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BIOCLIMATIC DESIGN OF MIDDLE HOUSING IN THE TIMES OF THE OIL BOOM IN TAMPICO, MEXICO (1912-1930)[1]

DISEÑO BIOCLIMÁTICO DE VIVIENDA MEDIA EN LA ÉPOCA DEL AUGE PETROLERO EN TAMPICO, MÉXICO (1912-1930)

PROJETO BIOCLIMÁTICO DE MORADIAS MÉDIAS DURANTE O BOOM DO PETRÓLEO EM TAMPICO, MÉXICO (1912-1930)

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RESUMEN

El presente trabajo tiene por objetivo determinar estrategias bioclimáticas adecuadas para el clima de Tampico y comprobar si fueron aplicadas en la vivienda media construida en la época del auge petrolero en la ciudad. Mediante la caracterización climática de Tampico y la revisión de recomendaciones realizadas por autores de arquitectura bioclimática, se establecen las estrategias aplicables al clima local. Se realiza un catálogo de viviendas de la época con características bioclimáticas, obteniéndose acceso a cinco. Mediante entrevistas a los usuarios, se buscó conocer su percepción sobre el confort interior y para profundizar, se estudiaron exhaustivamente las viviendas en cuanto a la existencia o no de estrategias bioclimáticas. Se concluye que dichas viviendas sí cuentan con estrategias bioclimáticas adecuadas para el clima y que eran las mismas que las utilizadas en las viviendas de la época de referencia (auge petrolero) y que han ayudado en la mejora del confort interior de los edificios. Utilizarlas actualmente ayudará a minorar el calentamiento interior, el uso excesivo de energías no renovables y los altos costos por consumo energético.

Palabras clave
arquitectura bioclimática, clima cálido-húmedo, vivienda, sistemas pasivos, flujo de viento.

ABSTRACT

This paper aims to determine bioclimatic strategies suitable for the climate of Tampico and to confirm whether they were applied in the middle housing built during the oil boom in the city. The strategies applicable to the local climate are established using a climatic characterization of Tampico and a review of the recommendations by bioclimatic architecture authors. A housing catalog of the time with bioclimatic characteristics is made, obtaining access to five. Users are interviewed to know their perception of indoor comfort, studying the housing in depth regarding the existence or not of bioclimatic strategies, concluding that they have climate-appropriate bioclimatic strategies, which are the same as those used in the houses of the time (oil boom), and that have helped to improve the indoor comfort of the buildings. Using them today will help reduce indoor heating, the excessive use of non-renewable energies, and the high energy consumption costs.

Keywords
bioclimatic architecture, hot-humid climate, housing, passive systems, wind flow.

RESUMO

Este artigo tem por objetivo determinar estratégias bioclimáticas adequadas ao clima de Tampico e verificar se elas foram aplicadas nas habitações de médio porte construídas durante o boom do petróleo na cidade. Por meio da caracterização climática de Tampico e da revisão das recomendações feitas por autores de arquitetura bioclimática, são estabelecidas as estratégias aplicáveis ao clima local. Elaborou-se um catálogo de residências da época com características bioclimáticas, obtendo-se acesso a cinco. Por meio de entrevistas com os usuários, buscou-se conhecer sua percepção em relação ao conforto interior e, para aprofundar o estudo das habitações, estudou-se exaustivamente a existência ou não de estratégias bioclimáticas. Conclui-se que essas residências possuem estratégias bioclimáticas adequadas ao clima, que são as mesmas utilizadas nas residências do período de referência (boom do petróleo) e que ajudaram a melhorar o conforto interno dos edifícios. Usá-las na atualidade ajudará a reduzir o aquecimento interno, o uso excessivo de energia não renovável e os altos custos decorrentes do consumo de energia.

Palavras-chave:
arquitetura bioclimática, clima quente-úmido, habitação, sistemas passivos, fluxo de vento.

INTRODUCTION

At the beginning of the 20th century, the Mexican city of Tampico was experiencing an oil rush that led people from all over the world to come to the area needing housing (Bartorila & Loredo, 2017). These imported constructions added design proposals adapted to the climate and environmental conditions, even though they had been designed for different climatic situations (Spuna-Mújica, 2011). In this historical period, it was observed that the house had passive systems that could be reused and extrapolated for the design of current housing in Tampico, whose climate has similar characteristics to those of that time. This constitutes a finding that adds a new patrimonial dimension linked to the bioclimatic behavior of buildings with an intrinsic value as cultural heritage (Domínguez Ruiz & Rey Pérez, 2019).

Rubio-Bellido et al. (2015), with their study on housing in the historic hub of Cádiz in Spain, and Beltran-Fernandez et al. (2017), with their analysis of Frank Lloyd Wright's Jacobs I house, among others, have identified the bioclimatic contribution that historical housing currently provides. The results show that despite global warming and having been built when there were no resources to obtain comfort, they still work for the climates in which they are located.

It is commonplace to observe that the climate has ceased to be considered in the architectural design of housing (Van Hoof et al., 2010). In this case, Tampico has a hot-humid climate (Cruz-Rico et al., 2015), with temperatures and relative humidity of 25.7°C and 75%, respectively. This situation, coupled with the increase in temperatures due to global warming (Fraser et al., 2018), has led the locals to widely use air conditioning equipment (Morgan & Gómez-Azpeitia, 2018) to achieve comfort. In this regard, authors such as De Dear (2004), Olgyay (2004), and Givoni (1992) have stated that if climatic conditions were taken into account through passive design strategies in buildings, hygrothermal comfort could be achieved inside and outside.

In this regard, Olgyay (2004) and Givoni (1992), consolidated pioneers of bioclimatic architecture, have developed methods and instruments to identify appropriate strategies for designing a building's urban and interior space, respectively, considering the climatic conditions of the place. Therefore, this research is based on these two complementary and parallel consolidated methods to analyze case studies in Tampico, adapting the phases developed by the authors to this research.

As for comfort, Monroy (2001)points out that for a building or public space to be comfortable all year round, it would be enough that it behaves appropriately on a typical winter and summer day. This reference has been taken as part of the research hypotheses, defining Tampico's extreme summer and winter conditions and extrapolating the intermediate stages to the rest of the year, given the low annual variation of local climatic conditions.

