Study of Passive Design in Architecture to Reduce Energy Consumption and Global Warming

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https://doi.org/10.5109/7323319

出版情報：Proceedings of International Exchange and Innovation Conference on Engineering & Sciences (IEICES). 10, pp.577-582, 2024-10-17. International Exchange and Innovation Conference on Engineering & Sciences
バージョン：

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Abstract: *The purpose of this paper is to study passive design in architecture as a strategy to reduce the effects of sunlight and address the issue of global warming. Passive design is designed by making use of natural sources such as sunlight, natural ventilation, and thermal minimise reliance on mechanical cooling and heating systems. This is achieved by creating a roster design on the North-South and East-West side walls to reduce the intensity of direct sunlight and provide soft, even lighting without causing glare. The roster is also flooded with water to provide a cool and cooling effect on the interior space of the building. If every residential environment applies this water roster system, namely in housing, schools, offices and public buildings until it is applied in cities to every country and throughout the world with even better water roster innovations, it will reduce heat and global warming for this earth.*

Keywords: *passive design; cool; roster; water; heat*

1. INTRODUCTION

Indonesia's energy consumption has increased from year to year. In the period 2000-2008, the final energy consumption increased on average per year by 2.73% from 764.40 million SBM (Standard Cost of Input) to 945.52 million SBM. By energy type, fuel energy consumption is the highest energy consumption followed by biomass, gas, electricity and coal, Ministry of Energy and Mineral Resources (2009). With the depletion of fossil energy reserves on the one hand, while on the other hand energy consumption continues to increase is a threat to the development of the Indonesian economy. Therefore, various efforts need to be made to encourage the efficient utilisation of energy use accompanied by an intensive search for new fossil energy sources and develop alternative energy that is renewable resources, [1], which comes from the environment. In addition, the residential building sector has become a major energy user. This can be seen from the rapid development of the economy and the improvement of people's living standards, most of the energy is consumed by residential buildings nowadays. In China, the residential building sector consumed 192.7 million tonnes of standard coal in 2003, accounting for 11.3 of the total primary energy used in the country and steadily increasing to 17.2 % in 2006. In addition, about 34.1 of the total energy in the building sector was used for domestic space heating [2]. In Japan, total carbon emissions from buildings in the commercial and other sectors will reach 182 million tonnes by 2020, accounting for 17.4% of total carbon emissions. Human culture, lifestyle and behaviour have a global impact on the issue of climate change and greenhouse gas emissions. For example, research results have shown that leaving lights and devices on after work, as well as inappropriate zoning and controls, human behaviour impacts building energy consumption even beyond their working hours. Numerous studies have emphasised the role of building occupants in influencing building energy, building energy consumption affects energy savings if occupant behaviour is changed. [3]. As environmental problems increase, the global environment will face more and more serious damage. One of the solutions in homes, offices in developing cities to control the environmental load with passive design strategies. In this regard, the government tries to address the environmental burden, the negative impact of economic growth on the environment and achieve sustainable growth, where natural resources are used efficiently without harming the environment. One area of sustainable growth is energy. Through energy security, it becomes an important factor for a country. Energy is not only an important factor of production for economic activity and growth, but also a strategic commodity that can threaten economic activity in times of crisis, especially when prices are uncontrollable due to limited supply. Current conditions in the world energy market are skyrocketing gas and coal prices, followed by rising oil prices. This has led to an energy crisis in Europe, particularly the UK, as well as in China. (Coordinating Ministry for Economic Affairs of the Republic of Indonesia, 2021). Future development is directed at maintaining a balance between economic growth, emission reduction targets, and the carrying capacity of natural resources. The government will make policies that accommodate the economic value of carbon, which will be implemented in stages. A passive design approach not only reduces energy consumption and carbon emissions, but also creates a more comfortable and healthy environment for residents. By making smart use of natural elements, buildings can function more energy efficiently and be more sustainable in the long run.

