
EVALUATION OF EDUCATION BUILDING BASED ON HEALTHY BUILDING ASPECTS (AIR CIRCULATION, HUMIDITY, NATURAL LIGHT INTENSITY)

Lutfi Landrian

Program Studi Arsitektur dan Sustentabilitas
Fakultas Teknik
Universitas Indonesia
lutfilandrian@gmail.com

Wilda Maulina*

Program Studi Arsitektur
Fakultas Teknik
Universitas Muhammadiyah
Surakarta
wm387@ums.ac.id

Amelia Rizyan Nyssa

Program Studi Arsitektur dan Sustentabilitas
Fakultas Teknik
Universitas Indonesia
ameliarizyan@gmail.com

Corresponding Author

ABSTRACT

This study aims to evaluate the condition of building quality by using the main principles of healthy buildings. The main principles of a Healthy building should be in good condition in three aspects, there are air circulation (air velocity and air temperature), humidity, and natural light intensity. The evaluation was conducted at Mochtar Riady Plaza Quantum (MRPQ), one of the Laboratory buildings at the Universitas Indonesia, Depok, Indonesia. The process is carried out by first analyzing the existing condition of the building and evaluating it with the standard of comfort in Standar Nasional Indonesia (SNI). Then it will be determined which parts need to be improved and continued with the intervention using simulation software Dialux, Ansys, and Revit. It was found that this building had shortcomings in all three aspects of the healthy building, such as humidity levels above the standard 40-60%, lack of natural air velocity for air circulation, high air temperature, and low natural light intensity in corridors and auditoriums. The results of interventions in all three aspects of health could increase by 66.5% in air velocity for air circulation, reduce 13.3% in humidity, and increase by 78.2% in natural light intensity aspects.

KEYWORDS: building evaluation, healthy building, air circulation, humidity, light intensity

Penelitian ini bertujuan untuk mengevaluasi kondisi kualitas bangunan dengan menggunakan prinsip-prinsip utama bangunan sehat. Prinsip utama bangunan sehat harus dalam keadaan baik pada tiga aspek yaitu sirkulasi udara (kecepatan udara dan suhu udara), kelembaban dan intensitas cahaya alami. Evaluasi dilakukan di Mochtar Riady Plaza Quantum, salah satu gedung Laboratorium di Universitas Indonesia. Prosesnya dilakukan dengan terlebih dahulu menganalisis kondisi eksisting bangunan dan mengevaluasinya dengan standar kenyamanan Standar Nasional Indonesia (SNI). Kemudian akan ditentukan bagian mana yang perlu diperbaiki dan dilanjutkan dengan intervensi menggunakan software simulasi Dialux, Ansys dan Revit. Ditemukan bahwa bangunan ini memiliki kekurangan pada ketiga aspek bangunan sehat, seperti tingkat kelembaban di atas standar 40-60%, kurangnya kecepatan udara alami untuk sirkulasi udara, suhu udara yang tinggi, dan rendahnya intensitas cahaya alami di koridor dan auditorium. Hasil intervensi pada ketiga aspek kesehatan dapat meningkatkan kecepatan udara untuk sirkulasi udara sebesar 66,5%, menurunkan kelembapan sebesar 13,3%, dan meningkatkan aspek intensitas cahaya alami sebesar 78,2%.

KATA KUNCI: evaluasi bangunan, bangunan sehat, sirkulasi udara, kelembaban ruang dalam bangunan, intensitas cahaya ruang dalam bangunan

INTRODUCTION

Humans basically in their activities are very dependent on the building. Humans spend 90% of their time doing activities in buildings (World Green Building Council, 2016). That is why a healthy indoor environment is essential for humans. If this is not considered, a building can have a big and long-term negative impact on health. Some elements can contribute to Healthy Building Design: (1) Healthy air circulation, (2) Healthy humidity for thermal comfort, and (3) Healthy light intensity (Loftness et al. 2007).

Various building functions can be optimized to provide a healthy and comfortable environment for its users. One of them is an educational building. In educational buildings, healthy buildings are intended to improve the performance or ability of teachers and students in teaching and learning activities (Delba et al., 2017).

Healthy Building Aspects

WHO (1989) defines environmental health as "aspects of human health and disease which are determined by factors in the environment". The

concept of healthy building was defined as an artificial environment that drives human welfare in a more positive direction (Ho et al. 2004).

Healthy buildings are described as "efficient buildings that allow people in the building to operate at their highest functionality (Loftness et al. 2007). Buildings are machines that function on behalf of humans. The purpose of buildings is to enable people working within structures to operate at their peak efficiency (Erika et al., 2019). If a building allows people inside to work in a productive and happy environment, it creates assets that are more efficient and profitable for building owners (Turner, 2016). There are various healthy building policies and principles. Some of them are used in this study because they cover many aspects of the building both in design and maintenance to get to a healthy building. "The 9 Foundations of a Healthy Building" has many aspects of a healthy building which are summaries designed for clear distillation and actionable from the core elements of a healthy indoor environment (Allen, J. G. et. al. 2017). Aspects emphasized as healthy building elements in this foundation are air circulation (temperature and velocity), humidity, and light intensity (Delba, 2017).

