Evaluation of Skylight as a Healthy Home Requirement in the Post Pandemic Era

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https://doi.org/10.5109/7183381

出版情報：Evergreen. 11 (2), pp.993-1001, 2024-06. 九州大学グリーンテクノロジー研究教育センター
バージョン：

Evaluation of Skylight as a Healthy Home Requirement in the Post Pandemic Era

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(Received October 31, 2023; Revised February 23, 2024; Accepted April 17, 2024).

Abstract: WHO has declared that the pandemic is over. However, calls for prevention are still recommended. The COVID-19 virus tends to weaken. The way to improve housing quality is to provide housing that meets health requirements. A small type of residential house with a row house arrangement pattern, which has a width of 6 m, does not allow openings on the right and left sides of the building. This study discussed the intensity of light produced by skylights and its relation to daytime lighting in buildings and sunbathing activities. This research used quantitative descriptive methods by measured the natural light intensity of the skylights to meet these needs. The results of this study indicate that skylights can meet the needs of natural lighting by light intensity requirements. Skylights can also play a role in helping sunbathing activities inside the building by setting a skylight planning strategy in terms of building orientation, the direction of the roof slope, the type of skylight material, and the depth of the ceiling.

Keywords: skylight, residential, natural lighting, sunbathing

1. Introduction

Government policy separates individuals from one another through isolation and quarantine efforts to suppress the spread of the virus. Confirmed COVID-19 patients are separated through isolation, while quarantine is an effective measure to prevent transmission to those who are healthy[1)]. Residential homes have an essential role during a pandemic. Residential buildings have 70% percentage of their role in dealing with a pandemic[2)] and awareness to be more prepared to face the possible future pandemics[3)]. Some patients with mild to moderate levels are isolated independently. The house is also the safest place to quarantine during a lockdown[4)]. Indonesia is a country with the fourth largest population in the world and is expected to be significantly affected in the longer term[5)]

Openings[6)] such as windows, clerestory windows, and doors provide natural lighting in small dwellings[7)]. While skylights provide natural lighting through the roof area. Natural lighting has various intensities because it comes from nature. Natural lighting depends on the angle of incidence of sunlight, the local climate, and the weather according to the building location. Natural lighting also plays a role in being a disinfectant for viruses at certain temperatures at the tropical climate area[8)]. Lechner says[9)] that many architects have used the design of side openings and top openings in a room to provide natural lighting. Three types of sunlight enter the building: direct diffused sunlight from the bright sky and diffused light from the reflection of the ground or other buildings[10)]. The ratio of opening dimensions is 1/6 to 1/3 of the room area to achieve adequate natural lighting[11)].

Therefore, this skylight system has the opportunity to challenge it to provide sufficient solar intensity for health and reduce virus transmission[12)]. There is an opportunity to examine indoors sunbathing activities to avoid the disadvantages of exposure to sun with high intensity. Photo-protective measures are recommended when the sun's UV exposure is high, because the UV dose required to produce vitamin D[13)]. Research into adding security layers to deal with similar viruses in the future still needs to increase[14)15)]. Then, how do skylight qualify the needs of natural lighting and indoor sunbathing activities?

2. Methods

This research will use a quantitative descriptive method. The research object is two residential houses in Jakarta that apply skylights at the 2-story residential houses, collecting data by measuring the light Intensity on each floor. The lighting standards are according to the activity in the area and health requirements guiding the research.

Measurements were taken on March 23, 2023, considering clear sky conditions[16)]. The value of extraterrestrial solar radiation increases from January to June, and March is the highest value[17)18)]. On March 23, light intensity and air temperature will be measured in two research objects from 8 am to 4 pm every hour. This

measurement evaluates the presence of skylights in distributing light into the space[19]. Measurements were taken on March 25 and March 26, 2023, under clear sky conditions, with hourly measurements from 8 to 10 am every hour. These measurements will assist in evaluating the availability of skylights for indoor sunbathing needs. The resulting luminance values can then be evaluated, for example based on the maximum acceptable luminance criteria in the visual. field, and contrasted with the observed object and its background with respect to further user needs[20].

Measurements using a Luxmeter (Fig.1). The Luxmeter is 1 meter above the floor at the measurement point. The measurement locations are under the skylight area and will be explained further through each measuring point. The measurement results will be brought into graphic form and used as evaluation material based on the theory of natural lighting and alongside the requirements for a healthy home in terms of light intensity for sunbathing activities.

Fig.1: Digital Luxmeter as measuring instruments.

Then the measurement data were analyzed using the DF (Daylight Factor) formula. According to SNI 03-2396-2001, the minimum standard of Daylight Ratio for residential is 6-14%.

$$C = \frac{E_n}{E_w} \times 100\%$$

C – Ratio Daylight

E_n – Indoor illumination value in the work area in lux

E_w – Outdoor illumination value under overcast sky condition lux

3. Result

The results of measurements at the Kelapa Gading house, which start from 8 am to 4 pm shown in the following table:

Table 1. Light Intensity (lux) at Rumah Kelapa Gading.

