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Concept of Thermal Comfort in Flats in Pondok Bambu – East Jakarta

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Abstract: All apartment buildings in the bamboo hut use an artificial air conditioning system that aims to create thermal comfort in the building. This should be minimized by taking advantage of the potential of natural ventilation. Aims to achieve the ideal thermal in the building of flats in bamboo huts and how to design the window openings in the building of flats in bamboo huts, in order to achieve ideal thermal in the building unit. Therefore, a solution is needed to maximize natural air conditioning in residential spaces by increasing wind speed through the design of window openings which then affects air temperature and humidity. To create thermal comfort in the space, a study is needed on the performance of window openings and their effect on thermal comfort which then continues to design window openings that are suitable for thermal comfort needs. This study uses a qualitative method that refers to books and journals about thermal comfort and the effect of window openings on flats buildings. This research was carried out during the building period and one of the flats in the bamboo hut. With the theoretical basis of thermal comfort, building orientation, architectural elements, building materials, openings to thermal comfort, occupancy density, ceiling height, and the layout of flats which are the reference in this study with a data collection method in the form of searching for physical data by choosing the theory of thermal comfort and the influence of window openings on flats buildings that are in accordance with the research. So that it was concluded that the window openings with the type of hanging windows (top hung) and the ventilation owned by the residential spaces had less than optimal performance. The addition of window openings and ventilation dimensions can increase the speed and distribution of wind in the residential space so that the wind movement pattern does not only flow towards the ceiling of the space but can spread horizontally. As well as the use of a mix costume window opening type where the jalousie inlet combined with the swing window on the ventilation can circulate the wind optimally.

Keywords: *Flats, Thermal, Window Openings.*

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I. INTRODUCTION

According to James Rilatupa (2008), Comfort is part of one of the goals of architectural works. Comfort consists of psychological comfort and physical comfort. Psychological comfort is psychological comfort (a sense of security, calmness, joy, etc.) that is measured subjectively (qualitatively). While physical comfort can be measured objectively (quantitatively); which includes spatial, visual, auditory and thermal comfort. Thermal comfort can be defined as a state of mind that expresses satisfaction with the thermal environment (Nugroho, 2011). Another definition mentions as an indoor environment and personal factors that will produce acceptable thermal environmental conditions up to 80% or more of the occupants in a space. Thermal comfort is one of the most important elements of comfort, because it concerns comfortable room temperature conditions. As is known, humans feel heat or cold is a form of sensory sensors on the skin against the surrounding temperature stimulus. Sensory sensors play a role in conveying stimulus information to the brain, where the brain will give orders to certain parts of the body to anticipate to maintain a temperature of around 37ºC. This is necessary for the organs of the body to be able to carry out their functions properly. In relation to buildings, comfort is defined as a certain condition that can provide pleasant sensations for building users. Man is said to be thermally comfortable when he cannot determine whether he wants a change in temperature that is hotter or colder in a room. Meanwhile, the American standard (Anonymous, 1989) defines thermal comfort as a feeling in the human mind that expresses satisfaction with its thermal environment. This standard also requires that a condition be declared comfortable if no less than 90 percent of the respondents measured state that it is thermally comfortable.

According to the American Society of Heating, Refrigerating and Air-conditioning Engineers / ASHRAE (1989), thermal comfort is the feeling where a person feels comfortable with the temperature of their environment, which in the context of sensation is described as a condition where a person does not feel heat or cold in a certain environment. So, thermal comfort is not only measured from the air

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temperature but from the number of individuals who are comfortable with the temperature of the environment.

According to Sugini (2004) research, the measurement of a person's thermal comfort can be grouped based on 6 (six) main criteria, which consist of 4 (four) environmental parameters: air temperature, radiation temperature, humidity, air speed and 2 (two) individual parameters: clothing and activity. The measurement of indoor thermal comfort from 4 environmental parameters, namely air temperature, radiation temperature, humidity and wind speed leads to thermal comfort standards by thermal comfort experts. According to Robert McDowall (Fundamentals of HVAC System, 2008, p32-42) there are several factors that affect comfort:

- *Temperatures*

Air temperature (Temperature), ºC It is very difficult to determine the ideal air temperature for the body, because the temperature in the head and feet will experience differences. However, for tropical areas, the ideal body temperature is in the range of 24-28°C.

- *Radiation*

Temperature radiation Heat transmitted from hot objects to cold objects is not affected by the intervention chamber. All objects have a coefficient in emitting heat radiation. In buildings, floors, ceilings, walls have almost the same temperature. However, if someone is sitting near a window, you will feel how the heat is convection through the glass.

- *Moisture*

Humidity (Relative Humidity), % • Low humidity: indications of low humidity are dry skin and dry eyes. • High humidity: when the concentration of water in the air is so high, it can technically be up to 100% at 16°C.

- *Air Speed*

The higher the air speed above the body, the greater the cooling effect, and the minimum speed required is about 0.2m/s.

- 0.25 m/s is comfortable, without any air movement being felt.
- 0.25 – 0.5 m/s is comfortable, air movement is felt.
- 1.0 – 1.5 m/s light to unpleasant airflow.
- Above 1.5 m/s is unpleasant
- Increased air speed

The air speed can speed up the process of passing if the speed is between 0.8-1m/s can be reduced to 2.8°C. For example, if the temperature is between 21.6-26.6°C, then the range can be extended to 21.6-29.4°C.

In an example, the movement of air near the ground level can be very different from movement at high altitudes. Hilly topographic forms, vegetation and of course buildings can inhibit or deflect air movement. For example, a thick forest in wet tropical areas and in areas with monsoon winds, the wind can cause the wind strength to decrease after 30 m to 60m-80%, after 60m-50%, and after 120m only 7% of the original wind strength remains. In rare trees, for example in palm forests in coastal areas and in savanna areas, there is a decrease in wind strength but the wind direction is fixed. On the other hand, logging in the middle of dense forests will result in an exchange of air movements. Mountains, cities, valleys can change the direction of the wind by up to 180° and reduce its speed. Studies in major cities show that the average wind speed on the road surface is only one-third of the speed on open landscapes. Tall buildings have better ventilation at the top, because here the intensity of air movement is greater than on the floor.

- Vertical temperature difference Between the legs and the head there is a temperature difference, warm air generally tends to rise so that the head feels warmer. The tolerance between head and feet is 2.8°C.

- *The Purpose of this Vertical Landscape is*

- Windbreaker
- Absorbs CO2 and CO and produces O2 (photosynthesis)
- Improving the on-site ecosystem
- Effective cooling
- Noise and odor suppression
- Temperature variation radiation People are used to warm walls, but when with hot ceilings people are usually not so comfortable, the safe limit is 8.4°C from the calculated temperature range.

The heat radiating from a surface will provide thermal discomfort to residents, if the difference in air temperature exceeds 4°C, this occurs on the lower surface of the ceiling or the lower surface of the roof. Thermal comfort research conducted by Tri Harso Karyono showed that people in Jakarta feel comfortable at an air temperature (Ta) of 26.4oC or an operating temperature (To) of 26.7oC. While the comfortable range is between 24.9 - 28 Ta and 25.1 - 27.9 To. The thermal comfort standard in Indonesia which is guided by the American standard [ANSI/ASHRAE 55-1992] recommends a comfortable temperature with a range between 22 - 26oC To. This difference will result in the amount of energy consumed by the building. A total of 596 employees and employees who work in seven office buildings, namely the Religious Building-Thamrin Building, the BPPT Thamrin Building, the BCA-Sudirman Building, the Ministry of Education and Culture Building-Sudirman, the Sudirman Tax Building, the Widjojo-Sudirman Building, and the LIPI-Gatot Subroto Building, participated in this thermal comfort research.

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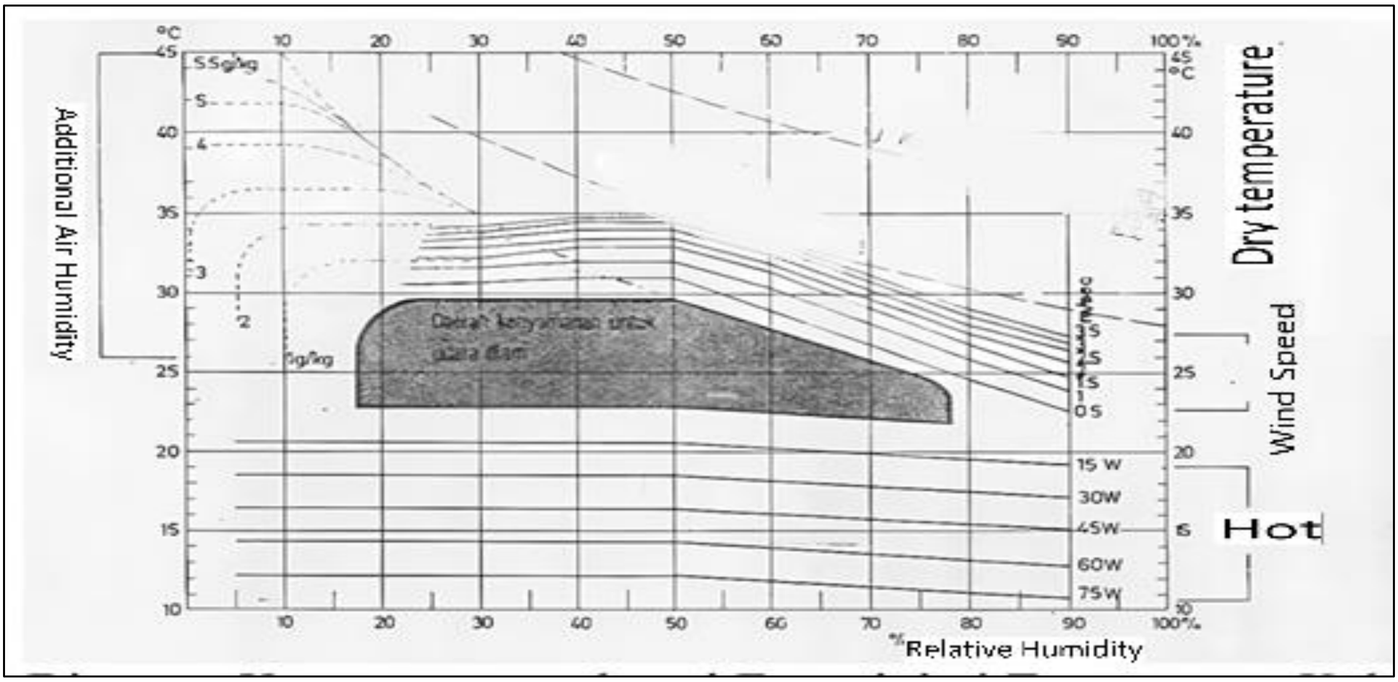

Fig 1 Comfort Diagram as a Function of Temperature, Humidity and Wind Speed

According to Lippsmeier's research (stating that at a temperature of 26°C TE (Effective Temperature) generally humans have started to sweat and human endurance and work ability have begun to decrease) with the division of comfortable temperatures for Indonesians according to the Public Works Building Problem Investigation Institute Foundation (LPMBPU), the temperature we need to be able to do our activities properly is the optimal comfortable temperature (22.8°C - 25.8°C with 70% humidity). This figure is below the air temperature conditions in Indonesia which can reach 35°C with a humidity of 80%. How to control the above climatic factors to obtain thermal comfort in buildings? The easiest way is to use a mechanical approach, namely using air conditioning but requires a lot of operational costs. The second approach is to condition the environment inside the building naturally with an architectural approach.

Environmental conditioning in the building can be architecturally carried out by considering the placement of the building (orientation of the building to the sun and wind), the use of architectural and landscape elements and the use of building materials/materials in accordance with the characteristics of a hot and humid tropical climate. Through the four things above, the temperature in the room can be lowered by several degrees without the help of mechanical equipment.

Based on the standard set by SNI 03-6572-2001, there are three levels of temperature that are comfortable for Indonesians which can be seen in the following table.