According to bioclimatic adaptation studies, the most effective strategies for a hot-humid climate, as is the case in Tampico, include solar protection and natural ventilation (Ahmed et al., 2021). Solar protection is crucial to reduce the cooling load in indoor spaces, while natural ventilation, as researched by Velasco-Roldán (2011), improves air movement and contributes to hygrothermal comfort.

On the other hand, it is essential to consider both the effectiveness of these systems in indoor and outdoor comfort and the reduction of indoor temperature and energy saving, as has been demonstrated by Hu et al. (2023) and Givoni (2011). The study by Elaouzy and Fadar (2023) looks closer at bioclimatic adaptation strategies for hot-humid climates, providing valuable information on how these strategies can be effectively applied in contexts such as Tampico. On the other hand, Serra Florensa and Coch Roura (1995) offer a detailed view of using natural ventilation systems as part of environmental control or passive systems, indicating their limits and hygrothermal comfort.

Rosas-Lusett et al. (2020) also conducted a study highlighting urban design strategies to achieve hygrothermal comfort in outdoor spaces. Among the recommendations to favor an adequate wind flow indoors is the appropriate integration of vegetation and its relationship with the facades and the separation between houses, among other suggestions. These strategies are fundamental to identifying and studying appropriate bioclimatic strategies, adapted to both climate and physical conditions, considering the geography, orography, and urban morphology (Manzano-Agugliaro et al., 2015), as well as to the cultural reality and local ways of life in the city of Tampico.

These investigations are framed within the connection between the development of life and the climatic conditions of a place for housing design, as highlighted by authors such as Gaytan-

Ortiz (2019) and Szokolay (1986). It is essential to consider these approaches to ensure a housing design that adapts effectively to climatic conditions and the historical-anthropological constraints of the cultural context (López de Asiain, 2001). Therefore, and given that the objective of this research is the identification and study of the bioclimatic strategies and passive systems used in the middle housing of the oil boom in Tampico, these will be identified, and the elements and/or systems will be recognized for each of the homes, thus analyzing their operation.

METHODOLOGY

The methodology to identify the bioclimatic systems and strategies in the homes of the oil boom in Tampico was based on extensive field research. Firstly, a climatic characterization of Tampico was made based on its hot-humid climate, with two distinguishable climatic periods (warmer and cooler months), using information from the SMN (1981-2010) in the EPW archive. Using a psycho-physiological adaptive model (Auliciems, 1981), the neutral temperature (Tn) and the limits of the comfort zone were calculated (Szokolay, 2014). Subsequently, using the psychrometric graphs of Givoni (interiors) and Olgyay (exteriors), the strategies recommended for the type of climate were identified in two aspects: characteristics of the set and passive architectural design of the housing. This analysis used programs such as Photoshop, WRPlot, Climate-consultant, and 2D-Sun Path by Andrew Marsh.

The sample selection for this research was non-probabilistic, as it depended on obtaining access permissions. The study area covered the Águila and Altavista neighborhoods, where a catalog of twenty-seven homes from the time of the oil boom was made, of which five were identified as case studies on potentially having a bioclimatic design. These homes were analyzed in depth through planimetric surveys, photographs, and interviews with users to find out the origin, the daily activities of the occupants, and the personal perception of thermal comfort, in addition to determining the current state compared to the original.

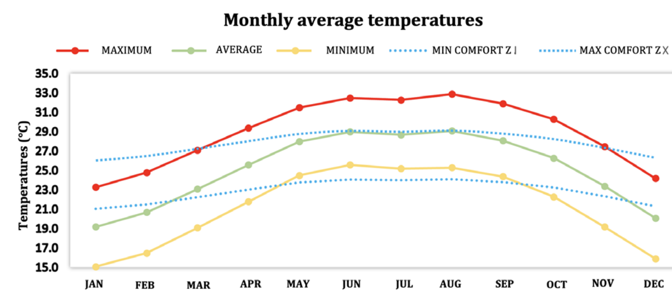
All this information was integrated into a typological file to identify the bioclimatic strategies and systems used, corroborating their proper operation when facing the city's climate. In addition, a review of strategies was carried out, observing that they were effectively used in the design of the average house built during the oil boom, identifying the passive systems used, and defining and characterizing them.

RESULTS AND DISCUSSION

CLIMATIC CHARACTERIZATION AND COMFORT ZONE

Temperature

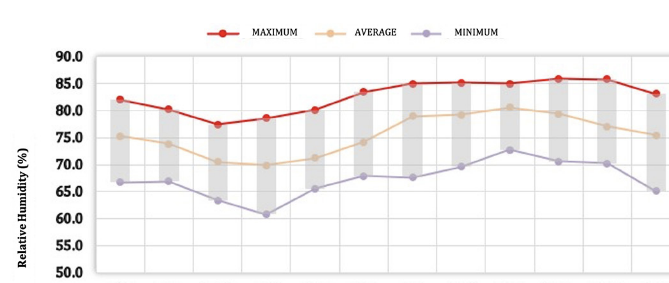
The average temperature in Tampico is 25.7°C. Graph 1 shows that the warmest months are from March to November, with average temperatures between 23 and 30 °C. In addition, the thermal oscillation in the two periods is between 7 and 8°C, and their average maximum is up to 33°C. The cooler months are from December to February, with temperatures from 15 to 20°C.



Graph 1. Monthly temperatures. Source: Preparation by the authors based on SMN data, Tampico Climatological Station, CONAGUA, 1981-2010.

Relative humidity

The city of Tampico, Mexico, is characterized by its environment, surrounded by bodies of water and its proximity to the coast of the Gulf of Mexico. This geographical location significantly influences the area's relative humidity, which is affected by the condensation of water vapor and high temperatures. Graph 2 shows that the months with the highest humidity extend from June to November, reaching 85% relative humidity. On the other hand, the months with the lowest humidity comprise the period from December to May, with values of up to 60%. Interestingly, February, March, and April are characterized by lower humidity coinciding with a higher wind speed, while the months with higher humidity, from July to November, coincide with a lower wind speed.