2. THEORY

Spatial problems are very disturbing to the activities inside the house. Space heat due to extreme weather outside causes the space inside the house to feel hot. Activities in the room are disrupted and not concentrated on work. Therefore, the occupants of the house use air conditioning to make the workspace cool. If humans use air conditioning more often, it will have an impact on the health of the residents of the house itself. Passive design is an approach in architecture that optimises the use of natural resources to achieve comfort. According to Ubinas, passive design strategies contribute to improving

interior comfort conditions, increasing energy efficiency in buildings and reducing energy consumption as a basis In this study, an analysis of the passive strategies used in the Net Energy Plus House has been conducted.[4]. The theory used in analysing passive design in residential houses is the applicable regulations in Indonesia, namely Circular Letter of the Director General of Cipta Karya Number: 03/SE/DJCK/2023, concerning technical guidelines for assessing Green Building Class Ia. [5]. The assessment criteria consist of 7, including; site management, energy use efficiency, clean water use, indoor air quality, environmentally friendly materials, waste management, waste water management and TKDN value. Passive design is an approach in architecture that optimises the use of natural resources to achieve thermal comfort in buildings without relying on mechanical systems that use additional energy. To get good sunlight for humans through building orientation. Choosing the right building orientation towards the sun is very important. This involves placing the building so that it maximises the use of sunlight during winter for heating (north-south orientation in the northern hemisphere), while reducing direct exposure to excessive sunlight in summer.

2.1 Building Envelope

Based on the Green Building Assessment of the Minister of Public Works and Public Housing Circular Letter Number 01/Se/M/2022 for Buildings and Circular Letter of the Director General of Cipta Karya Number: 03/SE/DC/2023 [5] concerning Technical Guidelines for Green Building Performance Assessment for Building Class 1a, that one of the 7 criteria for Green Building Assessment, which needs to be considered is the building envelope derived from the criteria for the Use of Energy Efficiency. The criteria include;

a. There is shading on all glass with North and South views.
b. There is shading on all glass with East and West views.
c. Cross Ventilation

Of the three Building Envelope criteria with points a, b, and c, only points a and b will be analysed in the discussion, which are related to the massive design or engineering of walls on residential facades.

2.2 Roster

Roster serves to improve natural ventilation in the room by allowing air to circulate through the gaps or holes in the roster wall. This is especially useful in hot and humid climates where good air circulation can help maintain thermal comfort and reduce humidity. Roster is usually installed on exterior walls and designed with a pattern that allows airflow. This helps to reduce reliance on air conditioning systems and improve indoor air quality. Roster also allows natural light to enter the room while reducing the intensity of direct sunlight. It provides soft and even lighting without causing glare.

2.3 Cross Ventilation

Cross ventilation research shows that cross ventilation can reduce energy requirements for cooling and heating. In a study published in Energy and Buildings, it was found that the use of cross ventilation can reduce a home's cooling load by 10-30%, depending on the design and location of the home. This is due to its ability to utilise cooler outside temperatures and natural air circulation to reduce interior temperatures. Cross Ventilation plays an important role in achieving thermal comfort. Research in Building and Environment shows that cross ventilation can improve thermal comfort by reducing interior temperatures during hot days and increasing airflow indoors. This is particularly beneficial in hot and humid climates, where high temperatures and humidity can make a room uncomfortable.

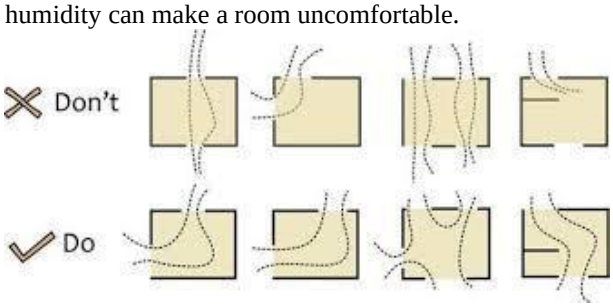

Fig 1 Cros Ventilation

Day lighting aims to obtain a daylighting system that meets the requirements of health, comfort and in accordance with other applicable provisions. Daylighting can be said to be good if: a) During the day between 08.00 to 16.00 local time there is enough light entering the room. b) The distribution of light in the room is quite even and or does not cause disturbing contrasts. Use of Sunlight: The building is designed to maximise the use of sunlight as a natural source of heat in winter. This can be achieved by placing large windows on the south side to capture sunlight, and using materials that can store and distribute heat. Natural Ventilation: Buildings are elaborately designed to allow sufficient natural airflow within the building. This can include the use of cross ventilation to take advantage of cool breezes in summer and stack effect ventilation systems that utilise air pressure differences to promote airflow.