Furthermore, there are other policies by the context of this building. The MRPQ building is located in Depok, Indonesia. The climate in this area is a tropical climate. Based on the record of the meteorology, climatology, and geophysics (BMKG), Depok has an average relative humidity of 70-80% (Menkes No. 1405 / Menkes / SK / XI / 2002). This percentage shows a relationship with the emergence of healthy building policies in Indonesia, one of which is motivated by the issue of Sick Building Syndrome (SBS), namely the relative humidity is not appropriate (40-60%) (Program Studi Arsitektur SAPPK ITB, 2015). This policy also mentions several reasons, namely poor room air quality and inadequate light for work tasks (SNI T-14-1993-03). From that, related to the survey and interview results previously mentioned, we took the key aspects that must be considered for evaluating the health conditions of buildings in the areas of air circulation, humidity, and lighting.

Non-Humid Air Conditions

One indicator of a healthy building is that the building must not have high humidity conditions (Program Studi Arsitektur SAPPK ITB, 2015). High humidity can occur due to the lack of natural ventilation. Ventilation in buildings is important to create natural air circulation (Allen, 2019). Air circulation will trigger the air exchange which removes polluted air inside the room. Fresh air also can roam freely from outside in a way to provide comfort, health, and freshness of living in high-rise housing or buildings, especially in tropical climates with hot air and high humidity levels (Allen, J.

G. et. al. 2017). Cross ventilation is one example method to create good indoor air circulation. The previous study claimed that wind speed in the context of an interior room is one of the parameters of thermal comfort (Rahimi, Syamsiah, Nugroho, 2021)

Based on the regulations of the Indonesian Ministry of Health (Menkes No. 1405 / Menkes / SK / XI / 2002) the recommended room humidity is between 40% - 60%. If the relative humidity of the water is maintained below approximately 50% for an extended period, mites will not survive. As humidity increases levels and levels tend to increase (Arlian and Gross, 1999).

Healthy Air Circulation According to Local Standards

Based on the regulations of the Indonesian Ministry of Health, the standard for air circulation recommended is 0.283 m³ / minute/person. For standard air velocity is 0.15 - 0.25 m / sec. Workspaces without mechanical air conditioning must have ventilation holes of at least 15% of the floor area to be able to implement a cross-ventilation system. A healthy air temperature recommended by the Indonesian Ministry of Health ranges from 18°C - 28°C (Menkes No. 1405 / Menkes / SK / XI / 2002).

Table 1. Air Temperature Criteria

20.5°C - 22.8°C	Cool-Comfortable
22.8°C - 25.8°C	Comfortable-Optimal
25.8°C - 27.1°C	Almost Comfortable

(Source: SNI T-14-1993-03)

There are several temperature comfort criteria based on SNI T-14-1993-03 (table 1). An increase in air velocity can increase room temperature. Room temperature can increase between 1.1-5°C if air velocity can be increased between 0.5-10m/s (Lechner, 2015).

Natural Lighting According to National Standards of Indonesia (SNI)

The average person spends time 90% of their time indoors (World Green Building Council, 2020), which has important implications for the well-being of building occupants. Exposure to lighting mainly comes from artificial lighting and natural lighting. The requirement for healthy lighting is to adjust the lighting intensity by regulations (Menkes No. 1405 / Menkes / SK / XI / 2002). According to SNI 03-6197-2000, natural lighting during the day can be said to be good if at 08.00-16.00 local time the room gets enough sunlight. This light distribution must also be evenly distributed so that there is no contrast that can disturb eye comfort. Good and healthy lighting can not only be felt but should also be measurable (SNI 03-6197-2000).

METHODS

The case study is the Mochtar Riady Plaza Quantum (MRPQ) Building in the Faculty of Engineering, Universitas Indonesia (see Figure 1).



Figure 1. Studi Case: Mochtar Riyadi Plaza Quantum Building in Engineering Faculty, Universitas Indonesia, Depok Indonesia.

(Source: www.itchcreature.com)

This four-story building was built in 2016. This building has laboratories as the main function of this building. Auditorium facilities on the third floor can accommodate up to 200 people. Our surveys and informal interviews with the users found that users complained of some damp and low-light areas such as the corridor area on the 1st floor and the auditorium area on the 4th floor (see Figure 2a - Figure 2c). The building context in Depok, Indonesia has a humid tropical climate. This type of climate tends to have high temperatures and low wind speeds, making it difficult for buildings to achieve thermal comfort from the start (Syamsiah, Izzati, 2021). Some rooms have openings but are blocked and covered by several items. This condition makes the area windowless. In previous studies, it was stated that this condition prevents users from accessing nature such as fresh air, light, and plants. This also affects the well-being of users (Maulina, Susanto, 2022).

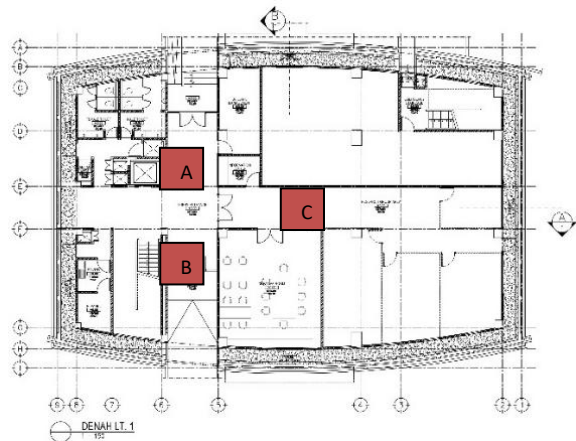


Figure 2a. Some Damp and low light areas in the corridor on the 1st Floor (A, B,C)