Table 1 Thermal Comfort Limit According to SNI 03-6572-2001

Comfort Level	**E ective Temperature (TE)**	**Humidity / RH (%)**
Cool and Comfortable	20.50C TE - 22.80C TE	50%
Upper Threshold	24.0C TE	80%
Optimal Comfort	22.80C TE - 25.80C TE	70%
Upper Threshold	28.0C TE	
Warm and Comfortable	25.80C TE - 27.10C TE	60%
Upper Threshold	31.0C TE	

Source: BMKG Data

According to the research of Basaria Talarosha (2005), there are several strategies for achieving thermal comfort, including:

➢ *Building Orientation*

- *Orientation to the Sun*

The orientation of the building to the sun will determine the amount of solar radiation that the building receives. The larger the area that receives direct solar radiation, the greater the heat that the building receives. Thus, the widest part of the building (for example: a building with an elongated shape) should have an orientation towards North-South so that the side of the building is short, (facing East – West) that receives direct solar radiation.

- *Orientation to the Wind (Cross Ventilation)*

Wind speeds in hot and humid tropical climates are generally low. Wind is needed for ventilation purposes (for the health and comfort of residents in the building).

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Ventilation is the process by which 'clean' air (outside air), enters (intentionally) into a space and at the same time pushes the dirty air inside the space to the outside. Ventilation is needed for oxygen purposes for the body's metabolism, dispel air pollution as a result of the body's metabolic processes (CO_2 and odor) and activities in buildings. For comfort, ventilation is useful in the process of cooling the air and preventing increased air humidity (especially in wet tropical areas), especially for residential buildings. The need for ventilation depends on the number of people as well as the function of the building. The position of the building that crosses the primary wind is needed to cool the air temperature. The type, size, and position of the window openings on the top and bottom sides of the building can increase the effect of cross-ventilation (air movement) in the space so that the replacement of hot air in the space and the increase in air humidity can be avoided. It is rare for a building to have a good orientation towards the sun as well as the direction of the primary wind. Research shows that if you have to choose (for wet tropical areas like Indonesia), the position of the building that crosses the direction of the primary wind is more needed than protection against solar radiation because the heat of radiation can be driven away by the blowing wind. The ideal indoor wind speed is 0.1 – 0.15 m/s. The magnitude of the airflow rate depends on:

- ✓ Free wind speed
- ✓ Wind direction against the ventilation hole
- ✓ Wide ventilation holes
- ✓ Distance between air inlet and outlet

Indoor obstructions that block air The pattern of airflow through the space depends on the location of the air inlet and shading devices used on the outside. In general, the position of the outlet will not affect the airflow pattern. To increase the air speed especially in hot times, the air inlet part is placed at the top, the outlet area is equal to or greater than the inlet and there is no furniture blocking the movement of air in the space. Air movement should be directed to the room in need or the family room. The use of insect screens will reduce airflow into the building. Window openings (Jalousie or louvered) will help direct air to places of need.

Ventilate the space between the roof and the ceiling (especially low buildings) so that heat accumulation does not occur in the space. The heat collected in this space will be transmitted to the space below the ceiling. Roof ventilation is very important to achieve low room temperatures. Insects will reduce the airflow into the building. Window openings (Jalousie or louvered) will help direct air to places of need.

Orientation of Residential Units Orientation is the direction facing the building based on the direction of the sun, in another sense orientation can also be interpreted as the position of the building on the earth which results in the formation of certain climatic patterns accepted by the building. The orientation in this study is more directed to the direction of the building based on the cardinal wind. The orientation of the building in the context of the flats can be interpreted as the direction of the line perpendicular to the longitudinal axis of the building, so that most of the building plane faces the cardinal direction. The direction facing the position of the residential unit is the direction facing the residential unit based on the location of the main entrance to the corridor of the apartment building. So that the observation point on the residential unit is determined in the main room adjacent to the entrance. The consequence of orientation is on the natural lighting system. Buildings with a west-east orientation have the opportunity to receive direct sunlight, which results in the room being distilled by direct sunlight. Buildings with a north-south facing direction have the opportunity to slightly incorporate direct solar radiation, so that daytime lighting in the room makes better use of sky light. According to the aspect of thermal and visual comfort, the result of direct sunlight in addition to causing a glare effect also results in high indoor temperatures. Buildings need more lighting effects sourced from sky light, in addition to light quality that is not dazzling, the room temperature is more comfortable. The magnitude of the direction of direct sunlight, both which has a west-east and north-south direction, is always different throughout the year. The sun's circumstance to the Earth's axis throughout the year is always changing, where in March and September the sun is right at the equator. The city of Bandung, which is located at about 90-00" South Latitude, is exactly in the city of Bandung is around the beginning of March and September. So these months are a good time to observe the air condition in the flats unit, so that the average value of the air condition can be used to draw conclusions from the condition of the building within one year.

Types of Buildings in typology. Typology is the science that studies the grouping of an object. Typology comes from the Greek language which consists of "tipo" which means grouping and "logos" which means science. Building typology means the science used in the grouping of buildings based on certain physical characteristics of buildings. Flats based on building typology can be interpreted as a grouping of apartment buildings based on certain physical characteristics. In this context, grouping can be done through grouping based on the pattern of indoor circulation as a means of communication between residential units, grouping based on the orientation pattern of the group of residential units in one block of flats, grouping based on the pattern of the arrangement of the floors of the building based on function, grouping based on the designation or target of the resident group, and other forms of grouping. The type of building in the context of this study is directed at grouping based on circulation patterns, the composition of residential units on one floor. Based on the circulation pattern, there are three types of circulation patterns that function as a link between residential units, namely the centralized pattern, where the circulation that occurs is concentrated at one point, the two linear circulation patterns which are further divided into two patterns, namely the linear circulation pattern with a single-sided service system (single loaded corridor) and the linear circulation pattern with two-sided service (double loaded corridor).

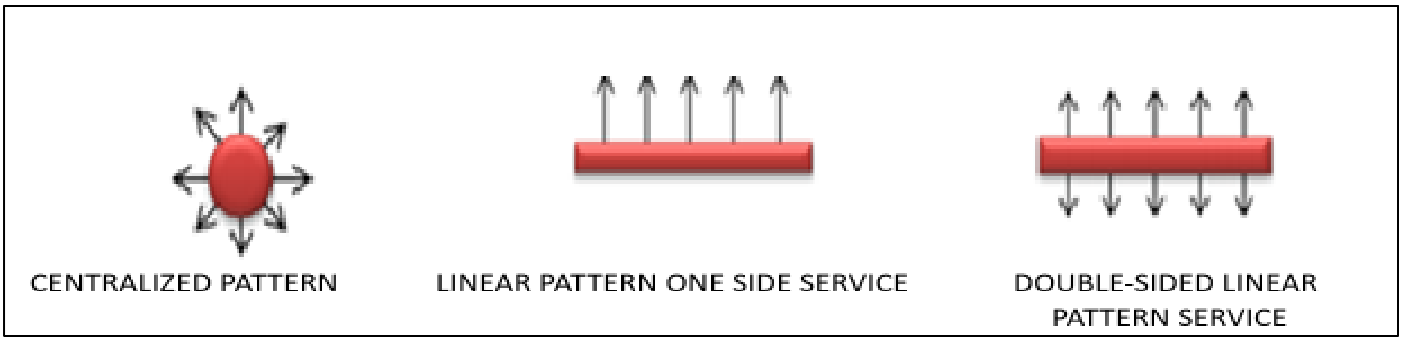

Fig 2 Grouping of Flats based on Circulation Patterns

Based on the type of circulation, flats can be divided into three, namely flats with concentrated circulation, flats with single-sided linear circulation of services and flats with double-sided linear circulation of services.

Fig 3 Grouping of Flats by Composition

Based on the composition of the group of residential units on each floor, it consists of three types, namely the group with the composition of residential units facing at one orientation point forming an orientation, the second composition is the composition of residential units with a linear longitudinal arrangement facing in one direction of the same cardinal, and the third composition is the composition of residential units that have two orientations and there are units facing each other. From the three typologies above, it can be concluded that flats have three types, which can be expressed as centralized type flats with the designation Tower type, linear elongated type with a single-sided service corridor, namely the Block Single Loaded type, and an elongated type with a two-sided serving corridor, namely the Block Double Loaded type. Between the composition and the circulation pattern, the two are integrated with each other to form a typology.

- *Position of Residential Units*

The position of the residential unit is the location of the residential unit relative to the building as a whole. The position of residential units is indicated to have different characteristics based on the position in the vertical and horizontal directions. In the vertical direction, it tends to experience different influences from the outside environment. From the aspect that the higher the wind has a higher speed, the higher the light has a lower chance of interference or shadowing from environmental elements such as trees or other buildings, the sound other than the top is farther away from the noise source. In the horizontal direction, which is the direction of extending parallel to the floor, there is a chance of a difference in the position of the residential unit that is on the corner side with the residential unit that is in the middle position. The difference in conditions between the corner position and the middle position is in the number of sides that interact directly with the outside air, which is more on the corner side, while the middle side actually has two sides that are directly adjacent to other residential units.

➢ *Architectural Elements*

If the position of the building in the direction of East and West cannot be avoided, then the free view through the window on this side must be avoided because the heat radiation that directly enters the building (through the opening/glass) will heat the space and raise the temperature/temperature of the air in the room. In addition, the glare effect that appears when the sun angle is low is also very disturbing. The image below is an architectural element that is often used as a shield against solar radiation (solar shading devices).

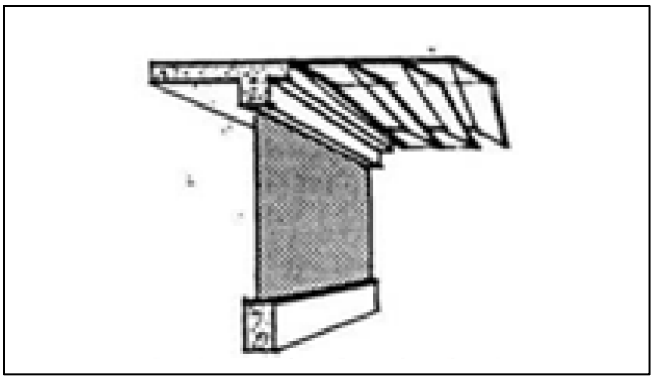

Fig 4 Contilever (Overhang)

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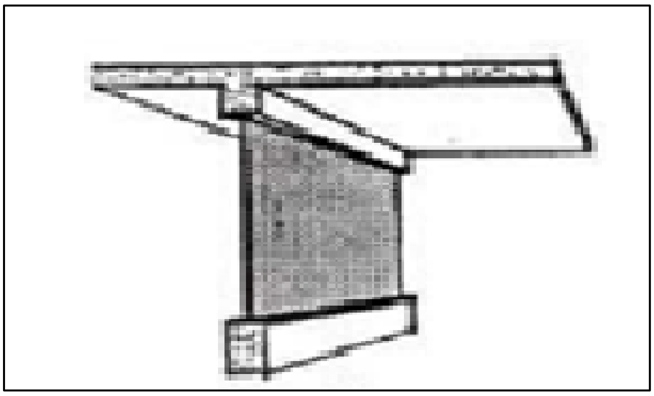

Fig 5 Louver Contilever

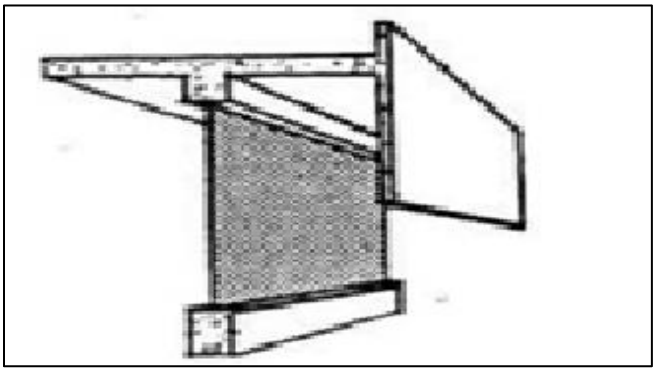

Fig 6 Panel (Awning)

