Original Research Article

Study of Huichol vernacular housing through thermal analysis of the construction elements characteristic of the pre-Hispanic era.

Comment [SMR1]: A) On the recommendation of the reviewer, this article has the potential to be published as a Review paper, not as a research article, due to its characteristics.

Comment [SMR2]: B) We reviewed and made the necessary language corrections throughout the document.

ABSTRACT

Comment [SMR3]: C) We delete "the extra word" and we supplement the abstract according to the SDI paper template.

Aims: Analyze the thermal quality provided by the building elements of Huichol vernacular housing concerning the climatic conditions of San Andrés Cohamiata, Jalisco.
Study design: The analysis was performed through a simulation of computer housing, for which the characteristics of the materials and EPW (Energy Plus Weather) data of 2018 from the study area were applied to the model, for which the characteristics of the materials and EPW (Energy Plus Weather) data of the 2018 study area were applied to the model, analyzed in programs such as 2D Sun-Path, 3D Sun-Path and Opaque.
Place and duration of study: Universidad Autónoma de Querétaro, Graduate of Architecture, Faculty of Engineering, between January and March 2019.
Methodology: First, a bibliographic and field study was carried out to verify the materials and construction processes of Huichol housing. The computer housing model was designed to apply the characteristics of the materials, as well as the location and orientation handled by the Huichol ethnic group. Subsequently, EPW (Energy Plus Weather) data from the study area were introduced to opaque software to perform thermal analysis of the house, and various factors are studied such as thermal mass and insulation, heat gain/loss, direct radiation, diffuse, dry bulb temperature, among others. Also, in software such as 2D Sun-Path and 3D Sun-Path, the study of sunbathing and shadows of the house was carried out.
Results: The orientation of the house allows them to make better use of solar radiation at different times of the year. Its construction elements (wall thickness, material, and ceiling structure) decrease the overheating of the space in summer. Adobe walls have a thermal delay of 4 hours, and internal conditions are optimal to maintain thermal comfort in summer and winter. Internal temperatures during the year range from 20 to 25°C.
Conclusions: Huichol culture has important knowledge in the construction with natural materials, as these allow positive thermal behaviour in the face of the climatic conditions of the area throughout the year. These housing characteristics may apply to other ethnic groups in the region with limited economic resources, to improve their living conditions.

Keywords: Thermal Behavior – Vernacular Architecture – Huichol Ethnicity

1.- INTRODUCTION

Humans have fairly broad adaptability, a capacity for acclimatization to different conditions, but we can become "spoilt". (Auliciems A. & V. Szokolay S., 2007, p. 3). Despite this biological adaptability, humans are looking for ways to prevent thee against different climatic adversities.

Comment [SMR4]: D) The references match the citations. Most of references are cited in the document and have been highlighted in the "References" section. The non-highlights were not cited; they were used as documentation.

Certainly, in indigenous cultures, there is extensive knowledge about construction with geological and biological materials. When we built, we built in the image of Nature's constructions: standing poles, rock upon rock, reconstituted earth, matted straw thatch on roofs. Most people knew intuitively and by practice from childhood how to follow Nature's basic rhythms, shapes, processes, and timescale. Our native wisdom came from daily immersion in the functions of the natural world because we had no other model. (Evans I., s.f., p. 8)

This ancestral wisdom confirms an understanding of the role and links with nature, with which they have managed to generate a link between their buildings, their activities, and the environment. The constructions are suitable for use and context, as well as to maintain thermally optimal environments within.

Vernacular architecture embodies mainly in the habitat and culture of indigenous communities. The application of this type of traditional housing has been losing value in the use of natural materials and importance in its relationship with the environment. Knowing the lifestyle, the use of housing and the characteristics of the vernacular architecture typical of the Huichol ethnic group brings us closer to understanding the link between this ethnic group and its context, as well as how they use natural resources to build their homes, adapting them to their needs.

Huichol housing belonging to the area of "San Andrés Cohamiata" (in the state of Jalisco, Mexico) is examined. The objective is to carry out the thermal analysis of Huichol housing and the characteristics of the materials that make up it, depending on the location and climates, so climate data from the 2018 area are used.

Besides, we address how this ethnic group lives and how its constructions develop from the elements that shape their homes and their ability to provide thermally comfortable spaces.

In the Mexican Republic, there is a great diversity of rural and indigenous populations in which the implementation of a vernacular architecture provides several benefits for its occupants. Building with natural materials allows reducing pollution and the use of alternative energies to condition spaces at the epidemic level, as mentioned by Evans I. (s.f.).

2.- HUICHOL ETHNICITY, LIFESTYLE AND USE OF SPACES

This section addresses some of the characteristics that represent the Huichol ethnic group, such as the typology, use and organization of its architectural spaces. The Huichol ethnic group is considered by some historians to be one of the oldest indigenous communities in Mexico. According to Neurath (2003), Huicholes live in a region known as the Great Nayar; this ethnic group is mainly found in the Sierra Madre Occidental, formed by Durango, Nayarit, Jalisco, and Zacatecas.

The National Institute of Indigenous Peoples (s.f.) and Ochoa H. (2001) mention that there are five ceremonial centres where traditional Huichol governments are installed corresponding to the communities of Tateikie (San Andrés Cohamiata), Tuapurie (Santa Catarina Cuexcomatitlán), Waut+a (San Sebastián Teponohuaxtlán) and its annexe Tutsipa (Tuxpan de Bolaños), as well as Guadalupe Ocotán in Nayarit. The relationship between geographical environment, culture, distribution, and organization of the population allows understanding the current structuring, use, appropriation, and boundaries of the Huichol territory. (Ochoa H., 2001, p. 3)

Note: According to Téllez (2006) the Huichol indigenous language contains the symbol (+) that represents a vowel and has a sound between i/ and /u/ so some words contain this symbol.