Fig.2. Natural Lighting coming in via Breezeblock

To ensure that the building is well insulated (see figure 2) to reduce heat transfer between indoors and outdoors. This includes the use of effective insulating materials in the walls, roof and floors of the building. The use of shading that can help reduce direct exposure to the sun in summer, thereby reducing the cooling load. Types of Shading; a) External Shading Devices: A shading device installed outside the building to block sunlight before it reaches the windows or walls. Examples: canopies, overhangs, louvres, and screens. b) Internal Shading

Devices: Shading devices installed inside the building. Examples: blinds, shades, and curtains. Although less effective in reducing heat load, they help control glare.
c) Natural Shading: The use of natural elements such as trees, vegetation, and topography to provide shadows. Vegetation can provide dynamic shadows and also improve the aesthetics and air quality around the building.

2.4 Pencahayaan Alami

Day lighting aims to obtain a daylighting system that meets the requirements of health, comfort and in accordance with other applicable provisions. Daylighting can be said to be good if: a) During the day between 08.00 to 16.00 seternpat time there is enough light entering the room. b) The distribution of light in the room is quite even and or does not cause a disturbing contrast. Natural Lighting in Passive design can utilise natural lighting as much as possible to reduce reliance on artificial lighting. This can be achieved by appropriately placing windows and openings to maximise the entry of daylight into the space, and using reflective materials and surfaces to reflect light into the space. Lighting System 1) The lighting system in green buildings is intended to optimise the comfort and productivity of building occupants with optimal operation and consideration of environmentally friendly aspects and costs. 2) Lighting systems in green buildings include natural lighting systems and artificial lighting systems that are used when natural lighting systems are unable to achieve the required minimum lighting levels (illumination). In the use of windows, for window types using pivot windows are in rooms with high productivity levels such as office space. In the use of windows, for window types using pivot windows are in rooms with high productivity levels such as office space, workshop space. Pivot windows provide the advantage of ventilation and air circulation flow. Because when the pivot window is open, the window will become two different areas, airflow can enter naturally on one side and exit on the other side.

Fig 3. Inspiration desan fixedwindow, Jakarta Creative Hub, Sumber Lim, 2020

This uPVC material has a long period of durability because it will not experience rust, weathering and colour changes that will reduce the quality of the material. For window glass that directly faces the outside of the building, using Low E coating, so that the sun's heat entering the building is not excessive and the incoming light intensity can be more optimal. Rainwater runoff by slowing the flow of water, increasing infiltration, and reducing erosion.

3. DISCUSSION

This discussion is carried out in stages. The planes of the North-South facade wall are designed with window openings, as well as the East and West facades. Roster on the wall is made hollow and criss-crossed with bricks so that air from outside can get inside. After that, there is a flow of water from the pipes above it to the roster, which functions to provide cool air on the inside of the room.

3.1 There is shading on all North and South facing glass.

Shading is designed and placed on the North and South of the building. The design emphasises the use of natural ventilation to regulate air circulation in the building. This can be achieved by installing openable windows with sufficient area, arranging breezeways, and utilising the air pressure difference between the sides of the building to facilitate natural and efficient airflow. Building Orientation also determines the orientation of the building towards the path of the sun to maximise or minimise sun exposure. For example, large windows are usually placed on the north side (in the northern hemisphere) to get natural light without too much heat. North-South Analysis; at the front there are windows in the living room and bedroom.

