Climate Responsive Design for Damayang Lagi Site

Design Recommendations Based on Local Context

Bc. Peter Panulin,

Lund University, Sweden

Introduction

Main factors shaping the design of housing units everywhere in the world are climate conditions. The man builds a house as a shelter from the unfavourable weather. Thus the design of a shelter in particular parts of the world has evolved differently depending on the climate.

The aim of this paper is to propose a certain material and design solutions for the Damayang Lagi site based on the climate analysis.

1 Traditional Housing Forms and Development

(The traditional housing types in Philippines with the focus on climatic design solutions)

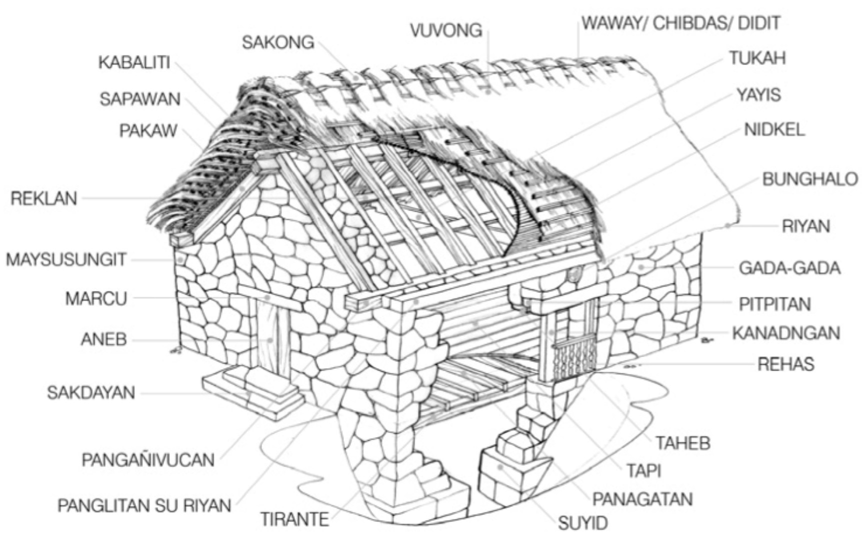
It is important to examine the forms of dwelling from the past and present time because those have been used for ages and can show us how the people dealed with the climate. Structures were not only shaped by the culture and traditions but by the external environment as well. In words of V.Olgyay, “the regional adaptation is an essential principle of architecture .”

The architectural forms of pre-colonial period in the Philippines were mainly rural houses made of indigenous materials. Their design may vary depending on the region and climate conditions.

A dwelling type representing that period which is widely used today is the **Bahay-kubo** (nipa hut). This rural house made of indigenous materials such as bamboo, nipa and local woods has not changed much for centuries. It’s a traditional house found in lowlands in the Philippines. The design varies by region with some similar features like steep roof over living area, the house structure raised on stilts (1-2meters above the ground or shallow water). The houses were temporary and suited the lifestyle of farmers who often had to move from place to place. Light construction of the walls made of bamboo slats and strips enables the air ventilation, materials itself have low heat capacity and don’t accumulate heat. Another feature which adds to the ventilation is gaps on the floor which is made of split bamboo pieces. Some families have replaced the Nipa roof for sheet metal which lasts longer but on the other hand it makes the inside of the house hotter.


During a 300 years of Spanish colonisation another distinct housing type has emerged - the typical Filipino noble house or the **Bahay na Bato** (the stone house). The Bahay na Bato was derived from Bahay Kubo with sturdier materials and construction. It used the same principle of open ventilation and elevated living area as Bahay Kubo. Because of the earthquakes, the lower level (the storage) is made of stone while the upper level, the living area, is constructed of wood. Sliding window panels usually covered the whole length of the second floor maximizing the effects of ventilation. These doors often had wooden louvers as a sun protection or translucent capiz shell panes. Roof is tiled or (later) made of metal sheets. The introduction of passive cooling devices like the ventanillas, capiz windows, brandilas, azoteas and indoor courtyards improved the indoor climatic conditions.

The **Ivatan house** is typical for the Batanes islands. The harsh conditions of the area (numerous typhoons and earthquakes per year) have influenced the design. Houses are built with thick limestone walls and reed or cogon (a kind of long grass) roofs and roof nets as a protection from the wind. Only 3 walls have windows, the one that faces the direction of strongest winds doesn’t. Stone walls absorb the heat during the day and release it in the night. There are different types of Ivatan houses: Lagatiti, Rakuh, Jin-jin, Sinadumparan etc.



