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Relieving a Tropical Vernacular Habitat Typology as a Source for Contemporary Social Housing Designs

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Abstract: This work presents an analysis for the rural vernacular dwelling (Culata Yovai), sited in the South America Guarani region, basin of Paraguay and Paraná rivers. Outdoor climate has conducted man to build along the time a habitat climatic responsive. Nowadays, studies in progress try to show how this vernacular typology can support new low-income house designs. The intent is to guarantee for new projects the socio-cultural image that people, coming from countryside to live in city outskirts, are accostumed. Also, to provide material improvements and functional adequation for a quality and healthiness. Natural ventilation is the main bioclimatic strategy during summer for thermal comfort, which influences the house characteristics. This is proven by calculation, and simulation with the CFX-ANSYS software. Thus, the analysis performed shows the real possibity to reconcile bioclimatism with the symbolic-cultural value represented by this vernacular architecture form. It is hopped that this study can be considered as a methodological contributition for new sustainable projects (materials, technics and services) of low-incoming houses in this Latin American region.

Key words: Bioclimatic design, sustainable architecture, vernacular habitat, social housing, natural ventilation.

1. Introduction

Nowadays, the study of vernacular architecture is very important, not only as a repertory of past traditions but to contribute for new methods, solutions and achievements for a contemporary built environment. A simple copy of certain formal vernacular qualities such as ceilings, volumes, details, etc., is not recommended if only inspired in a romantic view. It is important to consider the lessons and principles from previous performed vernacular studies, and apply this knowledge to building design, considering climate, energy uses, and indoor comfort [1]. A selected vernacular architectonic typology can not be suitable to be applied else-where without an appropriated analysis.

In the current context of searching sustainable solutions for social interest housing, a proposal is to extract hidden concepts from the vernacular architecture. Largely forgotten by the architects, the *Culata Yovai* typology begins to be considered by some architects as adequate and responsive for low-income habitat programs, mainly in Paraguay and Argentina. This vernacular is sought to aggregate a bioclimatic value and a symbolic-cultural image for the final user on city borderline, and usually coming from a peasant region (Fig. 1) [2, 3].

The given name for this dwelling comes from the spoken Guarani language. It means a habitat with opposite, and face to face rooms, "house with confronted rooms". It is a symmetrical construction, composed mainly by three spaces placed in line and covered with a roof. Each opposite room has only a windward facing window and a door open to the central space. This space is well ventilated during hot seasons, sun shaded, and being adequate to the daily resident activities. The kitchen and latrine are placed apart the house. During winter, air infiltration is

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Fig. 1 Photo of a vernacular habitat "Culata Yovai". Source: Refs. [2, 3].

prevented by closing windows, and using wind shields on the open parts of the middle space façades.

This vernacular dwelling maintains the ancient general features, under a reduced scale, a mixture of the elements from the native Guarani habitat (tapy'I) and the peninsular Iberic house, brought by the Spaniards [4].

Among other local existing forms of spontaneous housing, this habitat has the greatest iconic strength, earning even a proper name. The Culata Yovai construction has structured a wooden skeleton usually composed of *mbocaja* or *karanda'y* trunks to support the roof of kapi'I, straw or palm leaves. The ground is of beaten earth, and walls made with materials available in place. The walls and ceiling materials vary according to the zones of the region: adobe, karanda'y trunks and straw in dry areas; stick or wood with straw in forest areas; to bricks and ceramic tiles near urban nuclei [5]. Generally, the house spaces are modulated in *bids*, a structural-spatial module from the colonial period in Paraguay, equivalent to the length of wood trunks, 1 bid is approximately 4 m × 4 m in plant [6].

The construction is carried out by the residents themselves with a great economy of means, thus obtaining savings of work and materials, but looking for a certain degree of comfort and thus to minimize indoor the exterior climate influence. The basic house scheme is of pure and simple forms, and remains up today in the rural humid subtropical climate regions. Normally, this typology is built with several materials and variants on plant organization, and results responsive to socio-cultural and environmental constraints.

