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Influence of Traditional Wall Façade from Taneyan Lanjhang House to Thermal Sensation

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Abstract
Of the various ethnic groups that comprise Indonesia, Madurese ethnic belongs to the top five in ethnic group population numbers in Indonesia. As an ethnic group, Madurese developed a traditional settlement called natively Taneyan Lanjhang (TL). TL is described as a specific pattern settlement that follows local and Islamic-influenced cultural norms. This research aims to find local wisdom properties in tectonics configuration in Bangsal housing unit concerning thermal comfort and sensation aspect of a vernacular design. The study is using quantitative method with field observation using lidar scanner, hot-wire anemometer and model simulation using computational fluid dynamics. The final result of the study is finding a correlation between closing and opening wall configuration related to thermal comfort defined by airflow, temperature and relative humidity parameter.

***Keywords**: passive cooling; taneyan lanjhang; tectonics.*

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1. INTRODUCTION

Madura, a tropical island in Indonesia, has a typical monsoon climate with two main seasons: the rainy and dry seasons. According to BMKG (Indonesia's meteorological agency), the average highest temperature in Madura is 33°C, and the lowest temperature reaches around 26°C (BMKG, 2023). The traditional house of Tanean Lanjhang is a cultural heritage that reflects the richness of traditional Madurese architecture. Understanding the local climate is crucial in designing traditional houses like Tanean Lanjhang to ensure that these houses are suitable for the existing weather conditions. Traditional architecture considers the need for adequate ventilation, thermal comfort, and protection from weather elements. The design aims to optimize natural airflow and regulate indoor temperatures to create a comfortable living environment for the inhabitants (Purwanto, Hermawan, & Sanjaya, 2006). From a facade design perspective, Tanean Lanjhang Traditional house came under the categorization of a utilitarian façade (Cucuzzella, 2023), in which the facade came from structural material, an environmentally climate responsive and site-responsive functional usage indigenous to the location area. The Facade is consisted of cemented floor, brick elements for wall, wood structure roof, clay roof tile, uniquely, the front facing wall is made from wood structure, locally known as "Gebluk".

The Gebluk element in Taneyan Lanjhang houses in Madura serves as a decorative element and a contributing factor in creating thermal sensations that lead to the acceptability of living conditions. In the design and application of the Gebluk element, some holes function as small inlets, allowing the wind to enter the dwelling and create thermal sensations for the users inside the building (Agustin, Lailiyah, Fadhil, & Arya, 2020). In architecture, 'Gebluk' has a strong relevance to architectural tectonics. Architectural tectonics studies how architectural elements are designed and integrated into a building to achieve specific goals, including thermal comfort (Al-Alwan & Mahmood, 2020). Elements such as walls, windows, roofs, and ornaments like 'Gebluk' all play a role in creating an indoor climate that meets the needs of the inhabitants. This research aims to discover the properties of local wisdom in tectonic configurations in 'Bangsal' housing units concerning thermal comfort and the aspects of vernacular design sensation.