Other than these 3 there are more housing types with differences that developed for each particular area or social group like the torogan, lawig, mala-a-walai, the houses of Maranao people or the Ifugao house from northern Luzon.

Nowadays there can be seen a tendency to follow western styles in architecture which are not adapted to the climate. Material widely used in the cities is concrete. The houses usually have concrete floor, brick or concrete block walls and an iron sheet or tiled roof.

2 Climate Analysis

(Climate data and biological evaluation for the Metro manila area, Philippines)

Philippines islands lie between 6 and 19 latitudes north and between the 117 and 127 longitudes east. The climate is hot and humid with rainy season from May until October and dry season from November until April. The temperatures are relatively even throughout the year and throughout the day and night ranging from 23 to 31C.

The structure of a building should take advantage of the natural possibilities and use passive means of achieving comfort interior conditions. Methodology in evaluation of thermal performance of buildings has evolved to the level where we can, based on local climate data, properly set the principles of efficient design.

There are 4 traditional methods of bioclimatic analysis:

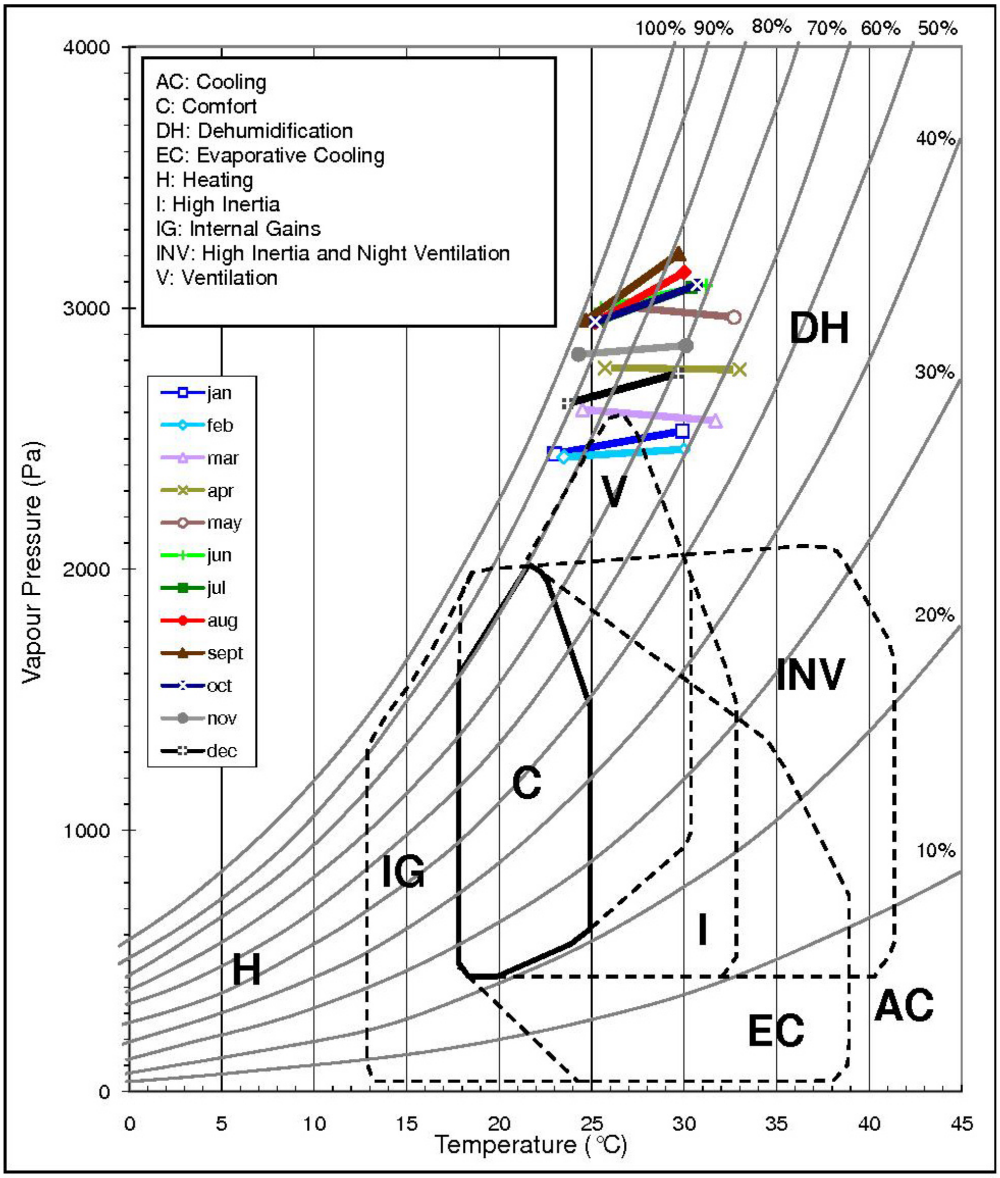
- Olgyay method
- Givoni method
- Fanger method
- Mahoney tables

