was still high.

Fig. 5 shows the trend of the average illuminance level at measurement points at 09:00. Integration of HLP and shading systems decreased the excessive illuminance level at the area adjacent to the East-facing window, while improved the illuminance level at 4.5-10 m from the East-facing window. At the area near the East facing window (measurement points at row 1-2), integration of HLP and shading systems reduced the illuminance level reached 48-73%. An acceptable illuminance level in the range of 300-2000 lx at the area near the East-facing window was achieved by HLP and shading systems integration.

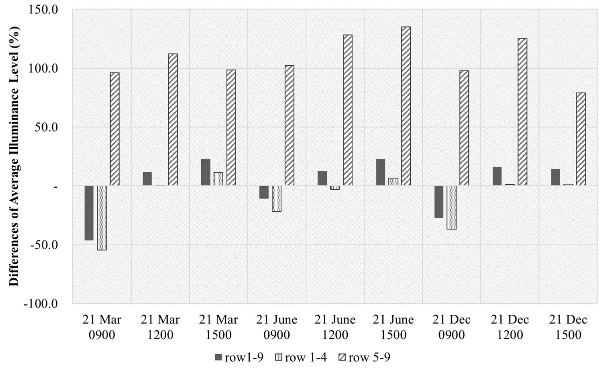



**Fig. 4.** Percentage of average illuminance level improvement and decrement after HLP and shading systems integration.

At measurement points in rows 3 and 4, the integration of HLP and shading systems improved the daylight level, reached 42-62%. The improvement of daylight level at measurement points at row 3-4 m from the East facing window showed the role of LS in bringing light deeper into the building. Under the HLP opening distribution (measurement points at row 5-9), integration of HLP and shading systems increased the illuminance level 52-203% on 21 March, 83-125% on 21 June, and 59-131% on 21 December.

Further analysis then focused on the simulation time when direct illumination from the sun reached the side window (at 09:00). Fig. 6 shows the percentage of the room daylight area above 300 lx on 21 March, 21 June, and 21 December 09:00. The results showed that the percentage of the room daylight area above 300 lx in the base case was 22% to 31%. The percentage of the room daylight area above 300 lx in the case were 33%-42%.

HLP and shading systems integration improved the percentage of the room daylight area above 300 lx. The improvement of the percentage of the room daylight area above 300 lx on 21 December, 21 March, and 21 June 09:00 reached 70.3%, 35.7%, and 15.2%, respectively. The integration of the HLP and shading systems decreased the average illuminance level at the overall area of office space but increased the percentage of the room daylight area above 300 lx.

Table 3 presents the comparison of the average DF level between the cases. Under overcast sky condition, the simulation results showed that HLP and shading systems integration improved the average DF inside office space reached 79%. Integration of HLP and shading system also decreased the average DF level at the area near the side window (measurement points row 1-4) as big as 5% and improved the average DF at the partially daylight area (measurement points row 5-9) as big as 120%. These results indicated the role of shading systems in decreasing the excessive DF level at the area adjacent to the East-facing window and the role of HLP in increasing the DF level in area 4.5-10 m from the perimeter window.

DF point analyses also showed that HLP and shading system integration improved the percentage of measurement points achieving the DF level of more than 1.5-2.5%. The percentage of measurement points reaching the DF level of more than 1.5-2.5% was 22% and 27% for base case and case, respectively.

### 4.2. Daylight Distribution Analysis

Table 4 showed the daylight distribution analysis of the base case and case under an intermediate sky condition. The results showed that both cases had a uniformity ratio below 0.8, but there was a significant improvement in uniformity ratio by HLP and shading systems integration. The uniformity ratio improvement was in the range of 143% to 800% (Fig. 7). The uniformity ratio improvement in most critical times at the East-facing window was 267%, 800%, and 210% for 21 March, 21 June, and 21 December 09:00, respectively. At 12:00 and 15:00, the improvement of the uniformity ratio was in the range of 143% to 363% (Fig. 7).

Illuminance distribution of HLP and shading system integration (Table 4) also showed the role of LS in distributing daylight further into the office room. HLP distributed daylight at the deep area of the office room (Table 4), especially when the HLP aperture received direct sunlight at 09:00. HLP improved the minimum daylight level located in the area distant from the East-facing window, while the shading systems decreased the excessive daylight level at the area near the building perimeter. The combination of those daylighting systems improved the uniformity ratio in the overall office room, by increasing the minimum daylight level and lowering the average daylight level.