2. METHODS

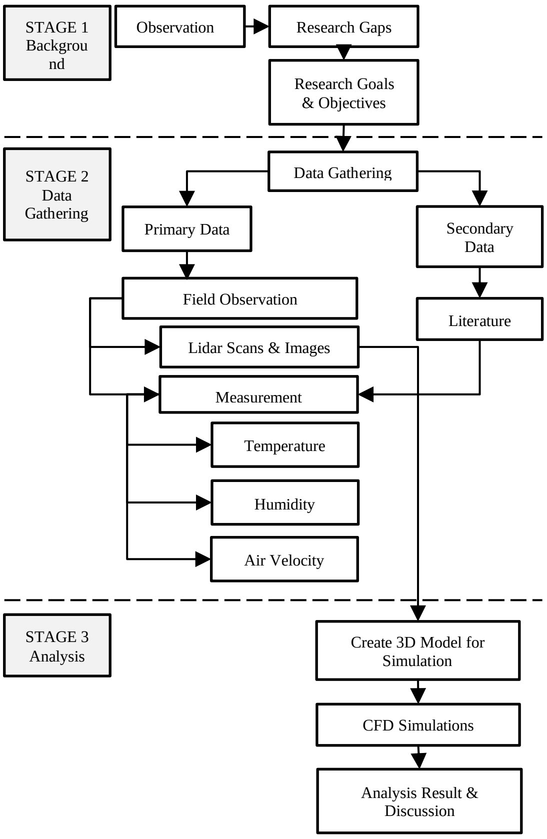

Figure 1. Research Method

The author used a quantitative descriptive method in this research described in Figure 1. Data are taken using a literature review and field observation. A 3d model is generated using data gathered from a Light Detecting and Ranging (lidar) device, which is used to scan the exterior and interior of the selected house and then exported to Autodesk Recap to remove unwanted features and artifacts, as seen in Figure 2. It produces point cloud data, a collection of points that will be used as a basis for modeling in Autodesk Revit, a BIM (Building Information Modeling), as seen in Figure 2. Based on the BIM model, a simplified 3d model is produced with Autodesk's Computational Fluid Dynamic (CFD) for airflow and thermal simulations as shown in Figure 3.

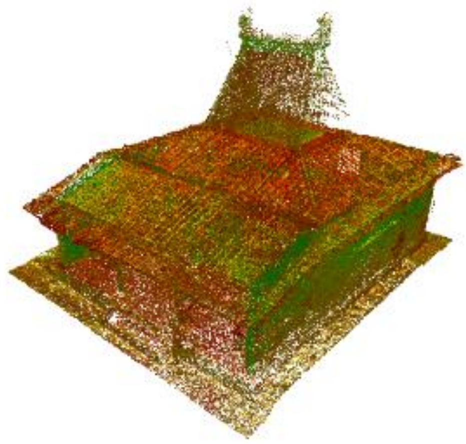

Figure 2. Point Cloud Data Recap

Figure 3. 3D Model Revit

3. LITERATURE REVIEW

3.1 Tectonics from Frampton's Perspective

A leading architecture critic, historian, and professor, Kenneth Frampton reintroduced the term 'tectonic' as a significant critical movement. Frampton enriched the term with an artistic dimension by describing it as "poetic construction" or a distinctive approach to construction that focuses on one aspect of architectural aesthetics. In his book "Studies in Tectonic Culture" in 1995, Kenneth Frampton extracted the main factors that describe the essential tectonic elements in architecture. These factors do not exist in isolation but are interconnected with each other. The key tectonic factors in architecture were identified as follows: object, details, joint, material, construction, structure, and interaction. From Frampton's perspective, tectonics in architecture should consider environmental issues and local culture. Frampton gave the term "Tectonics" an artistic dimension, describing it as a "poetic construction" (Al-Alwan & Mahmood, 2020).

In Frampton's vision, tectonics creates a strong relationship between architectural elements and construction, allowing architecture to convey the true character of materials and construction methods. It is about visual appearance and how building elements work together to achieve aesthetic quality and thermal comfort.

Thus, the theory of architectural tectonics, according to Kenneth Frampton, emphasizes the importance of respecting materials and structure, integrating them into design, and creating buildings that are honest and of high quality.

3.2 Thermal Comfort

Thermal comfort is a state of mind that expresses satisfaction with the built environment and can be measured based on subjective evaluation (ANSI/ASHRAE, 2015). Heat transfer is proportionally related to a difference in temperature, in which the human body in a cold environment will lose heat, and the human body in a hot environment will release little heat. In those two scenarios, both conditions are not thermal comfort for humans (Cengel & Boles, 2015). Keeping humans in comfort thermally in a built environment is an essential goal for HVAC (heating, ventilation, air conditioning) engineers. Core body temperature can be life-threatening to humans if it is above 37.5 – 38.3°C (hyperthermia) or below 35 °C (hypothermia (Brown et al., 2012).

Static temperature conditions can lead to comfort in the built environment. However, there is an opinion that humans are more susceptible to thermal variations in which thermal comfort is reached. In contrast, a shift from not comforting to a comforting condition is called positive thermal alliesthesia (Cabanac, 1972). There are six main factors for thermal comfort, categorized into two categories: a personal factor (metabolism rate and degree of clothing) and an environmental factor (air temperature, mean radiant temperature, wind speed, and humidity).