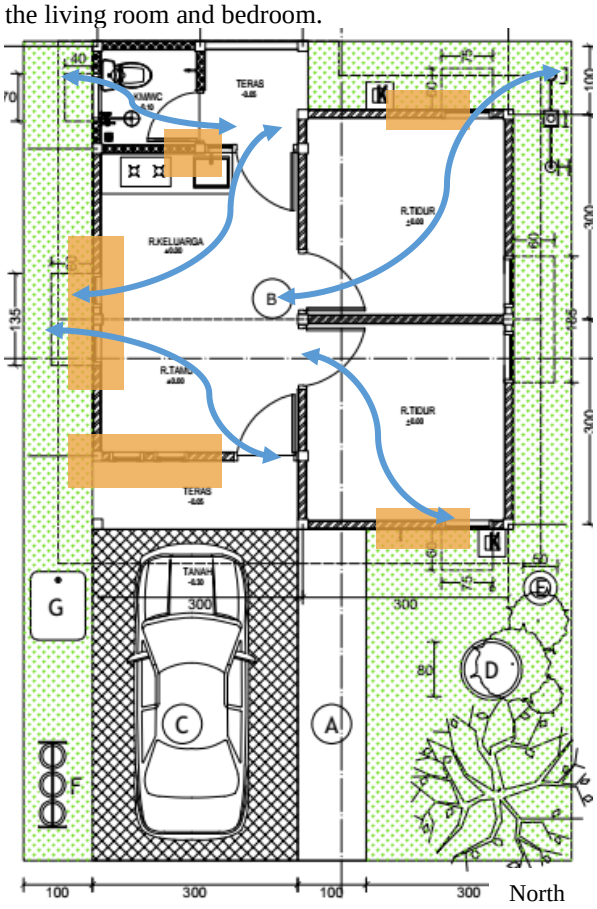

Fig. 4 Placement of wall design / passive design on Type 36 House Plan

= window position in front- right - left - back.
= Sirkulasi angin
A = Carport
B = Interior
C = Carport
D = Pohon (Vegetasi)
E = Komposter
F = Tempat sampah 3 bagian
G = Bio-Septictank

On this part of the wall is designed using a roster with a perforated surface. The purpose of the perforated design

is to introduce air into the interior space. This roster is flowed with water from above using a 3/4 "size pipe with the aim that the incoming air will feel cool by the wind from outside. In addition, there are door and window openings that cross the room (cross ventilation) which functions so that the air in the room fills and exchanges each other, this makes the space fresher and not hot. In the front yard, there is a vegetation element. The use of natural elements such as trees, vegetation and topography to provide shadows. Vegetation can provide dynamic shadows and also improve the aesthetics and air quality around the building.

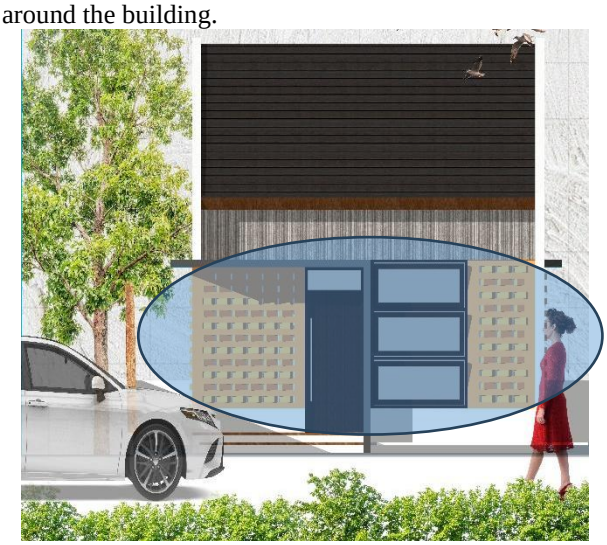

Fig. 5. Front view; Blue circle of the Breezeblock

3.2 Shading/shading on all glass with East and West views.

In the eastern part (see Fig. 4), on the left side the 2 bedrooms and the maasing each have a sash and a window. The wall design used is the same as the front wall with the aim that the incoming air will feel cold by the wind from outside. There is also cross ventilation from the door of the room to the window which functions so that the air in the room fills and exchanges with each other, this makes the space fresher and less hot. In Morning Sunlight, east-facing glass receives direct sunlight in the morning. At this time, the sun is low in the sky, and the sunlight tends to be more flat. While the duration of exposure to the eastern sun usually does not last all day but can become quite intense, especially in the morning towards noon.