Measurement Time	MP 1 (Lux)	MP 2 (Lux)	MP 3 (Lux)
8 am	34	134	204
9 am	68	115	447
10 am	123	155	669
11 am	84	194	663
12 pm	65	117	431
1 pm	76	158	629
2 pm	53	112	513
3 pm	45	82	308
4 pm	63	86	343

The result of the measurement times at 8 am, 9 am, and 10 am shown in the following table:

Table 2. Light intensity of Rumah Kelapa Gading at 8 - 10 am

Measurement Time	MP 1 (Lux)	MP 2 (Lux)	MP 3 (Lux)
Day 1			
8 am	34	134	204
9 am	68	115	447
10 am	123	155	669
Day 2			
8 am	172	340	1057
9 am	303	480	1233
10 am	281	444	1261
Day 3			
8 am	182	374	1203
9 am	247	384	1298
10 am	276	470	1351

The results of measuring the light intensity (lux) of research object 2 are as the following table:

Table 3. Light Intensity of Rumah Kembangan

Measurement Time	MP 1 (Lux)	MP 2 (Lux)	MP 3 (Lux)
8 am	111	638	1686
9 am	149	364	2104
10 am	195	506	2417
11 am	486	1081	10393
12 pm	165	518	6625
1 pm	1030	3320	10681
2 pm	758	5977	4846
3 pm	556	1501	2935
4 pm	306	1081	1848

To further see the potential light intensity obtained for sunbathing activities can be seen in the following table:

Table 4. Light intensity of Rumah Kembangan at 8 - 10 am

Measurement Time	MP 1 (Lux)	MP 2 (Lux)	MP 3 (Lux)
Day 1			
8 am	111	638	1686
9 am	149	364	2104
10 am	195	506	2417
Day 2			
8 am	124	395	1575
9 am	185	490	2301
10 am	263	715	3280
Day 3			
8 am	142	420	1702
9 am	233	501	2405
10 am	303	801	3406

4. Discussion

The following table shows the requirements for visual lighting needs based on the spaces in a residential:

Table 5. Recommended Lighting Levels in Residential.

Room	Lighting Level (lux)	Rendering Group Color	Color Temperature		
			Warm White < 3300 K	Cool White 3300-5300 K	Daylight > 5300 K
Residential :					
Living Room	120-150	1 or 2		√	
Dining Room	120-150	1 or 2	√		
Working Area	120-150	1		√	√
Bedroom	120-150	1 or 2	√	√	
Bathroom	250	1 or 2		√	√
Kitchen	250	1 or 2	√	√	
Garage	60	3 or 4		√	√

Source: SNI 03-6197-2000, 2021

Even though the pandemic was declared over by WHO last Friday, May 5, 2023, the Indonesian government is still assessing the situation and the right time for the next steps. An appeal to the public to remain vigilant, prepare for a transitional period, and educate the public that COVID-19 is still around. Covid-19 positivity rate data in Indonesia for the last ten days before the revocation of pandemic status by WHO can be seen in the following table:

Table 6. Confirmed Patient in Indonesia at the End of the Pandemic.

	Confirmed	Recover	Recovery Rate (%)	Death
Apr 26	1399	1191	97,5	14
Apr 27	1879	1825	97,5	17
Apr 28	2067	1310	97,4	37
Apr 29	2074	810	97	14
Apr 30	1575	819	97	12
Mei 1	892	839	97	16
Mei 2	1371	1019	97	27
Mei 3	2647	1120	97	25
Mei 4	2417	1139	97	32
Mei 5	2122	1146	97	20

Source: https://Covid19.go.id

The Table 6 contains information from April 26, 2023 to May 5, 2023. Based on the table above, COVID-19 is still infectious in Indonesia. Even though the recovery rate is quite good, the death rate per day still needs to be a common concern. The social restriction policy, which is no longer valid since December 30, 2022, has begun to weaken public awareness of health protocols, increase transmission, and affect the number of confirmed patients.

Natural lighting is an essential factor related to the health quality in residential[21]. Residential support, air circulation, and sufficient sunlight required as isolation rooms during a pandemic[22]. By paying attention to the dimensions and position of the openings, optimize the intensity of sunlight entering the room[23]. Skylights are an alternative solution to the need for sunlight in a room due to the position of the opening in the roof plane when it is not possible to make openings in the walls in a row house arrangement.