The humid subtropical climate of this region is identified as Cfa or Cwa from Köppen classification [7]. The seasons are characterized by a hot and humid summer and a cold winter with heavy rains in coastal areas, and dry in interior lands. This climate is known in South America as *pampas climate* and occurs in Northeastern Argentina, Uruguay, Southern Brazil and Eastern Paraguay. It is a complex climate for architecture design and very difficult to be achieved a compromising architectonic solution [8].

In the absence of a Paraguyan thermal comfort and a bioclimatic zoning standard, it is here considered the Brazilian standards established for the bioclimatic zone 3. This zone comprises geographical sites (in gray), with similar meteorological characteristics of these abroad regions (in red), a humid subtropical climate (Fig. 2).

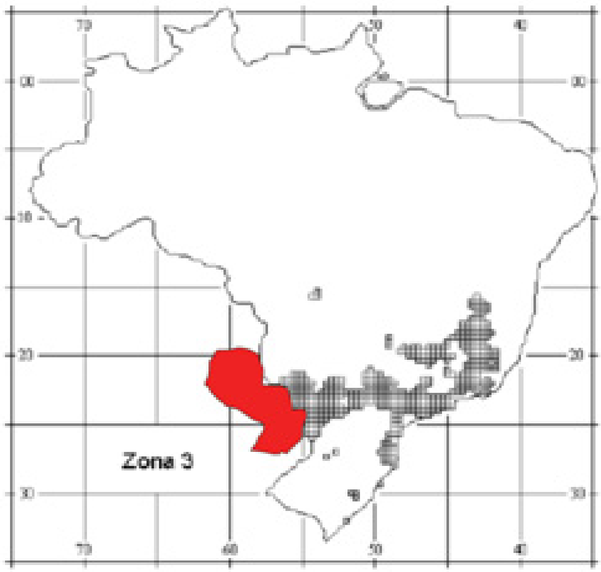

Fig. 2 Brazilian bioclimatic zone 3 (gray color) and the Paraguayan territory (color red). Source: Ref. [7]; adapted from Ref. [9].

2. Method and Materials

To reconcile into new projects bioclimatic values without affecting the symbolic-cultural value of this vernacular form, the first target is to search how an isolated rural house (made with original materials) operates by natural ventilation to maintain acceptable indoor conditions during summer and winter periods.

The second intent is to examine one project for low-income houses from a Latin American architect, presenting the Culata Yovai typology. The idea is to identify possible consonances or problems among architecture and the new chosen implantation site.

2.1 Site Characterization and the Chosen Vernacular House

The field survey performed, allows the first author to select a typological example of a single-family rural dwelling Culata Yovai, in the Paraguarí Department: 25º44'58.31″ (latitude), 56º48'10.11" (longitude), and altitude 134 m. Then, from this implantation site were raised: the prevailing winds, terrain roughness, vegetation, and climatic data (from the Paraguyan National Direction of Civil Aeronautics and Hydrology Coronel Oviedo Station). The topographic relief is smooth and has a shrub vegetation cover. January is the warmest month, a maximum average temperature of 33.3 °C, and prevailing winds from NNE (22.5º), with average velocity of 5.03 m/s. July is the coldest month with 10.5 °C for minimum average temperature, and 6.55 m/s winds from the South (270º) (Fig. 3).

This selected vernacular habitat has in plan three (4.00 m × 4.00 m) spaces, 2.30 m of indoor height, and two 60% sloped roofs. The two rooms are at the house extremities, and used mainly as collective dormitories. Each room has a (0.90 m × 1.00 m) window on the NE façade; and a (0.80 m × 2.00 m) connecting door to the middle open space. Portals and frames are of wood, and windows without glazes. The middle space is used for the daily people activities.