Fig. 6. West wall - right side wall; The breezeblock is next to the window.

In addition, on the West side is installed an *Overhang*: above the east window to block out the morning sunlight (see figure 5). The overhang design should be long enough to cover the window when the sun is low in the morning, but not block the light that comes in in the afternoon. On the west side, an overhang is installed that functions to block the afternoon sunlight that enters the inner space of the house. In the Afternoon Sun: install West-facing glass to receive direct sunlight in the afternoon. At this time, the sun is higher and the sunlight is more intense, often causing the interior temperature to rise significantly.

Fig. 7. Left Side West View (Shading-Roster Window Placement)

The Breezeblock design is made on the wall plane next to the window. (see figure 6) The goal is to get air into the space so that it is not hot. The working system of the breezeblock wall is to make holes with a diameter of 2 centimeters with a distance of 5 centimeters. The walls are made of brick material and are arranged vertically and horizontally with a distance of 5 cm. Above the breezeblocks and windows are installed pipes that drain water to the surface of the breezeblocks. This is useful so that the air entering the room feels cool and cold so as to reduce the heat in the room.

Fig. 8. Breezeblock in Interior Space
https://www.google.com/imgresDesainRoster

The Breezeblock function can help in temperature control by providing shade that reduces the amount of heat entering the room. This is very beneficial in reducing the cooling load and helping to keep the interior temperature stable. By setting the pattern and position of the breezeblock, architects can reduce the impact of direct sunlight and help keep the temperature in the room comfortable. Meanwhile, as an aesthetic, the breezeblock provides a unique aesthetic element to the façade of the building. The design and patterns used on the breezeblock can be a decorative feature that adds character and beauty to the building's architecture. The

breezeblock is designed in a square shape with a hole size of 15 x 20 cm or the size of a brick (see figures 9,10,11). to create visual effects that are interesting or reflect a particular architectural style.