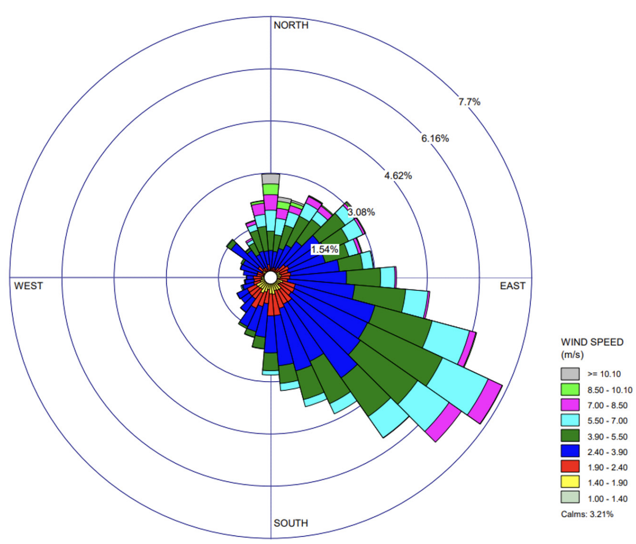
Graph 2. Monthly relative humidity. Source: Preparation by the authors based on SMN data, Tampico Climatological Station, CONAGUA, 1981-2010.

Solar radiation

In Tampico, the solar radiation is highest during the warmer months, with more sunny days and hours. During the summer solstice, the right angle of the sun at noon reaches 83.75°, indicating more direct exposure to the sun during this time of the year.

Winds

The average wind speed in Tampico is around 4.17 m/s, with the fastest speed being in February, March, and April. On the contrary, the month with the lowest speed is in August. The prevailing wind direction is usually from the southeast, with seasonal changes during the year. Thus, in June, July, and August, there is a higher presence of softer southeast winds (Graph 3), while in December and January, the north winds predominate, and in March, April, and May, the predominant direction is from the east and with a higher speed.



Graph 3. Wind rose of Tampico, Tamaulipas, 2020. Source: Preparation by the authors based on SMN data, Tampico Climatological Station, CONAGUA, 2020

Solar geometry

Tampico has a clear pattern in the length of days over the year, with the longest day in June (13 hours, 30 minutes) and the shortest in December (10 hours, 46 minutes). Figure 1 shows the relationship of the sun with the daily temperatures per month.

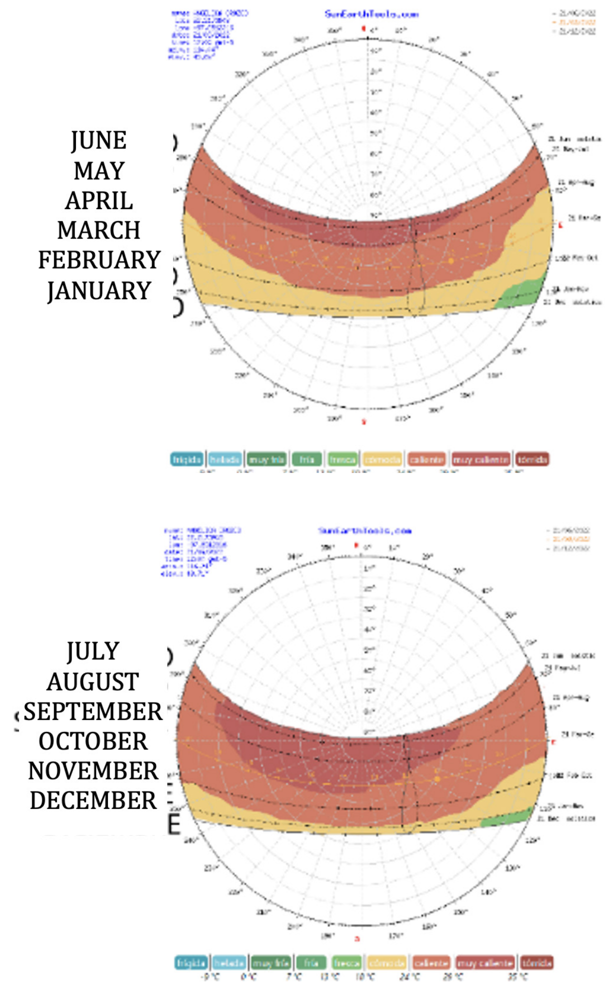


Figure 1. Stereographic solar graph + Hourly temperature for the months of the year in Tampico. Source: Prepared by the authors with data from the Tampico weather station, SMN

Comfort zones and neutral temperature

The analysis distinguishes two significant climatic periods in Tampico: the cooler months (December to February) and the warmest months (March to November). On the other hand, the comfort zones are determined using an adaptive model.

In another aspect, the neutral temperature (Tn) is calculated by a psycho-physiological thermal perception model proposed by Auliciems (1981), whose formula is as follows: Tn=(Tm*0.31) +17.60, where (Tm) is the average temperature of each month (Tm) obtained from the climatic characterization. The comfort zone is established based on the limits proposed by Szokolay, with 90% acceptance, +2.5°C upper limit, and -2.5 lower limit.

DETERMINATION OF BIOCLIMATIC STRATEGIES FOR THE CITY OF TAMPICO, ACCORDING TO GIVONI AND OLGYAY

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From the climatic characterization, the data of a typical day of each month of 2020 were obtained, using the maximum and minimum average temperatures as a guide. These data were plotted in the bioclimatic diagrams of Givoni (interior) and Olgyay (exterior), following what was indicated in Ribeiro et al. (2015).

The Givoni diagram (Figure 2) shows that solar heating and inertia in winter are recommended in the schedules outside the comfort zones for December, January, and February. On the other hand, March, April, September, October, and November are located within the comfort zone or in the area whose recommended strategy is ventilation. May, June, July, and August are mainly outside the comfort zone and within the A/C strategy.

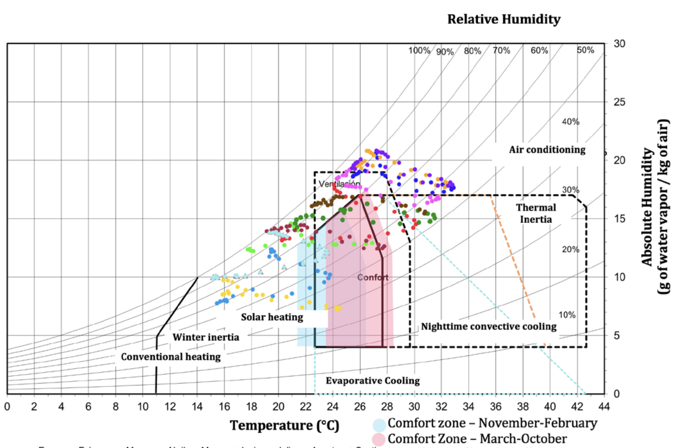


Figure 2. Psychrometric diagram of Givoni. Source: Preparation by the authors.