Comment [SMR5]: E) We correct the language and spelling throughout the document. In addition, we include a citation note in which it is emphasized that the + symbol is not a spelling error.

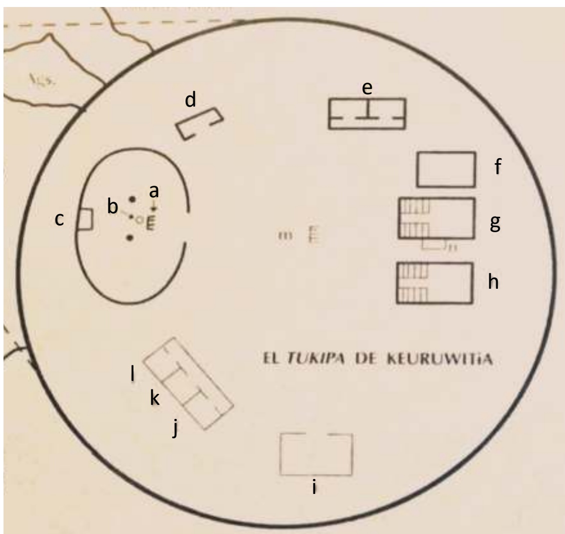
San Andrés Cohamiata consists of sixty-four Rancherias or kiekárite, of which seven are the most important because they concentrate a greater number of people and have an option to civilian charges. These ranches have an indigenous temple called tuki, which is dedicated to the most important deities, first of all to Tatewarí, conceptually: Our

Grandfather Fire. The rest of the kiekárites have only minor worshippers called xiríki. (Anguiano M., 2018, p 40)

Huicholes are an ethnic group faithful to their customs and customs, which come from an ancient worldview where they explain their presence in the world and how it is balanced with the life cycle. Among the Huicholes, the east-west axis relates to the mythical pilgrimage of ancestors from the west to the east, in search of dawn. (Chinchilla O., 2014, p. 1066)

The ceremonial centre called Tukipa, as mentioned by Neurath (2002, 2003, 2004), Téllez (2006), Delgado A. et al. (2017) is the religious, civic space, characterized by the sacred courtyard Quincunce "Eye of God" located centrally. The Tuki is the largest of the structures of an entire architectural complex called "La Casa Grande" (Delgado A. et al., 2017, p. 313), characterized by its conical roof and higher height unlike the rest of the spaces that are regularly gable roof. Figure 1 shows the distribution of tukipa, characterized by Quincunce.

Comment [SMR6]: F) Tables, graphics and figures are referenced inside the paper text.



a) Tatewarí / Te´akata
b) Tatutsa / Tatutsí Maxakwaxí
c) Tatei Haramara / Tatei Haramaratsie
d) Takutsi / Takutsá
e) Tatei Ni´ariwame / Kwixuxure
f) Tamatsi´eká Teiwari / Tamatsi Yuikwamuta
g) Tamatsi Kauyumarie / Paritekia / Reu´unari
h) Tayáu / Paritekia / Reu´unaxi
i) Santa Catarina
j) Tatei Xapawiyeme / Tatei Xapawiyemeta
k) Tatei Kiewimuka / Tsakaimuta
l) Tatei Yiameka / Tamatsi Teiwari Yuawi / (El Bernalejo)

Figure 1. General distribution of the Tukipa: The Tukipa of Keuruwit+a. Source: (Neurath J., 2002)

Comment [SMR7]: G) Highlight (in bold) the marks a, b, c, d, etc. in Figure 1 and improve visibility.

The habitable space of the Huicholes has two meanings: biophysical and symbolic. The first concerns the components of the environment and its geographical delimitation. The second represents the location according to the order of its worldview that is governed by the principle of the Quincunce "Eye of God" comprising the four cardinal courses and the centre, from this mythological conception order their territory. (Delgado A. et al., 2017, p. 309)

Based on this, the houses are installed radially to the Quincunce, and these are added as the families grow. The housing buildings that are built are monospace with an approximate dimension of 2.40m wide by 3.60m long (Delgado A., Azevedo E. M. & Gómez A., 2017, p. 316), with orientation and spatial arrangement similar to the Casa Grande or Tukipa.

The Huichol house stands out for the use of natural materials of the region, making its construction system a sustainable architecture. The Huicholes have culture rich in learning and autonomy, and they are responsible for the construction and architecture of housing. The Huichol builds their houses with abundant materials on their lands; these materials are of such effectiveness that even if there are other materials, they continue to choose them. (Huichol Dwellings Ethnicities, 2018).

However, housing not only reflects knowledge of natural construction and the relationship with the environment but also contains elements that carry a strong symbolic and cultural connection for community members, as shown in Figure 2.

Figure 2. Museum representation of a Xiriki. Source: Photographs by the authors of (MNA) National Museum of Anthropology, Permanent exhibition: El Gran Nayar, Mexico., (2019)

3.- BUILDING MATERIALS AND SYSTEMS

The vernacular construction systems in a large number of ethnic groups in Mexico and Latin America are apparently simple, consisting of adobe rooms mixed with stones, palisades of otates and rectangular or circular rods, with two to four gable roofs of zacate or plain palm, supported with horcones, crossbars, pine Rhys, oak, palm, according to the region where they are nodded, with the availability of forests, woodlands and scrub. (García J. B., Beas M. G., Angels G. I. & Crespo S. L., 2014, p. 144).