Others spaces as kitchen and latrine are located apart the house. The house is studied on its form, constructive characteristics, climatic compatibility,

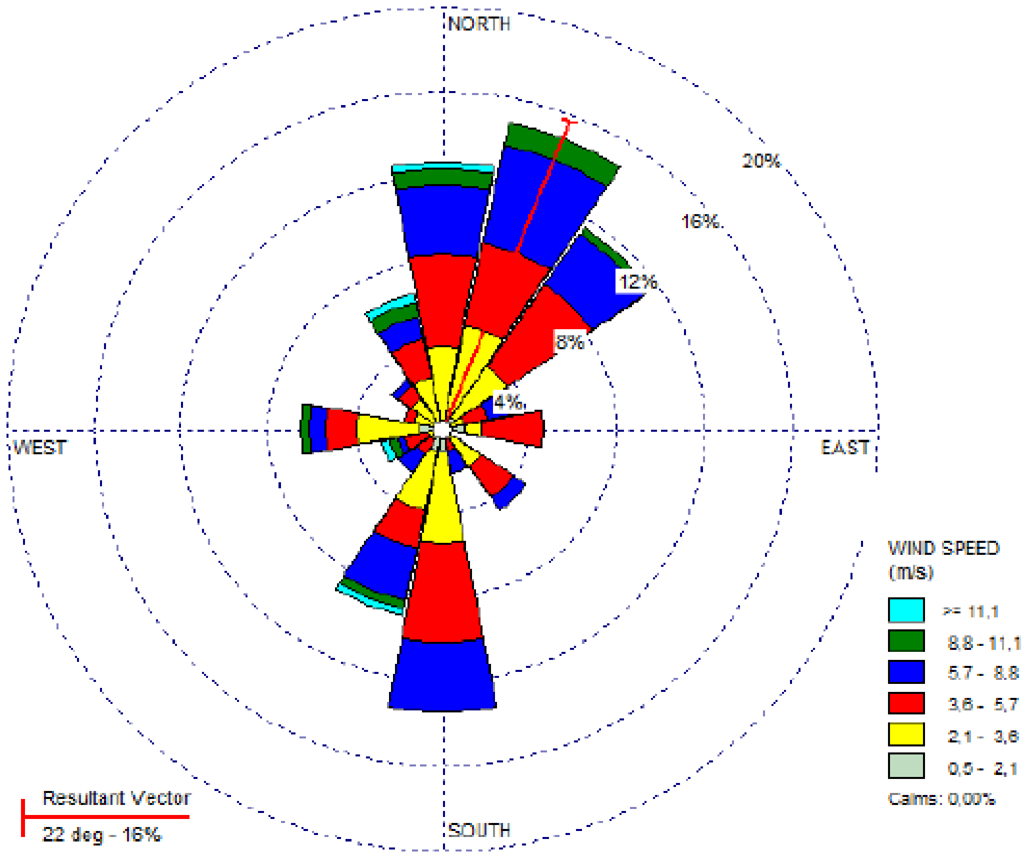

Fig. 3 Wind rose for January 2014 (Coronel Oviedo Station). Source: WRPLOT View Freeware 7.0.0.

and cultural constraints. Also, informal contacts with residents were made to obtain an inventory about their preferences, related with indoor conditions.

2.2 Virtual Model for a Culata Yovai Habitat

Due to the existent endemic Chagas disease in the region, at the present analysis, it was changed some used building materials as straw ceiling and fractured earth walls by roofing tiles and masonry walls, respectively for the model.

Thus, the virtual model for this vernacular typology is object of calculations and computer simulations, to verify its adequacy with the standards [9, 10]. Some virtual model characteristics are depicted in Figs. 4 and 5.

Indoor air flowrates due to the winds are obtained by calculation, and with the CFX-ANSYS, CFD software. To obtain the indoor heat to be exausted by natural ventilation, it was used the RADLITE software, Castro [11].