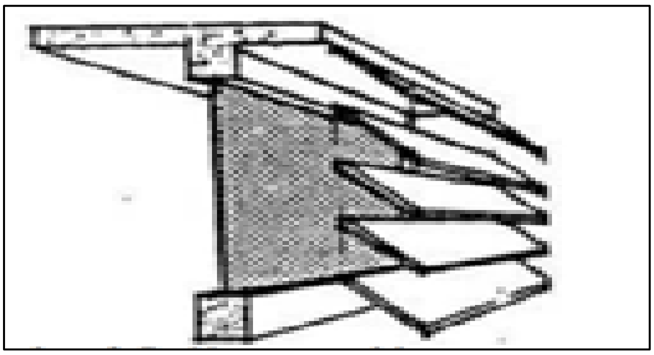

Fig 7 Horizontal Louver Screen

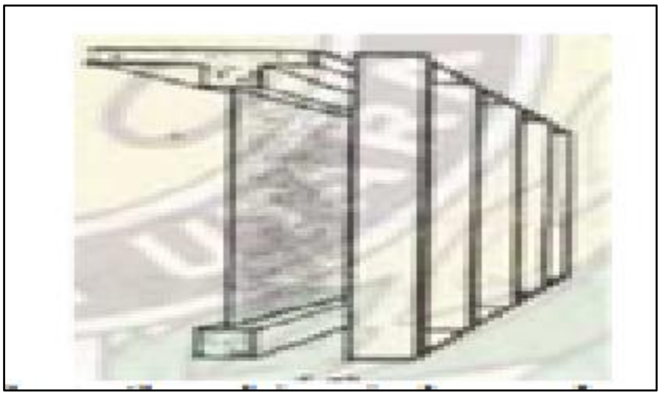

Fig 8 Egg Crate (Combination of Horizontal and Vertical Elements)

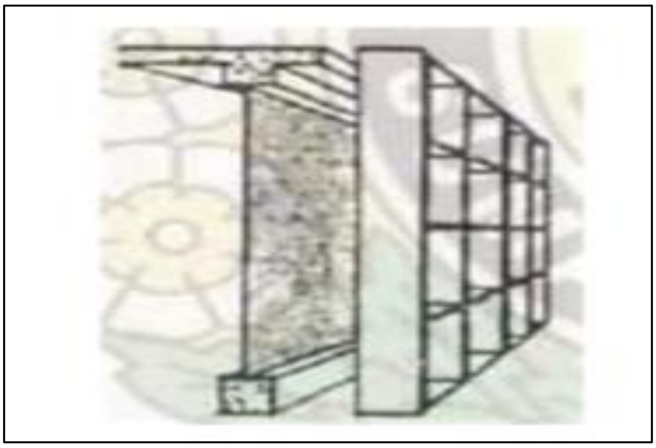

Fig 9 Vertical Louver

In figure 8 and figure 9 it is most effectively used in the plane of the building facing East-West. It also serves as a 'Windbreak', important for areas with 'abundant' winds. The effectiveness of sun protection is assessed by the shading coefficient (S.C) number which indicates the amount of solar energy transmitted into the building. In theory, the number shown is from 1.0 (all solar energy is transmitted, for example: the use of unprotected window glass) to 0 (no solar energy is transmitted).

Table 2 Shading Coeficient for Architectural Elements

No.	Protective Elements	Shading Coefficient
1.	Egg-Crate	0.10
2.	Panel or Awning (light color)	0.15
3.	Horizontal Louver Overhang	0.20
4.	Horizontal Louver Screen	0.60 - 0.10
5.	Cantilever	0.25
6.	Vertical Louver (permanent)	0.30
7.	Vertical Louver (movable)	0.15 - 0.10

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➢ *Materials/Building Materials*

Building materials have physical properties that allow them to have an impact on different residents, from the aspect of thermal propagation ability there are building materials that quickly propagate from one side to the other, building materials that have the ability to store heat and cold for a long time, there are also porous and solid building materials. All of these building materials can affect the comfort factor in the space in the building. From the aspect of the production process of building materials, it has several characteristics, building materials which are raw materials that are sourced directly from nature, secondary building materials which are the result of processing from raw materials, tertiary building materials and it is also possible to combine raw materials with secondary materials, such as conblocs which are products of the composition of raw materials such as sand with cement which are secondary building materials. In the process of producing building materials, a number of equipment is needed that is driven by a certain amount of energy through fuel combustion, in addition to that in some processes of making building materials there is an oxidation process. Heat enters the building through the process of conduction (through walls, roofs, glass windows) and solar radiation transmitted through windows/glass.

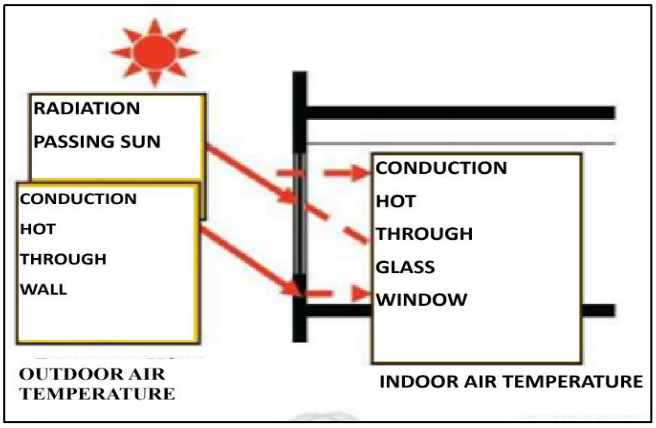

Fig 10 Impact of Glass Window

Solar radiation emits ultra violet rays (6%), visible light (48%) and infrared rays that give a very large heat effect (46%). The results show that solar radiation is the largest contributor to the amount of heat entering buildings. The amount of solar radiation transmitted through the building envelope is influenced by the façade of the building, namely the ratio of the area of glass and the area of the entire wall of the building (wall to wall ratio), as well as the type and thickness of the glass used.

Table 3 Shading Coeficient for different types of glass materials

No.	Type of Glass	Color	Thickness	Shading Coefficient
1.	Clear Glass	–	1/4 inch	0.95
		–	3/8 inch	0.90
2.	Heat Absorbing Glass	Gray, Bronze, or Green Tinted	3/16 inch	0.75
		–	1/2 inch	0.50
3.	Reflective Glass	Dark Glass Metallized	–	0.35 – 0.20
		Light Gray Metallized	–	0.60 – 0.35

Source: Concept in the Thermal Confort, M. David Egan

➢ *Opening to Thermal Comfort*

Cross ventilation should always be done, even in rooms that use air conditioning. Once in a while, fresh air is definitely needed to replace the hot air in the room. The vents on the side of the room can function as a wind shovel placed in the corner of the façade will catch the wind. It can be used when the wind speed is high. The pattern and configuration of the aperture affect radiation, airflow, and lighting. The light, shape, location, and position also affect the movement of air, lighting, and glare in the inner space. If the opening is not shaded, it will affect the radiation heat obtained. The opening at a higher level, increasing airflow, is known as the 'stack effect'. The position of the opening affects the distribution of light in the inner space as it affects the reflection in the inner space. For tropical areas, openings are indispensable to facilitate the entry of air. Wide sosorans are preferred when cutting through solar radiation. The height of the opening must cause good air distribution for the human body. Lower opening thresholds may be preferred. The tall window provides good distribution for direct and diffuse light. Low windows allow the ground to reflect light. Partitions should not be placed near windows because they will change and disrupt the direction of the wind flow. It would be preferable to provide each room with windows on at least two sides of the wall. Ventilation is required 85% a year, and east-west cross ventilation is required. Elements such as sails, louvres, and jalusion are used to circulate air and to protect from the sun.

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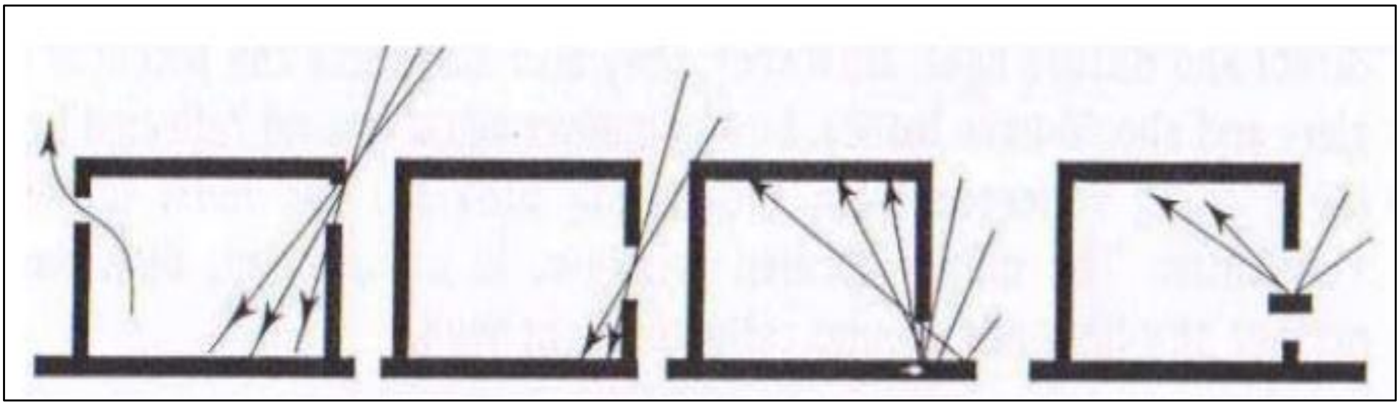

Fig 11 Window Position Relative to Lighting and Ventilation
Source: Krishan, 2000

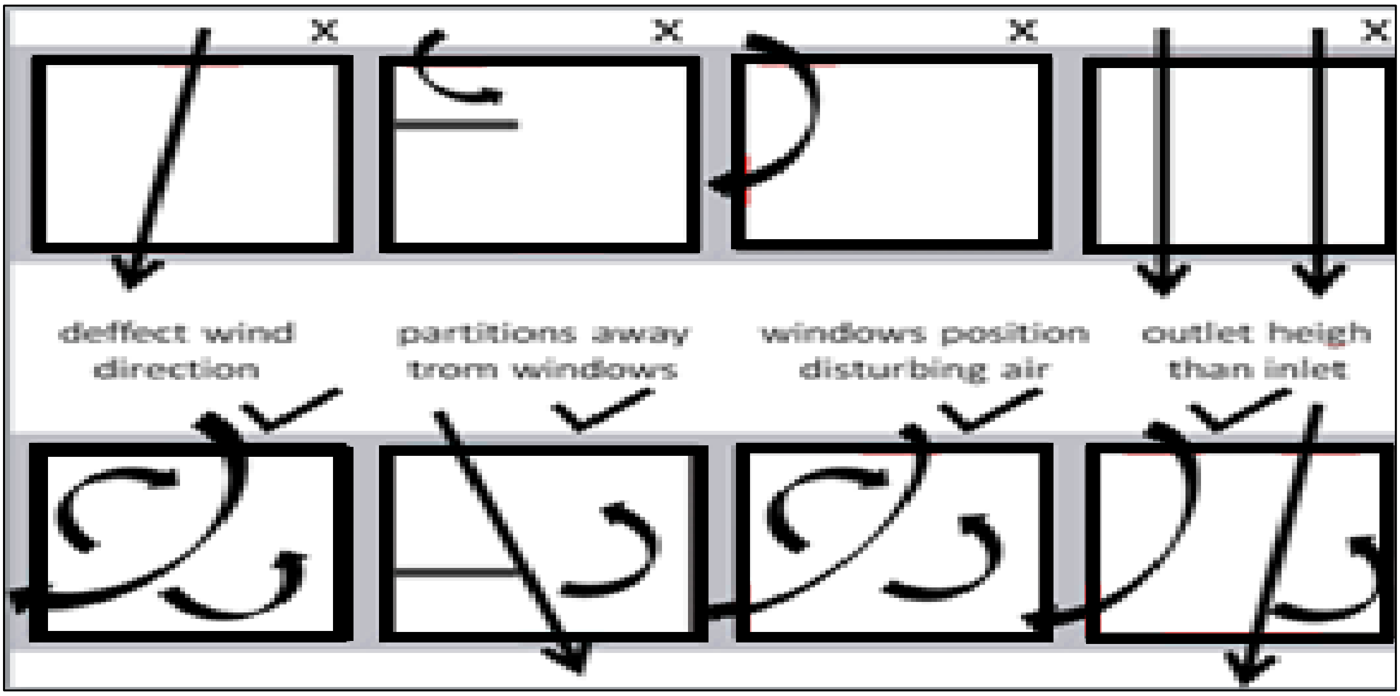

Fig 12 Aperture Configuration and its Effect on Airflow
Source : Krishan, 2000

The orientation of the opening affects the radiation of sunlight received and the movement of air. To produce a good distribution of airflow within a building, the wind direction and the inlet-outlet direction should not be the same. It should be between 45º perpendicular to the wind direction. Arranging buildings with their main openings facing north and south will provide advantages in reducing the load on air conditioners.

