Traditional Architecture and Bioclimatic Design Case of study: Tecozautla, Hgo. Mexico

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ABSTRACT: This work aims to analyze the bioclimatic behavior of traditional architecture for future constructions in Mexico. The focus of this study is in *Tecozautla,* México, located in a hot dry climate where an important number of traditional and historical houses still exist. The hypothesis was: the materials and constructive systems used in traditional architecture provide comfort conditions due to the bioclimatic concepts such as thermal mass, interior courtyards with vegetation or fountains, compact shapes, etc.

Keywords: Traditional architecture, bioclimatic architecture, passive architecture.

1. INTRODUCTION

Fossils combustion like coal, oil and natural gas provide majority of earth's energy demand. In return, the atmospheric emissions of these combustions have intensified impacts on our living environment.

For this reason, redefining our customary living concept becomes indispensable in order to relate our positions towards sustainable development. Hence, it is essential to:

a) Reduce environmental impact
b) Change the construction concepts of design and dwelling.

As well as taking into consideration the use of renewable energy resources (solar energy) and favoring the use of natural resources during the construction process.

The study has chosen Tecozautla, Hgo. due to its climatic conditions and because an important number of traditional and historic constructions are preserved.

The local practices addressed were the materials and constructive systems used in traditional architecture have been providing comfort conditions due to the bioclimatic concepts. This paper focus on thermal mass, interior courtyards with vegetation or fountains, compact shapes, etc.

2. CASE STUDY

2.1 Toponymy - Name place

Tecozautla is a *"Nahuatl*" word. It means "Place where the yellow ochre abounds" [1]

2.2 Physical Location

Located in the State of Hidalgo, Tecozautla is at latitude 20º32´, longitude 90º38 west and 1,700m above sea level [2].

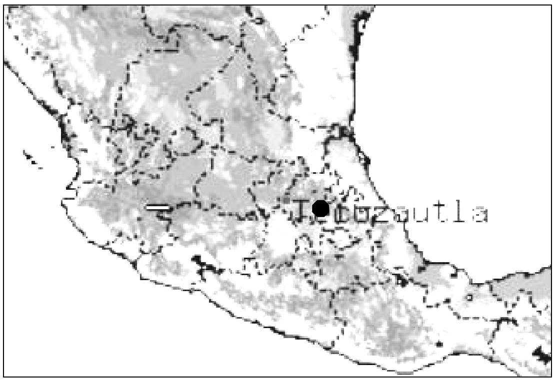

Figure 1: Tecozautla. (Mexican Republic Map)

2.3 Climatic Conditions

- Maximum Temperature: 32.7ºC
- Annual mean temperature: 19.2ºC
- Minimum Temperature: 4.7ºC
- Annual mean Relative Humidity: 55%
- Total Rainfall: 495 mm
- Total Solar Radiation: 692 W/m2
- Dominant Wind Direction: Northest
- Mean Speed wind: 2.5 m/s
- Climate: BS1hw(w)(e)gw''

3. METHODOLOGY

3.1 TYPOLOGICAL ANALYSIS

The main focus of this paper is to build up the local architectural typology by means of a typological analysis tool. In other terms to verify whether the traditional architecture responds to local climatic conditions.

A series of pictures all over town were taken to:

a) Define the local architecture and,
b) Find all the buildings that shaped this research

Twenty-one houses were selected taken in consideration its formal and functional features as well as its frequently used materials.

Figure 2: Typical street view of Tecozautla.

An information spreadsheet as an inventory certificate was designed to keep track of the Formal-Spatial and architectural elements. Constructive systems, materials and bioclimatic concepts were identified to define the local architectural typology.

3.2 CLIMATIC ANALYSIS

A complete climate analysis was carried out in order to compare with the "bioclimatic strategies" design concepts of Tecozautla traditional architecture.

Analysis involves all climatic parameters in yearly, monthly and hourly basis, which also includes solar geometry analysis. The main bioclimatic strategies of the region were supported by Bioclimatic [3] and Psychrometric [4] Charts, Comfort Triangles [5], Mahoney's Parameters [6] and the Summary of Strategies Chart [7].