### 4.3. Glare Analysis

Table 5 shows the simulation results of Daylight Glare Probability (DGP) for both cases. In general, the results showed that LS and blinds reduced the direct sunlight patches and reflected the sunlight into the ceiling area. The ability of LS and blinds in reducing the sunlight patches to avoid glare on the horizontal work plane is in agreement with the results of Lim et al., 2012 [28].

The simulation results showed that both cases had DGP under 0.35, which corresponds to an imperceptible glare by building users. Office space with HLP and shading system had a higher DGP than office space with an East

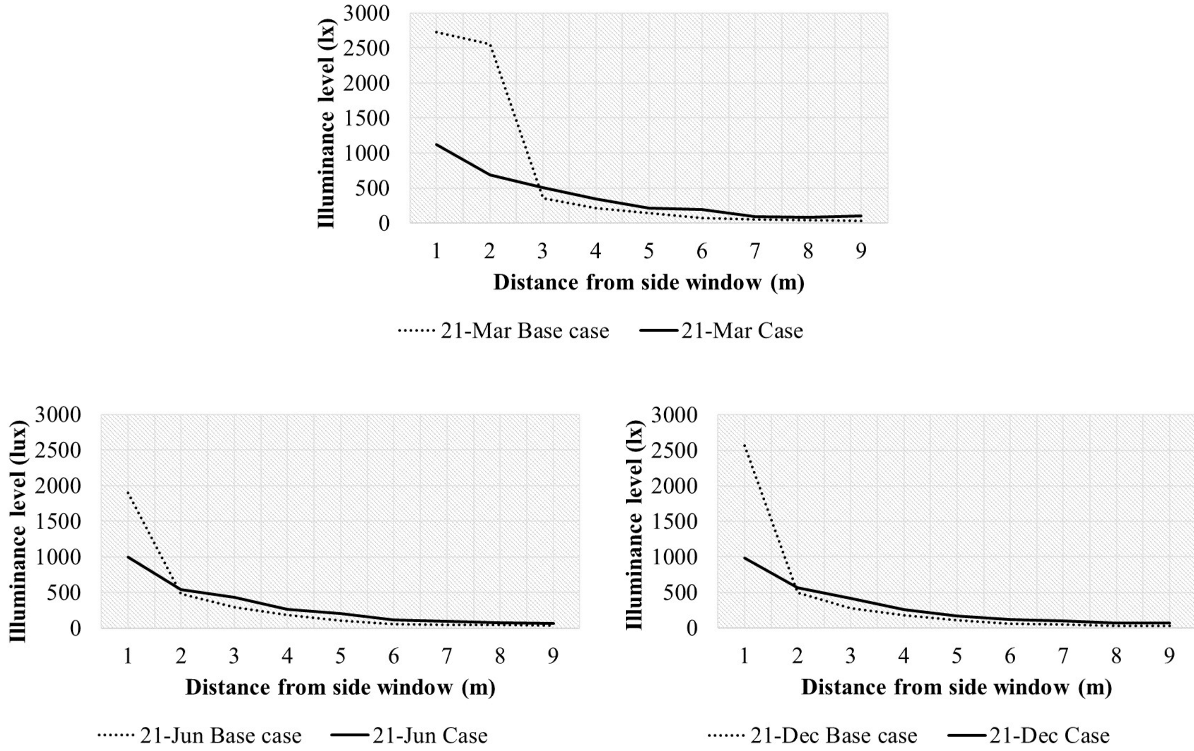



**Fig. 5.** Average illuminance level profile at measurement points for 21 March, 21 June and 21 December 09:00.

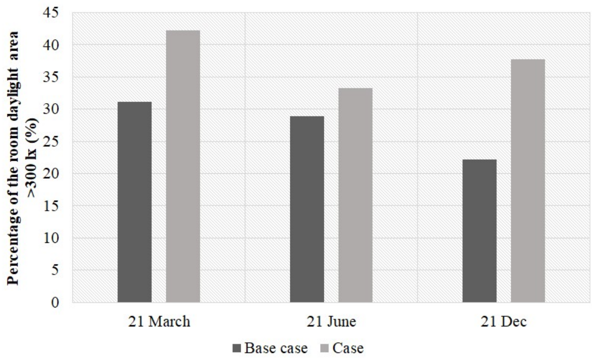



**Fig. 6.** Percentage of the Room Daylight Area above 300 lx at 09:00.

facing window only. The highest DGP in the base case was 22.21%, while in the case was 25.07%. The highest DGP for base case and case occurred on 21 June 09:00 when the East faced side window received direct sunlight.