The houses of the Huicholes are built from adobe, but there are also those of stones covered with mud and thatched roofs. (Origin of the Huicholes Ethnicities., 2018). The buildings that make up the houses are the ones that correspond to those of a common ranch; the xirikite are the dwellings, while the tuki is the kitchen. (Chinchilla O., 2014, p. 1064)

Also, Huicholes usually sleep in petates that extend at night and roll up in the morning, the location of these petates is accommodated next to the walls, since the material made up of stone or adobe generates a fresher feeling. This is due to some extent to the climates of the area and on the other hand, to the Huichol lifestyle.

The Huicholes build their houses with abundant materials on their lands; these materials are of great effectiveness for

Comment [SMR8]: H) According to the Reviewer's comments, we delete most of the definition of terms that are not necessary, since it is a research article and not a review article.

any climate. Construction systems vary according to the place of settlement either the mountain or the glen (Huichol Housings) Ethnicities, 2018). Its characteristics are described in Table 1:

Element	Feature	Dimensions	Other data
Floor	The floor is of land of the same place.	The interior floor has a level slightly lower than the outside.	The foundations are built of stone with mortar with a visible exterior height of 30 cm above the ground.
Walls	The walls are made of adobe or stone covered with mud; the adobes are settled with mortar.	The dimensions of the adobe are 10x20x60 cm. The walls have a height of 2.60 m high; the top is built toothed.	There are also walls built from carrizo, otate and jarilla.
Ceilings	It consists of a wooden structure with pine rods (Jukú) or oak (Xíu) and carrizos; it rests on the walls and poles.	The thickness of the rods is between 6 and 8 cm. The carrizos are placed every 20 or 25 cm between them.	The roof can be tapered or gable and covered with zacate. The moorings between the elements are made with izote ixtle, maguey ixtle or plastic thread.
Windows and doors	Windows and doors Spaces are devoid of windows. There is a slight separation between the wall shingle and the cover to provide ventilation.	The dimensions of the door are 1.20 m high by 60 cm wide.	The door contains a wooden frame. It is available on the shortest side of the house facing the central or east courtyard.
Surfaces and textures	The appearance of the materials goes according to the place of settlement with materials such as stone, mud, or adobe.		The colors are usually ochre, being natural materials of the place are completely mimicked with the environment.

Table 1. Characteristics of Huichol housing materials. Source: Own elaboration, based on data from (Delgado A. et al., 2017, Téllez, 2006 and Huichol Homes Ethnicities, 2018)

Comment [SMR9]: I) We appreciate the suggestion we have been able to organize and gather data from building elements in a table.

4.- STUDY AREA: COMMUNITY OF "SAN ANDRÉS COHAMIATA, JALISCO, MEXICO"

"San Andrés Cohamiata", is a community located in the municipality of Mezquitic, (in the state of Jalisco). This town is at 1950 meters above sea level with latitude: 22° 11' N and longitude: -104° 14' W. (San Andrés Cohamiata., s.f.). 99.77% of the population in this community is indigenous. (San Andrés Cohamiata (Mezquitic, Jalisco)., s.f.). Climatically it is considered "Colotlán, Jalisco" for its similarity in location and climates with the study area.

According to the 1961 Köppen-Geiger climate classification (Beck, C., J. Grieser, M. Kottek, F. Rubel, and B. Rudolf, 2006) Jalisco has five different climates Aw (Sabana), Csa (Mediterranean), Csb (Mediterranean of fresh summers), Bsh (Warm Steppath) and Bsk (Cold Steppary), but is dominated by Aw and Csa[1]. These two existing key classifications in Jalisco are explained below:

[2]**Aw - Sabana:** Warm all year round, with dry season. This climate appears as we move away from the equator.

Csa – Mediterranean: Mild winters and warm, dry summers. Most rains fall in winter or intermediate seasons.

The predominant climate in San Andrés Cohamiata is Csa, which will be taken as a reference. The EPW climate data reference closest to the settlement to be studied is 100km away, corresponds to the municipality of Colotlán, Jalisco; it is located in the northern region of Jalisco state, Mexico.

In addition, based on the climate data on the weather base page (2018) it is established that the municipality of Colotlán belongs to the climate classification of Köpen "Csa" (Mediterranean Climate). An area that usually consists of an average temperature of more than 10°C (50°F) in its warmer months, and an average of between 18 and -3°C (64 to 27°F) in winter. Summers tend to be dry with less than a third of the wettest winter month and with less than 30 mm (1.18 in.) of precipitation in a summer month.

Colotlán, Jalisco Travel Weather Averages (Weatherbase) (s.f.) dictates that the average annual temperature in Colotlán is 66.6°F (19.2°C). The warmest month, on average, is June with an average temperature of 74.3°F (23.5°C). The coldest month on average is January, with an average temperature of 58.1°F (14.5°C). The highest temperature recorded in Colotlán is 118.4°F (48°C) in June. The lowest temperature recorded is 22.1°F (-5.5°C) in November 2018.

