# VIGAN ANCESTRAL HOUSE: An Assessment of Thermal Properties, Daylighting and Natural Ventilation

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## Abstract

*Traditional Filipino houses such as "bahay-na-bato" were said to be effective in providing natural ventilation to achieve indoor thermal comfort. This study aims to analyze the thermal environment of common spaces inside selected Vigan ancestral houses. The quest for understanding the traditional housing in the Philippines is the main focus of the paper.*

*Passive Cooling is difficult to achieve in the tropical climate, with low level thermal comfort experienced during the daytime especially in the common areas such as the living room, dining, kitchen and family areas. Since the "sala"is the biggest and most important part of an ancestral house and was used for important family gatherings and occasions, this space was considered in the study.*

*A comparative study among the typologies of Vigan ancestral houses during the Spanish Colonial period include verification on whether native artisans and builders consider solar orientation in the positioning of the living spaces of the traditional houses and documentation of the unique features of the domestic houses that will be related to energy efficiency, sustainable design and verify compliances to the Standards.*

Keywords: passive cooling, u-value, energy efficiency

## I. Introduction

Based on the General Principles of Thermal Comfort (Department of Energy, 2007), there are five main variables that affect human comfort: dry bulb temperature, relative humidity or wet bulb temperature, air movement, ventilation, and thermal radiation from hot surface (ceiling, walls, and glass window).

In tropical climates, warm and humid conditions prevail during most parts of the year. Therefore, for non-mechanical buildings, the control of these factors affecting comfort – ventilation, air movement and heat radiation from ceiling and walls – is very important in the local context as considered in the study.

Vigan is the capital of Ilocos Sur, a coastal province in the northwestern part of the Philippines. Inscribed as a World Heritage Site by UNESCO in 1999 on the following criteria: (1) Vigan represents a unique fusion of Asian building design and construction with European architecture and planning; and (2) Vigan is an exceptionally intact and well preserved example of a European trading town in Southeast Asia.

Vigan is one of the oldest Spanish settlements in the Philippines. Claimed by force by the Spanish conquistador Juan de Salcedo in 1572, Vigan, then known as *Ciudad Fernandina*, became the center of Hispanic colonial power in Northern Luzon and the only surviving colonial settlement in the country, an intact relic of Hispanic colonial town planning.

The traditional houses of Vigan reflect the glorious past and rich culture and traditions of the locals. Their builders evolved a unique architecture which was a fusion of native, Chinese, Spanish and Mexican styles specially adapted to the earthquake-prone tropics and climatic systems of native houses.

Based on records, Vigan houses can be traced undergoing five stages of evolution. First, these houses evolved from the native *kalapaw*; made of bamboo and roofed with thatch, built by native themselves, then followed by the second stage of houses made of wood on both floors and thatched roof. The third stage of Vigan houses was made of brick masonry on the ground floor and wood flank walls on the second floors and initially with thatch roof. However, due to fire incidents in the past, this type of roofs was later replaced by corrugated metal sheets introduced in the 1800s. The fourth stage was a house made of brick masonry on both floors which are mostly found along the Crisologo Street owned by Chinese *mestizo* traders who became wealthy from the Manila-Acapulco galleon trade. More sophisticated brick wall houses on both floors were built with an *observatorio* when astronomy became a fad among the rich homeowners. A new type of house design was introduced during the American period (UNESCO Bangkok, 2009).

### A. Features of Vigan Ancestral Houses

Vigan houses were designed to maximize natural ventilation and day lighting in a hot and humid tropical

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climate which is evident in the exterior and interior of the houses. These features are the following:

1. ***Ceiling Heights***

The 3- to 3.5-meter high ceiling is higher than what is common today. It allows hot air to rise above the occupants, thus raising the comfort level inside.

2. ***Full Openings***

The combination of main sliding windows and smaller *ventanillas* below them virtually creates full-height openings. The ample number of windows also increases the flow of air to the interior, thus boosting ventilation especially during summer or dry periods. Operable storm shutters behind the windows allow air to enter while regulating sunlight and wind-driven rain.

3. ***Shading***

Roof overhangs and canopies with sheet metal fretwork are not merely ornamental because of their aesthetically pleasing exterior features, but also functional, screening the interior from direct sunlight and thus reducing heat gain inside. In addition, they also prevent rainwater from directly discharging into the façade.

4. ***Spaces***

The brick-tiled *azotea* provides space for sun drying and a cool area for inhabitants during warm, humid nights. It also interrupts and diverts the flow of smoke and heat from the kitchen, which is almost always on one side of the *azotea*, into the living areas.

There are three types of Vigan houses under the Spanish colonial period while another type is under the American colonial period. These are the following:

***Wood and Brick with Lush Façade***

The earliest type of Vigan House, the *balay a bato ken kayo*, has flush façade and is made of brick masonry on the ground floor and plank sidings on the second floor. The ground floor is used mainly for storage while the second floor, which is supported by wood columns embedded in the ground floor's brick wall, serves as the living quarters, with simple pilasters on the ground façade trace the outline of the embedded wood columns.

**Figure 1.** Padre Burgos House Built in 1788.

***Wood and Brick with Volada Façade***

A modification of the wood and brick house with a flush, this type has for its main feature a *volada*, an extension of the second floor over the street. It serves as a passageway around the living area of the servants to move discreetly between rooms. It also functions as overhang for the ground floor to protect it as well as pedestrians from rain and sun. Houses of this type are taller. They first appeared around the last quarter of the 1700s. The earliest recorded ad extent house of this type is the Leona Florentino house (1797).