The sun emits three types of UV rays based on their respective wavelengths: UVA, UVB, and UVC. UVA is the most extended wave, while UVC is the shortest. WHO divides the UV index into 11 groups (Table 3). The higher the UV level, the higher the risk due to exposure. Indonesia is on the equator: in April, it can reach level 11 (Weather Atlas). So, sunbathing at 10 am - 2 pm in Indonesia is not recommended because of the very high UV index. Thus, there is an opportunity to sunbathe indoors to avoid the risk of a high UV index by using skylights.

Table 7. UV Index according to WHO and Exposure Risk Level.

UV Indeks	Effect	Recommendation
1-2	**Low risk means that the sun is not harmful, but we must avoid direct contact for more than two hours**	Sunglasses (bright days), Cover Up (> 1 hour), Sunscreen SPF +30 (> 1 hour)
3-5	**Moderate risk means the skin will be burned within 30 to 60 minutes**	Sunglasses, Cover Up & hat, Sunscreen SPF +30, Seek shade (midday)
6-7	**High risk means it is very dangerous to be in direct sunlight without protection**	Sunglasses, Cover Up & hat, Sunscreen SPF +30, Seek shade, Limit sun from 11 am - 5 pm
8-10	**The risk is very high, which means we have to wear hats, closed clothes, glasses, and high SPF or not leave the house at all**	. Sunglasses, Cover Up & hat Sunscreen SPF +30, Seek shade, Avoid the sun from 11 am - 5 pm
11+	**Extreme risk means we should not leave the house at all. Unlike any other, Indonesia lies at the equator. The average UV Index can be higher than ever.**	Rare in Canada

Source: www.who.int

When COVID-19 infects a person, this sunbathing activity does not reduce cytokine levels[24], but sunbathing activities can help boost the body's immune system[25]. Morning sunlight, especially before 10 am, if absorbed through the skin, will stimulate the body to produce vitamin D[26]. Vitamin D, obtained by sunbathing in the morning, has many health benefits. Besides boosting the immune system, Vitamin D also helps patients reduce inflammation and acts as a disinfectant for the body[27]. Sunlight becomes an essential factor in increasing the body's immunity.

The research object is two houses with 2-story. The first research object is a residential located in Kelapa Gading, North Jakarta, with a building orientation facing south. The second research Object is a 2-story residential in Kembangan, West Jakarta, with a building orientation facing north. Both residences use skylights applied to the stairwell or void area. The skylight's position aims to get sunlight for both the 1st and 2nd floors.

This study will measure the intensity of light produced by skylights on both the 1st and 2nd floors. Considerations such as the skylight's area and measuring distance become considerations regarding the measurement results. In addition, the effects of heat that arise and aspects of air humidity are also measured in this study.

The First Research Object is a residential house at Kelapa Gading, North Jakarta. The built area is 33 m^2 with a land area of 42 m^2. Kelapa Gading House faces south and is on a corner. The back of the house, previously an open space, is maximized to become a whole building; the roof of the Kelapa Gading house slopes in one direction to the south. Rumah Kelapa Gading uses a white PVC roof, while the skylights use the same material.

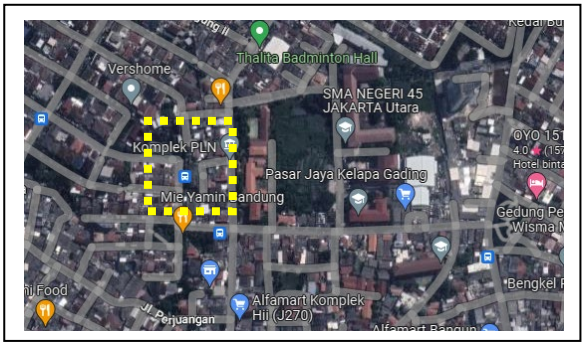


Fig.2: Research Object 1 Location, North Jakarta. Source:https://www.google.com/maps/@-6.1749555,106.9043129,89m/data=!3m1!1e3?authuser=0

Rumah Kelapa Gading places skylights in the stairwell area. The size of the skylights is 0.9 m x 0.6 m. The skylight material is a translucent PVC roof and is not completely clear. The roof is at an angle of 15º. Skylights are at a ceiling depth of 0.78 m.

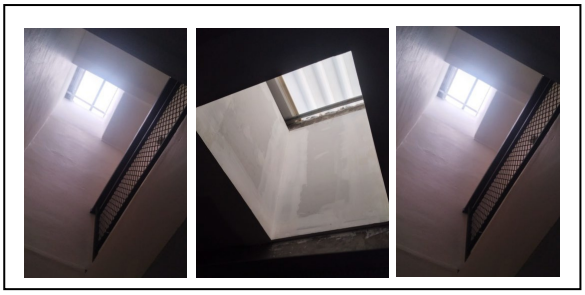


Fig.3: Skylights at Kelapa Gading House: (a) Depth of skylights. (b) Skylight from the 1st floor. (c) Skylight from the 2nd floor.

