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Identification of Traditional Housing in Tamaulipas: Adobe as a Bioclimatic Strategy

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Abstract This research analyses the thermal performance and sustainability of traditional adobe housing in Tamaulipas, Mexico, focusing on the use of earth and plant fibers as construction materials. The research aims to emphasize the advantages of adobe as an energy-efficient and climate-responsive building method, particularly in rural areas where such techniques remain prevalent. The study was conducted through a combination of literature review and case studies from three representative communities in the region. Thermal measurements and interviews with local experts and residents provided valuable insights into the thermal behavior of adobe and other materials traditionally used in rural housing. The findings indicate that adobe structures excel in maintaining stable indoor temperatures by leveraging their high thermal mass, significantly reducing the need for artificial climate control and energy consumption. This advantage positions adobe as an environmentally sustainable option, particularly in the face of global climate change, where energy efficiency and resilience are becoming increasingly important. In addition to traditional adobe construction, the study also explored the potential integration of bioclimatic design strategies to further enhance the thermal performance and resilience of residential houses in the region. The research suggests that incorporating modern materials and techniques, such as bamboo reinforcement or stabilizing cements, could strengthen the benefits of traditional adobe while promoting local economic development. Ultimately, the study highlights the enduring value of vernacular construction techniques in fostering sustainable housing solutions and calls for further research to optimize the integration of traditional methods with contemporary construction practices for enhanced environmental sustainability and energy efficiency.

Keywords Adobe in Tamaulipas, Traditional Housing, Bioclimatic Strategies, Jaumave and San Carlos Building

1. Introduction

The traditional housing of Tamaulipas, adapted to local climatic and cultural conditions, has been extensively studied concerning its materials and construction techniques. Notably, bahareque is a prominent method that combines earth and plant fibers, offering significant thermal and sustainability advantages. Morales-Cristobal et al. [1] analyze the heat transmission and fractal dimensions of representative materials used in rural housing in Veracruz, underscoring the critical role these aspects play in the energy efficiency of bahareque structures.

The research of construction materials has broadened to encompass sustainability. According to Suarez-Dominguez et al. [2], materials used in Mexican construction have been classified based on their carbon footprints, life cycles, and water usage—factors essential for contemporary housing. This research establishes a theoretical framework that highlights the necessity for sustainable approaches within vernacular architecture.

Furthermore, bioclimatic design strategies are vital for housing in regions prone to natural disasters. Montes et al. [3] explore the application of these strategies in disaster-affected areas, particularly relevant for Tamaulipas, where climatic conditions can be extreme.

The utilization of bamboo in construction has also gained attention. The historical and functional significance of bamboo in pre-Hispanic and 20th-century Mexico has been examined, enhancing the understanding of construction traditions that have persisted and evolved over time [4,5].

In a broader context, Carrobé et al. [6] review thermal monitoring and simulation of earthen buildings, providing evidence of the thermal performance of traditional constructions, which carries substantial implications for the design and preservation of housing in Tamaulipas.

These studies illustrate the intricate relationship between tradition, sustainability, and climatic adaptation in the architecture of housing in Tamaulipas.

History and Dissemination of Earth Construction Techniques

Earth construction techniques have been used since pre-Hispanic times in various regions of Mexico, including those that today make up Tamaulipas. These practices, mostly indigenous in origin, were initially developed by local communities to adapt to the climate and make use of available resources. Adobe, a mixture of earth, water, and plant fibers, is the most representative material of these traditions. Adobe structures not only provided thermal protection but also incorporated bioclimatic designs [7-10].

With the arrival of Spanish colonizers, these techniques were influenced by European knowledge, such as the use of fired bricks and more robust foundation systems. However, adobe and stone remained predominant, especially in rural communities, due to the availability of materials and their low cost. Over the centuries, traditional techniques were combined with modern elements, such as reinforcement with steel rods or the use of stabilizing cements [11,12].

Today, although earth construction has declined in favor of industrialized materials, it is still employed in certain rural areas of Tamaulipas. For instance, in the municipalities of Jaumave and San Carlos, adobe houses represent a significant portion of the buildings. These techniques are valued for their thermal efficiency and sustainability, factors that make them especially relevant in the context of climate change [13,14].