To estimate the wind velocity at the house roof top, a logarithmic velocity profile is used, see Eq. (1) [12]:

$$Vh = Vm.\, A(zo).\, \ln\,(h\,/\,zo) \qquad (1)$$

where,

h = house height (= 2.3 m);

Vm = wind average speed at meteorology station, 10 m high (= 5.03 m/s);

zo = ground roughness (= 0.25);

$A\,(zo)$: land type coefficient (= 0.21).

The indoor airflow rates Q (m^3/s) are obtained from the empirical expression (Eq. 2):

$$Q = Cd.\, S.\, Vh\,[(Cp1 - Cp2)]\,^{1/2} \qquad (2)$$

where,

Cd: infiltration factor (= 0.6);

$Cp1$, $Cp2$: average pressure coefficients on the building façades (+0.7) and (-0.25) respectively [13].

$1/S^2 = 1/A1^2 + 1/\,A2^2$)

$A1$, $A2$: aperture areas (m^2).

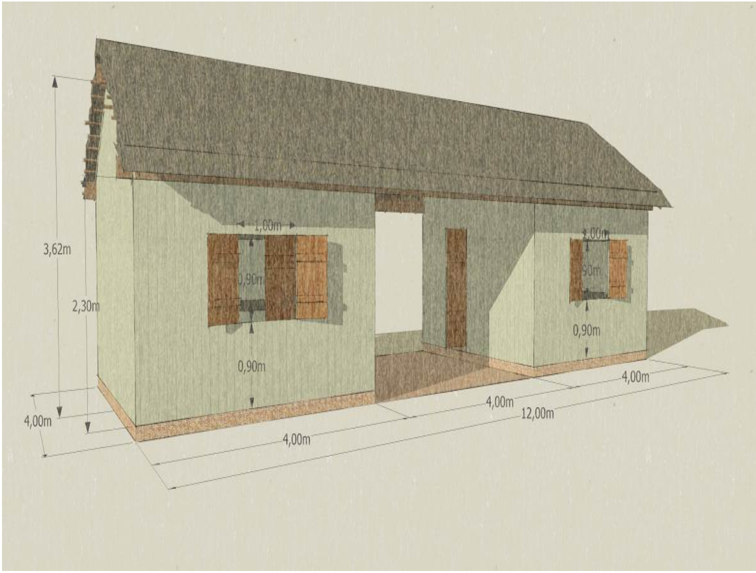

Fig. 4 Frontal house model view. Source: Authors.

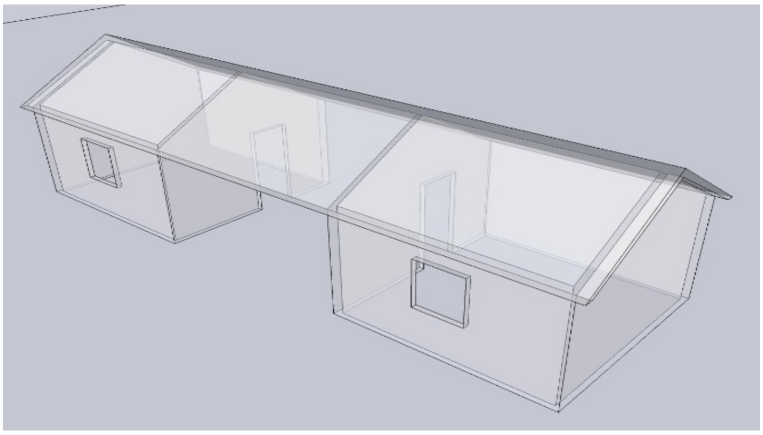

Fig. 5 Virtual model Culata Yovai. Source: Authors.

