Climatic building design in warm-humid areas

Passive and active houses

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1 Introduction

The main purpose of a shelter is to give privacy and thermal comfort. For thermal comfort, the building transforms the outdoor climate to conditions acceptable for indoor activities. In developing countries like Philippines many modern buildings are designed without thinking about climate which can affect indoor comfort, health and energy consumption. This is a problem not only for dwellings but also for public buildings. It is possible to improve the indoor comfort by having a good understanding of active and passive houses and by using architectural means.

In Philippines where the incomes are low and the climat hard, indoor thermal comfort is a real challenge.

2 Climatization challenges in urban shelter

CLIMATE

The climate of the Philippines is called warm-humid equatorial climate. The equatorial climate includes two subgroups, the tropical rain forest and the savannah, differenciated by the amount of rain. There are two seasons in this country, the wet season and the dry season, also based on the rainfall (Adamson & Olle, 1993).

The three main climatic elements caracteristic of this climate are the temperature, the air humidity, and the wind. These have an effect on the thermal comfort. The seasonal variation in temperature and humidity is small. The air humidity, which corresponds to a certain amount of vapour, is most of the time given in grams per m^3. The expression can also be the relative humidity (RH) which describes the portion of vapour in relation to saturation. During the dry season the relative humidity can vary from 95% in the morning to 60% in the afternoon. During the wet season the temperature and the relative humidity do not vary much over the day.

ENERGY CONSUMPTION

In 2012 the production of energy in the world was 13.5 million TOE (Tons of Oil Equivalent), although it was 9.8 TOE in 1999. The energy use was 13,2 million TOE in 2012 and 9,7 in 1999 (Roselund, Jianquing, & Guofeng, 2005), (www.eia.gov). In low and middle income urban households the rising living standards changes the energy utilisation. Several years ago cooking and heating were done by solid fuel, nowadays the electricity is used for different kind of activities in the home, such as air conditioning.

In the Philippines cooling equipment are often required during some parts of the year, which means higher use of energy and higher annual costs. Regulatory system and/or passive techniques can be used to have an efficient building. The building has to be designed to give the most economical annual cost.

THERMAL COMFORT

The human beings exchange heat with the environment through conduction, convection, radiation and evaporation/condensation. These factors are influenced by the environment and by individual caracteristics such as metabolic rate and clothing. (Roselund, 2000)

Activity	Metabolic rate Wet	W
Sleeping	0.7	75
Sitting	1.0	105
Standing relaxed, office/school work	1.2	125
Standing, light – medium activity	1.6-2.0	170-210
House cleaning	2.0-3.4	210-350
Walking (3-6 km/h)	2.0-3.8	210-400
Dancing, gymnastics	2.4-4.4	250-460
Pick and showel work	4.0-4.8	420-500
Running (15 km/h)	9.5	1 000

Clothing	clo
Nude	0
Shorts	0.1
Walking shorts or knee-length skirt + short level shirt	0.3-0.4
Trousers or knee-length skirt + long sleeve shirt	0.5-0.6
Trousers or knee-length skirt + long sleeve shirt + jacket	0.7-1.0
knee-length skirt + long sleeve shirt + half slip + pantyhose + long sleeve sweater or jacket	1.0-1.1
Men's heavy three piece business suit	1.5
Men's heavy suits and woollen overcoat	2.0-2.5

Table 1 - Metabolic rate and clothing - Roselund, 2000

Comfort is subjective that is why the comfort zone has been defined. In this zone the majority of people experience well-being. In the Gagge's DISC index the 'comfort zone' is DISC +/- 0.5, in which 80% of the population is satisfied.

	Gagge's DISC
Painful	+5
Very hot	+4
Hot	+3
Warm	+2
Slightly warm	+1
Neutral	+/- 0.5
Slightly cool	-1
cool	-2
cold	-3
Very cold	-4

Table 2 - Gagge's DISC index

HEALTH

With the modernization, the demand for comfort increases. Some families buy air-conditioning systems and install them in existing buildings. If these buildings are not designed to be used with air-conditioning it could imply some problems of condensation and mould. These could affect the building but also the human health. Buildings have to be correctly designed for a warm humid climate. Some consequences of this climate have to be taken into account. The relative humidy and the temperature outside is high during the whole year which can result in consendation and mould on indoor surfaces. Outside walls are wet and difficult to dry because of the rainfall. Black mould and algae can grow on them.

3 Active and passive houses

Improving the climatic design of public buildings could affect the design of informal private buildings surrounding it, by giving some good ideas and examples.

A building can be climatized by an air-conditioning system, and is then called an active house, and/or by the building itself, and is then called a passive house. The expectation of indoor comfort depends on several elements. In case of an active house, the upper comfort level is between 25 and 27°C and during house cleaning the temperature should not exceed 25°C. In a passive house a discomfort of DISC = 2,0 is acceptable if the air velocity is 0,5 m/s (cross ventilation) (Adamson & Olle, 1993). In a passive house, the comfort level can rarely be kept whereas in an active house the users choose the thermostat to be in their comfort zone. People living in warm-humid countries, especially in developping countries, usually accept higher temperature and humudity levels because of lower expectations and natural acclimatization.