**Figure 2.** Quema House built in 1820.

***All Brick Type***

Built of brick masonry (*balay a bato*) from ground floor up to the second floor, spatial functions are the same as to the first two architectural types. It was built in compliance with a 1797 decree by Bishop Pedro Agustin Blaquier requiring buildings and houses constructed near the Cathedral to be made of stone as a precaution against fire. Plasters rise from the ground up to the roof eave, and their vertical orientation and unity of appearance are relieved by horizontal band mouldings at the floor girder and cornice levels. The all bricks type has more surviving examples in the core zone than the first two.

**Figure 3.** Favis House built in 1852.

*American Colonial Period*

First built in the early 1900s, they are lighter in appearance and more vertical in proportion. The ground floor walls in early houses are brick, later replaced by reinforced concrete which resulted in a less massive-looking structure. Wood remained the material for the second floor. Most upper windows have galvanized iron sheet awnings supported by iron brackets. Large plain or colored glass panes replaced the *capiz* in window sashes. Also common are glass clerestory windows that vary from geometric to fan-shaped arches. This type retained the *ventanillas* which are fitted with wrought iron grilles with ornamental patterns rather than wood balusters. The entrance features a portico on columns with decorative lacework brackets.

## B. Assessment of Vigan Ancestral Houses

This study aims to look into how designers of the past position their living spaces. The particular focus of the research is given on identifying patterns, similarities and differences on the way designers apportioned their spatial elements in relation to solar and wind path orientation, to consider indoor environment and building materials.

To make comparison and determine the major factors that affects the thermal conditions of the selected samples of Vigan ancestral houses of the Spanish colonial typology, the following were analyzed in the study: building orientation and spatial organization (solar path analysis and wind analysis); building fenestration (indoor/outdoor temperature, daylight, and window opening) and building materials (heat gain transfer through the wall and roof).

## C. Methodology

This paper aims of investigating indoor thermal environment and comfort condition of selected Vigan ancestral houses. Air temperature and related humidity were selected as the main variables to determine the thermal environment, relating it to its position to solar orientation, street orientation, fenestration and building materials.

*Getting the Data*

A mapping inventory of selected samples/projects through photo documentation, printed documents, plans, literature and other archival material sources was done, as well as other field measurements and desk research.

*Planning Analysis*

A field survey was carried to determine the environmental parameters of the selected ancestral. The basis for selection of the case study was through random selection and was dependent on the approval of the owner and availability of documents such as floor plans. Results were analyzed based on the acceptable standards (National Building Code of the Philippines and Guidelines of Energy Conserving Design of Building Philippines) to derive design guide that could be useful to the design profession.

*Computation of Convection Ventilation*

One way to ventilate a building that is hotter or colder on the inside than outside is to use what is known as "stack effect". Because of the temperature difference, the air inside the building is either more or less dense than the air outside. If there is an opening high in the building and another low in the building, a natural flow will be caused. If the air in the building is warmer than the outside, this warmer air will float out the top opening, being replaced with cooler air from outside. If the air inside is cooler than that outside, the cooler air will drain out the low opening, being replaced with warmer air from outside.