2.3 A Contemporary Low-Income Housing Design

The study performed has considered several references on vernacular architecture and low-income regional government programs wich led the project “Casas de Cambio”, developed for the Provincia of Santa Fe, Argentine [14]. There is not any mention about vernacular references in the searched e-site[1]. Despite the fact that this house has an architecture form and a climatic operating way, emphasizing cross natural ventilation, similarly to the previous vernacular house, the climatic conditions of Santa Fe are obtained from the Santa Fe, National Meteorological Service[2].

The house presented by this project has six spaces with modulation of 3.45 m × 3.45 m, right-foot of 2.80 m, and the two inclined roofs with 15% slope. The opposite spaces are predicted as dormitories (rooms 1, 4 and 6), kitchen (room 2) and bathroom (room 5). The rooms 1, 2, 4 and 6 have (1.2 m × 0.8 m) windows. The room 3 is the central space and is the social living and dining room. It has two faces open, but depending on the users can be shut by sliding

[1] Available in: http://www.arquitecturacritica.com.ar/2011/04/casas-de-cambio-escuela-de-los-grandes.html>. Accessed May 12, 2014.

[2] Available in: http://www.smn.gov.ar/?mod=clima&id=30&provincia=Santa%20Fe&ciudad=Santa%20Fe>. Accessed May 14, 2014.

doors. In the analysis during summer the doors are always open. The ceiling is made of concrete and walls are stuccoed brick plastered and painted white (Fig. 6) and virtual model (Fig. 7).

3. Results and Discussion

Figs. 8 and 9 present the airflow paths, from the CFD simulations carried out, for the Culata Yovai and also “Casa de Cambio” models, respectively. Both cases present an increasing air velocity through the house central space, due to the Venturi effect.

The next enlarged Fig. 10 shows the air velocity vectors paths due to the incidente wind, trough and around the “Casa de Cambio” model. It is possible to see the high velocity reached inside the central space 3 (previous indicated in Fig. 7) Also, vortexes are generated inside all the rooms, showing acceptable air velocity levels for indoor people .

Table 1 presents for summer the air flowrate values obtained through the Culata Yovai model, from calculations by Eq. (2) and CFD simulations. The results show air flowrate values through the rooms with a same order of magnitude, and higher than the required levels to remove the indoor heat. These values satisfy the minimum air infiltration for an IAQ (indoor air quality) established by Ref. [10]. Also, for

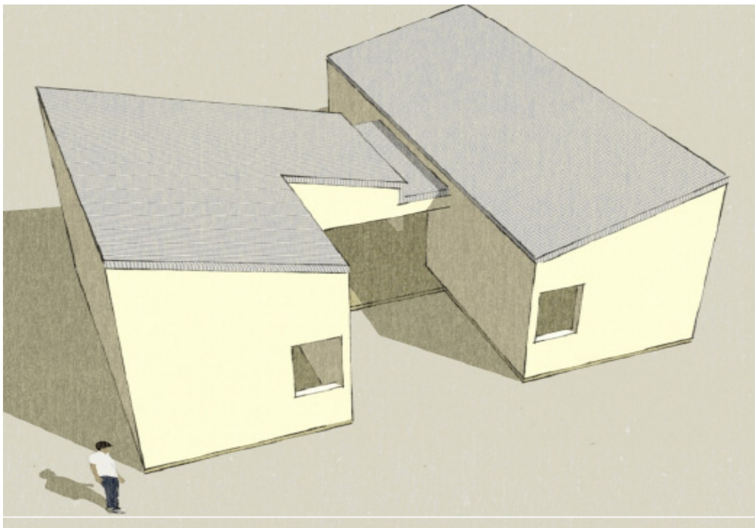

Fig. 6 Axonometric view of the house. Source: Authors.