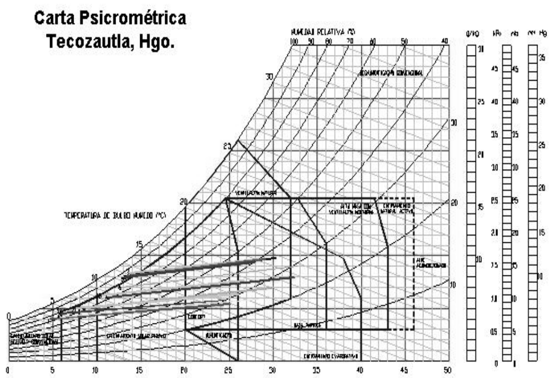

Figure 3: Psychrometric Chart for Tecozautla,Hgo

4. CLIMATE AND TYPOLOGY

Taking in account the previous analysis a data cross-reference was established to verify the assumptions and to define whether local architecture responds in a proper way to the climate.

The main regular typology concepts related with climate are:

- Squared configuration plan.
- Central Patio
- Rooms Height : 4.00 m
- Flat roof with wooden beams as support element, shingles "tejamanil" (0.03m thick, 0.20m x 0.10m tiled) and a layer of earth.
- Cantera stone tiles floor.
- White washed stone walls, (indoor and outdoor): 0.64 m thick
- The relationship between solid wall and opening is about 95%-5%

At this stage, the local typology responds to the local climate conditions ensuring comfortable lodging.

However, due to the rarity of these materials and constructive systems, it is presently, difficult to use.

This study proposes materials and constructive systems, both traditional and modern. An on-site numerical simulation of thermal behavior was necessary to considering all the bioclimatic design strategies.

5. HYGRO-THERMAL BEHAVIOR

In order to validate the numerical simulations, temperature and indoor conditions humidity were measured. This consists of identifying the positions of measuring devices taking into account some special circumstances:

a) Indoors: instruments were set at 1.5m above the floor level to avoid sensors recording the albedo effect from the floor and walls [8].
b) Outdoors: the climatic field station was placed on a cleared area according to the World Meteorological Organization [9]. This is to avoid natural obstructions above 4º from the horizon or artificial obstacles above 5º.

Measuring instruments include thermometer, hygrometer, anemometer, barometer, actinograph, thermograph, hygrograph, globe thermometer, maximums and minimum thermometer, anemometer, digital thermo-hygrometer and a pyranometer.

The parameters measure hourly for May and August temperature (DBT), humidity (RH), solar radiation, direction and wind speed, globe temperature (MRT) and atmospheric pressure.

Work cards were designed to register measures of each instrument. All data were transferred to electronic spreadsheets for further classification and analysis. The results are used to identify the hygro-thermal behavior of the building.

6. NUMERICAL SIMULATION

Several numerical simulations of thermal behavior (Thermal Balance) variables were to validate the numerical simulation, comparing with the on-site measurements. Henceforth, it becomes the tool to evaluate different traditional and modern materials and constructive systems.

Thermal loads calculations were based on heat transfer, conduction, convection, radiation and evaporation.

All calculations were performed on the same case study.

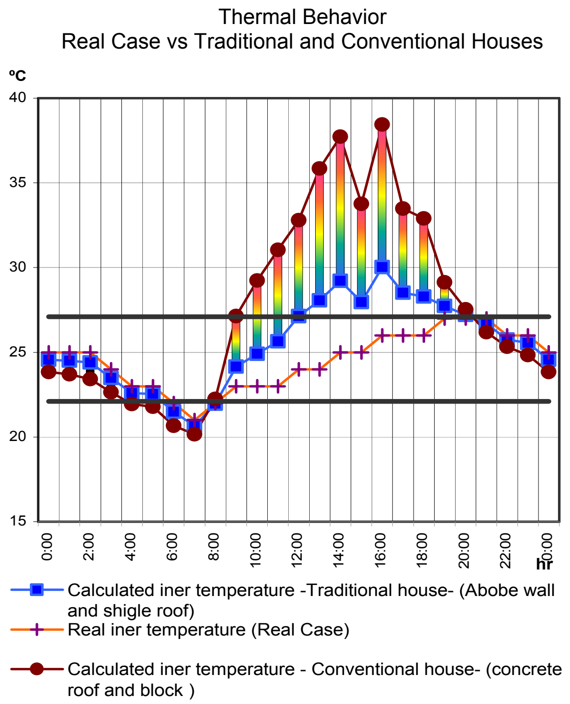

Figure 4: Thermal Behavior in the month of May for real case vs traditional and conventional houses (DBT).

The thermal balance simulation includes the majority of the climatic parameters and the sun-air temperature [10]. This model's result turned out to be very similar to the behavior of the on-site measurements.

Once the thermal balance was tuned up, different materials were simulated, based on their features and thickness, it also verifies their behaviors which fulfill the required thermal resistance of comfortable spaces.