5.- SUNBATHING STUDY

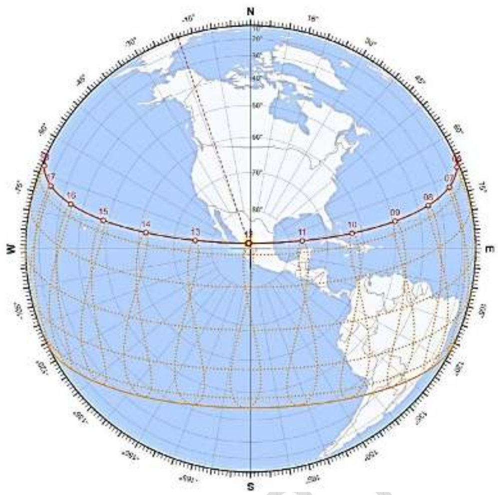
The sun is the main source of energy that affects buildings, so it is important to know how it behaves during its trajectory in the different seasons of the year. A study of the solar route was carried out on the village of San Andrés Cohamiata on the three most important solar change dates; March 21 (spring equinox), June 21 (summer solstice) and December 21 (winter solstice). It was not considered on September 21 as its solar characteristics are the same as on March 21.

For this purpose, the 2D Sun-Path application developed by J. Marsh A. (2014) was used; this application allows to interact dynamically with several two-dimensional diagrams of the projected solar path. The time for the analysis was at 12:00 P.M.

[1]Data Based on: Climate: Jalisco. (2015). Recovered 1 February, 2019, from https://es.climate-data.org/america-del-norte/mexico/jalisco-12/

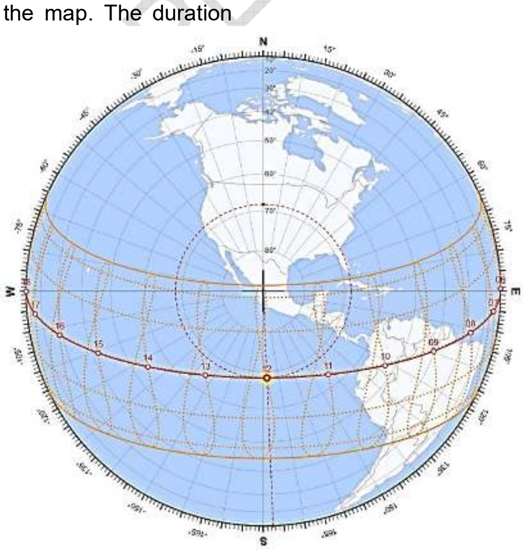
[2]Ratings A and C are data based on: Koppen climate classification - Meteo Navarra. (s.f.). Recovered 1 February, 2019, from http://meteo.navarra.es/definiciones/koppen.cfm

March 21: You can see in Graph 1, that the solar path on this date emerges exactly on the east side and is hidden on the west side of the map. The duration of the day is 12:08 hours, of which the presence of the sun is approximately 11:56 hours.



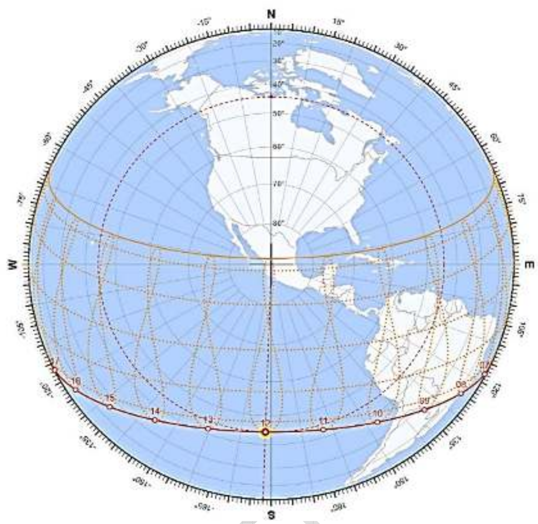
Graph 1. Representation of solar trajectory of March 21, Time: 12:00 P.M., in San Andrés Cohamiata. Source: Made in 2D Sun-Path from J. Marsh A. (2014)

June 21: Graph 2 shows that the solar route on this date emerges from the northeast side and is hidden on the northwest side of the map. The duration of the day is 13:29 hours, of which the presence of the sun is approximately 12:02 hours.



Graph 2. Representation of solar trajectory of June 21, Time: 12.00 P.M., in San Andrés Cohamiata. Source: Made in 2D Sun-Path from J. Marsh A. (2014)

December 21: Graph 3 shows that the solar route on this date emerges from the southeast side and is hidden on the southwest side of the map. The duration of the day is 10:47 hours, of which the presence of the sun is approximately 12:06 hours.



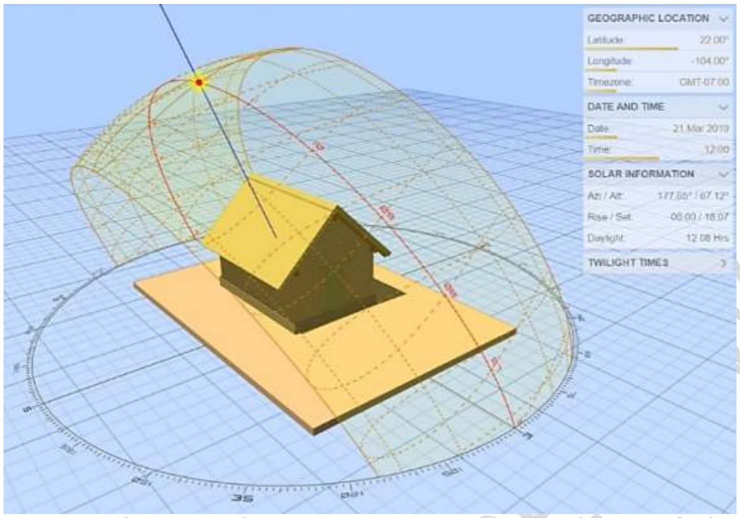
Graph 3. Representation of solar trajectory of December 21, Time: 12:00 P.M., in San Andrés Cohamiata. Source: Made in 2D Sun-Path from J. Marsh A. (2014)