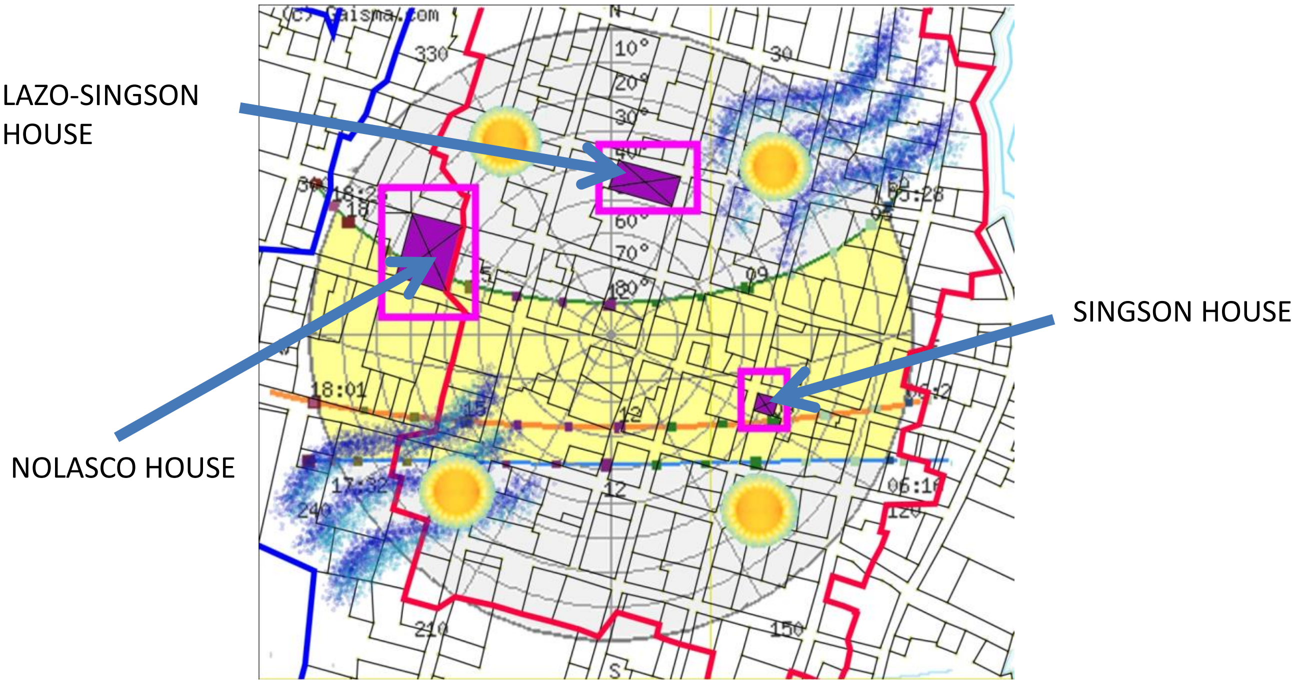



**Figure 4.** Map showing the locations of houses for case study.

One common use for stack effect would be nighttime flushing of a building's interior, to cool it for the next day. The rate at which air flows depends on several factors, the inside and outside air temperatures, the area of the openings, and the height difference between the top and bottom openings.

The 1999 Architect's Guide to Climate Design gives the following formula for convection ventilation (Hong, January 1999):

$$Q=7A\sqrt{H}(To-Ti)$$

Where as:

| | |
|---|---|
| H | height of duct (meters) |
| A | Area of duct (square meters) |
| To | "Outside" air temperature (°C) |
| Ti | "Inside" air temperature (°C) |
| Q | air flow up duct ($m^3$/min) |

***Measurements***

Room Temperature was measured using a Hydrometer (a device for measuring wet bulb temperature). The device was place in the living room area near the window, conducted in the entire house at the same time and day.

However, in the Nolasco house only one window and *ventanilla* was half open and all windows in the living room were closed, while in the Singson house, two windows were half open and the other two windows and *ventanilla* were closed and in the Lazo Singson house all windows were half open. The temperatures in ground floor were also measured in the entire house and the result was 28˚C throughout the day.

## II. Case Studies of Various Vigan Ancestral Houses

### Scope and Limitation

The specified historic zones were regulated with a special city ordinance passed by the City Council (Ordinance No. 12, Series of 1997) which identifies the historic core and buffer zones of Vigan City.

Vigan City is divided into three zones: first is the Core Zone (within the red line), second is the Buffer Zone (within the blue line) and the third is the Outside (the buffer zone (outside the blue line). Only ancestral houses located in the Core and Buffer Zones of Vigan City are considered in the study under the Spanish colonial period. The Lazo and Singson houses are both located inside the Core Zone while the Nolasco House is located within the Buffer Zone.

### A. Lazo-Singson House

The Lazo-Singson House is located within the Core zone. Its total floor area is 529.56 square meters (for each floor), with a height of 3.80 meters from ground floor to second floor and 4.10 meters in height from the second floor up to the ceiling. The main entrance and living room are facing northeast. The building envelope for both ground and second floors consists of 0.70 thick brick walls.