7. PROPOSALS

The result of this case study depends largely on the analysis in climate and typology, the bioclimatic design strategies as well as the thermal balance.

The "bioclimatic design concepts and strategies" recommendations for new houses in Tecozautla, Hgo are:

7.1 Facade

The best facade orientations are North-South and Southeast-Northwest. According to the typology, the facade faces the street should be at the same level.

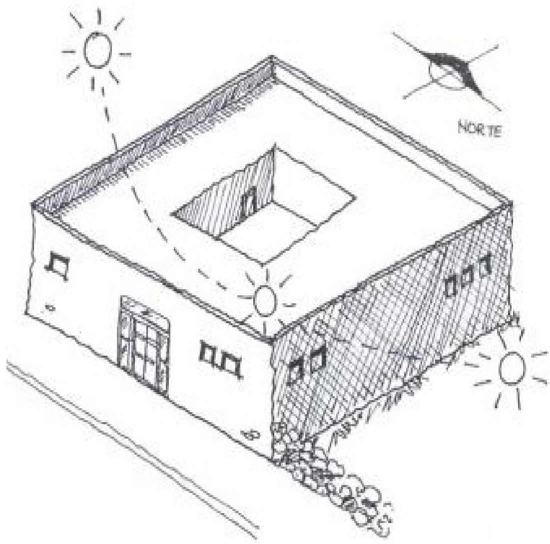

Figure 5: Best dwelling orientation

7.2 Habitable rooms

Rooms should face South, Southeast and East, due to early morning heat gain required. West facing walls should have no opening to prevent afternoon direct heat gain but this gain should be stored and delayed to be free at night or in early morning.

7.3 Square configuration plan

This configuration is compact and recommended for local climate as it reduces the exterior surface exposure hence reduces heat gain and losses.

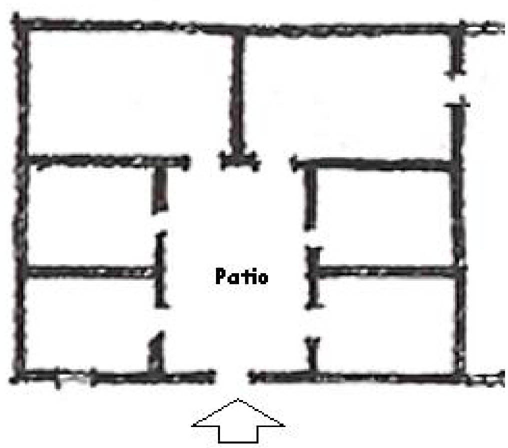

Figure 6: Squared configuration plant

7.4 Exterior flooring

Permeable material is recommended to allow rain filtering to the patio subsoil.

7.5 Interior floor

Cantera stone tiles floors or similar stone materials are suggested due to their respond capacity to the thermal mass strategy, storing the diurnal heat and freeing it at night

7.6 Cantera stone framed main entrance

The typology demands that entrance is used as a hall and serves as an access to the central patio.

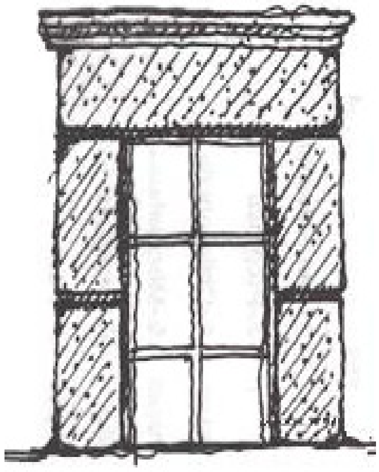

Figure 7: Cantera stone framed main entrance

7.7 Central Patio

The central patio is important which functions as a bioclimatic control element, regulating temperature and humidity conditions. It is recommended to use fountains mainly during February, March, April and May due to low indoor humidity levels (RH) reported (minimum 33%, maximum 50% in May). Vegetation is suitable as an evaporative cooling strategy providing favorable microclimate.