Integration of HLP and shading system resulted in a higher DGP, but still in the range of imperceptible by building user. Table 5 also shows the reflected light on the ceiling by LS, which had a reflective material on its upper surface. Application of LS and blinds decreased illuminance level near the East-facing window but slightly increased the Daylight Glare Probability. The trend occurs since the area near the East-facing window was shaded by LS and blinds, but the wall and ceiling area obtained more daylight reflected by the reflective upper surface of LS.

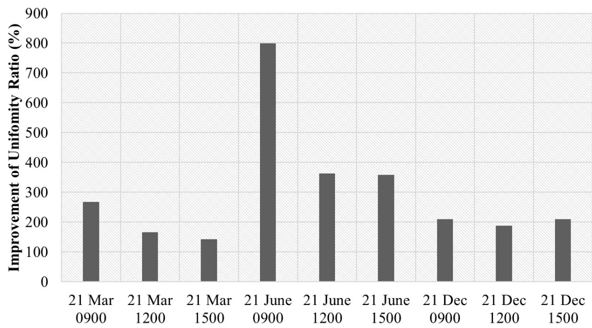



**Fig. 7.** Improvement of Uniformity Ratio by HLP and shading systems integration.

## 5. Conclusion

The integration of Horizontal Light Pipe and light shelves, blinds decreased the average illuminance level in the overall office space area but increased the percentage of the room daylight area above 300 lx. Under intermediate sky condition, both two cases provided an average illuminance level of more than 300 lx and met the illuminance target for a workspace that performs a visual task of high contrast or large size at 09:00, when the East-facing window received direct illumination from the sun. At time, the base case and case had an average illuminance level of 349 lx-688 lx and 305 lx-369 lx, respectively.

The role of shading systems in decreasing the excessive daylight level at the area adjacent to the perimeter window and HLP in increasing the daylight level at the office area distant from the perimeter window was significant when the East facing window received direct sunlight (09:00). At that time, HLP and shading system integration increased the average illuminance level at partially daylight area, reached 135%, and decreased the mean illuminance level at the area near the side window, reached 55%. Although the HLP received daylight from half of the hemisphere in front of its aperture, the improvement of average illuminance level at partially daylight area when the sun position was not in front of the side window was still high.

Under overcast sky condition, HLP and shading systems integration improved the average Daylight Factor inside office space reached 79%. HLP and shading systems integration also decreased the average DF at the area near the perimeter window (measurement points at row 1-4) as big as 5% and improved the average DF at the area distant from the perimeter window (measurement points at row 5-9) as big as 120%.

The uniformity ratio of both cases was below 0.8, but there was a significant improvement of uniformity ratio by HLP and shading systems integration, in the range of 143% to 800%. The combination of those daylighting systems increased the uniformity ratio in the office room by increasing the minimum daylight level and lowering the average daylight level. HLP and shading systems integration resulted in a higher Daylight Glare Probability, but still in the range of imperceptible by building users.

The office depth in this research was 10 m, representing a deep-plan office room in the Tropics. Further studies involving different room geometry will be investigating. Analysis of HLP and shading systems daylight performance in different window orientations will also be evaluating, while still considering the HLP orientation in the Tropics to the East or West. Further studies about HLP and shading systems daylight performance in different locations are also needed, with some adjustment on HLP reflector and shading systems geometry.

## References


**[1]** F. Linhart, S. K. Wittkopf, and J. L. Scartezzini, (2010) *"Performance of Anidolic Daylighting Systems in tropical climates - Parametric studies for identification of main influencing factors"* **Solar Energy *84***(7): 1085–1094. DOI: 10.1016/j.solener.2010.01.014.

**[2]** M. S. Alrubaih, M. F. Zain, M. A. Alghoul, N. L. Ibrahim, M. A. Shameri, and O. Elayeb. *Research and development on aspects of daylighting fundamentals*. 2013. DOI: 10.1016/j.rser.2012.12.057.

**[3]** D. A. Chi, D. Moreno, and J. Navarro, (2018) *"Correlating daylight availability metric with lighting, heating and cooling energy consumptions"* **Building and Environment *132***: 170–180. DOI: 10.1016/j.buildenv.2018.01.048.