Human comfort test has been studied in thermally uniform and nonuniform environments in which relations between thermal sensation and acceptability are understood as first clarified by Fanger (Fanger, 1970) and later on confirmed by Berglund (Berglund, 2004) by asking subjects whether thermal conditions are acceptable or not under uniform conditions. A nonuniform human subject test is also carried out in which human subjects are put into a thermally uniform chamber. Then, locally applied cooling or heating air is applied to 11 separate body parts to predict local and overall thermal sensations (Zhang, 2004).

3.3 Taneyan Lanjhang Traditional Settlement

Tanean lanjhang represents the traditional residence or village of the Madurese community, characterized by an elongated front yard where married children reside. The name 'tanean lanjang' is a combination of 'tanean' (yard) and 'lanjang' (long). Moreover, as the number of families within the settlement has increased and expanded, the 'tanean' within the community has also expanded, resulting in ongoing development and growth of the front yard of the houses, which is commonly referred to as 'tanean lanjang' (Sari, Budiarto, & Ekawati, 2022). The ‘bangsal house' is a traditional Madurese house with a roof resembling a 'joglo,' featuring only one front door and no windows. The air circulation into this house originates from the decorative openings on the building's facade, commonly called 'gebluk.' The 'bangsal house' is situated on the northern side, with the kitchen and cattle shed in the south and the 'khobung' at the western end (Mansur, Muhtadi, Kamali, & Rofiki, 2020).

The traditional housing unit selected for this research is a traditional house belonging to an ethnic Madurese group in Dusun Buddagan 2, Desa Larangan Luar, Kecamatan Larangan, Kabupaten Pamekasan, Madura Island, as shown in Figure 4. The house was built in 1980 and dubbed Potre Koneng, loosely translated as Yellow Daughter. The house is one of the typical settlement units for female members of the Madurese family unit, which is now renovated and used as a residence unit for Pak Adi family. The house is located at 7.1033649,113.5678512, 49S, based on the WGS84-UTM coordinate system commonly used in Indonesia, and has a site plan as shown in Figure 5.

Figure 2. Taneyan Lanjhang House

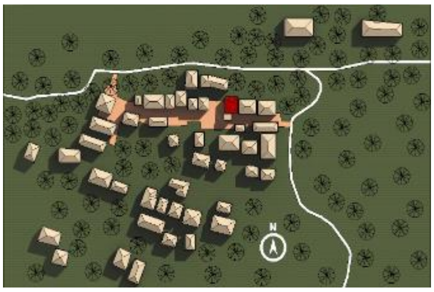

Figure 5. Taneyan Lanjhang Settlement

4. RESULT & DISCUSSION

4.1 Analysis of Gebluk from Frampton's perspective

In his book, Frampton writes those tectonics becomes the art of assembly or connection; art in this context is emphasized through tekne, so tectonics turns out to be not only a part of the building but also an object or a work of art in a narrower sense. Over time, understanding the word tectonic in construction tends to create artworks, depending on the correctness of applying its artistic value (Juniwati & C, 2003). In addition to serving as structural elements, gebluk also possesses a strong aesthetic aspect. The Madurese community creates decorative patterns on the building's facade. It aligns with Frampton's perspective on architectural tectonics as an element that provides an artistic dimension in the expression of construction. Gebluk creates ornaments that enrich the visual appeal of the building as shown in Figures 6 and 7.

Figure 6. Gebluk as a Construction with Aesthetics

Figure 7. Gebluk Ornaments with Openings for Airflow Entry

In addition to its artistic value in construction, from Frampton's perspective, tectonics must consider environmental and local cultural issues (Al-Alwan & Mahmood, 2020). It is evident in the function of Gebluk, which also plays a role in creating natural airflow and assists in regulating the house's interior temperature, thus creating a thermal sensation for its occupants. It reflects the concept of architectural tectonics that integrates environmental aspects into architectural design.