(Source: Author's Documentation, 2024)

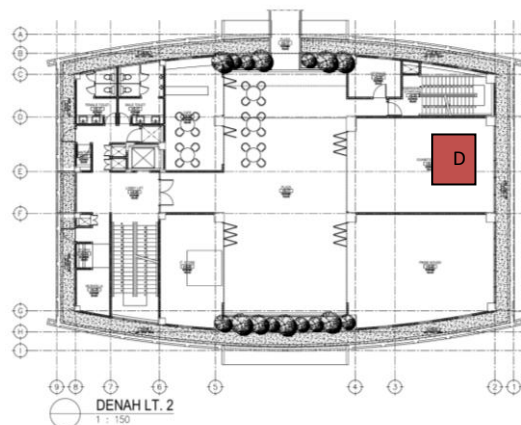


Figure 2b. one of the rooms in room discussion in 2nd floor (D)

(Source: Author's Documentation, 2024)

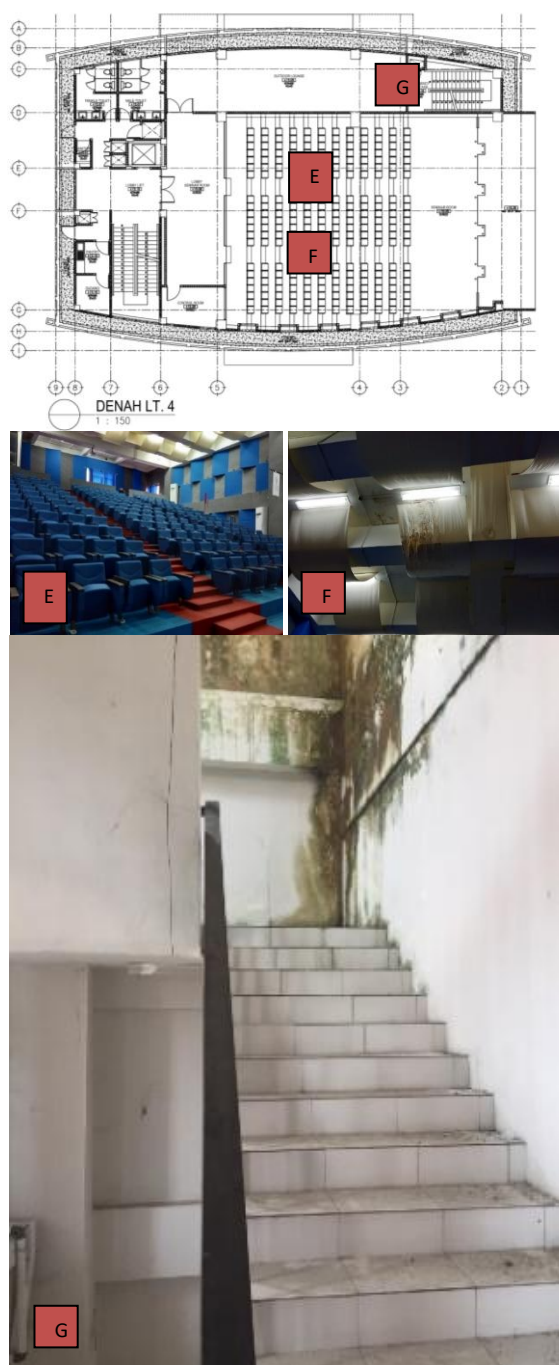


Figure 2c. Auditorium area on the 4th floor (E, F,G), and windows are blocked in some rooms.
(Source: Author's Documentation, 2024)

They feel less comfortable doing their activity. We suspect that there are aspects of healthy buildings indeed not met in this MRPQ building. This research will be focused on seeing which aspects do not comply with the healthy building standards. Intervene later will be conducted on the part that does not meet the healthy standard based on the evaluation.

This research was conducted using preliminary data obtained from previous studies and tools as evaluation supporting data. This data will be linked to the principles of healthy building. Preliminary data

were analyzed and which aspects are not by the principles of healthy building. Simulation using software is used to test the intervention (see Table 2). The simulation aims to see the distribution of humidity and air temperature, air circulation (air velocity), also natural light intensity in each room. Ansys simulation is used to find out air velocity and air circulation (distribution) in the room (<https://www.ansys.com/>). Insight Revit is a software to simulate or perform a building analysis with data integration in Revit (<https://www.autodesk.com/>). Insight is used to find out the humidity in the building. DIALux is software for lighting design, calculating and visualize light (simulating) for specific architecture/buildings (<https://www.dial.de/en/dialux/>) see Figure 3.