6.- SHADING STUDY

The shading of the facades is an important factor, as it is part of the conditions of thermal comfort inside the buildings. Orientation and geometry play a critical role in the passive use of solar energy through the layout of the building envelope. The shading study was conducted on the 3 most important dates mentioned above using the 3D Sun-Path application developed by J. Marsh A. (2014).

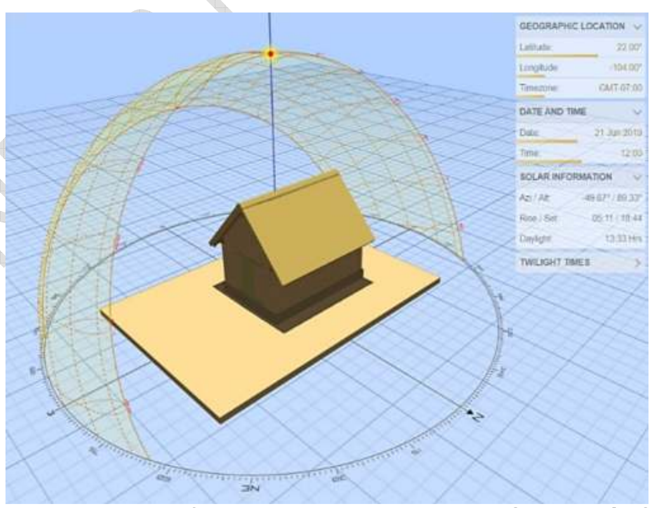
The diagram combines shadow projections and the path of the sun to causally relate the actual behaviour of the sun in the time and date analysed. The study did not consider the influence of context shadows such as trees or other buildings so that it could review how the house works on its own in this regard.

March 21: The sun projects a greater incidence on the east, west and roof facades during this date. The hours of the solar incidence in the elements of the envelope are as follows; East Facade: 6:30 A.M. – 12:00 P.M., West Facade: 12:30 – 18:00, South Facade: Partially protected during the day, North Facade: Fully protected during the day, South sloping deck: 7:30 A.M. – 5:00 P.M., North sloping deck: Partially protected during the day. Graph 4 shows an example.



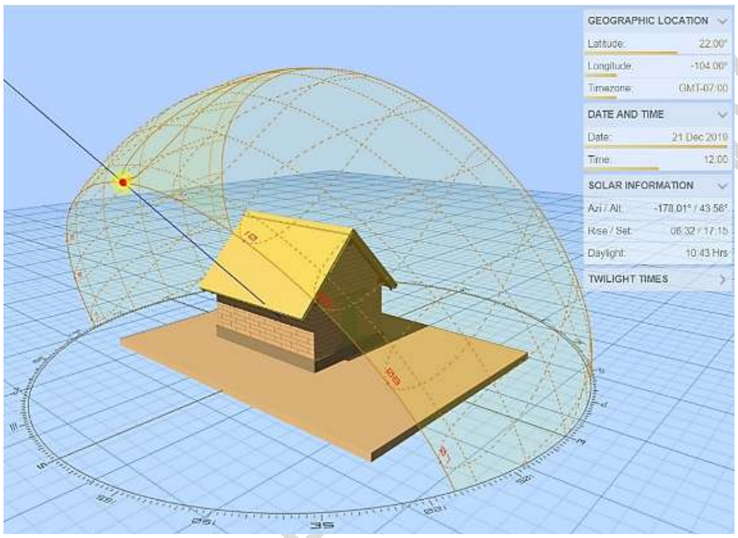
Graph 4. Analysis of shading of March 21, Time: 12:00 A.M., in San Andrés Cohamiata. Source: Made in 3D Sun-Path from J. Marsh A. (2014)

June 21: The sun projects a greater incidence on the east, west and roof facades during this date. The hours of the solar incidence in the elements of the envelope are as follows; East Facade: 6:30 A.M. – 12:00 P.M., West Facade: 12:30 P.M. – 6:30 P.M., South Facade: Fully protected during the day, North Facade: Partially protected during the day, Cover: 7:30 A.M. – 5:00 P.M. Graph 5 shows an example.



Graph 5. Shading analysis of June 21, Time: 12:00 P.M., in San Andrés Cohamiata. Source: Made in 3D Sun-Path from J. Marsh A. (2014)

December 21: The sun projects a greater incidence on the east, west, south, and south sloping facade during this date. The hours of the solar incidence in the elements of the envelope are as follows; East Facade: 7:00 A.M. – 12:00 P.M., West Facade: 12:00 P.M. – 5:00 P.M., South Facade: Totally affected by the sun during the day, North Facade: Fully protected during the day, Southern sloping deck: Totally affected by the sun during the day, North sloping deck: protected. As shown in Graph 6.