4.2 Airflow and Thermal Analysis in Taneyan Lanjhang House

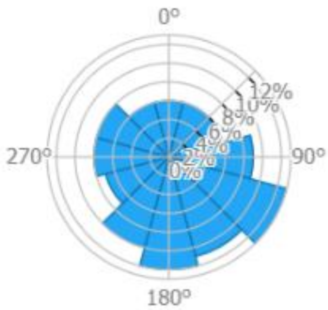

Figure 8. Wind Frequency Rose
Source: GWA, 2023

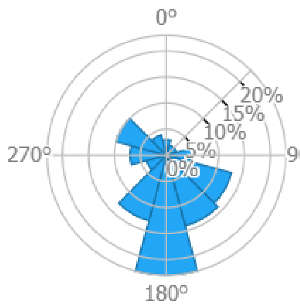

Figure 9. Wind Power Rose
Source: GWA, 2023

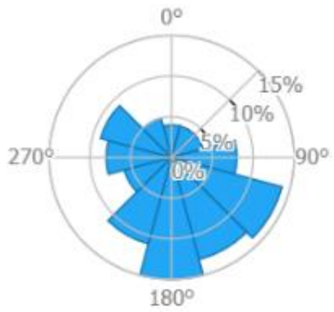

Figure 10. Wind Speed Rose
Source: GWA, 2023

An airflow calculation needs several data, like inlet information data, in which wind parameters are used for boundary conditions. To determine wind parameters like wind direction, speed, and power, information like Wind-Rose (Reboussin, 2005) and weather design data are gathered from Global Wind Atlas (GWA) web application, as shown in Figure 6, where wind comes from south and south-east and the strongest wind comes from the south with highest speed between 5.6 m/s and the lowest speed in 0.5 m/s dan ambient temperature between 20°C - 36°C as shown in Figure 8, 9 and 10. Also, measurement data is collected at the site, which collects wind velocity, humidity, and temperature, as shown in Table 1.

Table 1. On Site Data Measurement

Time	Outdoor Tempera-ture	Indoor Tempera-ture	Humidity	Wind Velocity
Field Measurement (Open Door and Windows)				
09.58	32.1 C	32.3 C	45.90%	0.055 m/s
12.35	34.2 C	34 C	41.50%	0.614 m/s
16.30	31 C	30.8 C	49.00%	1.06 m/s
Field Measurement (Closed Door and Windows)				
10.00	32.1 C	32.3 C	48.80%	0.0 m/s
12.36	34.2 C	33.6 C	42.60%	0.03 m/s
16.31	31 C	30.3 C	63.10%	0.059 m/s

CFD calculations can be time-consuming, need a lot of computing power, and have a limitation on what it can reasonably calculate. In this study case, the model needs to be simplified by surfaces that form an enclosure and inlet-outlet features, as shown in Figure 11. The model is then uploaded into CFD, and setup is performed for calculation, as shown in Figure 12.

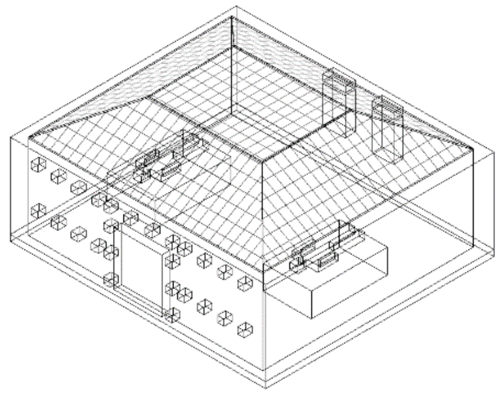

Figure 11. Simplified 3d Model for CFD Calculation by Revit

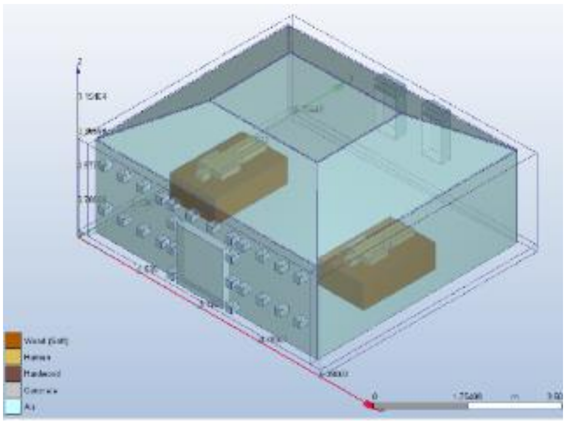

Figure 12. CDF Model

A valid CFD model needs an air-tight 3D model and approximation geometry that closely resembles the model and conditions that will be calculated. A model is then applied, and its material properties and boundary conditions are set, as seen in tables 2 and 3.