The first 3 methods use climate data to graphically show the climatic conditions of the area compared with the human comfort requirements.

The Mahoney tables give certain design recommendations.

Climatic data

Monthly mean…	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
Max. temp (°C)	29,9	30	31,7	33	32,7	31,2	30,4	30	29,7	30,7	30,1	29,7
Min RH (%)	60	58	55	55	60	68	71	74	77	70	67	66
Pressure (Pa)	2529	2459	2569	2764	2965	3087	3080	3137	3208	3089	2857	2750
Min temp (°C)	23	23,5	24,5	25,7	26,3	25,5	25,4	25,2	24,7	25,2	24,3	23,7
Max RH (%)	87	84	85	84	88	92	91	92	95	92	93	90
Pressure (Pa)	2442	2430	2611	2771	3008	3000	2949	2947	2953	2947	2823	2635



What can be seen from Givoni’s bioclimatic diagram is that the climate conditions of Manila are far from human comfort area. Passive air ventilation would be possible only for January and February. Air conditioning combined with dehumidification would have to be used to achieve the convenient indoor environment. Energy has registered a consistent increase in consumption (http://www.worldenergy.org/documents/phillipines.pdf). The majority of energy used in residential/commercial sector is for cooling. The initial and operational costs of air conditioning make it unsuitable for a low cost housing.

Manila (Int. Airport)
Latitude 15°N

Indicator totals from data sheet					
H1	H2	H3	A1	A2	A3
12	0	5	0	0	0

General recommendations

H1	H2	H3	A1	A2	A3		
							Layout
			0–10		5–12	X	Orientation north and south (long axis east–west)
			11–12		0–4		Compact courtyard planning
							Spacing
11–12						X	Open spacing for breeze penetration
2–10							As above, but protection from hot and cold wind
0–1							Compact layout of estates
							Air movement
3–12						X	Rooms single banked, permanent provision for air movement
1–2			0–5				
1–2			6–12				Rooms double banked, temporary provision for air movement
0	2–12						
0	0–1						No air movement requirement
							Openings
			0–1		0	X	Large openings, 40–80%
			11–12		0–1		Very small openings, 10–20%
Any other conditions							Medium openings, 20–40%
							Walls
			0–2			X	Light walls, short time-lag
			3–12				Heavy external and internal walls
							Roofs
			0–5			X	Light, insulated roofs
			6–12				Heavy roofs, over 8h time-lag
							Outdoor sleeping
				2–12			Space for outdoor sleeping required
							Rain protection
		3–12				X	Protection from heavy rain necessary

Detailed recommendations

H1	H2	H3	A1	A2	A3		
							Size of opening
			0–1		0	X	Large openings, 40–80%
			0–1		1–12		Medium openings, 25–40%
			2–5				
			6–10				Small openings, 15–25%
			11–12		0–3		Very small openings, 10–20%
			11–12		4–12		Medium openings, 25–40%
							Position of openings
3–12						X	In north and south walls at body height on windward side
1–2			0–5				
1–2			6–12				As above, openings also in internal walls
0	2–12						
							Protection of openings
					0–2	X	Exclude direct sunlight
		2–12				X	Provide protection from rain
							Walls and floors
			0–2			X	Light, low thermal capacity
			3–12				Heavy, over 8h time-lag
							Roofs
10–12			0–2			X	Light, reflective surface, cavity
10–12			3–12				Light, well insulated
0–9			0–5				
0–9			6–12				Heavy, over 8h time-lag
							External features
				1–12			Space for outdoor sleeping
		1–12				X	Adequate rainwater drainage

3 Factors Shaping Urban Shelter Design

(The Design parameters, methodology)

The structure which in given environmental setting reduces undesirable stress and at the same time utilizes all natural resources favourable to human comfort may be called climate balanced. The process of building a climate balanced house can be divided into four steps:

- Analyse of climatic data
- Biological evaluation
- Technological solutions
    - Site selection
    - Landform orientation
    - Vegetation
    - Street widths and orientation
    - Ground character
    - Plan form
    - Plan elements
    - Building orientation
    - Roof form
    - Fenestration pattern and configuration
    - Fenestration orientation
    - Fenestration controls
    - Walls and roofs materials
- Architectural application

Technological Solutions

Site selection

It may seem from the weather conditions data that the climatic conditions over large area are same. In fact the conditions in one area may vary depending on topography and microclimate of a certain area (for example northern slopes are usually colder than southern). These deviations in climate play important role in architectural land utilisation.

In hot and humid areas air movement constitutes the main comfort-restoring element. Sites off-set from the prevailing wind direction, but exposed to the high air stream areas near the crest of a hill or high elevations on the windward side near the ridge are preferable. Southern and northern slope directions are more desirable because of the less radiation they receive. However wind flow effects will remain the dominating consideration, as shading might be provided by other means.

Landform orientation

It has no meaning in conditions when the land is flat. Important factor is an orientation of a slope

For the hot climates the north oriented slopes are better for a placement of the building as they receive less direst radiation, but only in case when the slope shades the building. This arrangement is quite unique thus the orientation has a little consequence. Building should be placed in a way that maximizes air flow.

Vegetation

Vegetation and trees in general very effectively shade and reduce the heat gain, increase humidity levels and direct air flow. Plants absorb radiation in a photosynthesis process and therefore cool the surroundings.

Street widths and orientation

Street width determines the amount of radiation received, orientation affects the time of day when the radiation is received.

However, in hot and humid climates the significance of wind flow plays the most important role in street orientation.

Ground character

The heat gain from the radiation could be decreased, stored and re-radiated or increased depending on a ground surface. Important factors here are colour and texture. The pale and smooth ground surface also reflects daylight which may be uncomfortable during sunny days therefore the paving should be minimised and where possible rough.

Planform

The planform of the building affects ventilation heat loss and gain. An important indicator of heat loss and gain is perimeter to area ratio. A large perimeter to area ratio (P/A) means the small area is bounded by a large perimeter.

A priority for hot and humid regions is maximising ventilation through the building and minimizing the P/A ratio to reduce the heat gain.

Plan elements

The elements such as verandas, wind catchers or courtyards could be integrated in the building or the building complex to benefit the microclimate of the area. Shaded courtyards can be quite effective being places with cooler air. However the wind catchers are really effective only when there are strong breezes.

Building orientation

Orientation of a building determines the amount of radiation it receives. Orientation should be chosen according to the air patterns to increase the ventilation.

Roof form

Roof can be used to indirectly bring light into the building as well as to help direct the natural ventilation.

The building in hot humid climate should have high pitched roof with overhangs and be located perpendicular to the wind direction to maximise the pressure difference and the air flow.

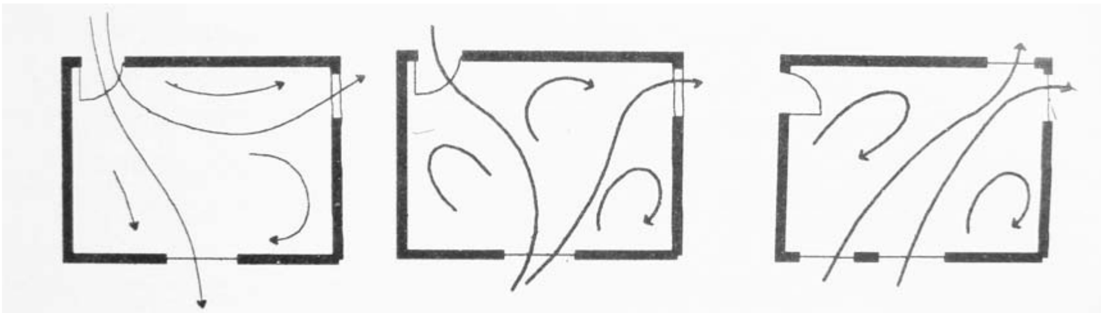
Fenestration pattern and configuration

The positioning, area and shape of the windows affect daylight, ventilation and glare to the interior of the building. Openings at the higher level (defined by the cill and lintel level) aid air flow. Placement of the openings also affects light distribution in the room as the windows at the floor level, window level and ceiling level distribute the light differently.