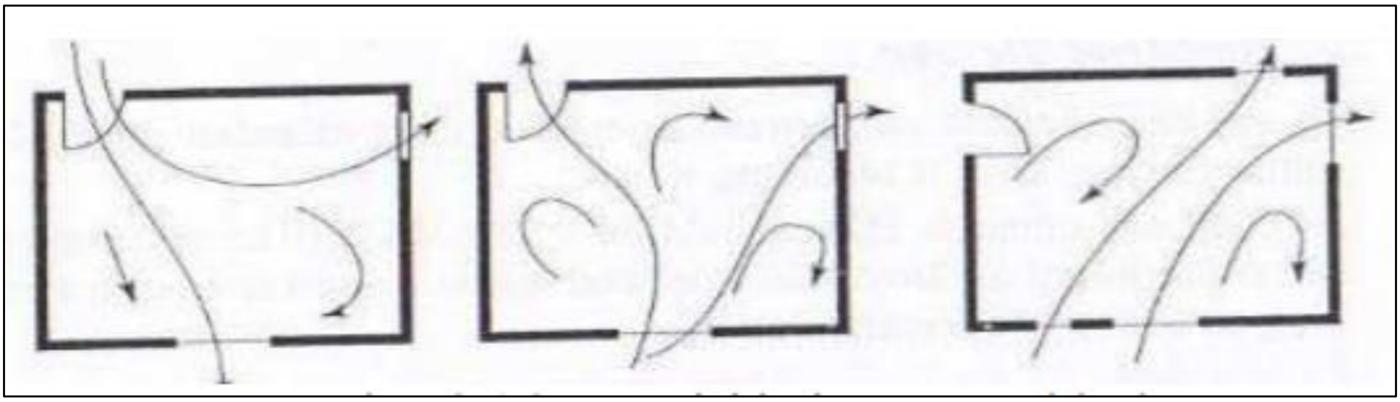

Fig 13 Ideal Opening Position
Source: Krishan, 2000

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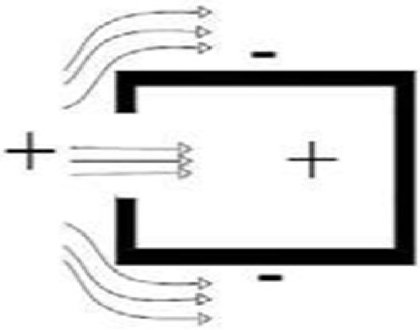
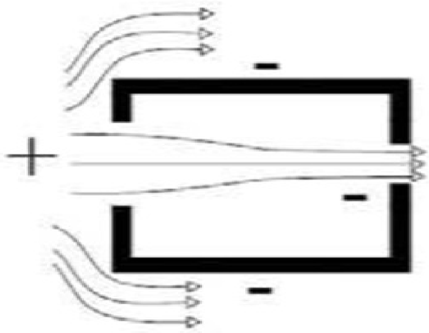
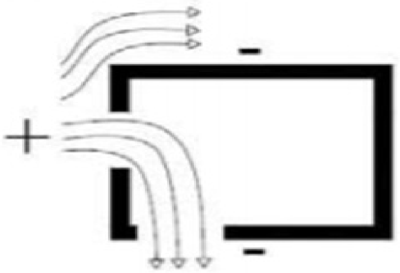
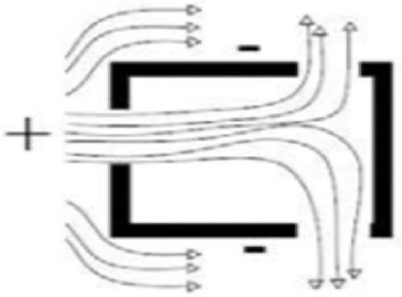
Opening control will affect radiation, air movement, and natural lighting. The placement of glass, shadows, screens, light shelves, and cross window areas can be a control. These things can prevent sunlight radiation. The use of glass will control solar radiation. Shadowing, vertical and horizontal will control the heat of the radiation. Light shelves will bring a lot of light into the room, which will be cut by horizontal shading. The gauze will control the entry of insects and reduce the wind speed inside the building. To improve ventilation, it can be obtained by modifying the window itself (Givoni B.: 1994).

What is meant by cross ventilation is an opening or hole for air flow that is placed not on one side of the wall but on two or three opposite sides so that wind can flow into the room.

The right ventilation openings are a very important factor for the comfort of the space. Good ventilation is what allows airflow for 24 hours without the help of mechanical equipment. There should be ventilation for the night when the windows and doors are closed. The placement and area of the vents can determine the direction of flow and the desired air volume. The airflow should be formed where humans are. Ventilation that is only on one side of the wall causes the wind not to flow.

Table 4 Air Flow

Type of Opening	AIR FLOW
	- Wind blows from high-pressure areas to low-pressure areas. Air inlet without an air outlet, air does not flow because the room air pressure becomes high.
	- With cross ventilation, opening the way for air to enter and exit, air flows. Outlet < inlet = Slow flow, Outlet > inlet = Fast flow.
	- Outlet close to the inlet creates areas not traversed by air.
	- If the outlet is desired on two sides, the air circulates further into the room.

Source: Concept in the Thermal Confort, M. David Egan

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In order for the wind to flow, there must be an air inlet or inlet and an outlet air hole. The placement and area of the inlet and outlet greatly determines the volume of air flowing. The area of the opening is highly dependent on the number of residents, the activity of the residents, the air temperature, the wind speed, the larger number of residents, and the heavier activities require greater air exchange under the same temperature and wind speed conditions. The area of the ventilation hole is also affected by the air temperature and wind speed. That the lower the air temperature, the slower the wind current. A wind speed of 0.5 m/s at 30oC still feels delicious, but a speed of 0.5 m/s at 12oC feels very cold. This means that the area of the ventilation hole must be smaller for cold areas. But it can also be said that it depends on the habits of its residents, who are used to cold, medium or hot temperatures. For places that are often blown by strong winds, such as coastal areas, the ventilation must be arranged so that the wind blows slowly on the land. So the ventilation area in one room depends on the number of residents, residents' activities, air temperature, wind speed (Sri Umiati: 2008).

➢ *Residential Density (Spatial)*

Spatial comfort is determined by the level of residential density, meaning that there is a compatibility between the area of residential units and the number of residents, according to the decree of the minister of the department of settlements and regional infrastructure (Kepmen Kimpraswil) Number 403/KPTS/M/2002, the minimum space requirement is 9 m2/person. For the average number of people in a residential unit of 4 people, the area of the residential unit required for the family is 36 m2.

➢ *Ceiling Height*

One of the important elements to consider in the interior is the ceiling. The ceiling is a part or boundary of a space that is right at the boundary of the wall and roof. The ceiling itself has several functions ranging from roof truss covers to aesthetics so that it looks neater and cleaner. For this reason, the ceiling or ceiling of the house must be a concern and planned well, one of which is about height. Although, there is actually no exact measure of the ceiling height standard. It's just that you still have to pay attention to the size of the ceiling based on the function of the space, aesthetics, and lighting. Determining the ideal size of the ceiling cannot be made arbitrarily. This is because it can have an impact on the aesthetics of the space and the comfort of the space itself.

- *Ceiling Height Based on Climatic Conditions*

Quoted by arsitur, a low ceiling height can make the room warmer, while a high ceiling makes the room feel cooler. Determining the height of the ceiling of the house can be determined based on climatic conditions. In Indonesia, ideally the ceiling height ranges from 2.8 meters to 3.5 meters or made higher. This is because Indonesia has a tropical climate with hot daytime temperatures so it requires better air circulation. While in Europe, the ceiling height can reach 2.4 meters to 2.5 meters. This makes the room can be warmer.

- *Ceiling Height Based on Space Function*

Determining the height of the ceiling is not only that, but it can also pay attention to the function of the space. This means that rooms used for joint activities usually use higher ceilings. The function of the room also determines the height of the ceiling in that room. For example, the family room at home. Generally, the height of the ceiling of the living room has a height of 3 meters. Meanwhile, for private spaces, for example, bathrooms or bedrooms have a ceiling height of 2.4 meters.

- *Ceiling Height Based on Proportion*

Ceiling Height Based on Proportion by applying the ceiling height formula. In determining the ceiling, it's a good idea not to just look at the ceiling model. The formula is ceiling height = 1/2 x (room length + room width). For example, a room with a size of 4 x 5 meters will appear more proportional if the ceiling height is (5+4)/2 = 4.5 meters. In addition, the ceiling height can also be determined for aesthetic purposes. One of them is a drop ceiling game that makes the ceiling seem to have different levels of height used for focus/focal points.

- *High Ceiling for Space Lighting*

Rooms with high ceilings require more lighting. Determining the right ceiling height also affects the lighting in the room. While rooms with lower ceilings have relatively smaller lighting needs. This will greatly affect the choice of the type of lamp and the placement of light points in a room. Higher ceilings can use more varied lighting. So, it all depends on the desired concept. If you want to maximize the skylight, you can use a height of up to 4 meters. (building ceiling height; *Source: dwell.com)*

- *Ceiling Height Based on Building Structure*

For buildings with multi-storey floors, there will be differences in how to determine the ideal ceiling height. Determining the height of the ceiling can also be based on the structure of the building. Multi-storey buildings will require structures in the form of beams and floor plates that can limit the height of the ceiling. Meanwhile, the floor level cannot be made too high because it will affect the number of stairs and the cost. Generally, the ceiling can only be made as high as the floor plate by appearing blocks that may be annoying. It is recommended that the distance between floors is at least 3.2 meters to be able to get a pafon with a height of 2.75 meters, which is ideal.