Table 2. Material Properties

Boundary Conditions	Applied to	Type	Parameter
Inlet	Opening in gebluk	Velocity	variable (in m/s)
		Temperature	variable (in Celsius)
Outlet	Windows Opening	Pressure	0 Pascal
Surface	Roof	Film Coefficient	0.54 W/m2/K
	Gebluk	Film Coefficient	0.54 W/m2/K
	Wall	Film Coefficient	1.9 W/m2/K
Human Model	Human	Total Heat Generation	60 Watts

Table 3. Boundary Conditions

Model	Material	Model Type	Material Environment
Typical Wall	Brick	Solid	Fixed
Gebluk	Hardwood	Solid	Fixed
Roof	Hardwood	Solid	Fixed
Floor	Concrete	Solid	Fixed
Bed (Furniture)	Softwood	Solid	Fixed
Human Model	Human	Solid	Fixed
CFD Model	Air	Air	Variable

One aspect of simplification is the feature modeling of a gebluk, which is a front-facing wall that incorporates details of wood sculptures. These details are complicated to model appropriately and can create problems in the calculation, as seen in Figure 13. The details are then modeled using proximation by the small, simple opening model that approximates inlet features that are adequate for CFD calculation in which the size is comparable to the area sizes of the actual inlet details. In this study case, the front-facing wall's inlet features are maintained by size and position approximation, as seen in Figure 14.

Figure 13. Gebluk- Front Wood Facade

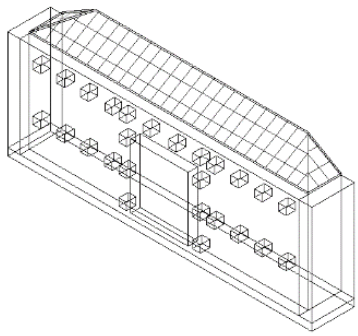

Figure 14. Gebluk Face Approximation for CFD

Table.4. Result

Time	Outdoor Temperature	Indoor Temperature	Humidity	Wind Velocity	Baseline Temp	Indoor Model Temperature	Wind Velocity @Inlet	Wind Velocity @Center
Field Measurement (Open Door and Windows)					CFD (Open Inlet and Outlet)			
09.58	32.1 C	32.3 C	45.90%	0.055 m/s	32.1 C	30.175 C	0.055 m/s	0.018 m/s
12.35	34.2 C	34 C	41.50%	0.614 m/s	34.2 C	34.1 C	0.614 m/s	0.158 m/s
16.30	31 C	30.8 C	49.00%	1.06 m/s	31 C	31.599 C	1.06 m/s	0.318 m/s

The computational calculation is then performed using the computational fluid dynamics method, a branch of fluid mechanics that uses numerical analysis and data structure to analyze and solve problems connected to fluid movements (Milne-Thomson, 1973). Scenario Environment use 1 ATM (101,325 Pa). The first calculation is to check the relationship between collected data in the field and the model behavior in CFD Calculation as seen in table 4.

It is common to have a discrepancy between field measurement and calculation since most calculations cannot model exact conditions as in the field, and approximation and approach are used. In this instance, the wind is simulated from the south with a minimum speed of 0.5 m/s and a maximum speed of 5.6 m/s. There are several calculations conducted for the selected house. The author starts with a maximum condition: all the inlets are functioning (main door is open), all outlets are also functioning (two window doors at the back are open), and wind velocity is 0.5 m/s and 5.6 m/s. The calculation is visualized in planes and trace mode, as shown in Figures 15 and 16.