The measuring point for the Rumah Kelapa Gading takes three measuring points (MP). Measurement Point (MP) 1 on the 1st floor is at the midpoint of the skylight with a distance of 6.38 m. MP 2 in the landing area is not right under the skylight but has shifted 1.6 m from the center point. MP 3 on the 2nd floor is at the midpoint of the skylight, with a distance of 3.38 m.

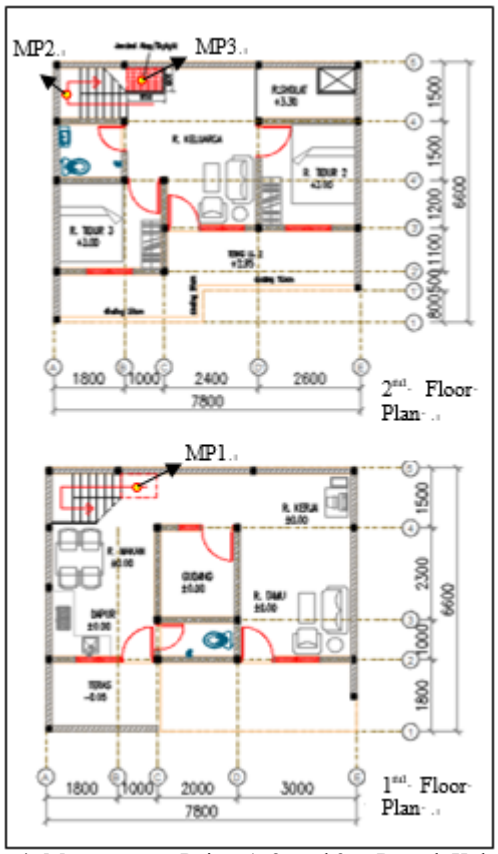


Fig.4: Measurement Points 1, 2, and 3 at Rumah Kelapa Gading

Based on the data above, if it is evaluated based on the space's function, then lighting needs in MP 1, which also illuminates the dining room on the second floor only at 10 am. If no cloudy conditions exist, visual comfort is provided until noon, whereas for MP 3, which functions as a family room, the lighting needs have taken even more than required. From 9 am to 4 pm of MP 3, the light obtained is above 250 lux. MP 2 shows results that meet the lighting needs as a circulation space in almost every measurement sampling.

The acquisition of natural lighting with an average light intensity of 61.1 lux at MP 1 as a stairwell has met the requirements. However, MP 1 is the dining room, which at least is helped by a skylight. Meanwhile, to fulfill sunbathing activities, light intensity measurements were carried out for 3 sample days during sunbathing.

Based on the measurement results above, the existence of skylights that meet the needs of sunbathing activities with a light intensity of ≤ 5760 lux outdoors[28] was obtained at MP 3. The duration from 8 to 10 am on the third day has an intensity quite big compared to the other two days, presumably due to the influence of the daylight factor[29], which causes the sky to produce sunlight in an area inconstantly.

Research Object 2 is a 2-story residential at Kembangan, West Jakarta. This residence has a building orientation to the north. The roof used is a sandy zinc alum roof with a slope of 15º with one slope to the north. Skylight uses a transparent corrugated plastic material.

Fig.5: Location of Research Object 2 in Kembangan, West Jakarta

Research Object 2, from now on referred to as the Rumah Kembangan is a residential area within a 500 m radius of only low-floor buildings. There are also no trees on the road or yard of the Kembangan House that have a height that exceeds the roof of the building, so the skylights in this residence do not have a barrier to the direction of sunlight.

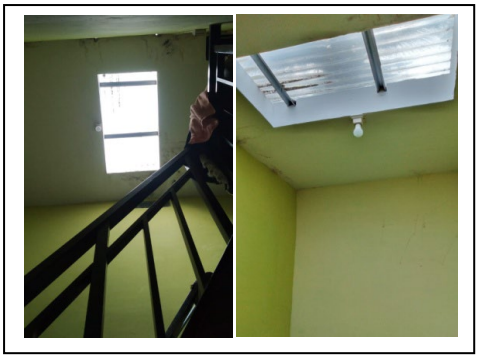
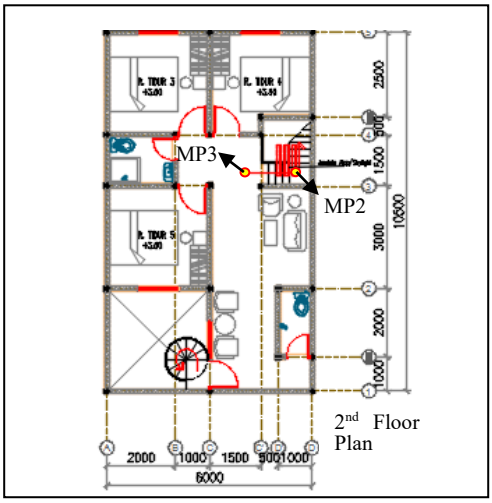


Fig.6: Skylights of Rumah Kembangan: (a) From the 2nd floor. (b) From the 1st floor.