➢ *Layout of Flats*

The basic module of the space must be able to be used to accommodate the activities of the residents and the most basic supporting furniture. The exersise in a space of 9m² is as follows:

- *Couple's Bedroom*

✓ Activities: sleeping, working, saving, putting on makeup, and praying
✓ Mobility space size: 9.6m² is required to obtain a clean space of 3m x 3m

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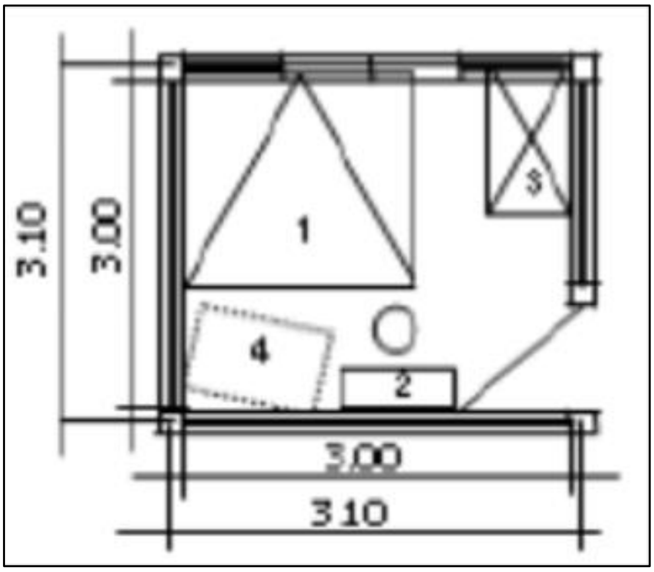

Fig 14 Couple's Bedroom Layout
Source: Riview design of non-Modular Flats into KPUPR-based Modular Flat design, 2008

- *Basic Furniture Needed:*

✓ Couple's bed 180 cm x 180 cm
✓ Socks 40 cm x 90 cm
✓ 1 cabinet 40 cm x 90 cm
✓ Prayer place 60 cm x 120 cm

- *Couple's Bedroom & 1 Baby*

✓ Activities: sleeping, working, storing, makeup, and praying, sleeping babies, storing baby clothes, bathing & changing baby clothes.
✓ The size of the movement space requires a clean space of 3 m x 3.60 m

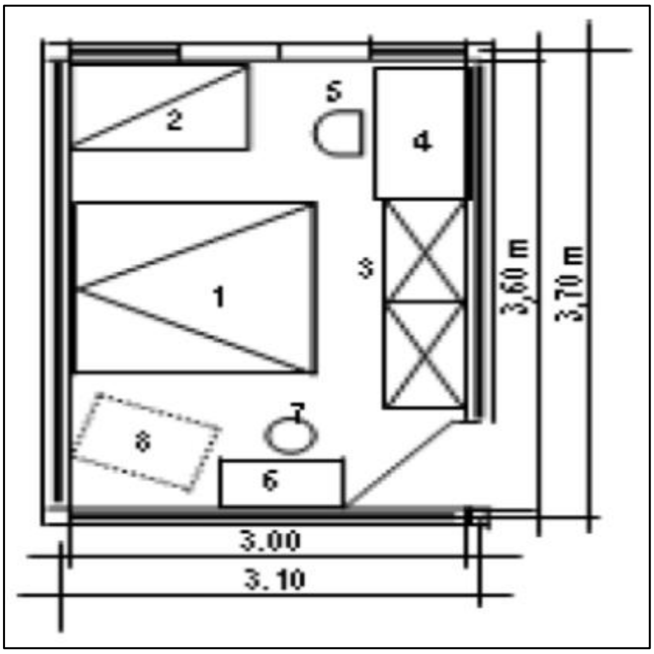

Fig 15 Bedroom Layout of Couple & 1 Baby
Source : Riview design of non-Modular Flats into KPUPR-based Modular Flat design, 2008

- *Basic Furniture Needed:*

✓ Couple's bed 180 cm x 180 cm
✓ Baby bed 60 cm x 120 cm
✓ 1 cabinet 50 cm x 90 cm
✓ 1 Workbench 60 cm x 120 cm
✓ Work chair
✓ Socks 40 cm x 90 cm
✓ Dressing chair
✓ Prayer place 0.60 m x 1.20 m

- *Bedroom for 2 Toddlers*

✓ Activities: sleep, study, save, play, and pray
✓ Mobility space size: 9.6 m² is needed to obtain 3m x 3m clean space

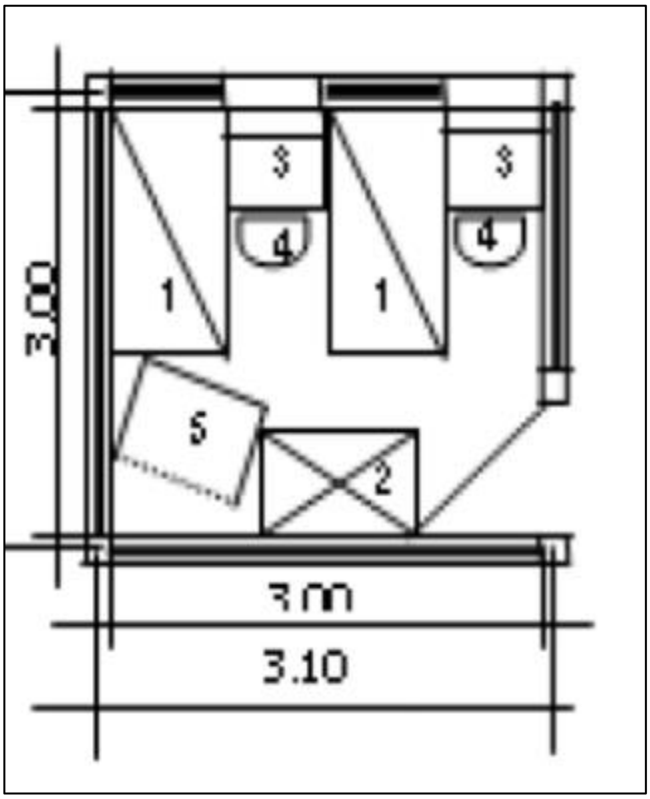

Fig 16 Bedroom Layout for 2 Toddlers
Source: Riview design of non-Modular Flats into KPUPR-based Modular Flat design, 2008

- *Basic Furniture Needed:*

✓ 2 Children's Beds 80 cm x 180 cm
✓ 2 Cabinets 40 cm x 90 cm
✓ 2 Study Desks 60 cm X 80 cm
✓ 2 Study Chair
✓ Prayer Place 60 cm x 120 cm

- *Adult Children's Bedroom*

✓ Activities: sleep, study, save, and pray
✓ Mobility space size: 9.6 m² is needed to obtain 3m x 3m clean space

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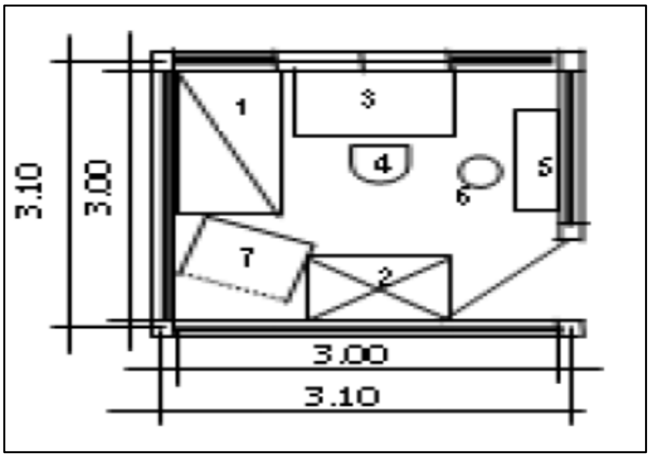

Fig 17 Adult Children's Bedroom Layout
Source: Riview design of non-Modular Flats into KPUPR-based Modular Flat design, 2008

- *Basic Furniture Needed:*

✓ 1 Children's bed 80 cm x 180 cm
✓ 1 cabinet 50 cm x 90 cm
✓ 1 Study table 60 cm x 120 cm
✓ 1 study chair
✓ 1 meja rias (pi) 40 cm x 120 cm
✓ 1 vanity chair
✓ Prayer place 60 cm x 120 cm

- *Multifunctional Room*

✓ Activities: storage (utensils, food), ironing, eating, family, work, reception
✓ Maneuver space size: minimum clean space required 4.5 m x 3 m

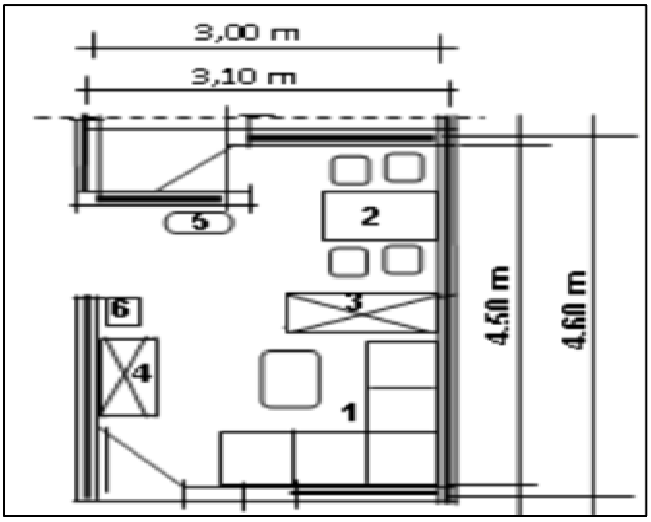

Fig 18 Multifunctional Room Layout
Source: Riview design of non-Modular Flats into KPUPR-based Modular Flat design, 2008

- *Basic Furniture Needed:*

✓ Sofa for family & reception
✓ Dining table & 4 chairs
✓ Cabinets (tools & food)
✓ Decorative shelves & TVs
✓ Ironing board
✓ Refrigerator

- *Service Room*

✓ Activities: Kitchen (cooking, washing tools, washing ingredients, and dining containers); Km & WC (bath, bath, defecation, laundry), drying.
✓ Maneuver space size: minimum clean space required 1.5 m x 1.5 m

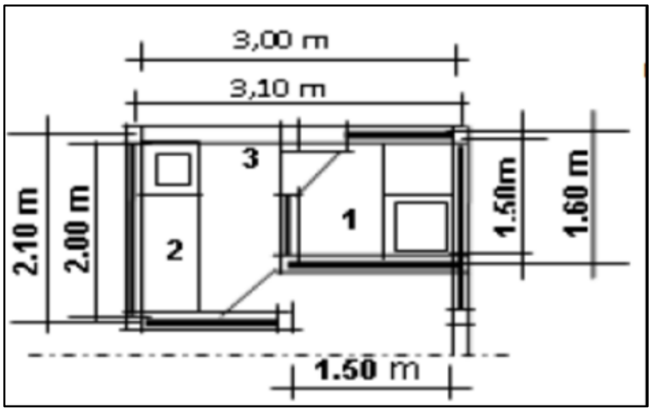

Fig 19 Service Room Layout
Source : Riview design of non-Modular Flats into KPUPR-based Modular Flat design, 2008

- *Basic Facilities Needed:*

✓ Kitchen countertops & kitchen sinks
✓ Toilet, and water faucet and shower.
✓ Drying area
✓ Student Dormitories
✓ Activities: sleep, study, save, and pray
✓ The size of the movement space for 3 people requires a net area of 6 m x 3 m

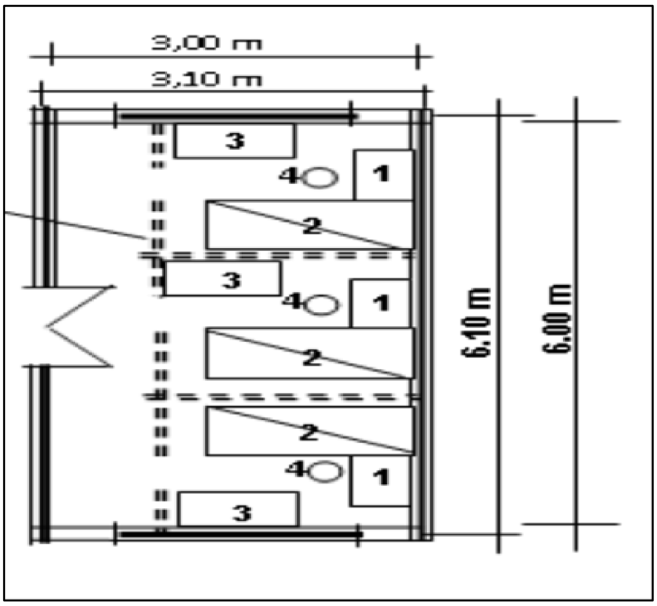

Fig 20 Student Bedroom Layout
Source : Riview design of non-Modular Flats into KPUPR-based Modular Flat design, 2008

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- ✓ In 1 sump a maximum of 3 people
- ✓ Each must have a private space, the room divider uses partitions

- *Basic Furniture Needed:*

- ✓ 1 study desk
- ✓ 1 single bed
- ✓ 1 Wardrobe etc
- ✓ 1 seat
- ✓ Service Room
- ✓ Activities: bathing, bathing, defecating, washing clothes etc, drying, storing, ironing
- ✓ Movement space size:
- ✓ Separate shower room with WC room 1.2 m x 1.5 m each
- ✓ Store & iron 1.8 m x 1.5 m
- ✓ Drying room on the balcony at least 1m x 1.6m

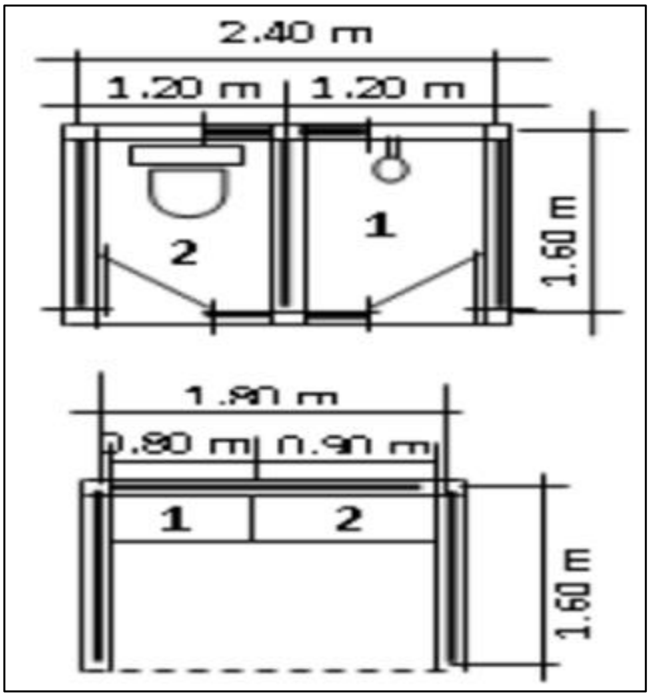

Fig 21 Service Room Layout
Source: Riview design of non-Modular Flats into KPUPR-based Modular Flat design, 2008

- *Staples*

- ✓ Bathroom with shower and water faucet
- ✓ WC with toilet and water faucet fittings\
- ✓ Pantry: store eating & drinking utensils
- ✓ Shelves: top for storing things, middle part for iron

II. RESEARCH METHODS

➢ *Research Methods*

This study uses a qualitative method that refers to books and journals about thermal comfort and the effect of window openings on flats buildings. This research was carried out during the building period and one of the flats in the bamboo hut.