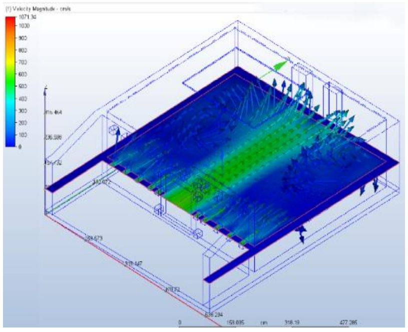

Figure 15. Planes Visualization Mode by CFD

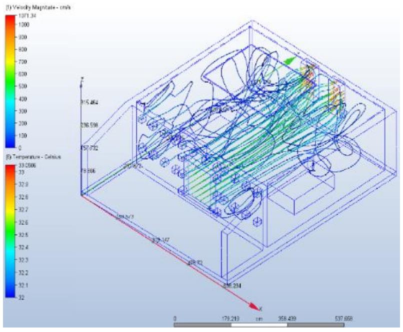

Figure 16. Trace Visualization Mode by CFD

The second calculation simulates a minimum condition where the house is usually used to sleep at night, in which the main inlet (front door) is closed, the rear outlet (windows) is closed, and wind velocity is at 0.5 m/s and 5.6 m/s. The calculation is visualized in planes and trace mode, as shown in Figures 17 and 18.

Together with airflow, computation is also used to calculate a thermal analysis in which a double body of a human in bed generated 60 Watts of heat generation with a reference temperature of 32°C. The result is shown in Figures 19 and 20. While there are little changes in temperature variation between exterior and interior calculation, there is a wind flow through the inlets that helps achieve a flow of wind into the interior and the body position.

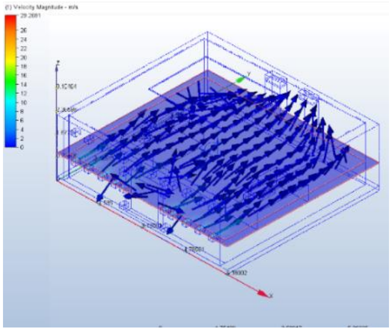

Figure 17. Planes and Trace Visualization Mode by CFD

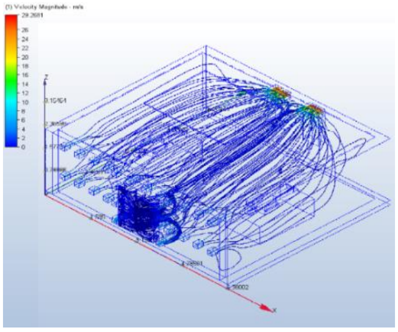

Figure 18. Trace Visualization Mode by CFD

During on-site measurement, there is little difference between outside and indoor temperature, suggesting that outdoor temperature will dictate indoor temperature. It also suggests that wind movement is a more significant factor in thermal comfort conditions.

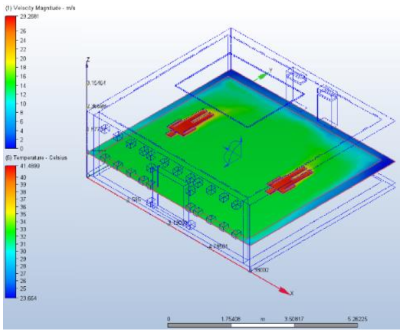

Figure 19. Temperature Planes by CFD

One of the conclusions found during the observation and CFD calculation is that the gebluk element, made from wood, incorporates small inlets other than the main door. These small inlets, built into the façade design as sculptures built into the wall panel, will allow wind to be carried over into the interior space even when the main door is closed. Whether these effects emerge by design or are purely coincidental, the tectonics configuration of gebluk allows wind to create a cooling sensation for the occupants, primarily when it is used at night for sleeping.

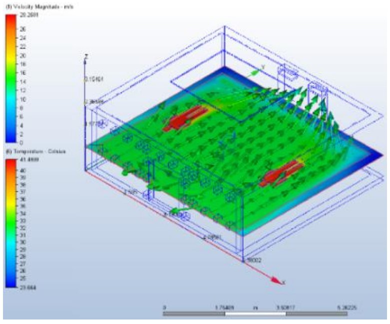

Figure 20. Temperature Planes with Velocity Vector by CFD

5. CONCLUSION

Most vernacular design settlements carry the history and a tried-and-true modifications from years of experience from the local builder, which has mostly been passed on from generation to generation. A design element in the vernacular built environment sometimes carries a wisdom that could be more easily identifiable and needs to be researched, as in the case of the Taneyan Lanjhang housing unit.

The gebluk element in Taneyan Lanjhang's house in Madura is a decorative element and a contributing factor in creating a thermal sensation that led to the acceptability of living conditions. The design and application of the gebluk element incorporate holes in the design, which contribute as small inlets that allow wind to get into the living habitat and create a thermal sensation to the user when it is being used.

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