As for the Olgyay graph (Figure 3), it is observed that most months of the year are within the ventilation strategy zone, which suggests that air movement is an effective strategy in these months. However, August exceeds the limits towards heat, which indicates a lower effect of the ventilation strategy and the need to consider other strategies, such as radiation, to counteract the excess heat in this month with lower wind speed.

The standout bioclimatic strategy, both indoors and outdoors, is air movement. In addition, the need to consider solar radiation for cooler months is indicated, as the sun regulates high indoor humidity levels.

This analysis of strategies is complemented by Olgyay's proposal (2004) for architectural design in hot-humid regions, focusing on two fundamental areas: the characteristics of the set and immediate environment and the passive architectural design of housing.

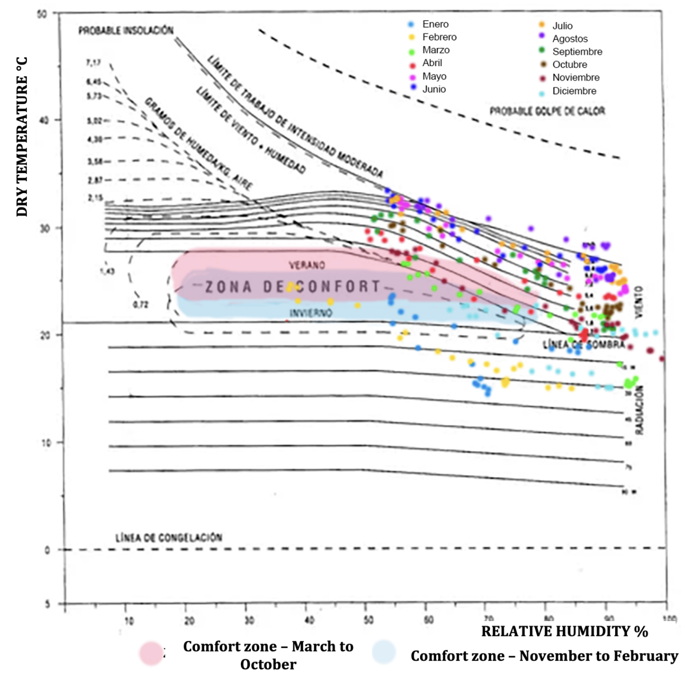


Figure 3. Olgyay's Graph. Source: Preparation by the authors.

Characteristics of the set

- Locations at high altitudes to capture the most wind.
- Houses separated from the surrounding areas to take advantage of air movements and direct it more easily indoors.
- High-branched trees located to the west provide shading without hindering air movement.

Passive architectural design of housing

- Prioritize the airflow inside using interior spaces connected to each other.
- The shape of the building is slightly elongated on the east-west axis, L-shaped, U-shaped, or with a central courtyard to favor the passage of winds and the movement of air inside. Attics, ceilings, and space between natural terrain and the interior floor will prevent heat from entering the living space. These spaces should be ventilated in summer and their ventilation controlled in winter. Interior heights greater than 2.60 mts so that the hot air rises and does not remain at the height of the users.
- Combinations of size and location in openings and windows that allow favoring cross ventilation, conserving or pushing the wind to obtain better results with the necessary ventilation most of the year. Lattices, blinds, and meshes reduce

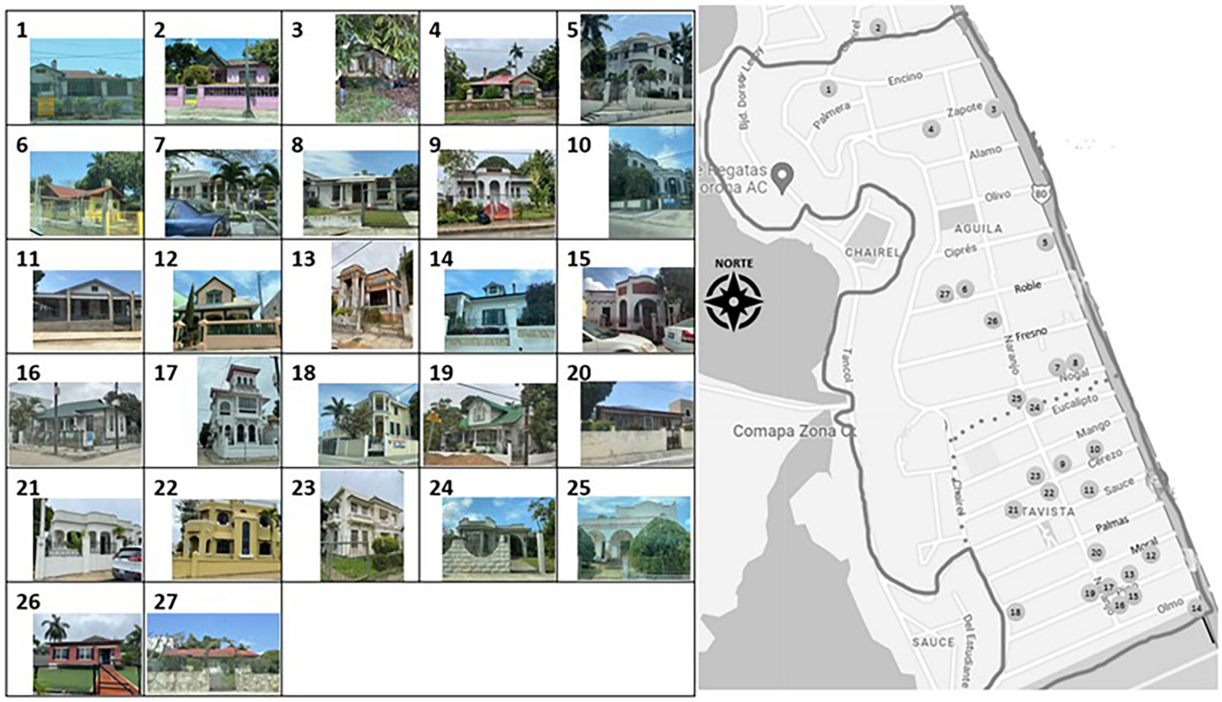


Figure 4. Total catalog of selected homes in Aguila and Altavista neighborhoods. Source: Preparation by the authors

radiation and allow air to flow into the spaces.