Like Rumah Kelapa Gading, the skylights at Rumah Kembangan are in the stairwell and are the same size, 0.9 m x 0.6 m. The skylight material is a transparent plastic corrugated roof installed at an angle of 15º. Skylights are at a ceiling depth of 0.2 m.



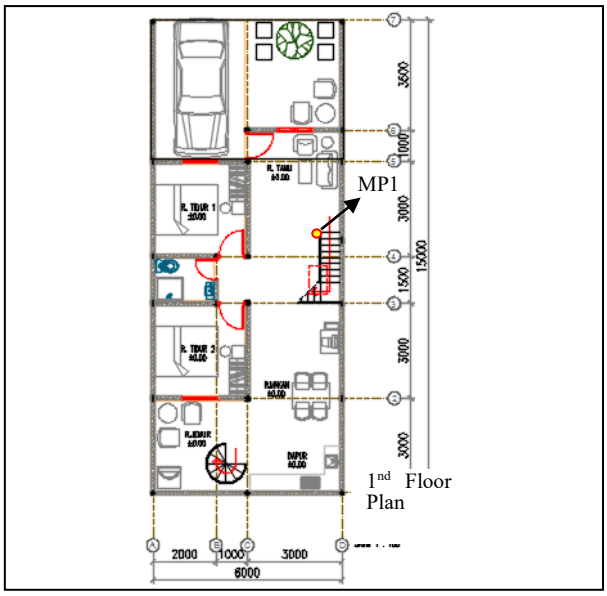


Fig.7: Measurement Point 1, 2, and 3 at Rumah Kembangan.

Determination by the Rumah Kembangan takes into three measuring points (MP). Measurement Point (MP) 1 on the 1st floor is at the midpoint of the skylight with a distance of 4.3 m. MP 2 in the landing area is not right under the skylight but shifted 0.4 m from the center point. MP 3 on the 2nd floor is at the midpoint of the skylight with a distance of 2.3 m.

MP 1 of the Rumah Kembangan lies on the 1st floor. Its function is as a living room. The measurement results show that only at 8 am is it at 111 Lux or below the required value. Another measurement result with a percentage of 82 % is that the value tends to be above the requirement (above 250 lux) according to the measurement of 11 am until 4 pm. It becomes two opposite sides; the positive side of the three measurement sites has the potential to become an area for sunbathing activities, while the negative side is the effect of glare and increased air temperature.

Evaluation from the intensity of light for sunbathing activities, Rumah Kembangan fulfilled the requirements for sunbathing at all three measuring points. At measuring point 3, most of them are even above 2000 lux. The recommended sunbathing activity is for 15 minutes from 8 until 10 am. However, if at 9 am, the intensity of incoming light is so large that it can cause the room temperature to increase. However, a study found a relationship that when the COVID-19 virus is in a high room temperature above 35ºC, the virus can weaken[30] or reduce around 50% of the virus' ability to survive. Another study said that giving vitamin D at a dose of 1000 IU per day to four patients infected with Covid-19 led to normalization of vitamin D oxygen levels, improved clinical conditions, decreased oxygen demand, reduced inflammatory markers, and shortened hospital stay[31].

Table 8. *Daylight Ratio* at Rumah Kelapa Gading.

MT	Ew (Lux)	E_oMP 1 (Lux)	C (%)	E_oMP 2 (Lux)	C (%)	E_oMP 3 (Lux)	C (%)
8 am	7800	34	0.44	134	1.72	204	2.62
9 am	11200	68	0.61	115	1.03	447	3.99
10 am	8900	123	1.4	155	1.74	669	7.51
11 am	13000	84	0.65	194	1.49	663	5.1
12 pm	15800	65	0.41	117	0.74	431	2.73
1 pm	19700	76	0.39	158	0.8	629	3.19
2 pm	16700	53	0.32	112	0.67	513	3.07
3 pm	14400	45	0.31	82	0.57	308	2.14
4 pm	10200	63	0.53	86	0.84	343	3.36

Daylight ratio analysis use the data of light intensity outside the room. Table 8 shows the daylight ratio of Rumah Kelapa Gading. If compared with minimum standard of the daylight ratio provision, then only 1 measurement data is fulfilled at Rumah Kelapa Gading. As the sun moves to the afternoon, usually the intensity of the light increases. But the data shows that at 11 am the light intensity decreased.

Table 9. *Daylight Ratio* at Rumah Kembangan.