Graph 6. Shading analysis of December 21, Time: 12:00 P.M., in San Andrés Cohamiata. Source: Made in 2D Sun-Path from J. Marsh A. (2014)

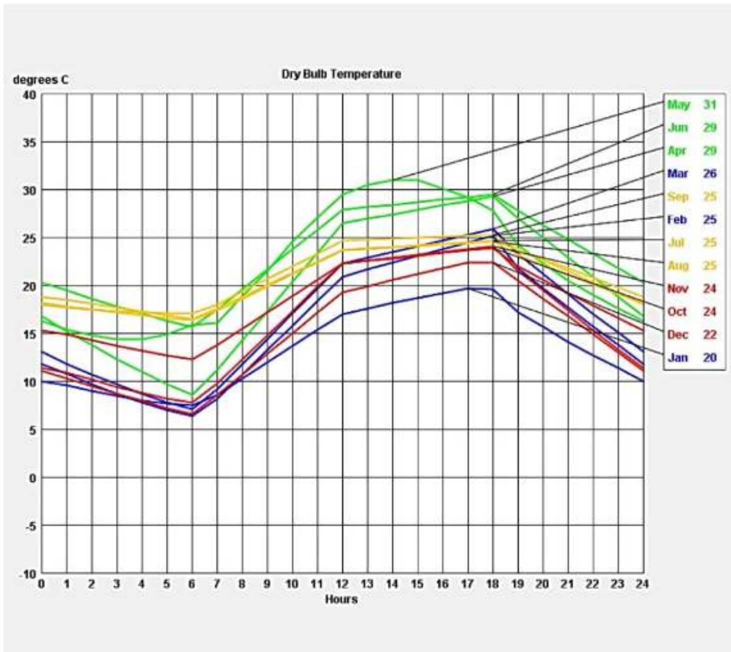
7.- THERMAL MASS AND RAVAGING

Thermal mass is a property of the mass of a building that allows storing heat, providing "inertia" against temperature fluctuations. Thermal mass will absorb energy from the environment when it has higher temperatures than mass and returns thermal energy when the environment is colder, without reaching thermal balance. Scientifically, thermal mass is a body's ability to store thermal energy.

Weather conditions affect the temperature inside the house through the characteristics of its materials. The following are the conditions that affect you:

Sun-to-air temperature: This is a variable used to calculate the cooling load of a building and to be able to determine the total heat gain through the outer surfaces of the house. The contrast of the maximum temperatures per wall is; on the east wall: the highest of 31°C and the lowest is 20°C in January, on the west wall: the highest temperature is 37°C and the lowest in January at 25°C, on the south wall: the highest temperature is 33°C in May and the lowest in January at 24°C, on the north wall: the maximum is 33°C, and the minimum is 20°C in January.

Dry Bulb Temperature: Indicates the amount of heat in the air and is usually measured in degrees Celsius (C), Kelvins (K), or degrees Fahrenheit (-F). Graph 7 shows the months with the highest dry bulb temperatures: May at 31°C, the months of February, July, August, and September average 25°C, January has the lowest air temperature at 20°C. This climatic variable is essential for the human comfort and energy efficiency of the building.



Graph 7. Opaque Dry Bulb Temperature Analysis per month in Colotlán, Jalisco. Source: Generated in Opaque from the data available in the bibliography

Comment [SMR10]: J) In the paper text it is highlighted that the data in graphs 7 to 10 are performed using data in the literature.

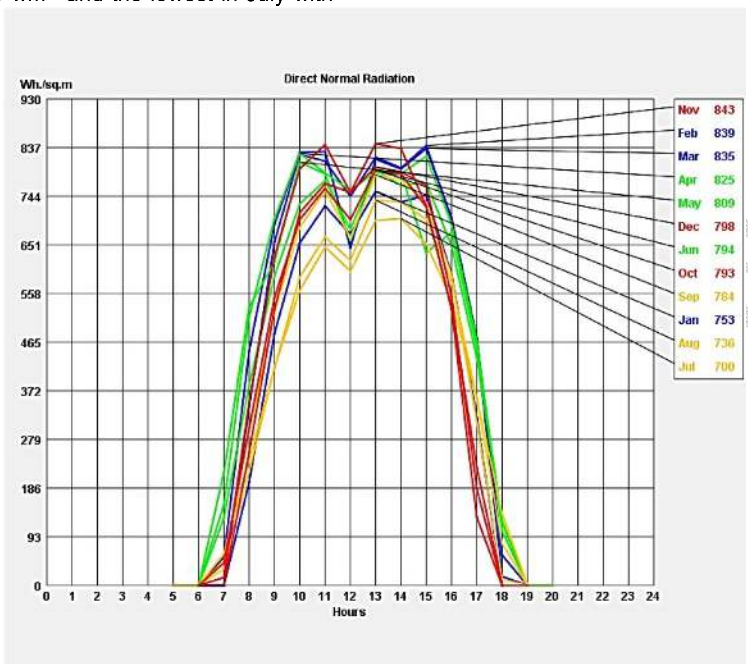
Gain/Heat Loss: Heat gain occurs when radiant heat enters space through the glass. Heat loss reflects heat transfer through the structure of the building from the inside out. The highest heat gains on the walls are on the east wall: in May with 9 wm^{-2}, west wall: in May with 14 wm^{-2}, south wall: in May with 10 wm^{-2}, north wall: in May with 10 wm^{-2}.

Comment [SMR11]: K) We perform the correction of the units in a scientific form as recommended

It should be noted that the walls of the Huichol house have an impact with a thermal delay of 4 hours.