Window areas in hot and humid climate should be large for the ventilation with overhangs to give protection from the radiation. Openings should be on at least 2 walls.

Fenestration orientation

The orientation of windows affects amount of radiation entering and can increase or decrease ventilation. To achieve a good air flow inside the building, the wind direction should not be the same as inlet to outlet direction. Here are some examples of ideal window positioning:



Windows should be within 45° of the perpendicular to the direction of an air flow.

Fenestration controls

Devices such as glazing, shades, lights shelves or the cross sectional area of the window can control the heat gain, daylight and ventilation.

Glazing - traps solar radiation and thus increases interior temperature. This feature is considered a setback in warm climates.

Shades - horizontal or vertical. Control heat gain from the radiation. Can be adjusted according to the time of the day/year with the udesirable heat gain.

Light shelves – horizontal projections in a window. They can be inside, outside or partly within or outside the glazing. They function partly as horizontal shades which reflect the light incident on the upper side inside the building.

Window cross section – Variation of the cross section of the area in which the air flows can influence the speed of the flow. Increasing the area decreases the speed and vice-versa.

Walls and roof materials

Significant role in the climatic design of the roofs and walls play materials. Besides the thermal properties of materials there are other factors such as availability, cost or fire resistancy that have to be considered. Here is a description of few thermal properties that are important for a climate design purposes:

Thermal conductivity (k)

It is the rate of heat transfer through a material in steady state. In other words, it predicts the power loss (in watts, W) through a piece of material. It is not easily measured, data for most common materials are readily available.

Thermal admittance (y)

the quantity of heat that passes in unit time through unit area of a plate of particular thickness when its opposite faces differ in temperature by one kelvin.

Thermal transmittance (U)

is the rate of transfer of heat (in watts) through one square metre of a structure divided by the difference in temperature across the structure.

Heat capacity (C)

characterizes the amount of heat that is required to change a body's temperature by a given amount. It’s also described as big or small time lag of a material, that means for how long can material radiate the acumulated heat.

Reflectivity

It is ratio of reflected and incident spectral intensity in other words a fraction of incident radiation reflected by a surface. White materials may reflect 90% or more, black materials 15% or less of received radiation.

Another feature concerning materials that may affect heat absorption but could not be called a thermal property is *the texture of surface*. A rought texture (extruded bricks on the facade) enables self shading, on the other hand the smooth surface would be more reflective.

In general, when designing for a hot humid climate, building material should have the following properties:

Low conductivity
Low admittance (small y value)
Low transmittance (small U value)
Low heat capacity (small time lag)
High resistance
High reflectivity and Low absorbtion

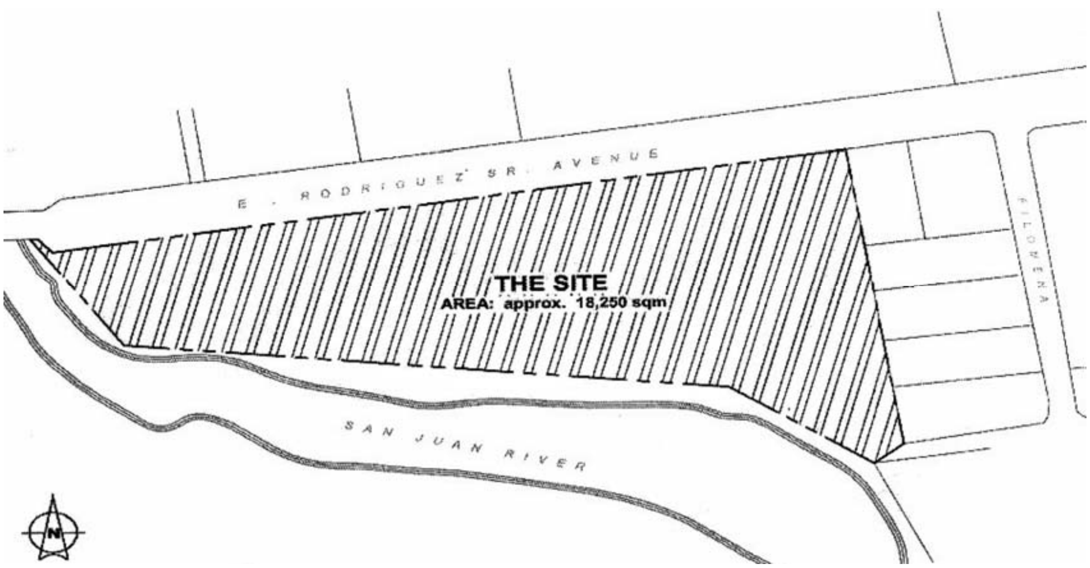
4 Shelter Design for Damayang Lagi Site

(Design recommendations for Damayang Lagi site based on the outcome of climate analysis)