MT	Ew (Lux)	E_oMP 1 (Lux)	C (%)	E_oMP 2 (Lux)	C (%)	E_oMP 3 (Lux)	C (%)
8 am	12200	111	0.91	638	5.23	1686	13.82
9 am	13500	149	1.1	364	2.7	2104	15.5
10 am	15100	195	1.29	506	3.35	2417	16.06
11 am	19800	486	2.36	1081	5.46	10393	52.48
12 pm	21700	165	0.76	518	2.39	6625	30.51
1 pm	24400	1030	4.22	3320	5.46	10681	43.77
2 pm	20800	758	3.64	5977	28.73	4846	23.29
3 pm	14900	556	3.73	1501	10.07	2935	16.69
4 pm	13100	306	2.34	1081	8.25	1848	14.11

Daylight ratio of Rumah Kembangan at table 9, shows that there are 4 calculation results fulfilled the minimum standard of daylight ratio provisions. There are also 8 calculation results that had values above the required ones. In MP3, most of the daylight ratios are above the required value. The peak was at 11 am, the value reached 52,58%.

This study both have the same roof slope, which is 15º. The difference lies in the building orientation and the skylight materials which may influence the light intensity value. The Rumah Kembangan, with an orientation towards the north, produces a greater light intensity than the Rumah Kelapa Gading, which has an orientation towards the south. In addition to the building orientation, the transparent skylight material for the Rumah Kembangan produces a greater light intensity than the Rumah Kelapa Gading, which uses translucent materials. The angle of incidence of the sun is related to the skylight installation strategy[32], the influence of the direction of building orientation[33] and the angle of the roof slope[34] influences the success of natural lighting from skylights[35].

Another aspect that may affected the light intensity is the type of material and the depth of the skylight. The skylights at the Rumah Kembangan have a depth of 18-20 cm from the ceiling, and at Rumah Kelapa Gading, they have a depth of 70-76 cm from the ceiling. From the measurement results, the farther the distance between the roof and the ceiling, the smaller the intensity of the light produced. As research says[36], distance is one of the elements that influences the light intensity in roof windows/skylights. The heat impact of the skylights also become consideration by providing adequate ventilation system[37][38].

5. Conclusion

The measurement results show that 96% of the total measurement data collection fulfilled the visual comfort requirements of the Rumah Kembangan. The measurement results show that 78% of the total measurement data collection fulfilled the visual comfort requirements of Rumah Kelapa Gading. Visual comfort is important to provide new daylight performance without the uncomfortable glare in buildings used for studying and getting office work done[39][40]. Findings from a field test also confirmed that the desired light level in the work area under the skylight ranges from 150 lux to 1000 lux[41].

This study also found the possibility of fulfilling sunbathing activities in space. The measurement results from 8 until 10 am for three days under clear sky conditions obtained 33% of the measurement data to fulfill sunbathing activities at the Rumah Kembangan. At the same time, the measurement results at Rumah Kelapa Gading obtained 22% fulfilling indoor sunbathing activities. The existence of skylights can be an alternative solution for sunbathing in the house to increase immunity.

Another consideration in skylight applications is the aspects that may influence the light intensity. Skylight design strategy that accommodate building orientation, roof slope direction, type of the skylight material and the ceiling depth are needed.

References

1) A. Wilder-Smith, and D.O. Freedman, “Isolation , quarantine , social distancing and community containment : pivotal role for old-style public health measures in the novel coronavirus (2019-ncov) outbreak,” 1–4 (2020). doi:10.1093/jtm/taaa020.
2) D. Singh, and A. Singh, “Role of building automation technology in creating a smart and sustainable built environment,” *Evergreen*, 10 (*1*) 412–420 (2023). doi:10.5109/6781101.
3) S. Surjono, D.K. Wardhani, A. Yudono, and M.R.K. Muluk, “Residential preferences of post great disaster in palu city , indonesia residential preferences of post great disaster in palu city , indonesia,” 8 (*4*) 706–716 (2021).
4) L. Carenzo, E. Costantini, M. Greco, F.L. Barra, V. Rendiniello, M. Mainetti, R. Bui, A. Zanella, G. Grasselli, M. Lagioia, A. Protti, and M. Cecconi, “Hospital surge capacity in a tertiary emergency referral centre during the covid-19 outbreak in italy,” 928 (*April*) 928–934 (2020). doi:10.1111/anae.15072.
5) R. Djalante, J. Lassa, D. Setiamarga, A. Sudjatma, M. Indrawan, B. Haryanto, C. Mahfud, M.S. Sinapoy, S. Djalante, I. Rafliana, L.A. Gunawan, G.A.K. Surtiari, and H. Warsilah, “Review and analysis of current responses to covid-19 in indonesia: period of january to march 2020,” *Prog. Disaster Sci.*, 6 (2020). doi:10.1016/j.pdisas.2020.100091.
6) M. Kalsia, A. Sharma, R. Kaushik, and R.S. Dondapati, “Evaporative cooling technologies : conceptual review study,” *Evergreen*, 10 (*01*) 421–429 (2023). doi.org/10.5109/6781102
7) X. Song, M. Cao, K. Zhai, X. Gao, M. Wu, and T. Yang, “The effects of spatial planning, well-being, and behavioural changes during and after the covid-19 pandemic,” *Front. Sustain. Cities*, 3 (*June*) 1–15 (2021). doi:10.3389/frsc.2021.686706.
8) S.M. Parsa, F. Norozpour, A.H. Elsheikh, and A.E. Kabeel, “Solar desalination/purification (solar stills, humidification-dehumidification, solar disinfection) in high altitude during covid19: insights of gastrointestinal manifestations and systems’ mechanism,” *J. Hazard. Mater. Adv.*, 10 (*January*) 100259 (2023). doi:10.1016/j.hazadv.2023.100259.
9) N. Lechner, “Heating, cooling, lighting: sustainable design methods for architect,” (*1*) (2014).
10) S. Szokolay, “Introduction to Architectural Science: The Basis of Sustainable Design,” Elsevier, 2004.
11) E. Neufert, “Data Arsitek,” Erlangga, 1996.
12) A. Kumar, and M.K. Sahu, “Design and development of novel solar concentrating spittoon to control the spread of covid-19 virus at public places,” *Evergreen*, 10 (*3*) 1430–1438 (2023).
13) J. Aguilera, “Recommendations on sun exposure and photoprotection following easing of the covid19