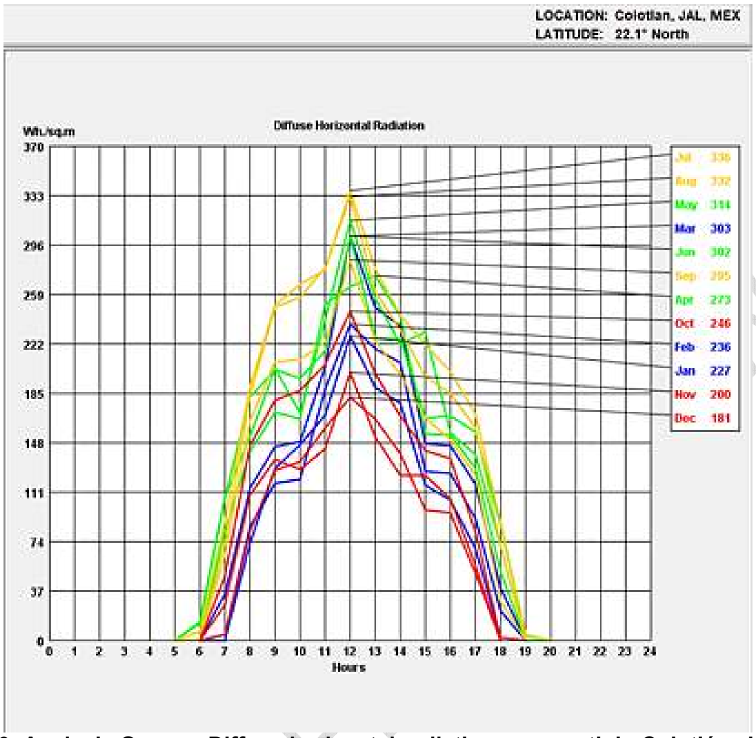
Total surface radiation: This is the total surface radiation that each wall receives according to its orientation. On the east wall, it is appreciated that the radiation received is above 400 wm^{-2} in all months, with April being the highest with 610 wm^{-2}. The west wall has minimal variation, this orientation is the most affected by radiation, with 739 wm^{-2} in March and the lowest of 581 wm^{-2}. The south wall has an affectation proportional to the sun position at different times of the year, with 7 wm^{-2} in June and 700 wm^{-2} in December. The north wall is the least affected orientation with a minimum of 5 wm^{-2} in March and a maximum of 248 wm^{-2}, the months of October to January have 0 wm^{-2}.

Direct normal radiation: This is the amount of solar radiation received per unit area of a surface that remains perpendicular to the sun's rays. Graph 8 shows the values for each of the wall orientations are similar throughout the year, with the highest being November with 843 wm^{-2} and the lowest in July with 700 wm^{-2}.



Graph 8. Analysis Opaque Direct horizontal radiation per month in Colotlán, Jalisco. Source: Generated in Opaque from the data available in the bibliography

Diffuse horizontal radiation: This radiation does not reach surfaces directly but has been dispersed by molecules and particles in the atmosphere. In principle, it is the enlightenment that comes from the clouds and the blue sky. Graph 9 shows per month with the largest diffuse horizontal radiation that is July with 336 wm^{-2}, April has a year-round average with 273 wm^{-2}, December has the lowest maximum horizontal establishment with 181 wm^{-2}.



Graph 9. Analysis Opaque Diffuse horizontal radiation per month in Colotlán, Jalisco. Source: Generated in Opaque from the data available in the bibliography

Direct horizontal radiation: The values are the same for all the walls of Huichol housing, as they are general conditions given by the climate of Colotlán, Jalisco. Values range from 500 to 780 wm^{-2}. The least affected by diffuse horizontal radiation is January with 527 wm^{-2}, October has an average year-round with 649 wm^{-2} and June with 771 wm^{-2}, the month being most affected.

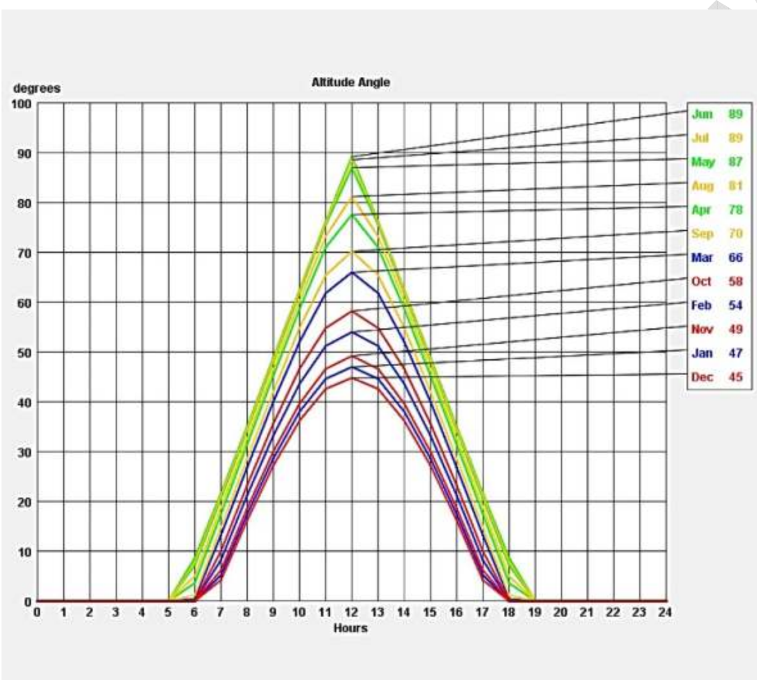
Direct surface radiation: On the east wall the radiation is above 200 wm^{-2}, with April being the highest with 487 wm^{-2}. The west wall has minimal variation; this orientation is the most affected by this type of radiation during the year, with 607 wm^{-2} in March and the lowest of 441 wm^{-2}. The south wall has a proportional impact on the sun position at different times of the year, ranging from 0 wm^{-2} in June to 557 wm^{-2} in December. The north wall is the least affected orientation with a minimum of 1 wm^{-2} in March and September, a maximum of 123 wm^{-2} in June, and the months of October to February have 0 wm^{-2}.