Table 2. Data Collecting Methods

Aspect	Tools and Simulation	Conditions	
		Existing	Target
Humidity	FLIR One Pro tool for iOS	Avg humidity: 74.4 - 91.4 %	40 - 60%
MENKES NO.1405 / MENKES / SK / XI / 2002)	BENETECH (Thermometer, Hygrometer, Humidity Meter)		
	HOBO		
Air velocity	Ansys: Engineering Simulation & 3D Design Software	Air velocity: 0.05 - 1.4 m/s	2 - 10 m/s
MENKES NO.1405 / MENKES / SK / XI / 2002)		Air temperature: 27.7 - 32°C	20.5 - 27.1°C
Air temperature) SNI T-14-1993-03			
Intensity of natural light	Dialux Evo	Classroom : Avg 211.4 lx	Classroom : Min 250 lx
SNI 03-6197-2000		Laboratory: Avg 278 lx	Laboratory: Min 500 lx
		Auditorium: 0 lx	Auditorium: Min 100 lx

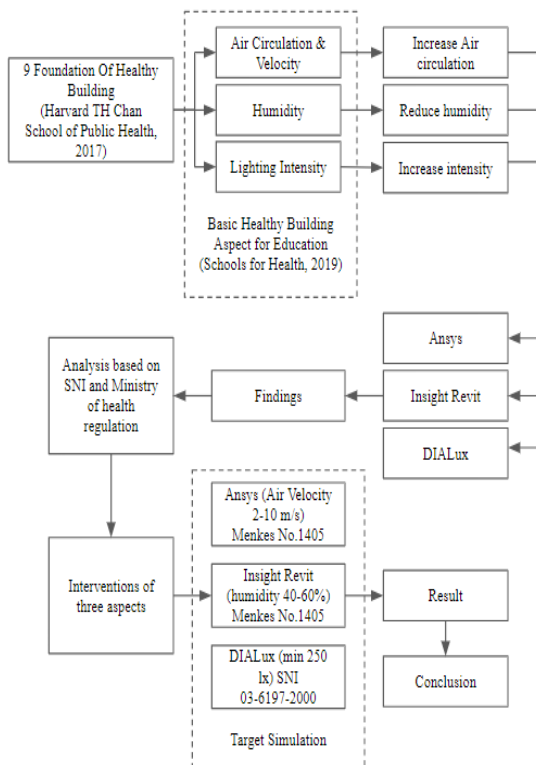


Figure 3. Diagram Research Methods
(Source: Author's Analysis, 2024)

Collecting Data from Tools

Data collection using tools and simulations. Using tools for data collection during direct observation of case study buildings namely thermal data. Collecting thermal data from each room temperature using the FLIR One Pro tool for iOS and humidity for each room using two devices namely BENETECH (Thermometer, Hygrometer, Humidity Meter) shows only numbers and HOBO to show relative humidity graphically (see table 2). These tools are used interchangeably to retrieve data about room temperature, surface, and humidity of the room scattered on each floor to determine the temperature at some point in the room and the peak humidity.

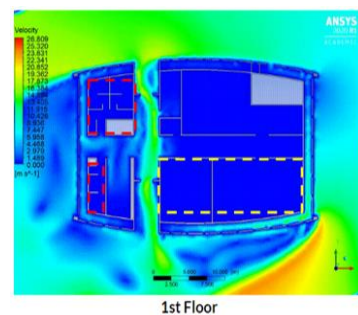
Simulation

The simulation is used to see the overall results of the evaluation of the MRPQ building related to the health aspects of the building. Air circulation simulation using Ansys: Engineering Simulation & 3D Design. That is software that simulates based on 3D models of buildings that are desired to analyze the direction of air circulation and air velocity in buildings. Humidity simulation uses Insight Revit. Simulation to see the relative humidity per floor. Finally, the lighting simulation uses Dialux Evo, which simulates daylight lighting (buildings are used only during the day) using a 3D model of the case study building to collect the light intensity of each room.

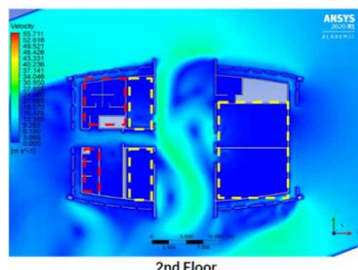
RESULT

Lack of Air Circulation and Air Flow

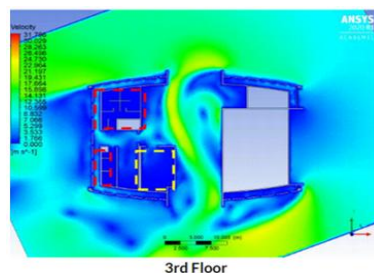
Based on the simulation results (figure 4) in the MRPQ Building, the air in each room on each floor does not circulate properly. Circulation of air that occurs only in the corridor and the center of the building. On the 1st floor, it only occurs in the corridor (0.09 m/s). On the second floor (1.4 m/s) and 3rd floor (0.05 m/s). Air circulation occurs very noticeably in the central area of the building (atrium). On the 4th floor, the air circulation only occurs on the side of the building or around the auditorium at 0.08 m/s. Most rooms do not have ventilation openings so it does not allow natural air circulation properly.



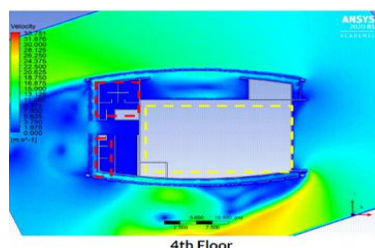
1st Floor



2nd Floor



3rd Floor



4th Floor

Figure 4a. Air Movement simulation (Existing Condition) using Ansys on 1st and 2nd floor MRPQ Building
(Source: Author's Analysis, 2024)

Figure 4b. Air Movement simulation (Existing Condition) using Ansys on 3rd and 4th floor MRPQ Building.
(Source: Author's Analysis, 2024)

High Humidity in The Room with Less Sunlight and Openings

The results of data collection using tools and simulations show the humidity conditions in several locations on each floor (figure 5). Based on the data, referring to Menkes No.1405 / Menkes / SK / XI / 2002 states that the standard relative humidity of 40% - 60% on almost each floor shows more humidity than the health standard (table 3). Especially for the auditorium (93%), the 4th floor corridor (93.5%), and emergency stairs. All three of these rooms have little in common, received sunlight, and no air flow (air circulation).