pandemic lockdown : spanish photobiology group of the spanish academy of dermatology and venerology recomendaciones sobre exposición solar y fotoprotección del grupo espa ," 799–801 (2020). doi:10.1016/j.adengl.2020.06.004.

14) N.A. Megahed, and E.M. Ghoneim, "Antivirus-built environment : lessons learned from covid-19 pandemic," *Sustain. Cities Soc.*, 61 (*June*) 102350 (2020). doi:10.1016/j.scs.2020.102350.
15) K.M.A. Kabir, M.A. Ovi, S. Murtyas, A. Hagishima, and J. Tanimoto, "Acceptance and willingness-to-pay of vaccine for covid-19 in asian countries : a hypothetical assessment survey," *Evergreen*, 10 (*02*) 617–625 (2023). doi.org/10.5109/6792807
16) A.H. Ismail, E.A. Dawi, N. Almokdad, A. Abdelkader, and O. Salem, "Estimation and comparison of the clearness index using mathematical models - case study in the united arab emirates," 10 (*02*) 863–869 (2023).
17) A.F. Pachman, D.H. Didane, Wijianto, M. Al-Ghriybah, N.F. Nasir, S. Al-Alimi, and B. Manshoor, "A study of global solar radiations measurement in java island, indonesia," *Evergreen*, 10 (*1*) 212–218 (2023). doi:10.5109/6781071.
18) S. Zaphar, M. Chandrashekara, and G. Verma, "Thermal analysis of an evacuated tube solar collector using a one-end stainless steel manifold for air heating applications under diverse operational conditions," 10 (*02*) 897–911 (2023).
19) B.B. Alikhanov, S. V Samoilov, B.B. Alikhanov, S. V Samoilov, V.I. Sokolov, and L.P. Seitova, "Theory of climate change intensity determination," *Evergreen*, 10 (*3*) 1253–1260 (2023). doi.org/10.5109/7148446
20) E. Dolnikova, D. Katunsky, and S. Darula, "Assessment of overcast sky daylight conditions in the premises of engineering operations considering two types of skylights," *Build. Environ.*, 180 (*June*) 106976 (2020). doi:10.1016/j.buildenv.2020.106976.
21) T. Peters, and A. Halleran, "How our homes impact our health : using a covid-19 informed approach to examine urban apartment housing," (*January*) (2021). doi:10.1108/ARCH-08-2020-0159.
22) Y.A. Yatmo, M. Mirza, Y. Harahap, and P. Atmodiwirjo, "Modular isolation units for patients with mild-to-moderate conditions in response to hospital surges resulting from the covid-19 pandemic," 12 (*November 2020*) 43–53 (2021). doi:10.14716/ijtech.v12i1.4115.
23) R.M. Lucas, R.E. Neale, S. Madronich, and R.L. McKenzie, "Are current guidelines for sun protection optimal for health? exploring the evidence," *Photochem. Photobiol. Sci.*, 17 (*12*) 1956–1963 (2018). doi:10.1039/c7pp00374a.
24) R.B. Kuncara, E.N. Sofyanita, A. Riadi, and D.E. Purlinda, "The effect of various sun time under exposure to ultraviolet light of the sun on interleukin 10 cytokine," 24 (*01*) (2022). doi:10.20473/jbp.v24i1.2022.29-33.
25) Muliani, "Waktu berjemur terbaik guna meningkatkan vitamin d dalam pencegahan coronavirus disease 2019 (covid19)," 2019 66–74 (2020).
26) D.H. González Maglio, M.L. Paz, and J. Leoni, "Sunlight effects on immune system: is there something else in addition to uv-induced immunosuppression?," *Biomed Res. Int.*, 2016 (2016). doi:10.1155/2016/1934518.
27) M. Wacker, and M.F. Holick, "Sunlight and vitamin d: a global perspective for health," *Dermatoendocrinol.*, 5 (*1*) 51–108 (2013). doi:10.4161/derm.24494.
28) N.P. wijaya Veramika, I.G.N. Sutapa, and N.N. Ratini, "Penentuan nilai sun protection factor (spf) sinar matahari dengan menggunakan kain katun, poliester dan rayon di pantai kuta," *Bul. Fis.*, 17 14–21 (2016).
29) J. Mardaljevic, and J. Christoffersen, "'Climate connectivity' in the daylight factor basis of building standards," *Build. Environ.*, 113 (*August 2016*) 200–209 (2017). doi:10.1016/j.buildenv.2016.08.009.
30) J. Biryukov, J.A. Boydston, R.A. Dunning, J.J. Yeager, S. Wood, A. Ferris, D. Miller, W. Weaver, N.E. Zeitouni, D. Freeburger, P. Dabisch, V. Wahl, M.C. Hevey, and L.A. Altamura, "SARS - cov - 2 is rapidly inactivated at high temperature," *Environ. Chem. Lett.*, 19 (*2*) 1773–1777 (2021). doi:10.1007/s10311-021-01187-x.
31) S. Padhi, S. Suvankar, V.K. Panda, A. Pati, and A.K. Panda, "Lower levels of vitamin d are associated with sars-cov-2 infection and mortality in the indian population: an observational study," *Int. Immunopharmacol.*, 88 (*August*) 107001 (2020). doi:10.1016/j.intimp.2020.107001.
32) W.M.P.U. Wijeratne, T.I. Samarasinghalage, R.J. Yang, and R. Wakefield, "Multi-objective optimisation for building integrated photovoltaics (bipv) roof projects in early design phase," *Appl. Energy*, 309 (*November 2021*) 118476 (2022). doi:10.1016/j.apenergy.2021.118476.
33) N. Nasrollahzadeh, "Comprehensive building envelope optimization: improving energy, daylight, and thermal comfort performance of the dwelling unit," *J. Build. Eng.*, 44 (*October*) 103418 (2021). doi:10.1016/j.jobe.2021.103418.
34) D.P. Sari, A. Sumarno, A.M. Prasetyo, and L.N. Ngeljaratan, "Energy conservation techniques in tropical climate - a comprehensive review and adaptation of the lamin house for nusantara," *Evergreen*, 10 (*03*) 2021-2028 (2023). doi.org/10.5109/7151769
35) Q. Xuan, G. Li, B. Zhao, B. Jiang, D. Sun, X. Zhang,