ACTIVE HOUSES

In warm-humid climate the relative humidity is high and at the same time the difference of temperature between the indoor and the outdoor is small. In that case a heating coil can be needed to cool the air beyond the desired temperature and then heat it. There are different ways to design an air-conditioning. The room unit

is the simplest system used for one room. The split unit is placed outdoors and serves several rooms. The central unit is connected to a ventilation system. This can be combined with the split system for an individual regulation of temperature.

PASSIVE HOUSES

Natural renewable energies have started to be used instead of conventional fuels in buildings after the energy crisis of 1970, but mainly for heating (Givoni, 1994). Around 1978 some research about passive cooling systems started. At the end of the 1980s, one factor of the emerging concern about passive cooling techniques are the rising cost of electricity. More recently, there has been a global environmental interest. Using passive systems can help to reduce the power consumption.

Historically, occupants used only passive techniques to cool houses. Now-a-days there are some technical solutions to ignore this passive use. However, there are still some good reasons to keep these passive techniques such as the environmental concern and the economic aspect. This last is a very important aspect for low-income people.

Furthermore, in developing contries the power cuts happen often and in case of problem the air-conditioning system can be very complicated to repair. The indoor climate of the house can be unbereable if the house is not designed to be used without air-conditionner. According to some researches, occupants in a naturally ventilated house are more tolerant about temperature swings. On the contrary, occupants in an air conditoned house are more rigid, they want a cool and uniform temperature and they are more sensitive to a difference of temperature. (Brager & Dear, 1998)

To design a passive house, some elements need to be considered: ventilation rate (possibilities for cross ventilation), window size and location in the wall, solar shading, colour of outer walls, thermal insulation and colour of the roof, the users. The behaviour of the users is very important for the effectiveness of the building in use. One solution could be to take into account the occupant’s demands.

4 Urban Shelter Design

VENTILATION

In a warm-humid climate shading and ventilation are really important. The flow of outdoor air may provide a direct physiological cooling effect even if the air is warm. The buildings have to be placed to increase the cross ventilation. Orientation of buildings for the ventilation does not mean that the buildings have to be perpendicular to the wind direction. Oblique winds between 30 and 120 degrees to the wall can also provide cross-ventilation. This can be intensified by some vegation wich provide shade and deflection. The attic spaces can also be used for ventilation, it helps to decrease the solar heating through the roof.
The ventilation and the protections against the rain are needed to prevent from the development of mould.

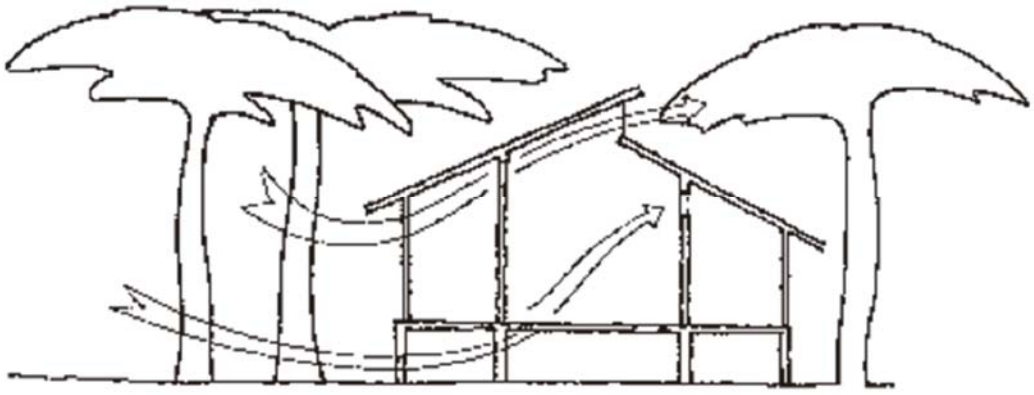

Figure 1 - Design principles for warm-humid climates – (Roselund, 2000)

WINDOWS

To increase the cross-ventilation large openings can be designed. However, in that case solar radiation can penatre directly into the interior of the building if they are not correctly shaded.

If the windows are unshaded, the glass area has to be limited to 15% of the facade area. An increase of the glass area to 30% will increase the room cooling power needed by 30%-50% and facades to the west are most affected. (Adamson

& Olle, 1993). It is possible to reduce the solar heat gain with solar shading glasses (reflecting and/or absorbing), blinds and shutters on the outside and shading by horizontal or vertical screens.

Windows in a passive house are used to regulate the ventilation and to guide the air flow. In an active house airtightness is essential.

FORM AND ORIENTATION

The shape of a building affects the ventilation. A spread-out building is better for the cross-ventilation than a compact one because it provides more wall area and in more directions for catching the winds. The building openings have to be well situated to increase this.