**Figure 5.** View of Lazo-Singson House along Plaridel Street and Gen. Luna Street.

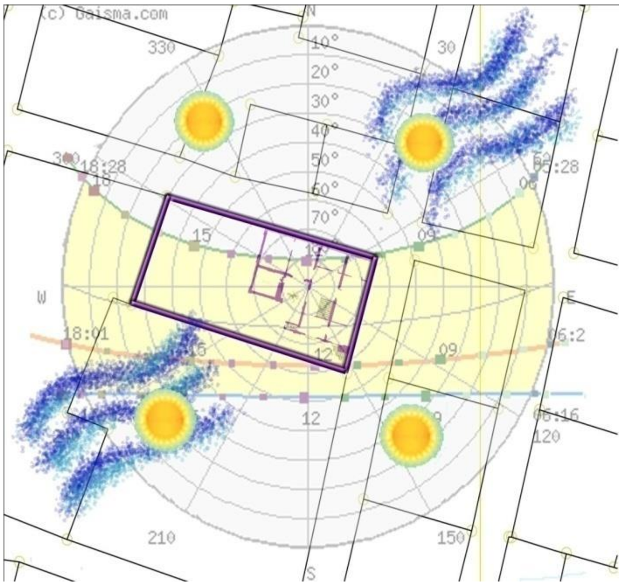



**Figure 6.** Orientation of Lazo-Singson House in relation to the sun path and wind path.

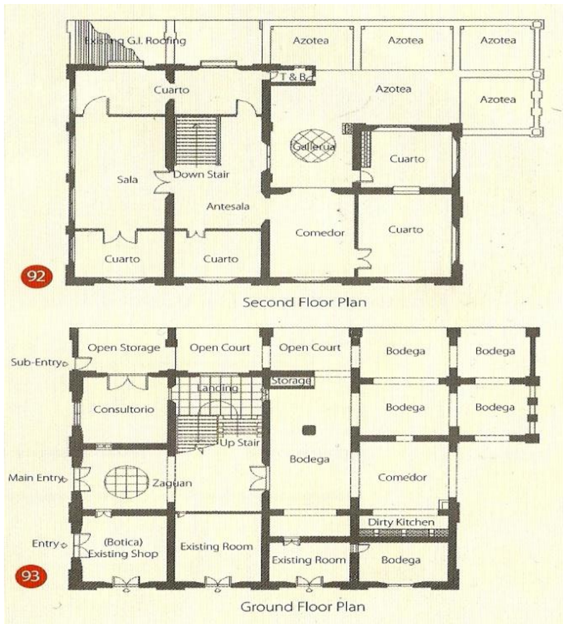



**Figure 7.** Floor plans of Lazo-Singson House.

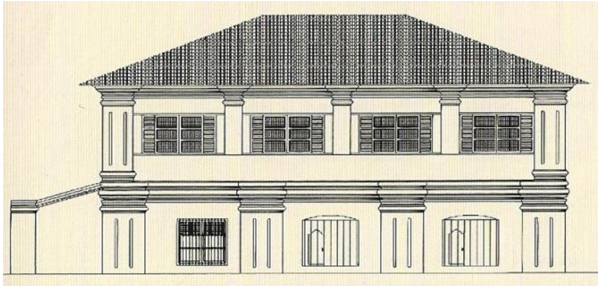


**Figure 8.** Facade of Lazo-Singson House.

## B. Nolasco House

The Nolasco House is located within the Buffer zone. Its total floor area is 522.56 square meters (for each floor), with a height of 3.10 meters from ground floor to second floor and 4.00 meters in height from the second floor up to the ceiling. The main entrance and living room are both facing north. The building envelope for ground floor consists of 0.70 thick brick walls while the main material for the second floor is made of timber construction.

**Figure 9.** Façade view of Nolasco House along Mabini Street.

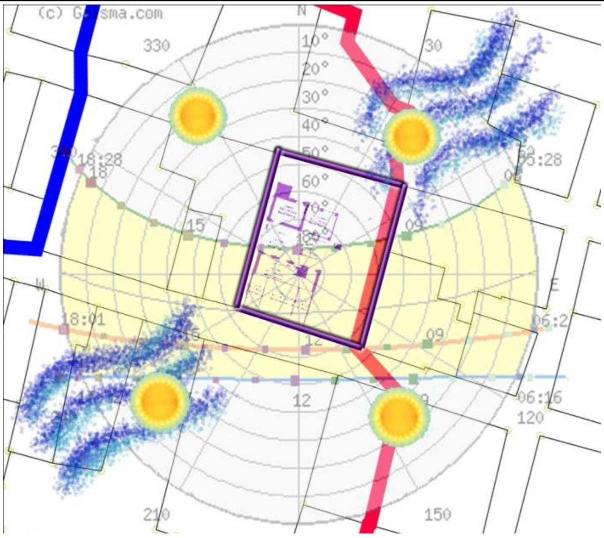
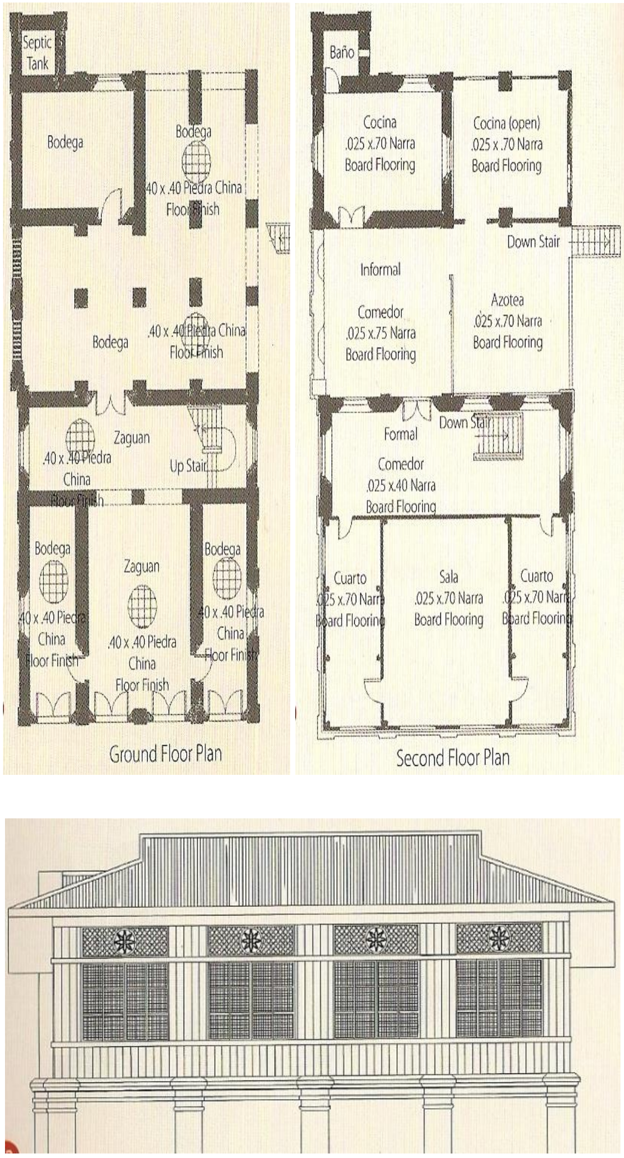



**Figure 10.** Orientation of Nolasco House in relation to the sun path and wind pat




**Figures 11 to 12.** Floor plans and facade of Nolasco House.

## C. Singson House

The Singson House is located within the Core zone. Its total floor area is 104.40 square meters (for each floor), with a height of 3.10 meters from ground floor to second floor and 3.30 meters in height from the second floor up to the ceiling. The main entrance is facing east while the living room is facing north. The building envelope for ground floor consists of 0.70 thick brick walls while the main material for the second floor is made of timber construction.