Reflected surface radiation: Reflected radiation is the amount of solar energy reflected from a surface, based on the solar reflectance or albedo of the surface material. Under this condition, the two walls of the house most affected by reflected radiation are the east wall with 130 wm^{-2} in January and with 197 wm^{-2} in May and the west wall with 144 wm^{-2} in December and with 207 wm^{-2} in April.

While on the south wall the radiation is 7 wm^{-2} in December and 197 wm^{-2} in April. The north wall is the least affected with 4 wm^{-2} in March, 202 wm^{-2} in April and 0 wm^{-2} from October to February.

Comment [SMR12]: L) Different line-types could not be included in the graphs, due to the features of the program. But we try to visually improved the quality of all the images in the document.

Solar altitude angle: The solar altitude angle is the angle between the sun's rays and a horizontal plane. In this case, the angles of the sun for the different months, analysed at 12:00 P.M. as shown in graph 10 showing the following angles of solar altitude: January 47°, February 54°, March 66°, April 78°, May 87°, June 89°, July 89°, August 81°, September 70°, October 58°, November 49° and December 45°. The angle of the solar altitude begins in January with 47 degrees peaking in June and July at 89 degrees; the following months begin to decrease closer and closer to the south in the winter solstice. This behaviour is related to the solar route at different seasons of the year.



Graph 10. Analysis Opaque Solar altitude angle per month in Colotlán, Jalisco. Source: Generated in Opaque from the data available in the bibliography.

8.- CONCLUSIONS

Humans have always sought environmental conditions in which they achieve well-being in terms of thermal comfort. Housing has been, is and will be one of the primary needs of society, regardless of its origin or ethnicity. In this space, the individual maintains a direct relationship, in which he performs most of his activities, in a few words in this type of spaces a person grows, learns, and develops.

However, vernacular architecture has a great influence on indigenous life, based on the previous study, and we can determine some characteristics of Huichol housing that allow having a thermally comfortable and habitable space:

- The Huicholes establish their settlements according to their religious beliefs (the principle of the Quincunce "Eye of God") symbolized by cardinal points. This feature is reflected in the orientation and location of the Huichol house. That, under this condition, is taking advantage of solar radiation at different climatic times of the year.

- The orientation and location of the house (east to west) allow you to take advantage of solar radiation in winter times by mainly heating the wall and the south canopy of space, while in summer the ceiling provides shade to all walls most of the day, decreasing the internal heat.
- Note that the house is devoid of windows and only has an access door of minimum dimensions of 1.20m high by 0.60cm wide. However, the separation between the sloping wall and the ceiling allows the wind to fluctuate, with a minimum of ventilation required.
- The walls are mainly made of soil of the same site (adobes) usually with measures of 10x20x60cm, which leads to a higher quality thermal mass. According to the study, the walls have a thermal delay of 4 hours, allowing to have warmer internal spaces longer in winter times.
- Temperatures within the house during the year range from 20 to 25°C. This means that it meets the ranges of thermal comfort for human beings according to Olgyay parameters.
- The dimensions of this type of housing are 2.40m wide by 3.60m long; however, it is suitable for the people who reside in it as the activity is reduced to the rest and shelter of some objects. All other activities are performed in separate spaces.
- The materials used in the house are beneficial to cope with the inclement weather of the area, as they are providing optimal levels of thermal comfort inside the spaces.
- In the Huichol worldview, the house is not only the space delimited by the walls but includes the entire environment, forests, animals, rivers, trees, wind, rain, air, sky, and stars. So its habitat is its home, and therefore architecture coexists in the same importance margin of the environment. This is reflected in the physical characteristics of the house as it is fully formed of natural materials and maintains the appearance of surfaces, textures, and materials.

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Comment [SMR13]: The references match the citations. Most of references are cited in the document and have been highlighted in the **"References"** section. The non-highlights were not cited; they were used as documentation.

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The authors have carried out a variety of research on topics related to architecture, habitability, environmental psychology and energy analysis. For example: Juan Serrano Arellano has developed studies of energy efficiency in sustainable buildings with topics such as lighting, thermal comfort and ventilation quality; Sergio Magos Ramírez addresses environmental psychology studies, sensory influences of the elements of the environment, thermal comfort and bioclimatic analysis.   para Damarix Sarai es su primera participación este tipo de investigaciones, pero igualmente ha desarrollado investigaciones en cuanto a la recuperación de espacios en abandono; Avatar Flores aborda temas relacionadas con la complejidad humana, herramientas y procesos de diseño para la conformación de espacios habitables y el fenómeno arquitectónico. Varun Thautam desarrolla investigaciones dedicadas al confort térmico, importancia de la arquitectura vernácula y su relación con grupos étnicos, comportamiento de los materiales, radiación entre otros.

Comment [SMR14]: M) We include the brief review of the authors' previous studies, requested by the reviewer.