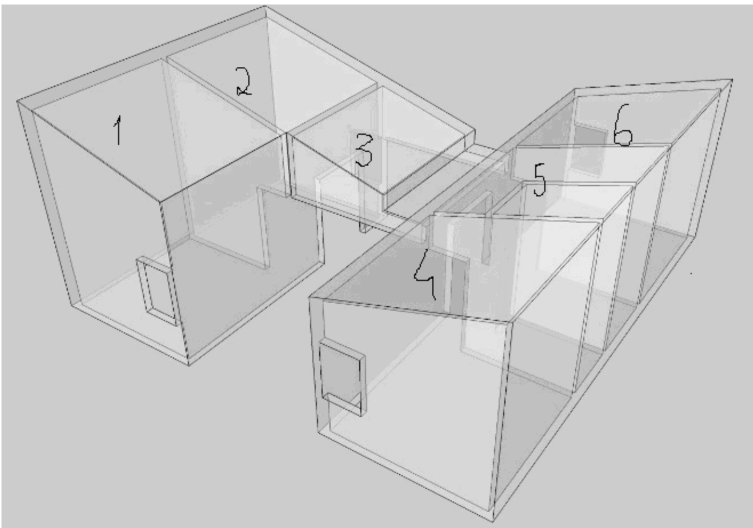

Fig. 7 Virtual model Casa de Cambio. Source: Authors.

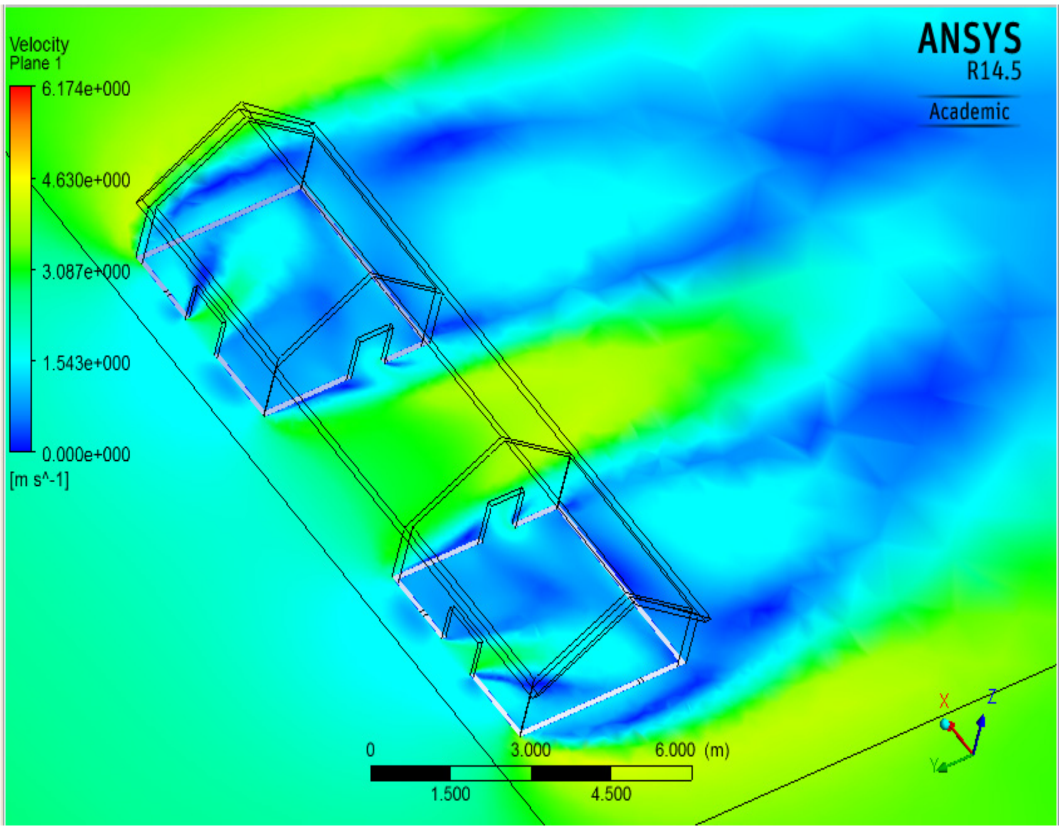

Fig. 8 Airflow simulation for the Culata Yovai model. Source: Authors.