**Figure 13.** Façade view of Singson House along Mabini Street.

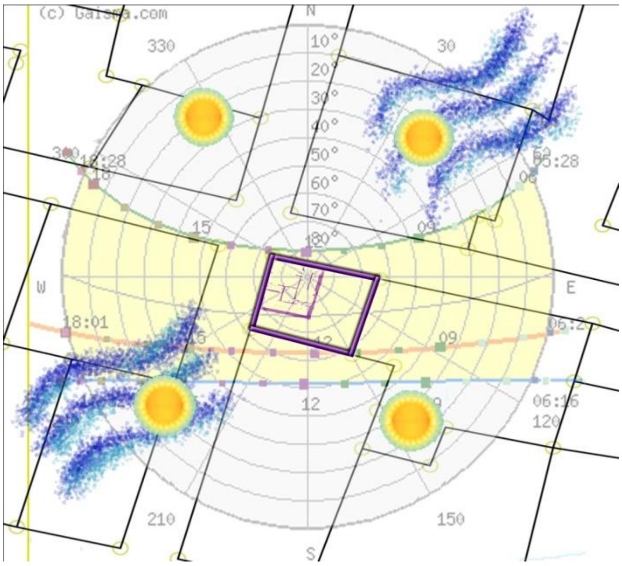
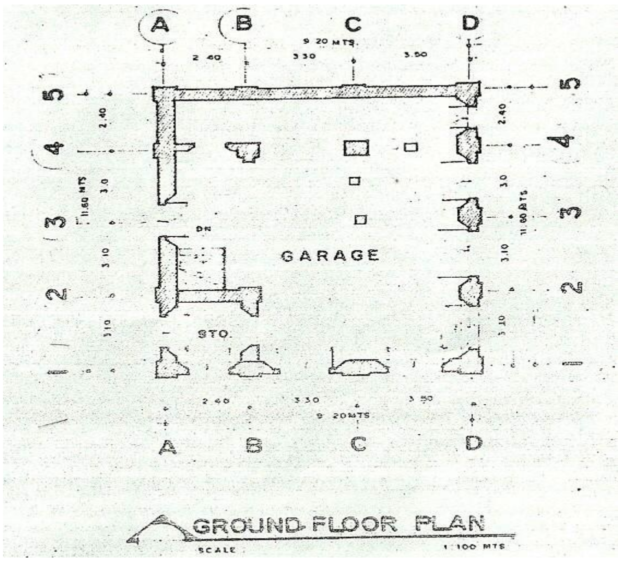
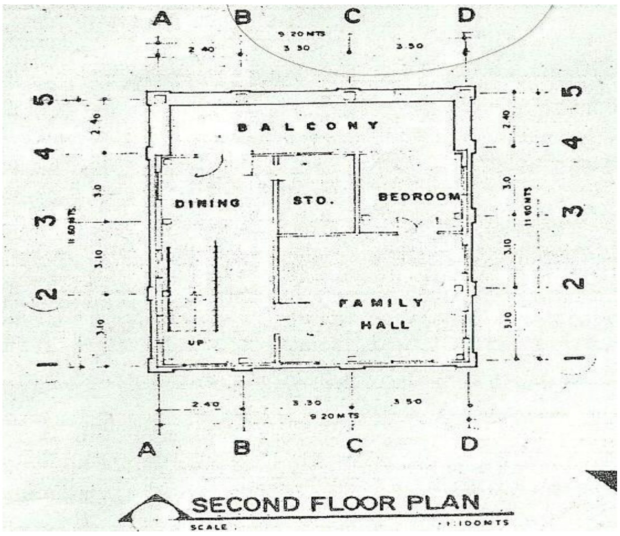
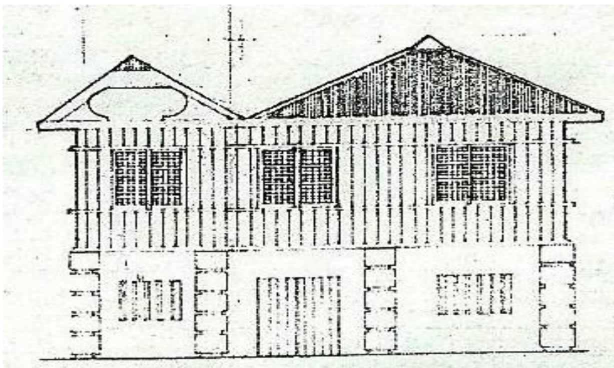



**Figure 14.** Orientation of Singson House in relation to the sun path and wind pat



**Figures 15 to 16.** Floor plans and facade of Singson House.

# III. Results

## A. Building Orientation and Spatial Organization

As per analysis of the sun and wind paths, it was observed that the longer sides of Nolasco House facing the East and West were extremely exposed to solar radiation. On the other hand, the shorter sides of the house facing Northeast and Southwest interrupt the wind breezes coming from those directions.

The longer sides of Lazo-Singson House facing Northeast and Southwest take full advantage of the *Amihan* (northeast) and *Habagat* (southwest) wind breezes. The shorter sides of the house facing the East and West were tilted towards North to avoid too much solar exposure.

Same with the Nolasco House, the longer sides of the Singson House facing the East and West receive the strongest solar radiation and penetration due to exposure. As for the shorter sides of the house facing Northeast and Southwest, they take advantage of the *amihan* and *habagat* wind breezes.

## B. Building Fenestration

*Identifying the Comfort Zone in Vigan City*

The mean annual air temperature in the province is 27˚C. April and May were observed to be the hottest months, with temperatures of 28.3˚C and 28.7˚C, respectively. Meanwhile, the coldest month is January with average temperature of 25.4˚C.