**[4]** M. Boubekri. *Daylighting, architecture and health: Building design strategies*. 2008, 1–144. DOI: 10.4324/9780080940717.

**[5]** L. Edwards and P. Torcellini. *A Literature Review of the Effects of Natural Light on Building Occupants A Literature Review of the Effects of Natural Light on Building Occupants*. Tech. rep. July. 2002, 55.

**[6]** A. D. Galasiu and J. A. Veitch, (2006) *"Occupant preferences and satisfaction with the luminous environment and control systems in daylit offices: a literature review"* **Energy and Buildings *38***(7): 728–742. DOI: 10.1016/j.enbuild.2006.03.001.

**[7]** G. D. Ander. *Daylighting: Performance and design*. 2007.

**[8]** Y. W. Lim, M. Z. Kandar, M. H. Ahmad, D. R. Ossen, and A. M. Abdullah, (2012) *"Building façade design for daylighting quality in typical government office building"* **Building and Environment *57***: 194–204. DOI: 10.1016/j.buildenv.2012.04.015.

**[9]** M. Roshan and A. S. Barau, (2016) *"Assessing Anidolic Daylighting System for efficient daylight in open plan office in the tropics"* **Journal of Building Engineering *8***: 58–69. DOI: 10.1016/j.jobe.2016.07.002.

**[10]** A. Zain-Ahmed, K. Sopian, Z. Zainol Abidin, and M. Y. Othman, (2002) *"The availability of daylight from tropical skies—a case study of Malaysia"* **Renewable Energy *25***(1): 21–30. DOI: 10.1016/S0960-1481(00)00209-3.

**[11]** Y. W. Lim and C. Y. Heng, (2016) *"Dynamic internal light shelf for tropical daylighting in high-rise office buildings"* **Building and Environment *106***: 155–166. DOI: 10.1016/j.buildenv.2016.06.030.

**[12]** C. Lavin and F. Fiorito. “Optimization of an External Perforated Screen for Improved Daylighting and Thermal Performance of an Office Space”. In: *Procedia Engineering*. ***180***. 2017, 571–581. DOI: 10.1016/j.proeng.2017.04.216.

**[13]** E. Lee, S. Selkowitz, V. Bazjanac, V. Inkarojrit, and C. Kohler. *LBNL-50502 High-Performance Commercial Building Façades*. Tech. rep. 2002.

**[14]** R. Urbano Gutiérrez, J. Du, N. Ferreira, A. Ferrero, and S. Sharples, (2019) *“Daylight control and performance in office buildings using a novel ceramic louvre system”* **Building and Environment *151***: 54–74. DOI: 10.1016/j.buildenv.2019.01.030.

**[15]** V. R. G-Hansen, (2006) *“Innovative daylighting systems for deep-plan commercial buildings”* **Faculty of Built Environment and Engineering, Queensland University** (Ph.D. Thesis):

**[16]** International Energy Agency. “A source book on daylighting systems and components”. In: *Daylight in Buildings*. 2000.

**[17]** R. Canziani, F. Peron, and G. Rossi, (2004) *“Daylight and energy performances of a new type of light pipe”* **Energy and Buildings *36***(11): 1163–1176. DOI: 10.1016/j.enbuild.2004.05.001.

**[18]** V. Duc Hien and S. Chirarattananon, (2009) *“An experimental study of a facade mounted light pipe”* **Lighting Research and Technology *41***(2): 123–139. DOI: 10.1177/1477153508096167.

**[19]** L. O. Beltrán, E. S. Lee, and S. E. Selkowitz, (1997) *“Advanced optical daylighting systems: Light shelves and light pipes”* **Journal of the Illuminating Engineering Society *26***(2): 91–106. DOI: 10.1080/00994480.1997.10748194.

**[20]** L. O. Beltrán and B. M. Mogo. “Development of optical light pipes for office spaces”. In: *Sun, Wind and Architecture - The Proceedings of the 24th International Conference on Passive and Low Energy Architecture, PLEA 2007*. 2007, 368–374.

**[21]** C. M. Kwok and T. M. Chung, (2008) *“Computer simulation study of a horizontal light pipe integrated with laser cut panels in a dense urban environment”* **Lighting Research and Technology *40***(4): 287–305. DOI: 10.1177/1477153508094584.