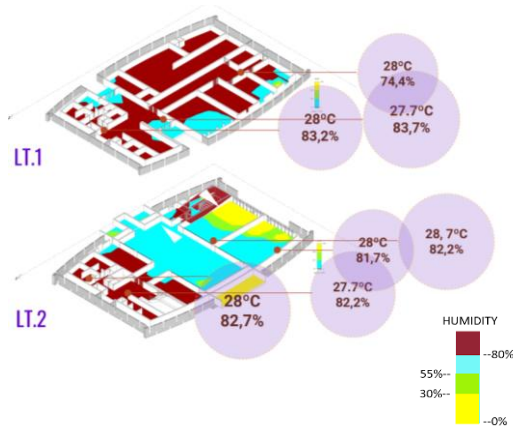


Figure 5a. Humidity Existing Condition in MRPQ Building (1st floor and 2nd floor).

(Source: Author's Analysis, 2024)

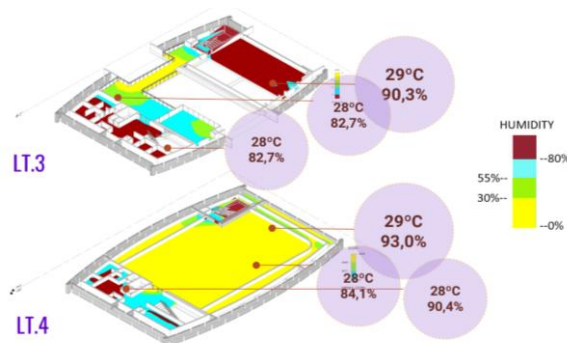


Figure 5b. Humidity Existing Condition in MRPQ Building (3rd floor and 4th floor).

(Source: Author's Analysis, 2024)

Auditorium rooms that have absolutely no openings and no natural lighting. Previous studies have shown that indoor humidity tends to respond negatively to existing ventilation, that is, indoor air humidity is reduced by increasing ventilation, resulting in a reduction in health risks from mold, moisture, or house dust mites (Gross, 2000). High temperatures in the auditorium (29 ° C), on the 4th floor of the corridor (29.7 ° C), and emergency stairs (32 ° C). This data was taken using a BENETECH Thermometer sure tool to find out the temperature of a room.

Table 3. Humidity and Temperature of each floor

Area	Humidity (%)		Temp (°C)		
	Average	Peak	Standard Healthy	Average	Standard Healthy
1st floor (corridor)	74,4	83,7	40-60	27,7	18-28
2nd floor (corridor)	82,2	82,7	40-60	27,7	18-28
3rd floor (Atrium)	79	90,25	40-60	28,7	18-28
4th floor (corridor)	91,4	93,5	40-60	29,7	18-28
Auditorium	90,325	93	40-60	29	18-28
Emergency stair	88,2	92,5	40-60	32	18-28

Natural Lighting Intensity Does Not Meet Health Standards

Natural lighting the researcher using Dialux for simulation (see figure 6).

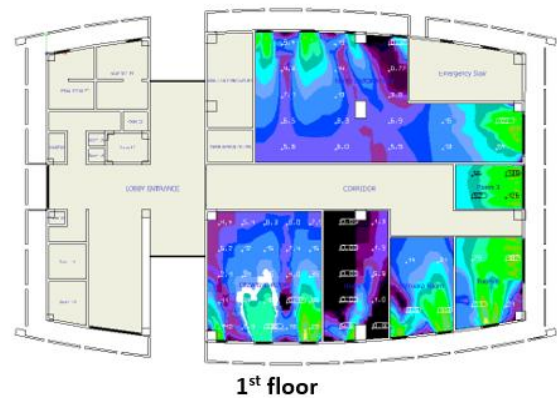


Figure 6a. Result of natural lighting (existing condition) simulation in DIALux (1st floor) in MRPQ Building

(Source: Author's Analysis, 2024)

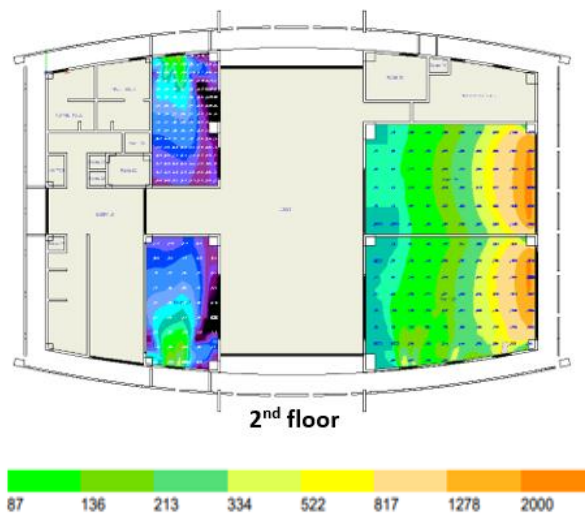


Figure 6b. Result of natural lighting (existing condition) simulation in DIALux (2nd floor) in MRPQ Building

(Source: Author's Analysis, 2024)

After performing an existing lighting simulation (Figure 6), it appears that the spaces that are often used are much less active than the standard recommended health lighting intensity. Data on the average lux of each space can be seen in Table 4.