- Solar protection elements to the east and west. Eaves or slab extensions that help with shading. Porches, terraces, or balconies that keep the sun away from the building and allow taking advantage of the wind in the area.
- The most suitable orientation is north-south.
- Light colors that ensure reflectance indoors and outdoors.

CASE STUDIES AND ANALYSIS

For the selection of the study homes, a catalog of twenty-seven homes was made using the following criteria (Figure 4):

1. Houses built during the study period (1912-1930).
2. Currently inhabited dwellings.
3. Houses in very good condition.
4. Homes that have not undergone significant modifications.
5. Houses that are naturally ventilated in most of their spaces

Access was requested to the twenty-seven homes, and permission was obtained for only five, confirming that they met all the selection criteria. The dwellings that constitute the sample of case studies of the research are the following (Figure 5):

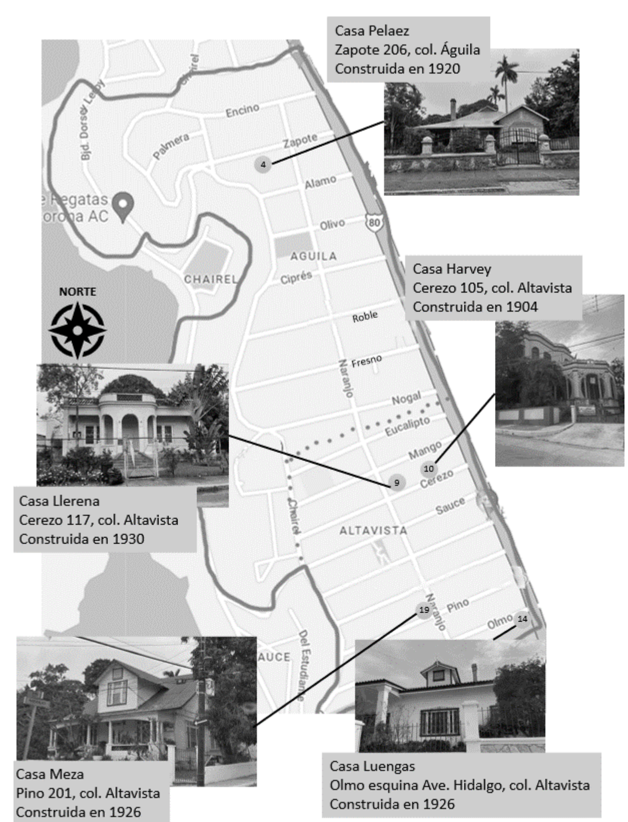


Figure 5. Location of case study housing. Source: Preparation by the authors

The detail of the houses is explained below:

1. Casa Harvey, located at 105 Cerezo Street, Altavista neighborhood. Built in 1914 and restored in 2004, it has had several owners. It is inhabited by a young couple with a child (Figure 6).

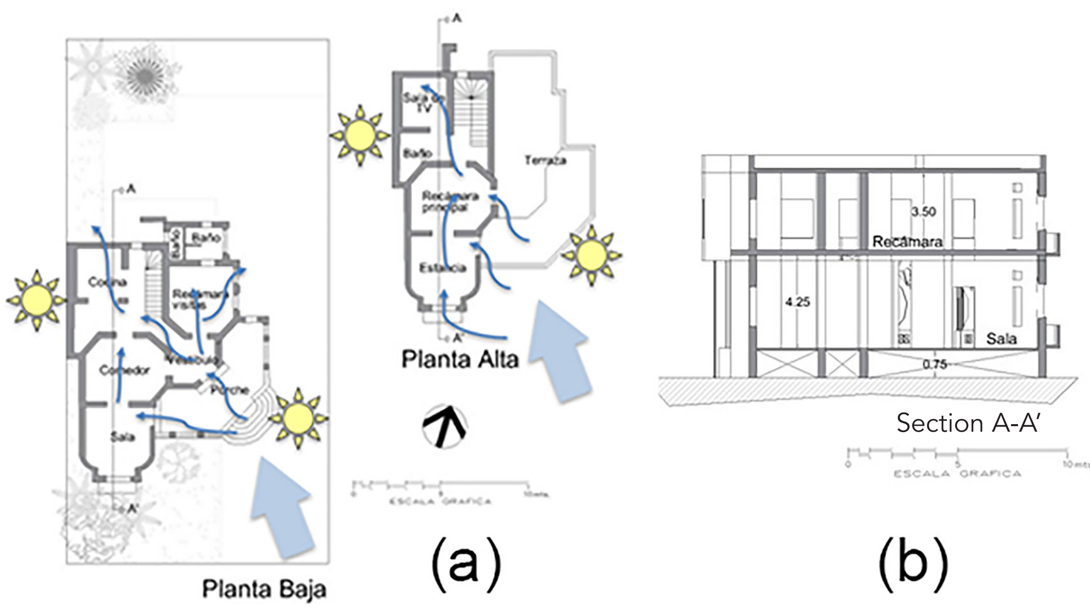
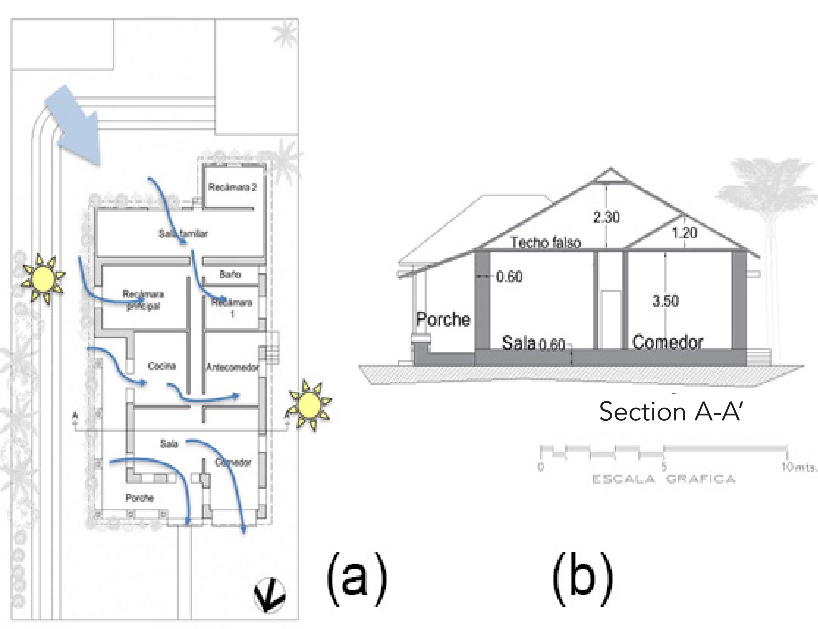