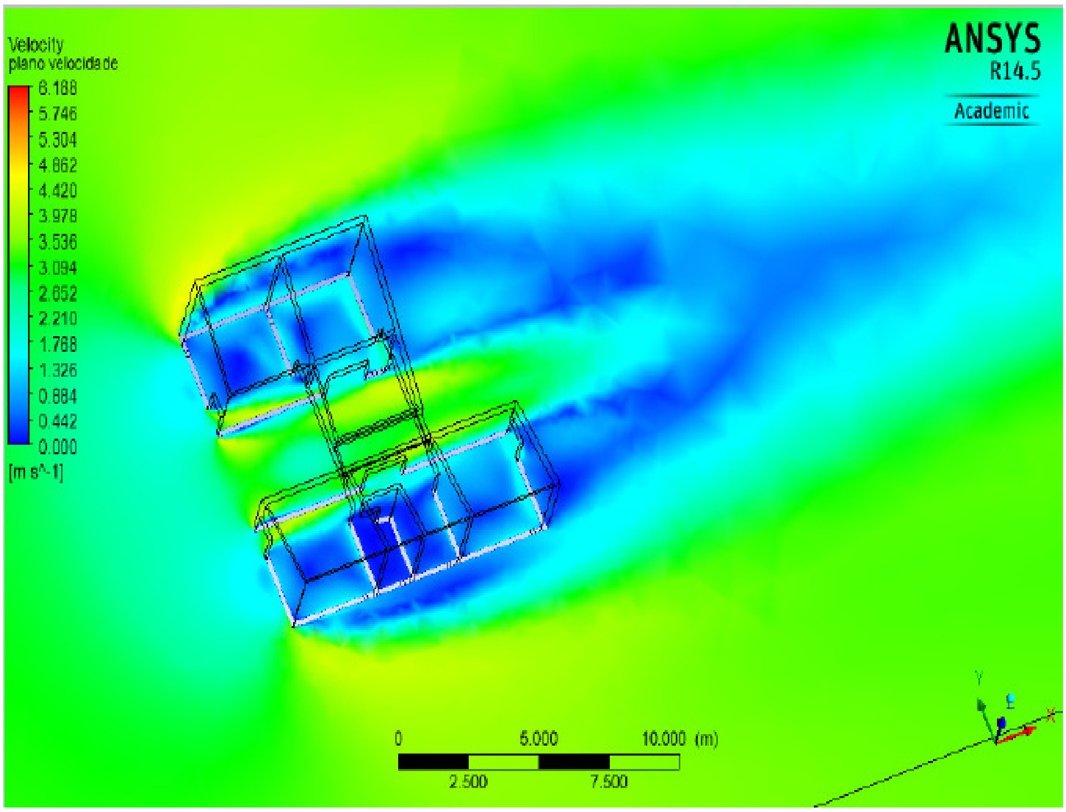

Fig. 9 Air flow simulation for the "Casa de cambio" model. Source: Authors.