Table 4. Average lux of each room

Floor	Room	Avg Lux	Standard (SNI 03 6197 2000)
1	Nano Lab	24.2 lx	Min 500 lx
	Creative Room	60 lx	Min 500 lx
	Shizuoka Room	49.4 lx	Min 250 lx
2	Electro Lab 1	19.5 lx	Min 500 lx
	Electro Lab 2	36.2 lx	Min 500 lx
	Electro Lab 3	638 lx	Min 500 lx
	Electro Lab 4	677 lx	Min 500 lx
3	Lecture Room	102 lx	Min 250 lx
4	Auditorium	0 lx	Min 100 lx

There are two rooms that are by minimum health standards, electro lab rooms 3 and 4. Other rooms need intervention in the form of window openings with certain dimensions and positions to meet the minimum health standard requirements of lighting intensity in the room.

Findings

The results showed that MRPQ buildings do not meet the aspects of healthy buildings. The secondary facade is not able to improve air circulation in buildings. In some places, it blocks sunlight into buildings (see figure 7). That resulted in the emergence of mold on the wall or ceiling like in the auditorium.

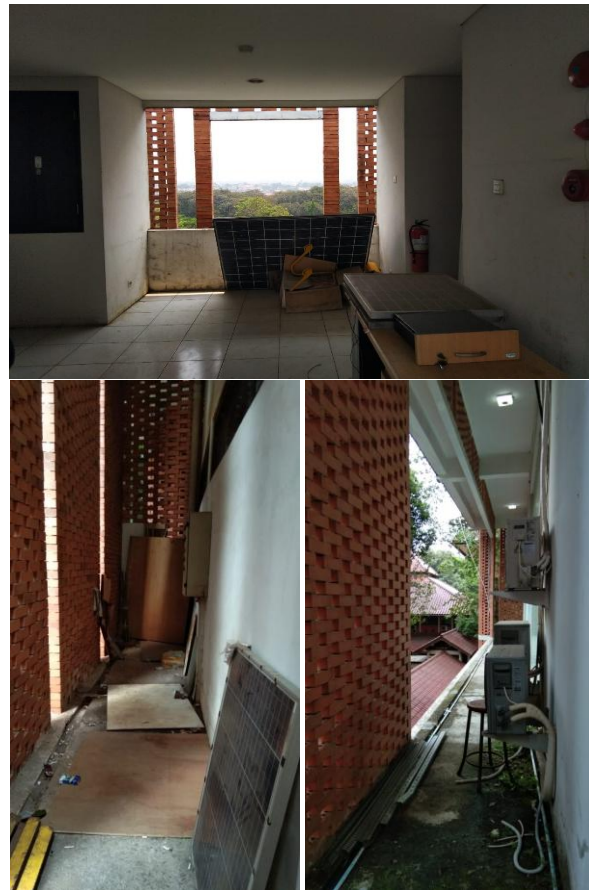


Figure 7. The secondary facade, which should be able to circulate fresh air, is instead damp and dusty, covering several opening areas and becoming a place to store unused items.

(Source: Author's Documentation, 2024)

DISCUSSION

In the aspect of air circulation, there's the absence of good air velocity in most rooms that do not have ventilation. Among the rooms on the first floor, are the Nanotech Laboratory, Creative Room, Shizuoka Room, and Meeting Room. The 2nd floor is Electro Lab 1 and Electro Lab 2, the 3rd floor is the Lecture Room and the 4th floor is the auditorium. These rooms use air conditioning and the room openings are permanently closed so there is no air circulation in there. This relates also to data on the relative humidity of the building. Some rooms that have relatively high humidity are on the 1st floor there is a Nano Lab room, Creative room, Shizuoka Room and Meeting Room, and Auditorium room on the 4th floor.

The lighting aspect also shows the same thing, the intensity of the natural lighting does not meet the health standards. For the air and light aspects, it can be concluded that the absence of ventilation for air circulation and natural lighting. The humidity aspect, it can be decreased by increasing ventilation, resulting in a reduction of health risks from mold, moisture, or house dust mites.

Due to some facts from the results of the data above, it can be concluded to provide interventions related to adding ventilation in some rooms or reopening some existing ventilation periodically.

Reactivate and Add Some Ventilation for Air Circulation, Reduce Humidity, and Increase the Intensity of The Room's Natural Light

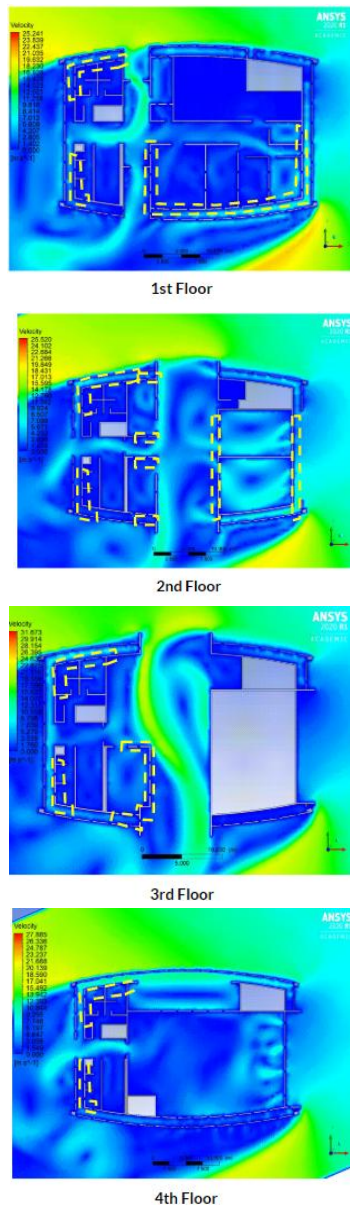


Figure 3. Result of natural lighting simulation in Ansys after intervention.