Using the formula for Climate having Tam above 10˚C,

$$Tcc = Tam/4 + 17.2$$

wherein

Tam refers to annual mean temperature(˚C), and

Tcc refers to the center of the Comfort Zone,

the computation for the Comfort Zone is as follows:

$$Tcc = (27/4) + 17.2$$
$$= 23.95^{\circ}C$$

Therefore, the computed Comfort Zone (Zone 5) is between 21.45˚C to 26.45˚C (with discrepancy of +2.5˚C).

*Indoor and Outdoor Temperature*

The Graph shows that the hottest time of the day occurs from 2 o'clock to 4 o'clock in the afternoon. The indoor air temperature in all types of the Vigan ancestral house is relatively low as compared to the outdoor air temperature.

**Table 1.** Measured indoor and outdoor temperatures (within the day) for the three (3) case studies.

| TIME | OUTDOOR TEMP. (˚C) | INDOOR TEMPERATURE (˚C) | | |
|---|---|---|---|---|
| | | NOLASCO HOUSE | SINGSON HOUSE | LAZO HOUSE |
| 8:00 AM | 29 | 28 | 28 | 28 |
| 9:00 AM | 30 | 29 | 29 | 29 |
| 10:00 AM | 31 | 30 | 30 | 29 |
| 11:00 AM | 32 | 30 | 31 | 29 |
| 12:00 AM | 32 | 31 | 31 | 30 |
| 1:00 PM | 33 | 31 | 31 | 30 |
| 2:00 PM | 34 | 31 | 31 | 31 |
| 3:00 PM | 34 | 31 | 31 | 31 |
| 4:00 PM | 34 | 31 | 31 | 31 |
| 5:00 PM | 33 | 31 | 31 | 30 |
| 6:00 PM | 30 | 30 | 30 | 29 |
| 7:00 PM | 29 | 29 | 29 | 29 |

*Computation of Convection Ventilation*

Nolasco House has computed airflow up duct (Q) of around 36 cubic meters per minute, while Singson House has 24 cubic meters per minute, Lazo-Singson house was not considered in the computation of convection ventilation since it has no *ventanilla*. Referring to Section 807 (page 126) of the National Building Code of the Philippines, it is stated that the acceptable size of a habitable room is 14 cubic meters of air space per person (stated also in Section 811). On the other hand, the data on the Minimum Requirement for Air Changes states that the minimum Q for artificial ventilation is 0.29 cubic meters per minute per person and the maximum is 0.443 cubic meters per minute per person.

As a general rule based on the guidelines on energy conserving design of buildings, a ventilation rate of 2.8 $m^3$/min to 5.7 $m^3$/min per person is adequate in practice if the average indoor air temperature rise of not more than 14°C is to be maintained as a result of body heat. Where power-driven and other heat sources are present, a higher ventilation rate is necessary. Therefore, both the Nolasco and Singson Houses provide more than the maximum requirement for ventilation.

**Table 2.** Computation of convection ventilation for Nolasco and Singson houses.

| Q=7A √H(To-Ti) | | NOLASCO HOUSE | SINGSON HOUSE |
|---|---|---|---|
| | H-Height of the duct(meters) | 2.15 | 3 |
| | A- Area of the duct($m^2$) | 2.032 | 1.419 |
| | To-outside air temperature(˚C) | 34 | 34 |
| | Ti - inside air temperature(˚C) | 31 | 32 |
| | Q-Airflow up duct ($m^3$/min.) | 36.124 | 24.33 |

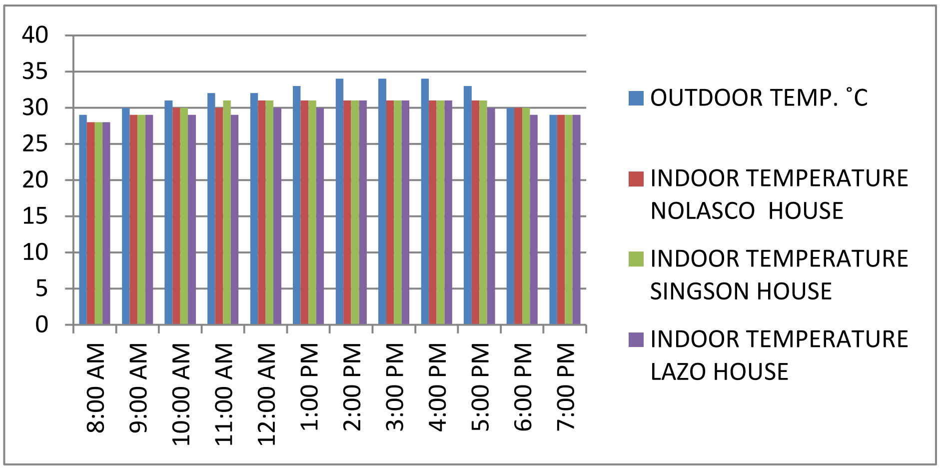



**Figure 17.** Graph showing the comparison of indoor and outdoor temperatures (within the day) for the three (3) case studies.