➢ *Research Location*

Fig 22 Location of Pondok Bambu Flats

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➢ *Data Collection Techniques*

The data collection method in this study is to search for physical data. In searching for physical data, namely by choosing the theory of thermal comfort and the influence of window openings on flats buildings that are in accordance with the research.

➢ *Data Collection Strategy*

Secondary data obtained from various sources, including:

- Books related to research
- Journals related to research
- Internet: e-book, website, on-line journal

III. RESULTS AND DISCUSSION

➢ *Overview of Bamboo Cottage Flats*

Bamboo cottage flats are rental flats managed by the DKI Jakarta Provincial Government Housing and Building Office. The bamboo hut flats are located on jl. H. Dogol Pondok Bambu Village, Duren Sawit District – East Jakarta. This apartment consists of 2 building periods named tower a, and tower b. the arrangement of the period faces the same orientation east-west where each longest side faces the south-urata.

Fig 23 Existing Bamboo Cottage Flats

Bamboo cottage flats have one type of residence. The type of residential unit has an area of $30m^2$. Each residence in this flat has the same needs and air quality, starting from natural ventilation, cross ventilation and window openings in residential units are placed equally opposite the inlet and outlet positions.

➢ *Building Time Analysis*

- *Analysis of Buildings Around the Site*

Fig 24 Condition of the Site and its Surroundings

It can be concluded that the height of the building around the site is at most 2 floors, so that it does not interfere with the circulation of wind flowing into the flat unit.

- *Building Period Analysis*

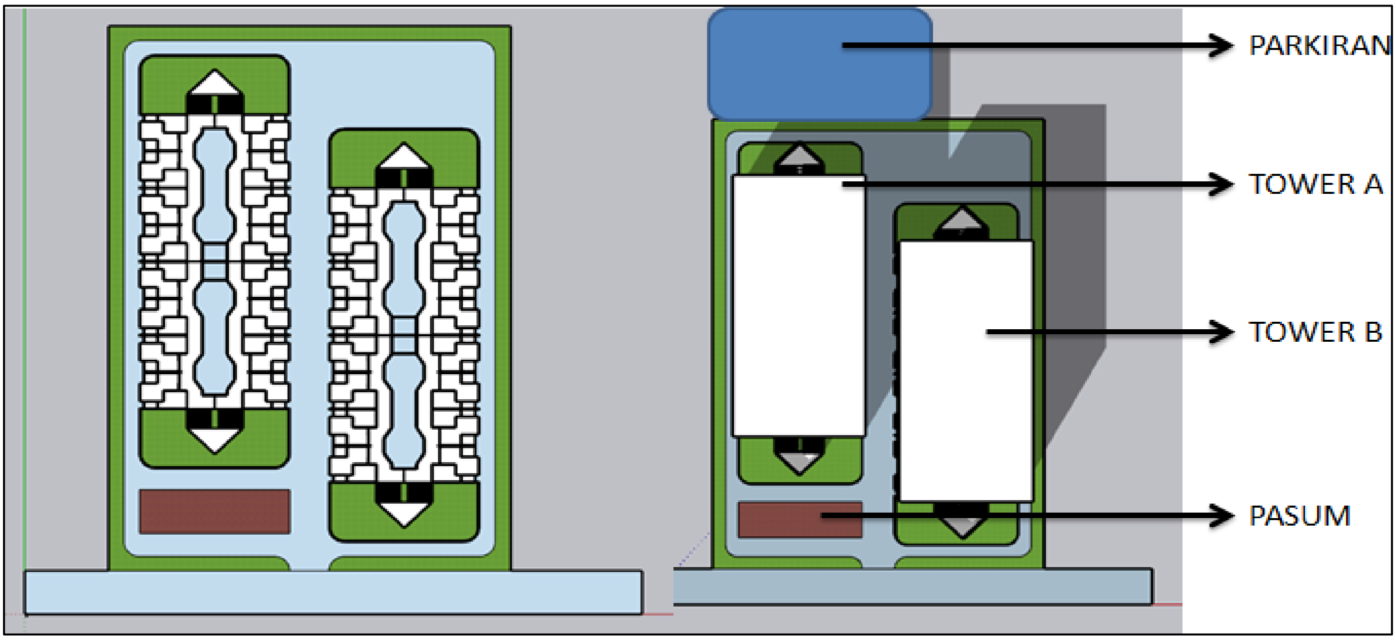

Fig 25 Composition of the Building Period

The building mass follows the shape of the footprint and uses *a single loaded circulation system* so that the shape of the building is elongated.

- *Solar Analysis*

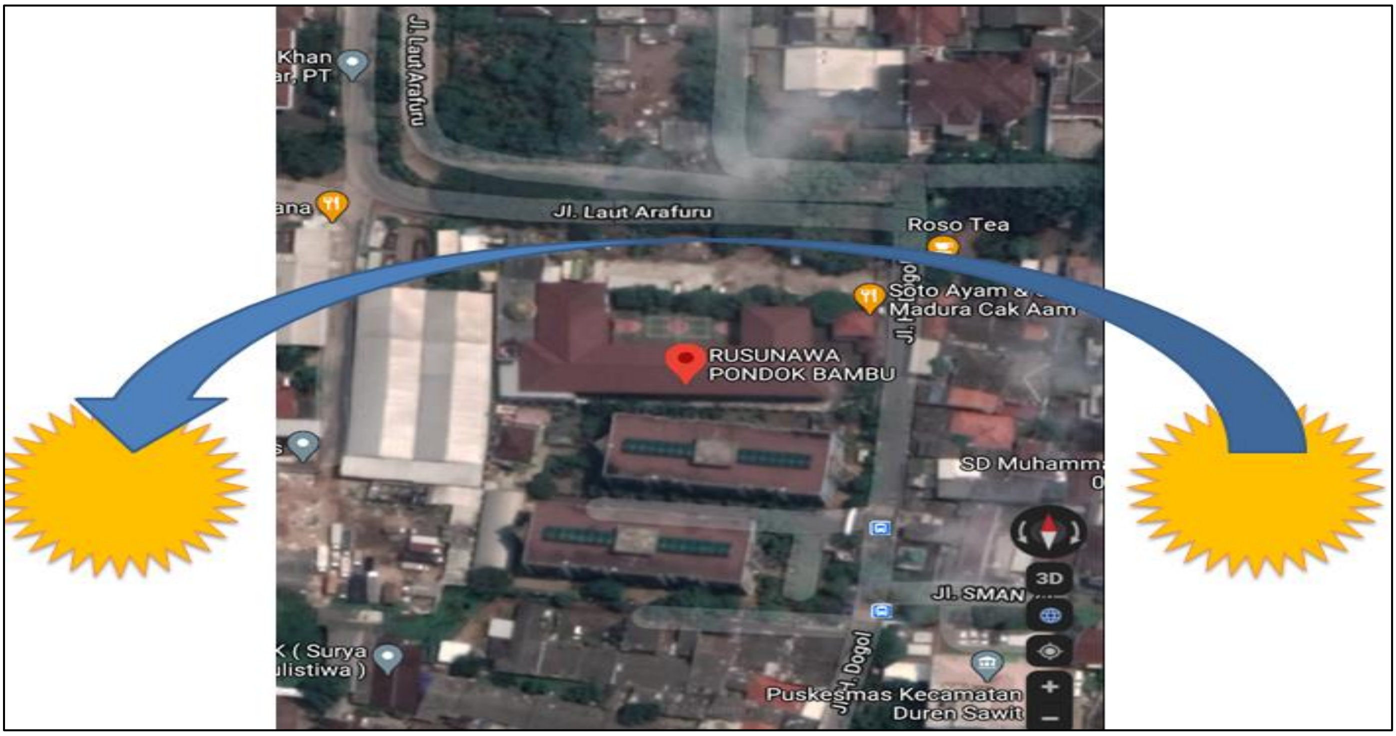

Fig 26 Orientation of the Building to the Sun

In this analysis, the orientation of the building which is elongated is designed with the left and right sides being emergency staircase access and building circulation openings that lead directly to East-West, and each building unit is faced in the south and north directions so that it can minimize the sun's heat entering the building.

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- *Wind Analysis*

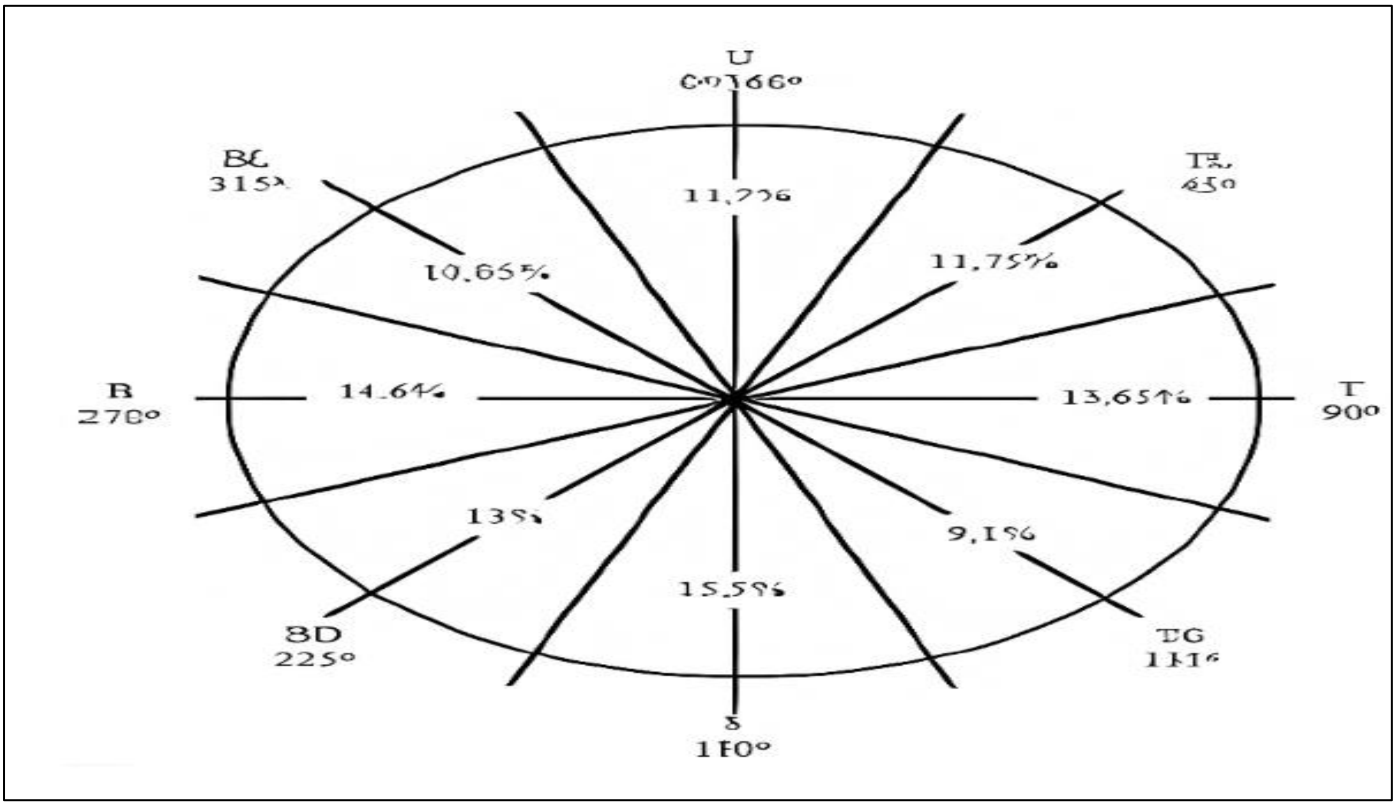

Fig 27 WindRose and Percentage of Dominant Wind Direction

From the results of the percentage of wind direction in the windrose, there are 3 dominant wind directions, namely West (14.6%), East (13.65) and South (15.5%). Because the height of the building around the highest footprint of the 2-storey building, the wind obtained is large enough that it can flow into the building through the window opening. Analysis of Flat Unit Arrangement