Figure 6. (a) Architectural floorplans (b) Cross section. Source. Preparation by the authors

2. Casa Peláez, located at Calle Zapote 206, Águila neighborhood. Built in the 1920's by the company El Águila. It has belonged to the current owner since 1940 and is inhabited by an older adult and a young person (Figure 7).



.Figure 7. (a) Architectural floorplans (b) Cross section. Source. Preparation by the authors.

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3. Casa Meza, located at 201 Pino Street, Altavista neighborhood. Built in 1926. It has belonged to the current owner since 1930 and is inhabited by a couple of adults (Figure 8).

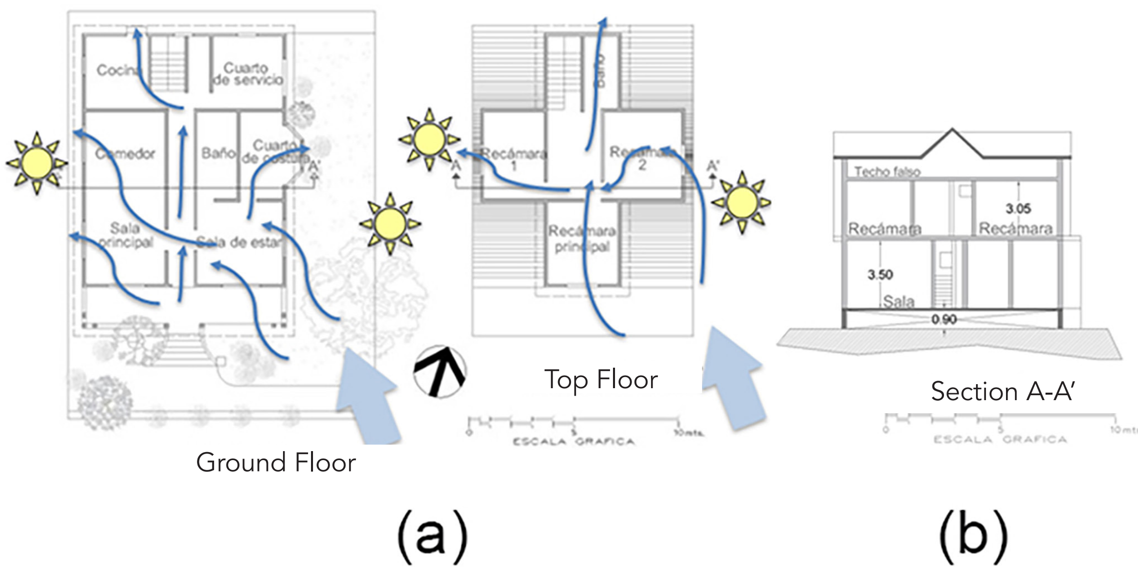

Figure 8. (a) Architectural floorplans (b) Cross section. Source. Preparation by the authors

4. Casa Llerena is located at 117 Cerezo Street in the Altavista neighborhood. It was built in 1929. It has been owned by the current owners since 1936 and is inhabited by one adult (Figure 9).

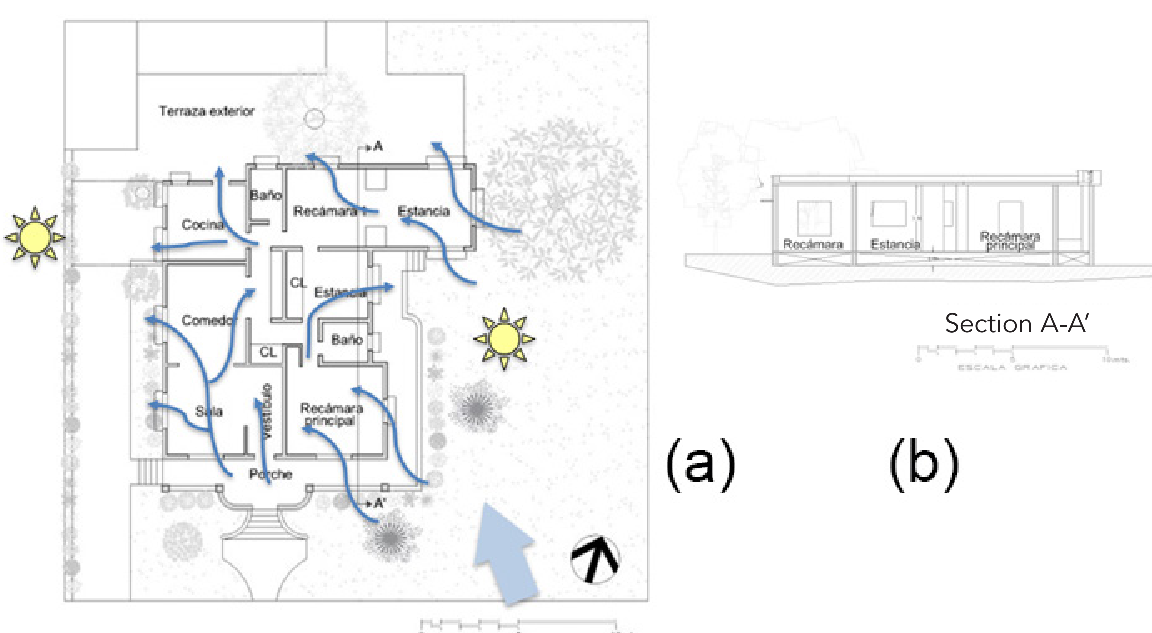

Figure 9. (a) Architectural floorplans (b) Cross section. Source. Preparation by the authors

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5. Casa Luengas in Avenida Hidalgo, in the Altavista neighborhood. It was built in 1926. It has been owned by the current owners since 1938 and is inhabited by an older adult and a young person (Figure 10).