When we consider the orientation of a building, the main issue is the orientation of the windows. If there is a conflict between the wind and the solar consideration, the cross ventilation should be the primary factor to consider in warm-humid climate (Givoni, 1994). It is possible to take care of the effects of indirect solar gain by using reflective color and by shading with plants. Plants can also be used to provide shade for the walls.

ROOF

The main purpose of a roof is to protect against rain. It is also used to decrease the heat gain in the building in two ways: removing the solar heat gain by ventilation of the roof and by thermal insulation of the roof. The height of the roof is not a real issue. According to Giovoni, decreasing the hight of the roof from 3.6m to 2.4m corresponds to about 2% increase of the cooling requirements of the body. A lower ceiling can also reduce constructions costs. The roof colors must be bright or white to decrease the solar heat gain. (Givoni, 1994)

MATERIALS

In warm-humid climate building materials are deteriorated rapidly.Concrete is a good material for permanent structures in the tropics. However, the lifetime of a concrete structure decreases with increasing temperature and humidy. The rate of deterioration of concrete and plaster doubles with a temperature increase of 10°C (Adamson & Olle, 1993). A solution can be to use a low water-cement ratio, maximum 0,6. Wood can be used for several functions if it is installed properly. A

wood structure must be designed so wooden parts can be easily replaced and have to be treated against rot, mould and termites. All organic materials placed against masonry or concrete need a vapour barrier between the materials. Such as the roof, walls must be painted in a bright color.

SURROUNDINGS

Surrounding plants can be used to protect the walls and windows from the solar radiation. Trees with high canopies can reduce the solar heat gain with a small blockage of the wind. Vines climbing over the walls and next to windows can also reduce the heat gain. According to some research done in Miami, Florida, the effect of vines on wall temperature was measured (Givoni, 1994). Climbing vines can reduced the surface temperature by 10°C to 12°C.

PASSIVE AND ACTIVE HOUSE

Using passive systems does not exclude the use of an active system when it is needed. A particular attention has to be given to the building design. To design a dwelling for partial cooling, for example the bedroom, the cooled rooms have to be placed to not disturb the cross-ventilation. The cooled room must be airtight. To install air-conditionning in separate rooms can cause some problems. If a room has a lower temperature than the other one, some condensation can occur. The walls and floor of the this room should be insulated to raise the temperature. The passive room has also need to be cross-ventilated.

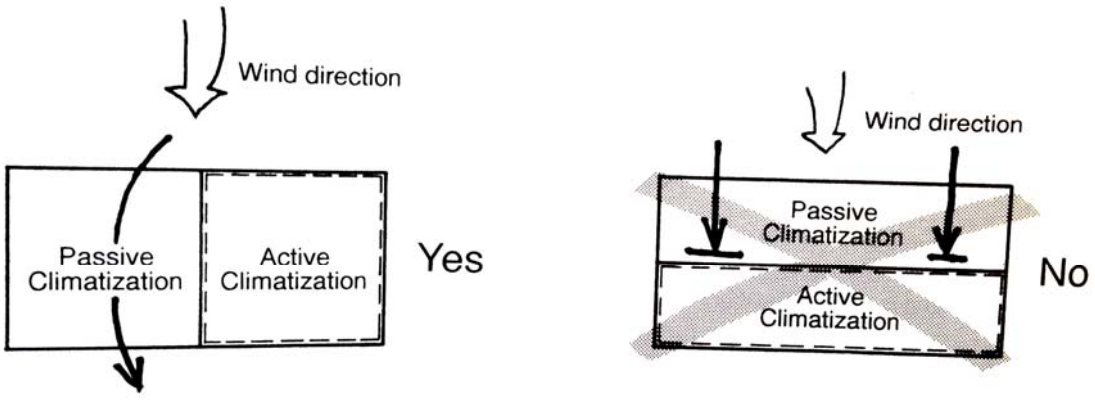

Figure 2 - Passive / Active house - (Adamson & Olle, 1993)

5 The Role of Architects

The architects have to understand the different caracteritics of the site climate. They also have to know the needs, hopes and limits of the futur users. Having a very deep analysis of the site climate is important to understand which elements should be considerated as a priority. As we saw in the previous parts, in a warm-humid climate the ventilation is the most important caracteristic to consider. The architects have to design a building keeping in mind the cross-ventilation but also the orientation of the buildings and all the other points given earlier. They have to find some solutions to think about all these elements in the building design.

With the design of the building the architects will also influence the quality of life of the futur users, such as health, thermal comfort, energy cost. With the building desing, the consumption of energy can be minimized and so the energy cost. If the users don't spend money to pay energy, they can use it for something else. Designers have to understand that the users will want or need some active systems for the thermal comfort, if they are affordable to them. In that case they should design an active/passive house to reduce the energy cost, to consider the human health and the risks of power cuts for example. If the benificiaries are not able to optimize the use of a passive house, the role of the architects can be to teach them.

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