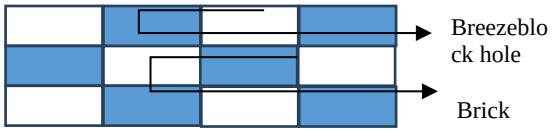

Fig. 9. Batubata and Breezeblock arrangement

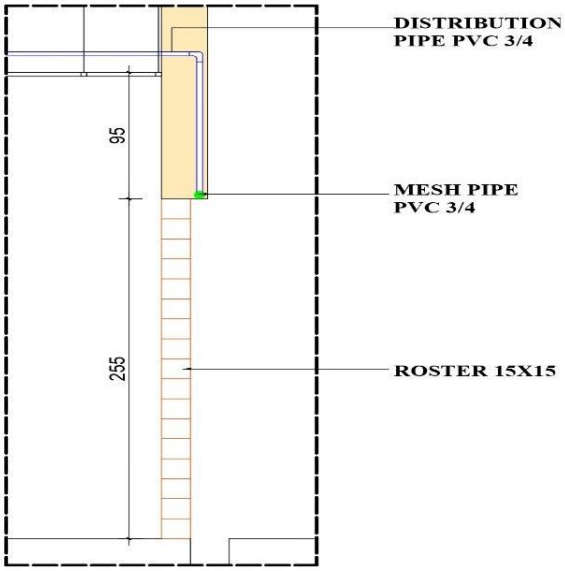

Fig. 10. Cutouts on the breezeblock and windows

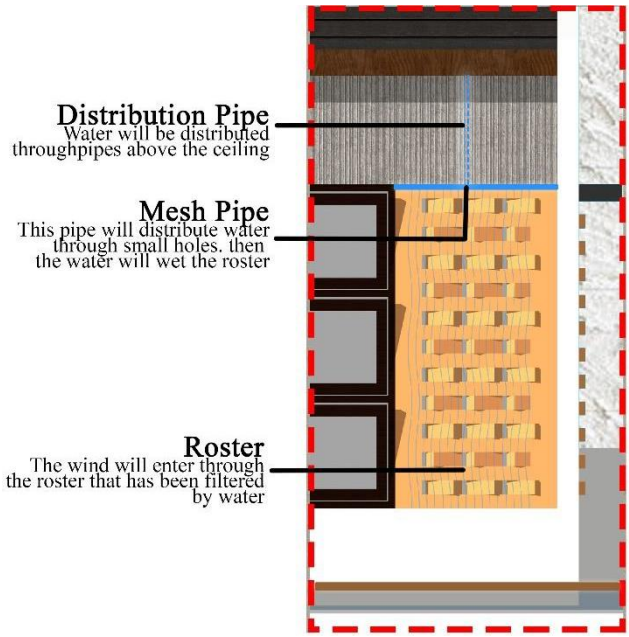

Fig. 11. Design of Water Flow from pipe to wall rosting, Type 36

3.3 Tank Placement

The placement of the water tank on top of a type 36 house is done carefully and several factors are taken into account to ensure its safety and effectiveness. Type 36 houses are types of houses with a building area of about 36 m², which often means limited space and not too large structures. Some important considerations for the placement of a water tank on top of a type 36 house. This tank functions as a rainwater reservoir that will be used to distribute water to each breezeblock on the North-South and East-West façade walls of residential buildings. There is a tank This tank functions as a rainwater reservoir that flows on the breezeblocks of the walls of the house building as shown in the design in the details of figure 9.10. Water that falls from the breezeblock is accommodated by creating a retaining pond and reservoir to accommodate the runoff of the breezeblock water, which can then be flowed to the tank and so on.

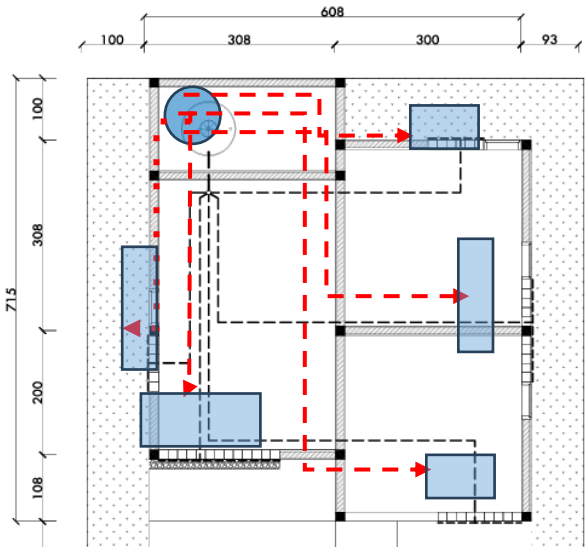

Fig. 12. Placement of the Water tank on the back

Fig. 13 Cutouts on the breezeblock and windows

4. CONCLUSION

Passive design not only reduces energy consumption and carbon emissions, but also creates a more comfortable and healthier environment for its occupants. By utilizing natural elements intelligently, buildings can function more efficiently and more sustainably in the long run. There are several uses of shading in passive design and are the assessment criteria, namely;

1. The design of the wall surface of the type 36 house above greatly affects the temperature of the room inside. The application of breezeblocks on the North-South, East-West sides of the house provides fresh air, due to the presence of flowing water breezeblocks. In addition, vegetation also contributes cool air and improves the aesthetics around the building.

2. The Breezeblock design provides cool air, reduces heat in the space with flowing water as well as a unique aesthetic element on the façade of the building. The design and patterns used on the breezeblock can be a decorative feature that adds character and beauty to the building's architecture.
3. If every residential environment applies this water breezeblock system, namely in residential houses, schools, offices and buildings that are special and general until it is applied in cities to each country and around the world with even better water breezeblock innovations, it will reduce heat and global warming for this earth.
4. The study of the massive wall design (wall surface) with the water breezeblock has not calculated how much electrical energy and the use of *Air Condition (AC*) are saved compared to not using the breezeblock. It can be recommended in subsequent research or studies

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