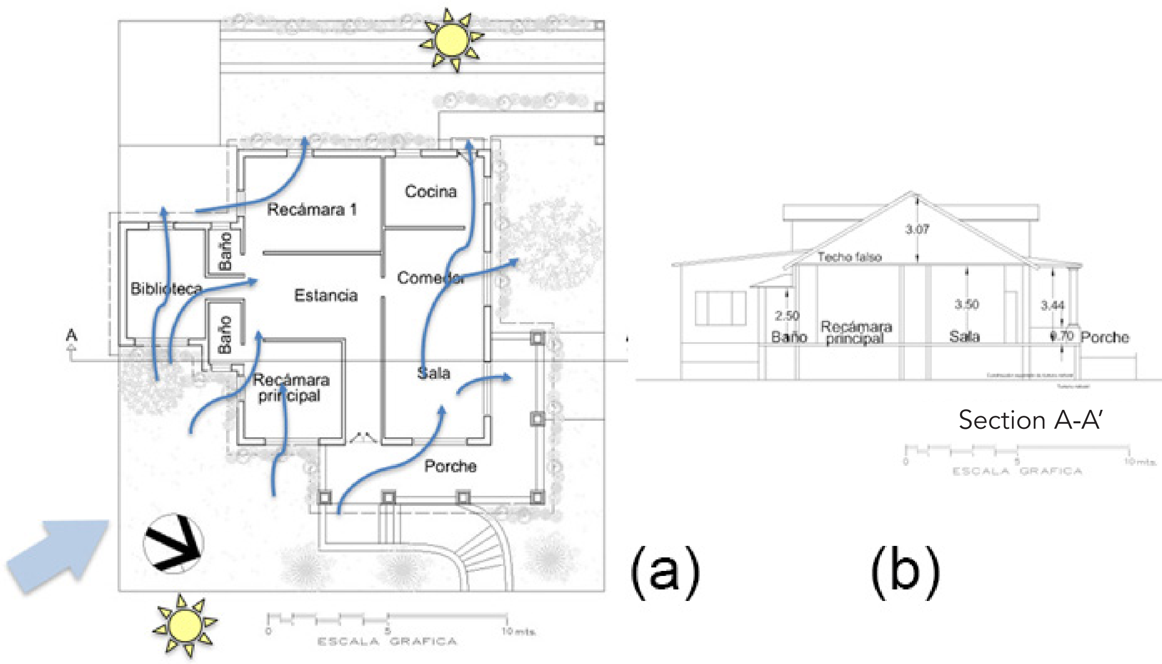


Figure 10. (a) Architectural floorplans (b) Cross section. Source. Preparation by the authors

Characteristics and immediate surroundings of the set

Considering the characteristics of the immediate surroundings of Tampico's Águila and Altavista neighborhoods, it is observed that these areas have an average altitude of 20 masl, with north-south oriented terrain and an area of 500-1000m^2. Sufficient vegetation favors the shading of the facades and the surrounding environment, contributing to the proper bioclimatic operation and the interior comfort of the houses. The same happens with the layout towards the center of the houses, as this allows an optimal wind flow, which is beneficial for thermal comfort inside.

These conditions provide a favorable environment for the effective implementation of bioclimatic and sustainable strategies, providing comfort and energy efficiency for the inhabitants. In new urbanizations, it is recommended to prioritize these favorable conditions, including sufficient vegetation for shading, open spaces, and efficient distribution of housing to favor air movement. In those cases where these conditions cannot be replicated, complementary recommendations should be considered, such as shading strategies and landscape design, to ensure indoor comfort and the effective operation of the bioclimatic strategies.

ARCHITECTURAL DESIGN OF THE HOUSES

The study's objective was to identify the bioclimatic strategies and/or systems incorporated in the architectural design of each of the study homes, considering the bioclimatic strategies recommended for the climate of the city of Tampico. This process involved identifying and describing the bioclimatic strategies and systems identified in the studied homes. All this is briefly summarized in Table 1.

When comparing the findings of this study, it can be observed that the case study homes have incorporated, in a generalized way, design criteria aligned with the bioclimatic strategies defined in the research. These strategies represent elements and systems that have endured over time, thanks to their good performance in terms of occupant comfort.

As for the housing design, case studies with a semi-compact shape are observed, which is not recommended. However, cross ventilation and air movement inside are favored by having porosity characteristics (openings in all facades), interior openings, high mezzanines, and ventilated double slabs.

The strategies are generally met with the passive systems from Table 2.

Table 1. Elements identified for ventilation, air movement, and shading strategies. Source: Preparation by the authors.