As mentioned before, interior climate comfort could not be achieved by passive means of cooling. Despite that the design should be as responsive to the harsh climate as possible and reduce the effect on the inhabitans. To do that, it is necessary to decrease the heat gain from radiation wherever it is possible and enable air movement through the streets and structure.

The traditional architecture has dealed with this by opened plan where air can flow from one rom to another and through floors and walls. Materials used were locally available, light, with low heat capacity and appropriate for self help construction.

Context of the Damayang Lagi site is different than of traditional rural houses. Site is located in the center of Manila on the San Juan river. Application of traditional materials is inappropriate due to their cost, durability, availability and fire safety. Also the one storey structures are not suitable for the site for economic reasons.



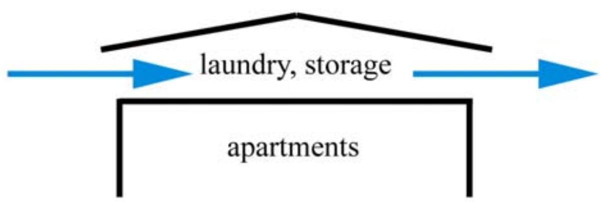
Structure and Material Recommendations

Structure should be oriented North/South to form long streets to direct the air flow and allow the breeze penetration. It is possible to adjust the street directions parallel to the Rodriguez avenue.

Windows should be placed on north and south facade on windward side. Prevailing wind direction is from east to west. Openings over the windows (ventanillas) right under the ceiling would improve air movement.

Vegetation in form of plants on the balconies, trees and bushes should be used as much as possible in the area in a way that it doesn't affect the air flow.

The roof should have large overhangs to provide as much shade as possible. The area right under the roof construction could be used for laundry or as a storage. This arrangement will act as a ventilated roof and provide shade for ceiling of the apartments below as shown on the picture.



Shading is a basic method how to influence the comfort of the area. All the windows should be equipped with shading devices which design will be based on computer animated shading tests.

Materials used for a construction should be locally available, fire resistant with low conductivity, low admittance, low transmittance and low heat capacity

Table 1: Thermal Properties of Building Materials

Material	Density (kg/m^3)	Thermal Conductivity (W/m K)	Specific Heat Capacity (J/kg K)
Brickwork	1700	0,84	800
Castst concrete	2100	1,40	840
Concrete block	1400	0,51	1000
Stone (limestone)	2180	1,5	910

The best material solution for multi storey structure will be concrete skeleton with light concrete block walls. After the skeleton is done by the qualified construction workers the partitions can be erected by self-help housing. Thermal performance of walls can be increased by using isolation although this raises the building cost.

Another way how to decrease heat absorption from radiation is appropriate finish of the outer walls.

Table 2: Reaction of Materials to Solar and Thermal Radiation

Material	**Solar Radiation (% of reflectivity)**	**Thermal Radiation (% of reflectivity)**
Whitewash	80	-
Light Green paint	50	5
Wood	40	5
Red clay brick	23-30	6
Black matte	3	5

Reflectivity of concrete blocks is somewhere between 23-30%, White plaster can reflect 80% of solar radiation, thus can significantly lower the heat gain.

Insulation

References

Krishan, Tewari, Jain

1995 *Climatically Responsive Energy Efficient Architecture.* New Delhi: Center For Advanced Studies In Architecture.

Olgyay

1963 *Design With Climate.* New Jersey: Princeton University Press.

Compendium of Independent Papers by course participants

1996 *Architecture, Energy & Environment, Tools For Climatic Design.* Lund: LCHS

Rommel C. Gavietta

1990 *Mass Housing Based on the Traditional Design and Indigenous Materials for Passive Cooling in the Tropical Urban Climate of the Philippines.* University of the Philippines, Buliding Research Service

Internet:

http://www.worldenergy.org/documents/phillipines.pdf

http://www.gaisma.com/en/location/manila.html

Climatic Data

http://www.livinginthephilippines.com/history_of_philippine_architecture.html

History Of Philippines Architecture by Architect Manuel D. C. Noche