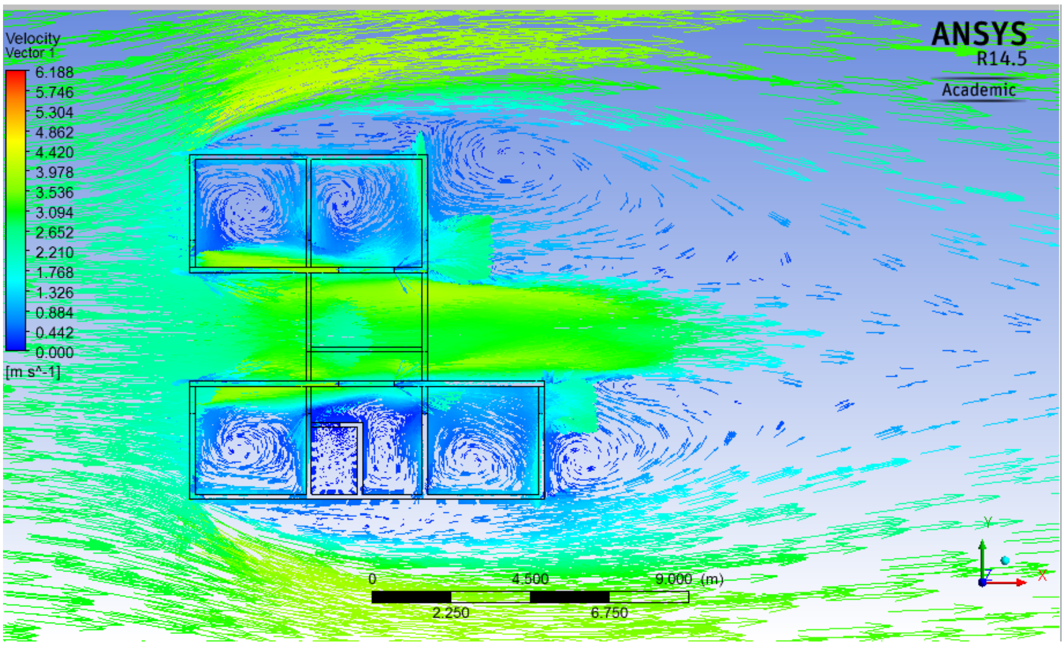

Fig. 10 Velocity vectors on a plan 1.20 m above the floor. Source: Authors. ANSYS CFX-Post.

Table 1 Ventilation and infiltration conditions for the vernacular house model.

House spaces	Air flowrate from Eq. (1) (C STB)	Air flowrate from simulation (CFX)	Required air flowrate to extract the indoor heat due people and solar load (thermal comfort)	Minimum required air infiltration for IAQ	Obtained air infiltration during winter
Central space	8.74 m^3/s	9.85 m^3/s	0.19 m^3/s	0.0278 m^3/s	….
Room 1	2.18 m^3/s	2.10 m^3/s	0.32 m^3/s	0.0198 m^3/s	0.069 m^3/s
Room 2	2.18 m^3/s	2.059 m^3/s	0.33 m^3/s	0.0198 m^3/s	0.069 m^3/s

Source: Authors.

Table 2 Ventilation conditions for the “Casa de cambio” model.

House spaces	Air flowrate from CFD simulations	Required air flowrate to extract the indoor heat
3 (Central space)	5.47 m^3/s	0.23 m^3/s
1	1.17 m^3/s	0.22 m^3/s
2	0.91 m^3/s	0.31 m^3/s
4	1.05 m^3/s	0.21 m^3/s
5	….	0.18 m^3/s
6	0.73 m^3/s	0.22 m^3/s

Source: Authors.

the open central space the air flowrate value is higher than the one from the other rooms. Also, this calculated value is 12% lower than the simulated one. During winter time, windows beside the connecting and sliding doors are closed. Thus, the air infiltration for the rooms 1 and 3 (opposites), under the South winds are examined. These infiltration values are higher than the required for IAQ, and perhaps can interfere on the indoor acceptable thermal comfort conditions.

Table 2 shows for the “Casa de Cambio” model that the air flow-rate values by simulation are higher than ones required to extract the indoor heat, and also satisfy IAQ conditions for the summer period.

4. Conclusions[3]

The study performed for the Culata Yovai typology

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model reveals this habitat as responsive to the environmental conditions presented, during the periods of hot summer, and cold winter under strong winds. It is emphasized for new projects replacement some original materials, and integrate kitchen and bathroom to the house body. The wind simulations for the "Casa de cambio" model demonstrate to be possible to design contemporary houses based on the Culata Yovai typology, for this climatic conditions.

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