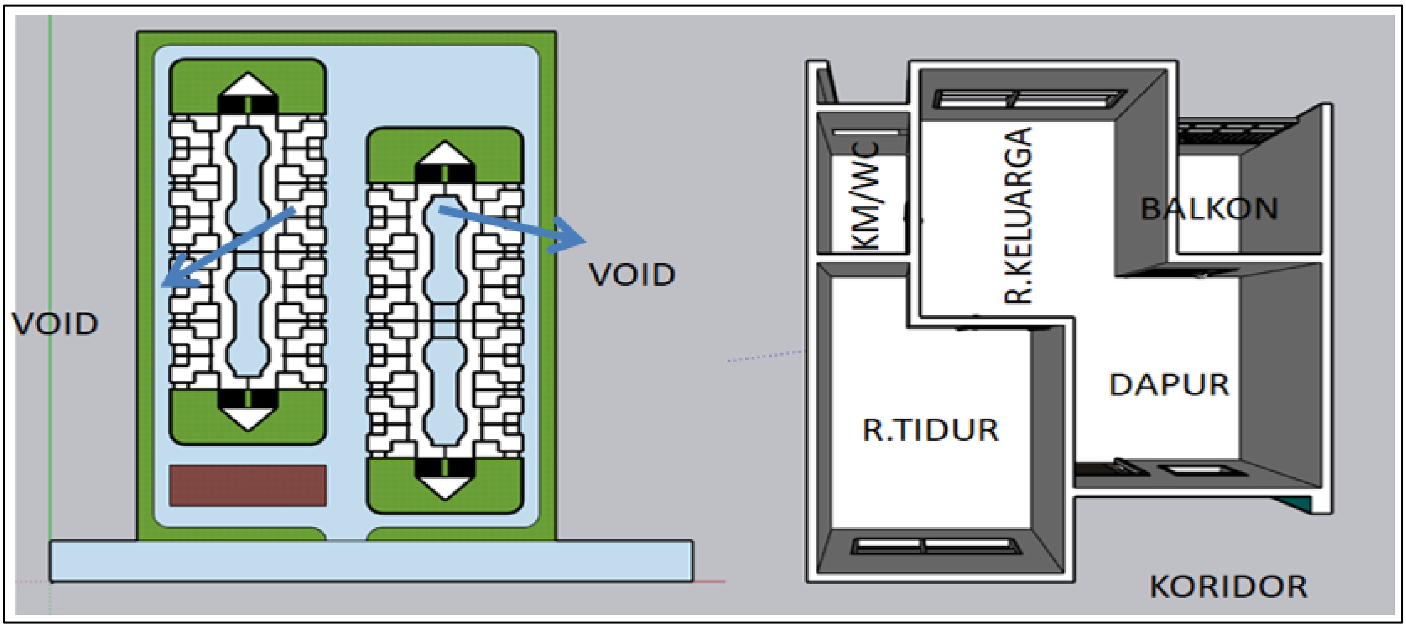

Fig 28 Arrangement of Flat Units

The air vents in the building mass are intertwined with each other and there is a difference in the area of *the inlet* and *outlet* openings, namely for the outlet opening area is made smaller than the inlet opening area, which can accelerate the speed of the wind flowing out.

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- *Climate Analysis*

Climate is one of the main factors to achieve thermal comfort, namely temperature, humidity and wind speed. The following is the average air temperature according to BMKG in 2011:

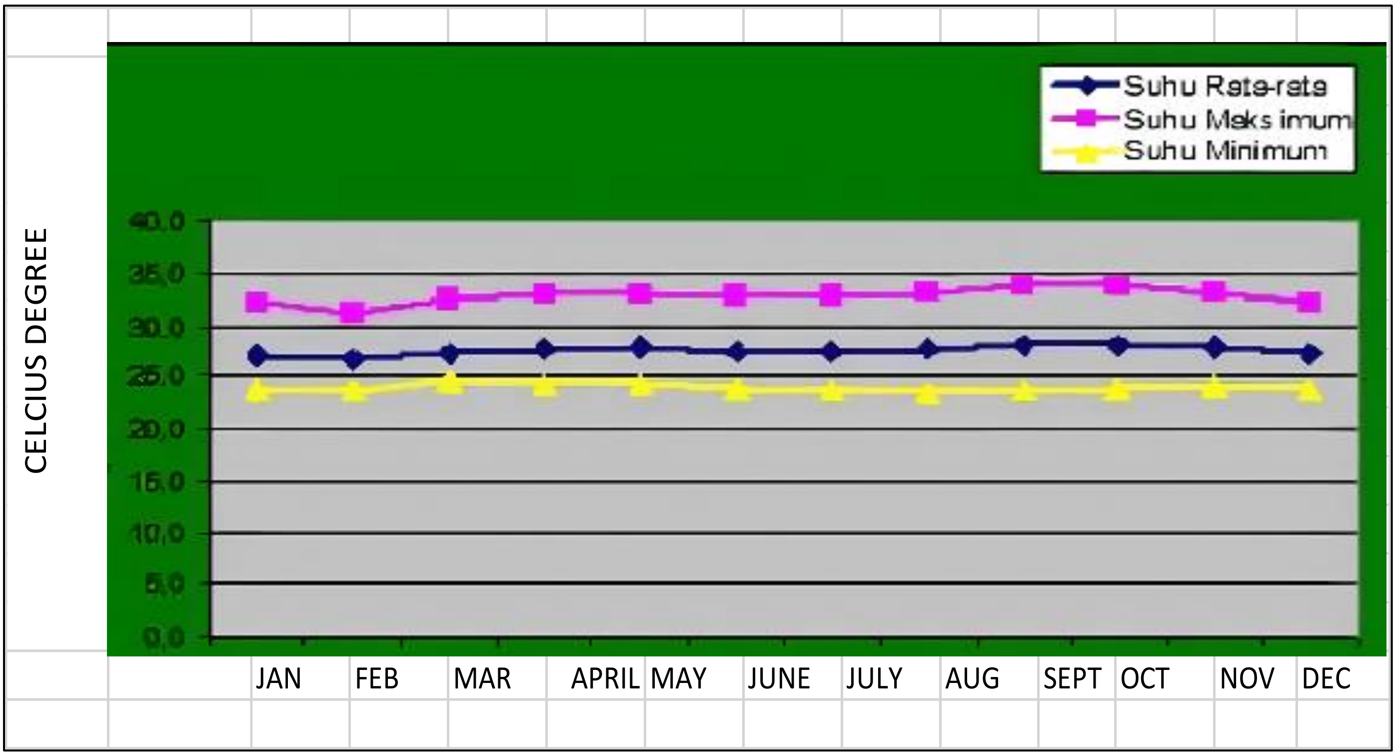

Fig 29 Average Temperature per Month in 2011
Source: BMKG

Based on the thermal comfort figure by the lippsmeier diagram about the air temperature is 24oC – 28oC. Based on figure 4.6 above, the average air temperature is close to the thermal comfort area, so the building can use a natural lighting and ventilation system. The design of the opening is very suitable for reducing heat entering the building and can also include air flow to cool the air temperature in the room and reduce high humidity.

- *The Following is the average Picture of Air Humidity in 2011 according to BMKG:*

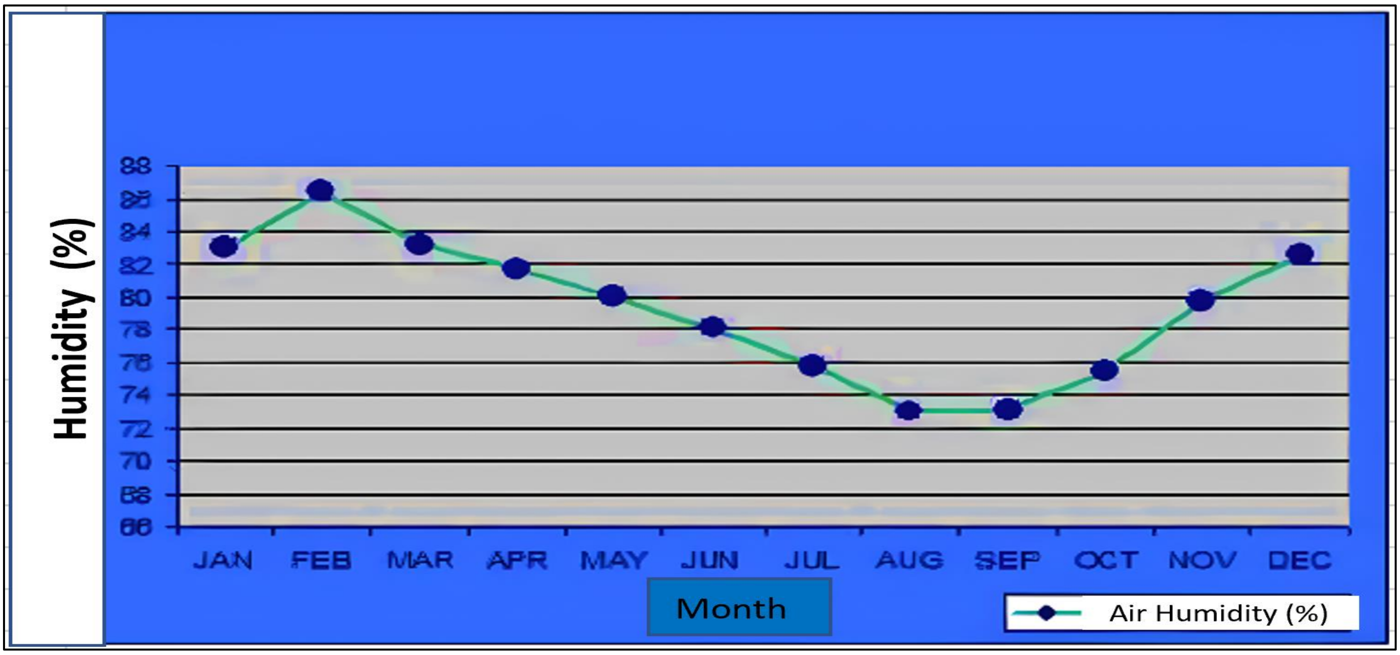

Fig 30 Average Monthly Air Humidity in 2011
Source: BMKG

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From the table above, the average air humidity in Jakarta throughout the year is 75%. Based on the air humidity standards in the lipsmeier diagram, it ranges from 60-70%. Where high air humidity can be driven away by airflow. With a design that circumvents the flow of air into the room so that air humidity can be reduced and thermal comfort is achieved.