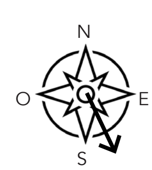
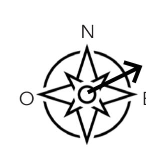
Bioclimatic strategies for the climate of Tampico	Casa Harvey	Casa Peláez	Casa Meza	Casa Llerena	Casa Luengas
Open interior spaces. VENTILATION	Cross ventilation in bedrooms and social area. Low fences with ironworks favor the passage of the wind to the site.	Interior spaces with facing accesses favoring wind flow. Low fences with ironworks favor the passage of the wind to the site.	Interior spaces with facing accesses favoring wind flow. Very low fences with ironworks favor the wind's passage to the site.	Large spaces with two windows or more favoring cross ventilation. The very low fence favors the passage of the wind to the site.	Large spaces with two windows favoring cross ventilation. Mesh fence favoring the passage of the wind to the site.
Shape AIR MOVEMENT	Semi-compact and porous construction. The ratio is 1:1.30, raised +0.75m from the floor—3.50 m high mezzanines.	It has elongated north-south construction. The ratio is 1:1.80, raised +0.45m from the floor. It has an attic, a false ceiling, and openings to get the hot air out—3.50 m high mezzanines.	Semi-compact and porous construction. The ratio is 1:1.50, raised +0.90m from the floor. It has an attic, false ceiling, and openings to get hot air out. The apartment is separated from the natural terrain and has openings on the perimeter, with mezzanines that are 3.50 m high.	Semi-compact and porous construction. The ratio is 1:1.25, raised +0.90m from the floor—3.50 m high mezzanines.	Semi-compact and porous construction. The ratio is 1:1.20, raised +0.30m from the floor. It has an attic, false ceiling, and openings to get hot air out—3.50 m high mezzanines.
Openings and windows VENTILATION	Openings percentage: Southeast 13.13%; Northwest 18.91%; East-north: 12.58%; West-south: 9.29%	Openings percentage: Southeast 35.16%; Northwest 27.41%; East-north: 15.73%; West-south: 15.09%	Openings percentage: Southeast 29.42%; Northwest 12.84%; East-north: 22.44%; West-south: 17.10% *The roof was not considered.	Openings percentage: Southeast 17.11%; Northwest 13.25%; East-north: 13.38%; West-south: 15.85%	Openings percentage: Southeast 8%; Northwest: 18.21%; East-north: 21.44%; West-south: 12.21%
Solar protection elements SHADING	Roofed southeast-facing porch that is 3.15m wide by 10.8m.	40 cm wide perimeter eaves. Roofed Northwest and East-North facing L-shaped porch, 3.5m average width.	40 cm wide perimeter eaves. Roofed southeast-facing porch, 1.74mts wide.	Wide eaves with 50 cm windows. "L"-shaped roofed Southeast and East-North facing porch, 1.6m average width	40 cm wide perimeter eaves. Covered "L" shaped West facing porch, 2 m average width.
Orientation VENTILATION AND LESS PERPENDICULAR RADIATION	 South 23°East	 North 14°West	 South 26°East	 South 23°East	 East 22° North
Reflective colors inside and outside. ENSURING REFLECTANCE	Light gray paint outdoors, white indoors. White roof.	Apparent light-yellow stone finish outdoors, beige indoors. Red sloping roof.	White paint on the exterior, white on the interior. Green sloping roof.	Light gray paint outdoors, white indoors. White roof.	White paint outdoors, beige indoors. Green sloping roof.

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Table 2. Elements and/or systems identified. Source: Preparation by the authors.

Recommended strategies for the city's climate	Systems identified in the studied housing
Open interior spaces to favor ventilation.	Spaces with interior openings facing each other. Doors with openings that allow wind to pass through. Cross ventilation in bedrooms and social spaces.
Open outdoor spaces to favor ventilation.	Use of low fences or meshes to favor the passage of the wind inside the site.
Shapes that allow reducing the radiation inside	Housing with attics and double ceilings with ventilation to get the hot air out. Houses on the level of the natural terrain. In a house separated from the natural terrain, there are openings for air movement and humidity reduction.
Shapes that favor air movement	High ceilings favor the air movement and allow the hot air to rise and not be at the user level.
Openings and windows that favor ventilation with shading systems and decrease indoor radiation	Large clearings on the south and north facades. Perimeter eaves on roofs. Individual eaves by window. South, east, and west-facing porches.
Solar protection elements that they prevent radiation inside the openings	Porches that prevent radiation from coming inside. Eaves by windows and perimeters.
Orientation that favors ventilation.	Large-sized windows face the prevailing winds, which may not cause high air pressures but allow the wind to pass inside.
Reflective colors inside and outside to decrease heat transfer.	In general, light colors are observed on indoor and outdoor walls. On roofs, some houses are white, two are green, and one is red.
Vegetation within the property to favor shading	The houses have medium to large-sized vegetation—trees placed on the east and west facades, which helps with shading.

After analyzing the results, it is demonstrated that the passive bioclimatic strategies defined in the Givoni psychrometric diagram are applied in the homes under study in their original design. Likewise, the most crucial strategy in the interior is natural ventilation, especially in the warm months, corroborating the conclusions of Velasco-Roldán (2011). The observation of simple design systems in these homes, such as large windows facing windward and interior doors with upper windows, favor cross-ventilation and the passage of air between spaces. These systems can be extrapolated to current housing designs, as they can significantly improve indoor hygrothermal comfort.

Regarding the strategies defined by the Olgyay outdoor graph and corroborated by the studies of Roses-Lusett et al. (2020), it can be concluded that they are suitable depending on the greater comfort in the immediate surroundings of the buildings, which can positively influence the air temperature before entering the house, also improving indoor comfort.

Finally, it is shown that the follow-up of the criteria defined by The New York Times (2014) and Lopez de Asiain (2001) regarding the methodological process and strategic approach of analysis of the physical and cultural-anthropological context has produced significant results that confirm that the homes studied and built during the oil boom in Tampico can be an important reference to improve the bioclimatic design of current housing in the area, in addition to standing out as a cultural and environmental heritage that deserves recognition (Domínguez Ruiz & Rey Pérez, 2019).

CONCLUSIONS

This study highlights the importance of housing architecture built during the oil boom in Tampico, as it is evident that the fact of having locally adapted bioclimatic strategies and systems manages to provide better and adequate comfort conditions to the houses (Espuna-Mújica, 2011). Although these original designs were imported from other contexts, they could be adapted to the local climatic context, demonstrating that the bioclimatic strategies were necessary and potentially usable for Tampico.

These systems characterized both generically in the studies of Serra Florensa and Coch Roura (1995) and specifically in those of Manzano-Agugliaro et al. (2015), have been validated as suitable to face the hot-humid climate. Likewise, the initial expectations about the city's historical housing contribution to a specific climate are confirmed, which could be critical for the current housing being built in the same city. These contributions should be studied and quantified in their extrapolation to the current housing in Tampico in future research.

It is concluded that, even though these houses, despite their aesthetic-historical-constructive interest, have not been classified as cultural heritage, they can make a significant contribution in environmental terms and bioclimatic behavior, so they could be considered environmental heritage, according to the proposals of authors such as King (2017). However, this research does not allow quantitatively determining the potential for comfort improvements of the studied designs. In this sense, this work can be considered the first part of more comprehensive research, where it has been possible to identify the bioclimatic strategies and systems used for the architectural design of housing. In this way, to continue this study, it will be necessary to make measurements and/or simulations of this behavior to check the effectiveness of housing comfort and thus know accurately the benefits of implementing the strategies and systems presented in this research in the current design.

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