It is important to highlight the diversity of earth construction types. In Tamaulipas, the following can be identified:

- Adobe houses stabilized with cement or lime.
- Traditional houses made with mixtures of earth and natural fibers, such as straw or manure.
- Hybrid designs combining stone and compacted earth.

These practices, although less frequent than in the past, continue to be passed down orally within communities. The recovery and strengthening of these techniques could play a crucial role in the preservation of cultural heritage and in promoting sustainable housing.

This paper aims to determine the thermal performance and sustainability of traditional earth housing in Tamaulipas, analyzing its materials and construction techniques. The study seeks to demonstrate the advantages of these traditional methods in achieving energy efficiency and resilience against extreme climatic conditions while highlighting the potential for integrating bioclimatic design strategies to enhance contemporary housing practices.

2. Materials and Methods

This study employed a qualitative approach, combining a literature review with case analyses of earthen houses in Tamaulipas. Three representative communities where adobe is predominant were selected for investigation. Data collection involved interviews with local experts, architects, and residents, along with direct observations of the houses. Thermal measurements were also conducted to evaluate the energy performance of the constructions.

The methodology employed in this study is grounded in a pragmatic research philosophy, emphasizing the practical application of findings to address real-world challenges in housing design and sustainability. This research adopts a qualitative, exploratory type, leveraging a case study strategy to delve deeply into the characteristics of traditional housing in Tamaulipas. The research design follows a cross-sectional time horizon, capturing data during a specific period to evaluate the thermal and structural properties of housing materials and their implications for sustainability. Sampling for the study involved a non-probabilistic, purposive approach, selecting 580 rural residential houses across the municipalities of Jaumave and San Carlos. This sample aimed to capture a diverse representation of housing typologies, though its significance relative to the total population of rural houses in the region requires further clarification. Future iterations of this research will address this limitation by estimating the total population and calculating a statistically representative sample size. Information about the population in the zones is found in

Table 1 according to the results obtained, and Census 2020 from INEGI [15] Population Census, San Carlos, Tamaulipas, recorded 2,361 households, while Jaumave has 1,200 households [11,16].

Data collection methods included semi-structured interviews with local experts, architects, and residents, direct observation of construction techniques, and thermal performance measurements using the KD2 Pro equipment and SH-1 Sensor. The collected data were analyzed using a mixed-method approach, integrating qualitative content analysis of interview transcripts with quantitative evaluation of thermal properties derived from Fourier's law of heat conduction.

The study acknowledges methodological limitations, including the absence of a probabilistic sampling frame and potential biases introduced by purposive sampling. These limitations highlight the need for a more robust sampling strategy and further research to enhance the generalizability of the findings.

The method for determining thermal conductivity using the KD2 Pro equipment, as described in the studies by Morales-Cristóbal et al. [1] and Suarez-Dominguez et al. [2], is based on the heat flow technique. This equipment allows for precise and efficient measurement of the thermal properties of construction materials.

First, samples of the material to be studied are selected and prepared, ensuring they have appropriate dimensions and flat surfaces for optimal contact with the sensor. Next, the KD2 Pro uses a thermal-conductivity sensor that is inserted into the sample. This sensor is heated, and the variation in temperature is measured over time. During the test, the sensor injects heat into the material and records how that heat transfers through it, logging both the initial temperature and the temperature of the sensor at regular intervals.

From the temperature measurements and the elapsed time, thermal conductivity (λ) can be calculated using Fourier's law of heat conduction, which relates heat flow to the temperature difference and the thickness of the material. Finally, the results are analyzed to determine thermal conductivity, thermal resistance, and other related parameters, allowing for an evaluation of the thermal behavior of the material under specific conditions.

Initial tests to determine the Heat Transfer Coefficients in the hybrid typology were conducted using the KD2 Pro Thermal Conductivity Meter and the SH-1 Sensor. Additionally, Thermal Diffusivity (α) in mm^2/s was measured, necessary for subsequent analyses, along with values for Thermal Conductivity (λ) in W/m·K, Thermal Resistance (ρ) in °C·cm/W, Specific Heat (C) in MJ/m^3K, and measurement Error (Err), including the initial temperature of the sample (Temp) in ℃, for materials such as wood, bamboo, and clay-sand mixtures. The value for the Thermal Diffusivity Coefficient of the cement-sand mortar was sourced from [17].