**[22]** G. Hansen and I. Edmonds, (2003) *“Natural Illumination of Deep-Plan Office Buildings: Light Pipe Strategies”* **ISES Solar World Congress** (June): 14–19.

**[23]** F. Elsiana, F. Soehartono, and L. Kristanto. “Daylight performance of horizontal light pipe with egg-crate reflector in the tropics”. In: *IOP Conference Series: Earth and Environmental Science*. ***490***. 1. Institute of Physics Publishing, 2020. DOI: 10.1088/1755-1315/490/1/012006.

**[24]** C. Y. Heng, Y. W. Lim, and D. R. Ossen, (2020) *“Horizontal light pipe transporter for deep plan high-rise office daylighting in tropical climate”* **Building and Environment *171***: DOI: 10.1016/j.buildenv.2020.106645.

**[25]** M. Kischkoweit-Lopin, (2002) *“An overview of daylighting systems”* **Solar Energy *73***(2): 77–82. DOI: 10.1016/S0038-092X(02)00036-1.

**[26]** A. Kontadakis, A. Tsangrassoulis, L. Doulos, and S. Zerefos. *A review of light shelf designs for daylit environments*. 2017. DOI: 10.3390/su10010071.

**[27]** A. A. Freewan, L. Shao, and S. Riffat, (2008) *“Optimizing performance of the lightshelf by modifying ceiling geometry in highly luminous climates”* **Solar Energy *82***(4): 343–353. DOI: 10.1016/j.solener.2007.08.003.

**[28]** Y. W. Lim, M. H. Ahmad, and D. R. Ossen, (2013) *“Internal shading for efficient tropical daylighting in malaysian contemporary high-rise open plan office”* **Indoor and Built Environment *22***(6): 932–951. DOI: 10.1177/1420326X12463024.

**[29]** I. L. Wong. *A review of daylighting design and implementation in buildings*. 2017. DOI: 10.1016/j.rser.2017.03.061.

**[30]** M. G. Nair, K. Ramamurthy, and A. R. Ganesan. *Classification of indoor daylight enhancement systems*. 2014. DOI: 10.1177/1477153513483299.

**[31]** S. Chirarattananon, S. Chedsiri, and L. Renshen, (2000) *“Daylighting through light pipes in the tropics”* **Solar Energy *69***(4): 331–341. DOI: 10.1016/S0038-092X(00)00081-5.

**[32]** Y. Chen, J. Liu, J. Pei, X. Cao, Q. Chen, and Y. Jiang, (2014) *“Experimental and simulation study on the performance of daylighting in an industrial building and its energy saving potential”* **Energy and Buildings *73***: 184–191. DOI: 10.1016/j.enbuild.2014.01.030.

**[33]** A. A. Freewan and J. A. Al Dalala, (2020) *“Assessment of daylight performance of Advanced Daylighting Strategies in Large University Classrooms; Case Study Classrooms at JUST”* **Alexandria Engineering Journal *59***(2): 791–802. DOI: 10.1016/j.aej.2019.12.049.

**[34]** S. N. Kamaruzzaman, R. Edwards, E. M. A. Zawawi, and A. I. Che-Ani, (2015) *"Achieving energy and cost savings through simple daylighting control in tropical historic buildings"* **Energy and Buildings *90***: 85–93. DOI: 10.1016/j.enbuild.2014.12.045.

**[35]** G. R. Steffy. *Architectural lighting design*. 2002.

**[36]** A. Nabil and J. Mardaljevic, (2006) *"Useful daylight illuminances: A replacement for daylight factors"* **Energy and Buildings *38***(7): 905–913. DOI: 10.1016/j.enbuild.2006.03.013.

**[37]** J. Lee, M. Boubekri, and F. Liang, (2019) *"Impact of building design parameters on daylighting metrics using an analysis, prediction, and optimization approach based on statistical learning technique"* **Sustainability (Switzerland) *11***(5): DOI: 10.3390/su11051474.

**[38]** M. Bodart and C. Cauwerts, (2017) *"Assessing daylight luminance values and daylight glare probability in scale models"* **Building and Environment *113***: 210–219. DOI: 10.1016/j.buildenv.2016.08.033.

**[39]** H. Djamila, C. C. Ming, and S. Kumaresan. *Estimation of exterior vertical daylight for the humid tropic of Kota Kinabalu city in East Malaysia*. 2011. DOI: 10.1016/j.renene.2010.06.040.