J. Tang, Y. Zhuang, J. Liu, and L. Li, “Evaluation of the smart daylighting control performance of the concentrating photovoltaic/daylighting system as the skylight in the building,” *Sol. Energy*, 238 (*March*) 17–29 (2022). doi:10.1016/j.solener.2022.04.021.

36) M. Marzouk, A. Eissa, and M. Elsharkawy, “Influence of light redirecting control element on daylight performance : a case of egyptian heritage palace skylight,” *J. Build. Eng.*, 31 (*March*) 101309 (2020). doi:10.1016/j.jobe.2020.101309.
37) H. Han, M. Hatta, and H. Rahman, “Smart ventilation for energy conservation in buildings smart ventilation for energy conservation in buildings,” 6 (*1*) 44–51 (2019).
38) R.T. Muehleisen, “Simple design tools for earth-air heat exchangers,” *IBPSA-USA J.*, 5 (*1*) 723–730 (2012). doi:10.13140/2.1.2854.5607.
39) Z. Shirzadnia, A. Goharian, and M. Mahdavinejad, “Designerly approach to skylight configuration based on daylight performance ; toward a novel optimization process,” *Energy Build.*, 286 112970 (2023). doi:10.1016/j.enbuild.2023.112970.
40) M.L. Meena, and G.S. Dangayach, “Investigation of musculoskeletal disorders among pregnant women working in education and information technology sector during homestay in covid-19 pandemic,” *Evergreen*, 10 (*3*) 1588–1595 (2023). doi.org/10.5109/7151707
41) Y. Bian, J. Luo, J. Hu, L. Liu, and Y. Pang, “Visual discomfort assessment in an open-plan space with skylights : a case study with poe survey and retrofit design,” *Energy Build.*, 248 111215 (2021). doi:10.1016/j.enbuild.2021.111215.