To ensure a robust methodological foundation, this study explicitly addresses its ontological, epistemological, and axiological stance, aligning them with the research objectives and design [18]:

- This research adopts a realist ontological stance, recognizing the physical and measurable properties of traditional housing materials, such as adobe, while acknowledging the social and cultural factors influencing their use. This dual perspective allows for an objective analysis of thermal properties alongside a contextual understanding of the inhabitants' experiences and preferences.
- The study operates under a pragmatic epistemology, combining positivist and interpretivist approaches to address the research problem comprehensively. Quantitative measurements of thermal performance provide objective data, while qualitative insights gathered through surveys and interviews reflect the subjective experiences and values of the residents. This mixed-method approach ensures a holistic understanding of the housing typologies under investigation.
- Given the practical focus of the study, the overarching research paradigm is pragmatism. This paradigm supports the integration of diverse methods to address complex, real-world issues, such as improving thermal comfort and sustainability in rural housing. By adopting pragmatism, the study prioritizes actionable outcomes while remaining sensitive to contextual variables.

Table 1. Information about population and houses in the area [15]

	Population	Population in poverty (extreme)	Population in houses without services	Population in houses without services	Vernacular houses	Population living in fragile housing
Jimenez	6375	405	489	161	100	52
San Carlos	7411	1306	626	626	800	285
Jaumave	15994	2260	5723	1340	400	104
Ocampo	13190	1322	5365	1090	400	127
Tula	28230	3805	10335	1339	200	47
Hidalgo	17012	2466	4700	1356	500	201
				Total:	2400	816

- This research employs a predominantly inductive approach, allowing findings to emerge from the data collected on thermal performance and resident perspectives. Elements of deduction are also presented, as the study tests existing theories on the effectiveness of adobe as a sustainable construction material. Where unexpected patterns or phenomena are identified, an abductive approach is used to generate plausible explanations, enriching the overall analysis.

2.1. Distribution of Housing Types in the Study

The survey conducted covered 580 rural residential houses in the municipalities of Jaumave and San Carlos. Of these, approximately 42% are houses built with some traditional materials, such as adobe and stone or partial brick-vernacular materials, while the remaining 58% use industrialized materials, such as concrete blocks and metal roofing.

Within the group of traditional residential houses, three main categories were identified:

1. Stabilized adobe or earthen construction: Represents 24% of the total houses studied. This type combines earth with cement or lime, improving its mechanical strength and reducing its vulnerability to moisture.
2. Traditional adobe: Made from a mixture of earth, water, and plant fibers or additives, it accounts for 12% of the houses. These structures are known for their low cost and ease of construction, though they require periodic maintenance.
3. Stone and ashlar constructions: Used in 6% of the houses, these techniques combine local materials with compacted earth, offering greater durability.

In contrast, industrialized residential houses present disadvantages in terms of thermal insulation and environmental sustainability. For example, houses with concrete blocks tend to generate higher energy costs due to their low thermal regulation capacity.

The observed distribution reflects how economic limitations and access to materials determine construction choices. This highlights the need to promote solutions that integrate the benefits of traditional techniques with the advantages of modern materials.

3. Results

The findings reveal that adobe houses in Tamaulipas maintain more stable indoor temperatures compared to modern constructions. The insulating properties of earth and the organic materials utilized in adobe contribute to reduced energy consumption for climate control. Interviews indicated a preference for this construction method, attributed not only to its efficiency but also to its cost-effectiveness and harmonious integration with the local environment.

Despite advancements in modern construction, traditional techniques remain valued for their environmental and economic benefits. The incorporation of bioclimatic design strategies, as suggested by Montes et al. [3], could further enhance the performance of these houses in response to natural phenomena. The acknowledgment of materials such as bamboo [4] may also open new avenues for innovation in rural construction.

Two specific traditional housing types were reported in Tamaulipas based on this research.