**Table 3.** Computation of daylighting compliance for Nolasco House.

| SPACE | FLOOR AREA (sq.m.) | WINDOW AREA (sq.m.) | WA / FA | % | COMPLIED | WFA | COMPLIED |
|---|---|---|---|---|---|---|---|
| LIVING | 70.31 | 14.742 | 0.209671455 | 21 | YES | 0.21 | YES |
| BEDROOM (L) | 31.15 | 13.606 | 0.436789727 | 44 | YES | 0.44 | YES |
| BEDROOM (R) | 31.15 | 13.606 | 0.436789727 | 44 | YES | 0.44 | YES |
| FORMAL DINING | 33 | 13.606 | 0.41230303 | 41 | YES | 0.41 | YES |
| STAIRCASE | 5.22 | 2.106 | 0.403448276 | 41 | YES | 0.41 | YES |
| LAUNDRY | 51 | OPEN | | | YES | | YES |
| INFORMAL DINING | 51 | OPEN | | | YES | | YES |
| KITCHEN | 34.3 | OPEN | | | YES | | YES |
| KITCHEN | 36.75 | 6.7758 | 0.18437551 | 18 | YES | 0.18 | YES |
| TOILET & BATH | 3.7925 | 0.105 | 0.027686223 | 3 | NO | 0.03 | NO |

**Table 4.** Computation of daylighting compliance for Lazo-Singson House.

| SPACE | FLOOR AREA (sq.m.) | WINDOW AREA (sq.m.) | WA / FA | % | COMPLIED | WFA | COMPLIED |
|---|---|---|---|---|---|---|---|
| LIVING | 54 | 9.2 | 0.17037037 | 17 | YES | 0.17 | YES |
| ROOM1 | 25.5 | 6.256 | 0.245333333 | 25 | YES | 0.25 | YES |
| ROOM2 | 23.375 | 2.944 | 0.125946524 | 13 | NO | 0.13 | NO |
| ROOM3 | 42.7 | 6.992 | 0.163747073 | 16 | YES | 0.16 | YES |
| ROOM4 | 46 | 10.712 | 0.232869565 | 23 | YES | 0.23 | YES |
| DINING | 48.6 | 6.072 | 0.124938272 | 12 | NO | 0.12 | NO |
| KITCHEN | 42.7 | 6.992 | 0.163747073 | 16 | YES | 0.16 | YES |
| STAIRCASE | 30.8 | 5.28 | 0.171428571 | 17 | YES | 0.17 | YES |
| TOILET & BATH | 7.6 | 0.105 | 0.013815789 | 1.4 | NO | 0.014 | NO |

**Table 5.** Computation of daylighting compliance for Singson House.

| SPACE | FLOOR AREA (sq.m.) | WINDOW AREA (sq.m.) | WA / FA | % | COMPLIED | WFA | COMPLIED |
|---|---|---|---|---|---|---|---|
| LIVING | 30.16 | 11.52 | 0.381962865 | 17 | YES | 0.17 | YES |
| ROOM1 | 14 | 5.76 | 0.411428571 | 25 | YES | 0.25 | YES |
| DINING | 10.2 | 2.88 | 0.282352941 | 13 | YES | 0.13 | YES |
| STAIRCASE | 10 | 2.88 | 0.288 | 17 | YES | 0.17 | YES |
| BALCONY | 22.08 | OPEN | | | YES | | YES |

*Daylighting Compliance*

Almost all the domestic areas of the three case studies complied under the National Building Code, Chapter 8 on Light and Ventilation, Sec. 808 page 20, which states that windows should have a total free area openings equal to at least ten percent (10 percent) of the floor area of a room. Based on Guidelines on energy conserving design of buildings, the size of openings for natural lighting and ventilation of residential units must be equal to or at least 15 percent of the floor area of an enclosed space or room and at least 10 percent or 0.2 square meter (whichever is greater) for toilet and bath and laundry. The results show that all areas complied with daylighting requirements, except for the Toilets and Baths (T&Bs), in Nolasco and Singson houses, since the said spaces were only added to the house in the later years to provide more functional and comfortable T&Bs to the occupants.

## C. Building Materials and U-Value

*Solar Heat Factor for Roofing*

**Figure 18.** Photo of Metal Roof.

**Table 6.** Solar Heat Factor of Metal Roof.

| ROOF 1 (5%) | THICKNESS (m) | K VALUE | RESISTANCE | U-VALUE 1/R |
|---|---|---|---|---|
| Outdoor Air | | | 0.050 | |
| Metal Roof | 0.014 | 2 | 0.028 | |
| Cavity (Ventilated) | | | 0.176 | |
| Plywood | 0.019 | 7.25 | 0.138 | |
| Indoor Air | | | 0.105 | |
| TOTAL | | | 0.497 | 2.013 |

**Figure 19.** Photo of Clay Tile Roof with Plywood Ceiling.

**Table 7.** Solar Heat Factor ofClay Tile Roof w/Plywood Ceiling.

| ROOF 2 (3%) | THICKNESS (m) | K VALUE | RESISTANCE | U-VALUE 1/R |
|---|---|---|---|---|
| Outdoor Air | | | 0.050 | |
| Clay Tile | 0.1875 | 0.83 | 0.156 | |
| Lime | 0.1875 | 1.88 | 0.353 | |
| Clay Tile | 0.1875 | 0.83 | 0.176 | |
| Lime | 0.1875 | 1.88 | 0.353 | |
| Clay Tile | 0.1875 | 0.83 | 0.156 | |
| Cavity (Ventilated) | | | 0.176 | |
| Plywood | 0.019 | 7.25 | 0.138 | |
| Indoor Air | | | 0.105 | |
| TOTAL | | | 1.661 | 0.602 |