(Source: Author's Analysis, 2024)

The intervention is to add openings in the relevant space. The opening has dimensions of 30x90cm with glass fins. Openings are positioned on the side of the room that allows air to enter and circulate properly so that it can cause the effect of cross ventilation.

Simulation results after the intervention can be seen in Figure 8. On the 1st floor, the air moves from

the outer wall through the entrance to the main corridor. On the 2nd floor, all the rooms are well-aired. The electro-laboratory rooms 3 and 4 are the most visible cross-ventilation effects that occur in figure 7. On the second floor, indoor air velocity is 2-10 m/s and can reduce air temperature by 3.9-5 C to 23.8-22.7 C. On the 3rd floor, air moves from the atrium spreads into small rooms then into the lift lobby. On the 3rd floor, indoor air velocity is 2-10 m / s and can reduce air temperature by 3.9-5 C to 24.8-23.7C. On the 4th floor, there are very visible cross-ventilation effects in the auditorium. In the auditorium, openings are made on the west wall of the building. The west side of this building is the most often passed by air into the building. As seen in the figure 7, the air in the auditorium moves from the west wall (right) to the entire room and moves into the lift lobby. On this floor, the air velocity in the room becomes 2-7 m / s and can reduce air temperature by 2.2 C to 25.8-24.7 C. From all the results, the average temperature derived from the movement of air in rooms can be categorized as optimal comfort on each floor. This meets with the regulations of the Health Minister and SNI.

Humidity decreases after adding ventilation openings. The air flows and circulates in buildings to reduce the humidity of the room. The average humidity reduction on each floor is 13.3%. The data can be seen in detail in Table 5.

Table 5. Average Humidity

Floor	Before (Existing Condition) (%)	After Intervention (%)	Standard (%)
1	83.7	73.75	40-60
2	82.7	76.4	40-60
3	90.25	74.24	40-60
4	93.5	79.06	40-60
Auditorium	93.5	73.6	40-60
Emergency stair	92.5	80	40-60

To increase the intensity of natural lighting, an intervention was carried out using a combination. The ventilation with glass fins keeps light and air in. The ventilation used has the same dimensions (figure 6) as the previously used as a design intervention in increasing air movement in buildings. This opening always known as the nako window, one of the windows that has been used for a long time still has the flexibility of opening size manually and its use does not require electricity or others. This is like what a previous study claimed, that traditional architecture sometimes had climate-responsive solution (Syamsiah, Priyatmono, 2024)

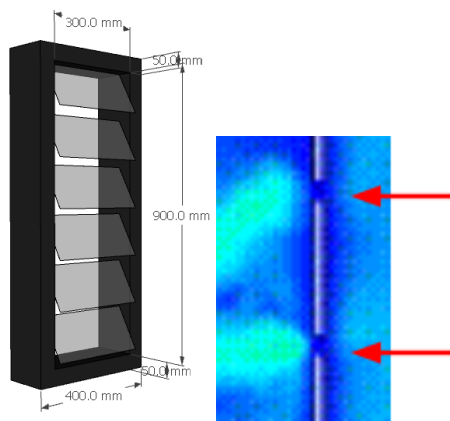


Figure 9. (Left) Ventilation design. (Right) Air movement through ventilation (Ansys Simulation).
(Source: Author's Analysis, 2024)

The increase that occurred is very significant in every room except electro lab 3 and 4 (table 6) because it meets the standards. Other rooms' problems can be solved by opening up some parts of the facade so that sunlight can illuminate the room or by adding several artificial lights to each room.

Table 6. Average lux of each room

Floor	Room	Average Lux	Standard Lux (SNI)
1	Nano Lab	44 lx	Min 500 lx
	Creative Room	62.1 lx	Min 500 lx
	Shizuoka Room	92.5 lx	Min 250 lx
2	Electro Lab 1	257 lx	Min 500 lx
	Electro Lab 2	222 lx	Min 500 lx
	Electro Lab 3	638 lx	Min 500 lx
	Electro Lab 4	677 lx	Min 500 lx
3	Lecture Room	668 lx	Min 250 lx
4	Auditorium	202.5 lx	Min 100 lx

After the intervention in the design of these three aspects of health, the building will be healthier by local standards. In the air circulation aspect, the air velocity increased by 66.5%. In the aspect of humidity decreased to close to the standard of 13.3% and in the aspect of natural lighting increased by 78.2%. Therefore this building can be said to be healthy in all three aspects.