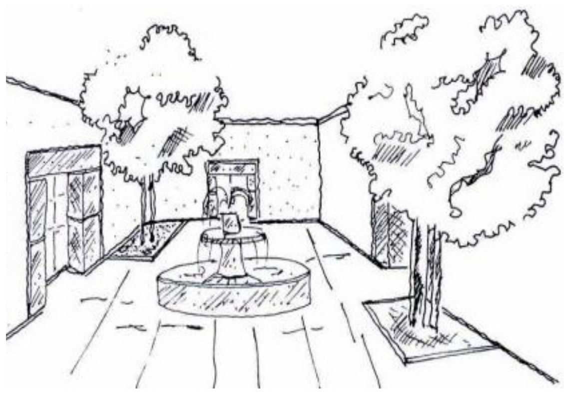

Figure 8: Central Patio

7.8 Exterior walls.

According to the Psychrometric Chart, massive walls for all interior and exterior are recommended. This strategy should take into consideration the Southwest and West Facades critical in their thermal resistance, which should be greater than 0.72m^{2}K/W.

The thermal simulation, materials and most recommended thicknesses are:

- Stone: 0.64m thick
- Adobe: 0.30m thick
- Brick: 0.28m thick
- Concrete Brick: 0.40m thick

Interior Temperature ºC	Numerical Simulation. Wall Materials				Real Temperature (case of study)	
	Stone	Adobe	Brick	Concrete Block	Interior	Exterior
Maximum	27.3	30.0	31.1	38.4	27.0	34.5
Minimum	21.9	20.1	24.8	20.1	21.0	18.7
Swinging	5.4	9.8	6.3	18.3	6	15.8

Table 1: Interior temperatures reached using different construction materials on exterior walls vs temperature of real case.

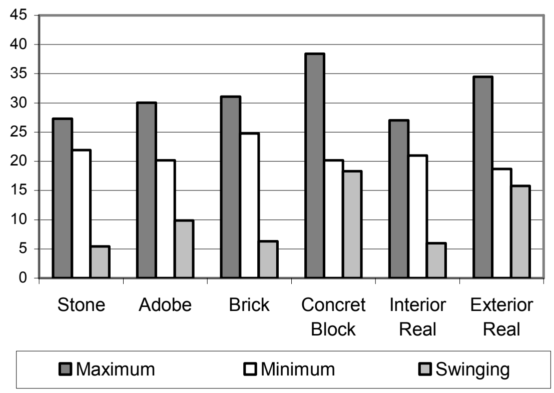

Figure9: Interior calculated temperature using different construction materials on exterior walls and real case temperature.

7.9 Interior walls.

According to the thermal simulation the interior walls can be medium or high mass. Their color must be clear to increase the lighting levels - between 60% and 85% reflectance - due to small openings recommendation.

7.10 Flat Roof

This kind of roof corresponds to the dry local climate. Massive slabs are recommended to absorb solar radiation, responding to the thermal mass strategy. Their thermal resistance should be greater than 1.32m^{2}K/W.

According to the thermal simulation, materials and the most suitable thicknesses are:

- 0.20m wooden beams, 0.06m wooden layer and 0.10m layer of earth.
- 0.25m wooden beams, 0.06m wooden layer and 0.10m layer of earth layer.
- 0.12m concrete roof, 0.20m volcanic stone (tezontle) filler and 0.04m of brickwork.

- 0.18m small beams and small vaults, 0.15m volcanic stone's (tezontle) backfill and 0.04m of brickwork.

7.11 Cantera stone framed opening

To take advantage of direct solar radiation, openings should be orienting East, South and Southeast to profit the early morning sunbeams especially in winter.

Tucked in the walls windows could be used as solar control devices. The relationship between solid wall and opening should be about 90%-10% or 80%-20%. Small openings can avoid heat gain as well as heat losses at night.

7.12 Analysis demonstrates that crossed ventilation is an important strategy.

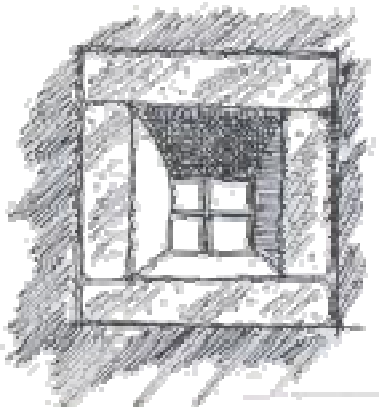

Figure 10: Tucked in the wall window

7.13 Outdoors Vegetation

It is recommended to set up vegetation at Northeast of houses so as to protect from direct cold winds.

7.14 Interior Courtyard Vegetation

Using deciduous vegetation as shading device can regulate direct solar radiation in summer and in winter.