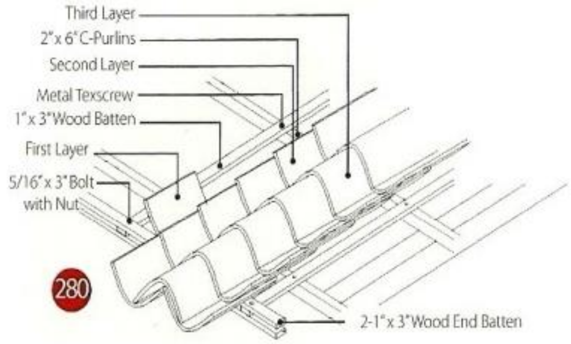



**Figure 20.** Detail of Clay Tile Roof with G.I. Sheet Ceiling.

**Table 8.** Solar Heat Factor ofClay Tile Roof w/ G.I. Sheet Ceiling.

| ROOF 3 (5%) | THICKNESS (m) | K VALUE | RESISTANCE | U-VALUE 1/R |
|---|---|---|---|---|
| Outdoor Air | | | 0.050 | |
| Clay Tile | 0.1875 | 0.83 | 0.156 | |
| Lime | 0.1875 | 1.88 | 0.353 | |
| Clay Tile | 0.1875 | 0.83 | 0.176 | |
| Lime | 0.1875 | 1.88 | 0.353 | |
| Clay Tile | 0.1875 | 0.83 | 0.156 | |
| Cavity (Ventilated) | | | 0.176 | |
| G.I. Sheet | 0.019 | 2 | 0.038 | |
| Indoor Air | | | 0.105 | |
| TOTAL | | | 1.561 | 0.641 |

*Note: Roof 2 (clay tile roof with plywood) is within 3 percent while both Roof 1 (metal roof) and Roof 3 (clay tile roof with G.I. sheet) are above 5 percent. Based on the standard u-value of 3 percent, roofs above the standard (Roofs 1 & 3) need to shade it or add insulation.*

Based on the Department of Energy (2007), the maximum allowable u-value is 0.80 for roofs with weight under 50 kg/m$^2$, 1.1 for roofs with weights ranging from 50-230 kg/m$^2$, and 1.5 for over 230 kg/m$^2$ and for non-air-conditioned buildings. With this, Roofs 2 (Clay Tile Roof with Plywood Ceiling) and 3 (Clay Tile Roof with G.I. Sheet Ceiling) were the only ones that complied with the allowed solar heat factor for roofing system.

*Solar Heat Factor for Walls*

**Figure 21.** Photo of Wooden Wall.

**Table 9.** Solar Heat Factor of Wooden Wall.

| WALL 1 (above 5%) | THICKNESS (m) | K VALUE | RESISTANCE | U-VALUE 1/R |
|---|---|---|---|---|
| Outdoor Air | | | 0.070 | |
| Timber Hardwood | 0.025 | 6.25 | 0.156 | |
| Indoor Air | | | 0.123 | |
| TOTAL | | | 0.349 | 2.863 |

**Figure 22.** Photo of Brick Wall.

**Table 10.** Solar Heat Factor of Brick Wall.

| WALL2 (below 3%) | THICKNESS (m) | K VALUE | RESISTANCE | U-VALUE 1/R |
|---|---|---|---|---|
| Outdoor Air | | | 0.070 | |
| Plaster | 0.025 | 1.88 | 0.047 | |
| Brick Dry | 0.23 | 0.83 | 0.191 | |
| Rubble Stone | 0.41 | 6.25 | 2.563 | |
| Brick Dry | 0.23 | 0.83 | 0.191 | |
| Indoor Air | | | 0.123 | |
| TOTAL | | | 3.184 | 0.314 |

*Note: Wall 1 (wooden wall) is above 5 percent & while Wall 2 (brick wall) is below 3 percent. Based on the standard u-value of 3 percent, walls above the standard (Wall 1) need to shade it or add insulation.*

## IV. Conclusions and Recommendations

The orientations of the Vigan houses are dependent on the shape and orientation of the lot. The location of the living room is always on top of the main entrance, overlooking a major street in front of the house, regardless of the orientation. With this, the Vigan houses took advantage of the natural (cross and convection) ventilation in their design. Also, Vigan ancestral houses were designed with ample daylighting through the large window sizes.

For roofing material, the combination of clay tile roof with plywood ceiling is the most effective of the three types, followed by the combination of clay tile roof with G.I. sheet ceiling. The results for metal roof with plywood ceiling show that it is just near the standards.

Besides roof insulation, the building regulations also specify that in the case of a non-mechanical building, any external wall abutting a habitable room shall have u-value of not more than 3.5 W/m. Based on the results of the study, all walls considered in the study complied with the said requirement, with the 0.8m-thick brick wall of lime and cobbled stones as the more effective material, having a u-value of 0.314.

This research shows that from the three types of Vigan ancestral houses studied, the all-brick type is the more efficient in terms of thermal performance, although all of the types have the same features such as profuse and bigger upper window openings, large protruding eaves, roof vents, shutters and shell-panelled windows, *ventanillas* and *callados*, and bricks masonry envelop. This is probably due to the thick brick walls at ground floor and upper floor that regulate the fluctuation in temperature even without the *ventanillas*.

Using Carl Mahoney's method, even with the thick walls (0.8-1.0 meter) of the ancestral houses included in the study, the internal temperature is measured between 28°C to 31°C from 8am to 7pm, which is over the comfort zone computation in Vigan (24°C ± 2.5°C). The natural lighting entering the ancestral houses featured in the study is between 12-44 percent or more than the standard value of 10 percent as stated in the National Building Code of the Philippines.

Researchers in this field can use LEED and ASHRAE ratings in the green and sustainability assessments of ancestral houses for future studies.

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