CONCLUSION

Evaluation of the MRPQ building based on three aspects of healthy building (thermal health, air circulation, and lighting) in this study was successfully carried out. Based on the data obtained, it appears the MRPQ building has several problems such as humidity levels above the standard 40-60%, lack of natural air velocity for air circulation, high air temperature, and low natural light intensity in corridors and auditoriums. Then in the discussion, we carried out several interventions to see the improvement in

numbers related to the three aspects of healthy building. The results of interventions in all three aspects of health can increase by 66.5% in healthy air circulation, 13.3% in humidity, and 78.2% in natural lighting aspects. The problem of high humidity, lack of light, and high temperature in the building's room can be overcome by carrying out a simple intervention by ventilation. Some problematic rooms strive to get good air circulation and natural lighting, but the user's need for air conditioning causes it to be ignored. This case can cause users to be unaware of the long-term effects of rooms with poor air circulation on their health. The results of this study are expected to be one example of how buildings can be made better in terms of the comfort and health of residents.

For further research on healthy buildings, it is necessary to take a sample of building user data regarding their health problems. It also needs data retrieval about the composition of the material contained in the material used. This can make interventions carried out more precisely according to the needs of building users.

REFERENCES

- Allen, Joseph G.; et al. (2019). *"Schools for Health: Foundations for Student Success."* Harvard: Harvard T.H. Chan School of Public Health. www.ForHealth.org.
- Allen, J. G. et. al. (2017). *Building Evidence For Health: The 9 Foundations of A Healthy Building.* Cambridge, MA: Harvard TH Chan School of Public Health. Harvard Center for Health and the Global Environment. <http://schools.forhealth.org>
- Arlian, L.G., J.S. Neal, and D.L. Vyszynski-Moher, (1999) Reducing relative humidity to control the house dust mite *Dermatophagoides farinae*. *J Allergy Clin Immunol*, 104(4 Pt 1): p. 852-6.
- Bean, Robert. (2004) *Lighting Interior And Exterior.* Massachusetts: Architectural Press.
- Building the Business Case: *Health, Wellbeing and Productivity in Green Offices | World Green Building Council.* n.d. Accessed June 13, (2020). <https://www.worldgbc.org/news-media/building-business-case-health-wellbeing-and-productivity-green-offices>.
- Della Barba, M. P., & McCarthy, J. F. (2017) *Research Summary: Building Commissioning.* Cambridge, MA: Harvard TH Chan School of Public Health. Harvard Center for Health
- Gross, I., et al., (2000) Indoor determinants of Der p 1 and Der f 1 concentrations in house dust are different. *Clin Exp Allergy*, 30(3): p. 376-82.
- Ho, D. C. W., Leung, H. F., Wong, S. K., Cheung, A. K. C., Lau, S. S. Y., Wong, W. S., et al. (2004). Assessing the health and hygiene performance of

- apartment buildings. *Facilities*, 22(3/4), 58–69. <https://doi.org/10.1108/02632770410527789>.
- Lechner, Norbert. (2015) *Heating, Cooling, Lighting: Sustainable Design Methods for Architects*. Fourth Edition.
- Loftness, Vivian, Bert Hakkinen, Olaf Adan, and Aino Nevalainen. (2007). "Elements That Contribute to Healthy Building Design." *Environmental Health Perspectives* 115 (6): 965–70. <https://doi.org/10.1289/ehp.8988>.
- M. J. Mendell, A. A. Ekaterina, M. Spears, R. W. Chan, S. Chon, D. P. Sullivan and W. J. Fisk, (2014) "A Prospective Study of Ventilation Rates and Illness Absence in California Office Building,".
- Mangunwijaya, YB. 2000. *Pengantar Fisika Bangunan*. Djambatan: Jakarta
- Maulina, Wilda; Susanto, Dalhar (2022). Biophilic Design: Virtual Nature Application In A Windowless Room. *Sinektika Jurnal Arsitektur*. Vol 20. No 1, p. 90-98.
- Ministry of Health Indonesia about Healthy Building MENKES NO.1405 / MENKES / SK / XI / 2002
- National Standard of Indonesia About Thermal Comfort in Building - SNI T-14-1993-03
- Program Studi Arsitektur SAPPK ITB. (2015) *Manual Desain Bangunan Sehat*. Vol. 3.
- Rahimi, Muhammad Unggul Muhajiri; Syamsiah, Nur Rahmawati; Nugroho, Muhammad Siam Priyono (2021). The Effect of Wind Speed on the Thermal Sensation in the Siti Walidah Building (Non-AC Area). *Urecol Journal. Part E: Engineering*. p 7-15.
- Standar Nasional Indonesia tentang Konservasi Energi pada Sistem Pencahayaan - SNI 03-6197-2000
- Syamsiyah, Nur Rahmawati; Izzati, Hanifa Nur (2021). Strategi Kenyamanan Termal Masjid (Studi Kasus Masjid Al-Kautsar Kertonatan, Sukoharjo, Jawa Tengah). *Lankai Betang Journal*. Volume 8. p. 98-109
- Syamsiyah, Nur Rahmawati; Priyatmono, Alpha Febela (2024). E3S Web of Conferences 517, *ICETIA* 2023.
- Turner, S. (2016). *Healthy buildings international*. Healthy Buildings Core Purpose. Inc. and Healthy Building Solutions, LLC. Retrieved November 2, 2018, from <http://healthybuildings.com/>.
- W.J. Fisk, How home ventilation rates affect health: a literature review. *Indoor Air* 28 (4) (2018) 473–487