- *The Following is a Picture of the average wind Speed in 2011 according to BMKG:*

Fig 31 Average Monthly Air Speed in 2011
Source: BMKG

The average wind speed is in the range of 1.02–1.53 m/s. The thermal comfort figure about wind speed according to the Lipsmeier diagram ranges from 0.2m/s to 1.5m/s. So that the thermal obtained can be ideal.

➢ *Building Unit Analysis*

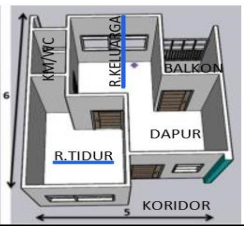
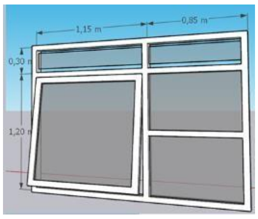
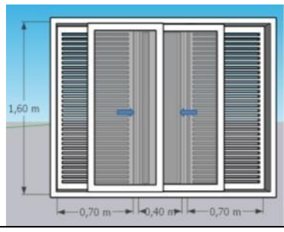
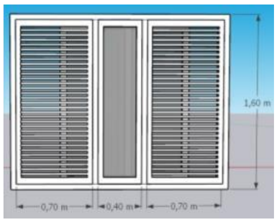
- *Visual Analysis of Main Room*

This residential space consists of one bedroom, one main room, one bathroom and one drying room. The dimensions of the room are 5 m x 6 m = 30 m^2. This room faces north-south. The position of the inlet is on the south side, because the building faces outwards. Meanwhile, the position of the outlet is on the north side facing the corridor.

The size of the Inlet and outlet in this residence with the north orientation has the same dimensions. The type of window opening used (existing) is the casement top hung type or hanging window. The minimum area of an air opening in a room according to SNI 03-6572-2001 is 5-10% of the area of the room.

The following is a table of the percentage area of the existing window inlet opening and design recommendations:

Table 5 Visual Analysis of the Main Room of the Inlet Window

No	**Opening Position**	**Type Window Inlet**	**Design Recommendations**	
	Against Space	**Excision**	**Inside View**	**Exterior View**
1				
	Main Space Area	Inlet Opening Area	Inlet Opening Area	Inlet Opening Area
	13.32 m2 /10% = 1.33m2	1.98 m2	2.24 m2	2.24 m2
		Information	Information	
	Main Room	The opening on the window meets the	The opening on the window is quite large	
		standard. But air circulation	The wind can enter through the network	

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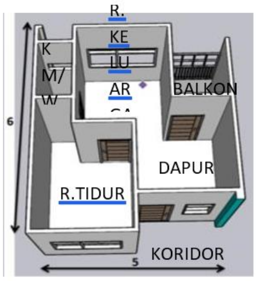
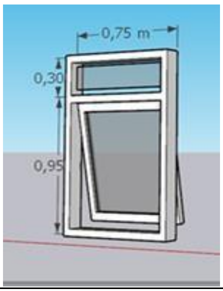
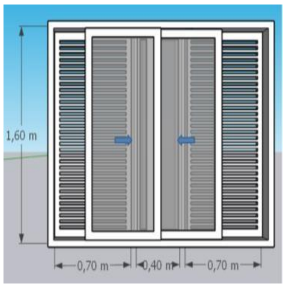
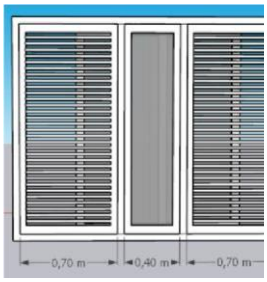
		The amount obtained is very small.	so that air can flow
		because the wind that enters a little	Each room is inside, and can
		so that the space becomes stuffy	making the space inside not hot

Table 6 Visual Analysis of the Main Room of the Outlet Window

No	Opening Position	Outlet Window Type	Design Recommendations	
	Against Space	Excision	Inside View	Exterior View
1				
	Main Space Area	Inlet Opening Area	Inlet Opening Area	Wide Opening of Inle
	13.32 m2 /10% = 1.33m2	1.98 m2	2.24 m2	2.24 m2
		Information	Information	
	Main Room	The opening on the window meets the	The opening on the window is quite large	
		standard. But air circulation	The wind can enter through the network	
		The amount obtained is very small.	so that air can flow	
		because the wind that enters a little	Each room is inside, and can	
		so that the space becomes stuffy	making the space inside not hot	

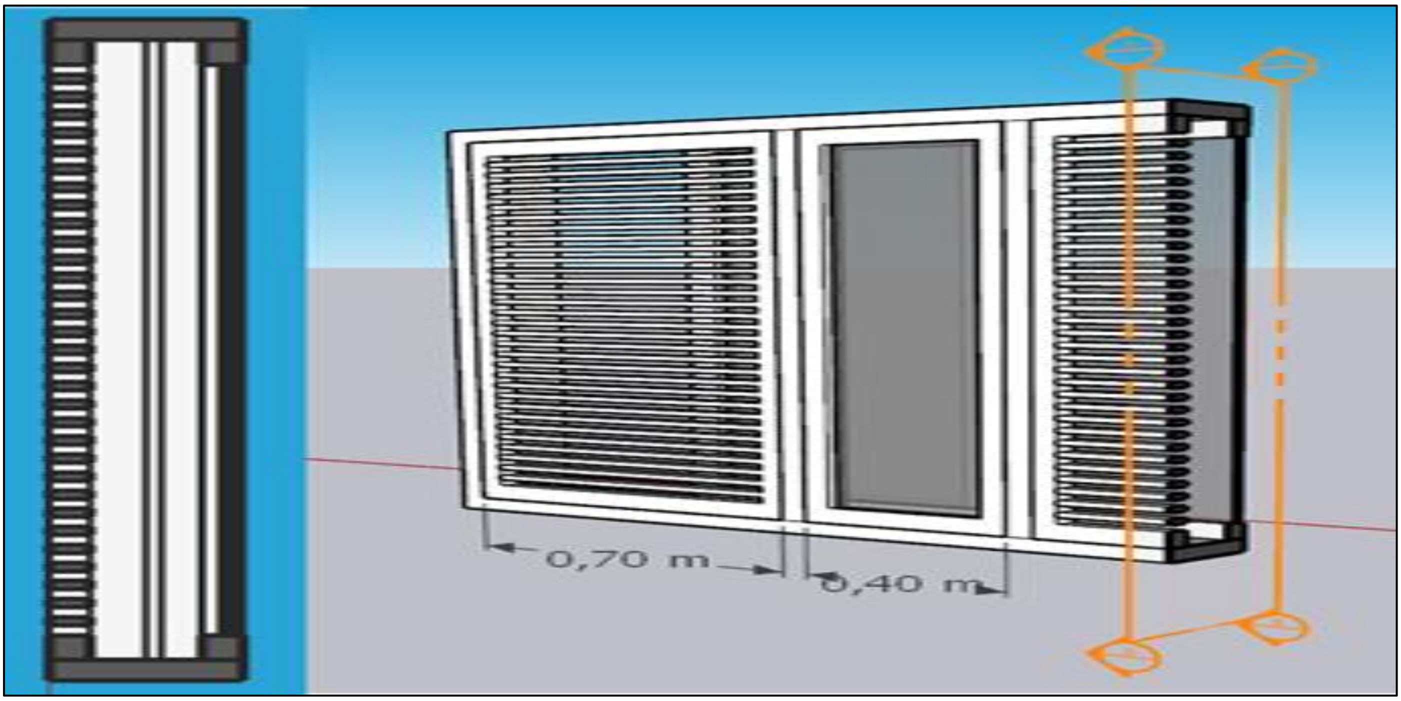


Fig 32 Vertical Window Cuts

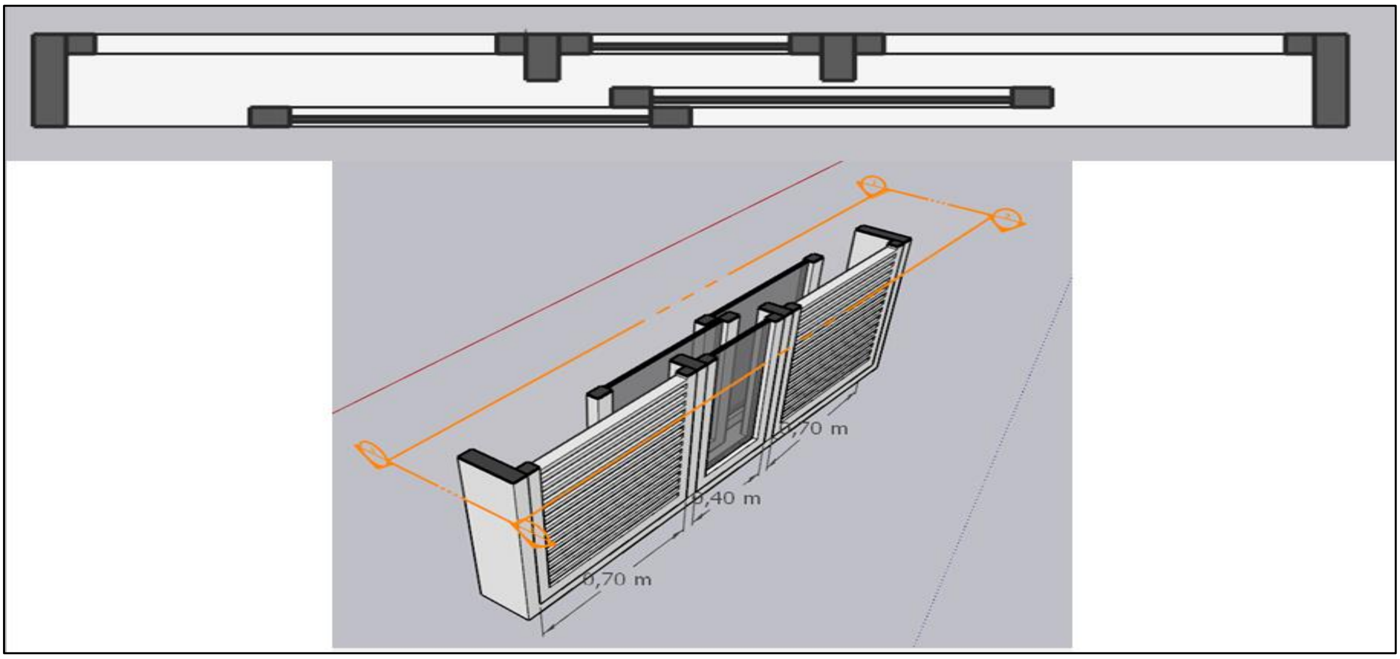


Fig 33 Window Cuts Horizontally

The movement of the wind horizontally spreads evenly. This is because the dimensions of the inlet and outlet openings are the same width. The same outlet dimension width is able to increase the capacity and speed of the wind flowing in the space.

IV. CONCLUSION AND ADVICE

➢ *Conclusion*

Based on the results of the study, it can be concluded that there is an influence on the type and dimensions of window openings on thermal comfort in residential spaces. Based on the results of visual analysis, the following conclusions can be drawn:

- Window openings with hanging windows (top hung) and ventilation owned by residential spaces have less than optimal performance.
- The addition of window openings and ventilation dimensions can increase the speed and distribution of wind in the residential space so that the wind movement pattern does not only flow towards the ceiling of the space but can spread horizontally.
- The use of a mix costume window opening type where the jalousie inlet combined with the swing window on the ventilation can circulate the air optimally.

V. SUGGESTION

It is time for architects to think about the design of energy-efficient flats, not only from the aspect of windows with passive design, but also from the design of active window models and from other aspects of the building.

The technical solution to the design of energy-efficient buildings in Indonesia is different from that of the subtropical region. It is important for architects to realize that in adopting the form of the architectural design concept from western countries (which generally have a subtropical climate) not to be trapped in fundamental mistakes. This can be seen from the uniform size and shape on all sides of the building, while on each side of the building receives different intensity and radiation of sunlight. Through a study on windows in existing flats and window model simulations, this research is expected to produce an energy-efficient window model, in this case the best shape and size will be produced specifically on the side of the building and its position in the height of the building. The model produced from this study can then be used as a reference for many parties in designing windows in flats in Indonesia.

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