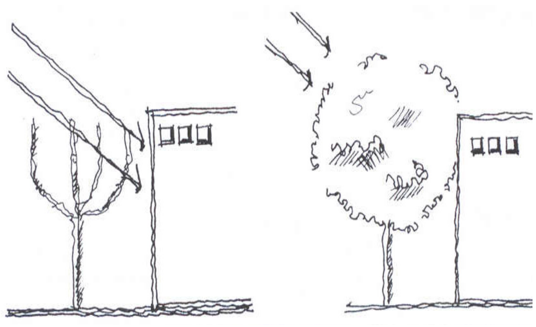

Figure 11: Vegetation as a Solar Control Device

7.15 Room Height

The rooms' height should be between 3.50m to 4.00m. Double height spaces are recommended to privilege comfort conditions.

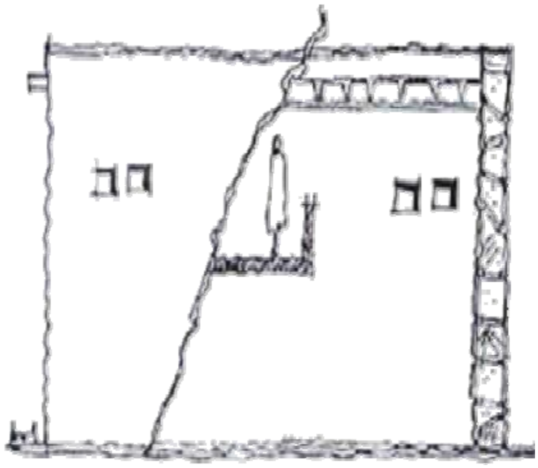

Figure 12: Rooms height

7.16 Porch.

The porch or portico is an excellent element in this climate. It should face south, southeast or east to provide shade in summer time and allow low angle winter sunbeams.

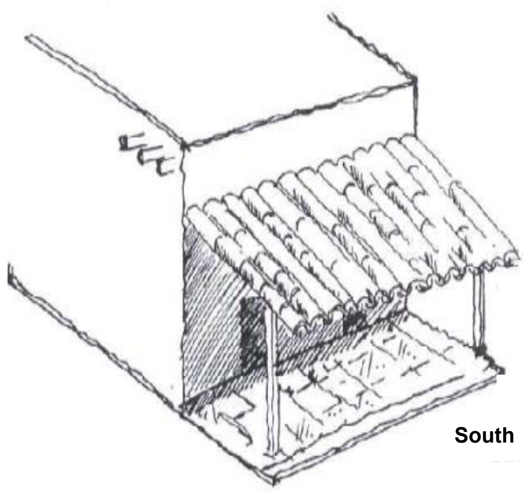

Figure 13: Porch as a solar control device.

7.17 Solar hot water system.

Solar hot water system can be very efficient, considering the direct solar radiation is about 500 W/m^2 and there are a high percentage of clear days during the year.

7.18 Garden

Garden is an important space to create a comfortable microclimate. It should orient towards summer wind directions to allow increasing humidity levels.

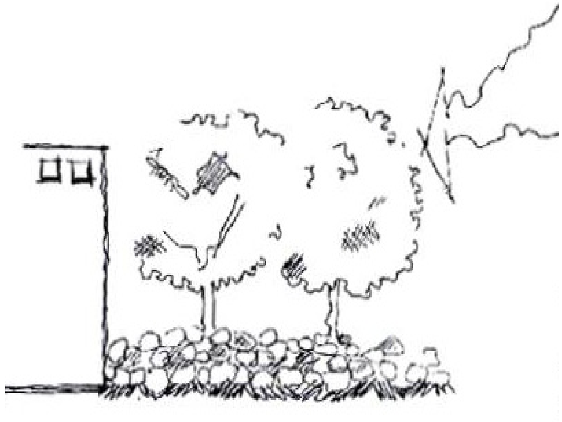

Figure 14: Garden

8. CONCLUSIONS

The case study analysis demonstrates the main bioclimatic strategies for this hot and dry climate are:

- Thermal mass
- Evaporative cooling
- Ventilation
- Solar control

The study confirms that local typology responds in an appropriate way to the local climatic conditions.

The "bioclimatic design concepts" created for this research will certainly contribute to the construction of comfortable housing.

The proposed materials and constructive systems behave like the traditional ones, which can avoid the use of air conditioning systems. Moreover, the architecture can be integrated to the local typology.

The main target of this research was to analyze vernacular architecture and to recover the bioclimatic design concepts, which should be used in modern architecture, taking into account the environment and local traditions.

We hope this research helps to reduce emissions from burning fossils fuel and participate in making our world cleaner, hence improve the environmental preservations for us and future generations.

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