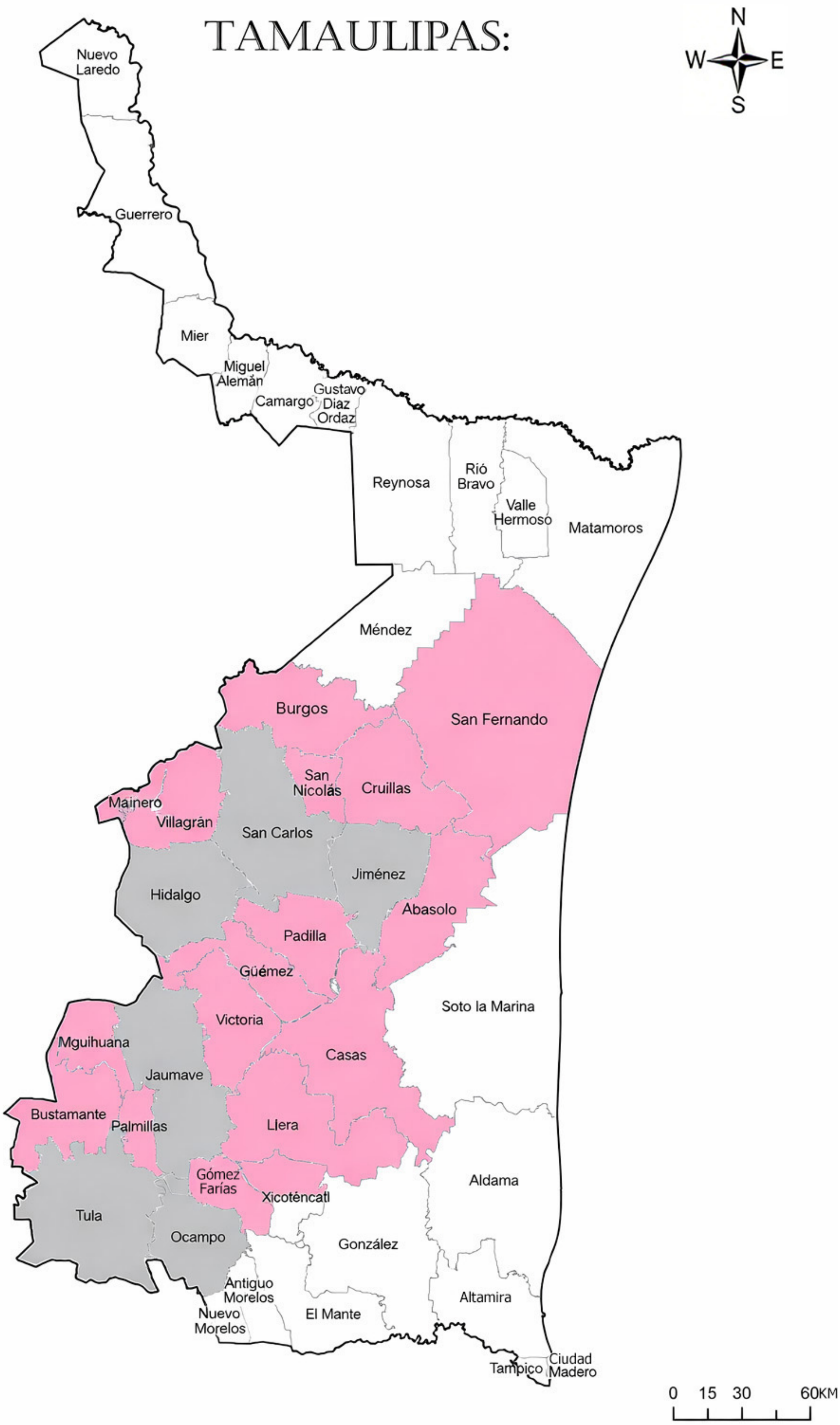
The evaluation of construction systems in traditional housing—excluding the Huasteca style from the southern part of the state—is presented in Figure 1. It reveals a diversification in material use that directly impacts comfort levels. Houses constructed with adobe and those using sillar and stone were identified, facilitating a comparative framework for analyzing the thermal and structural properties of each material.

Adobe houses, exhibiting a thermal mass exceeding 800 kg/m³, demonstrate a notable capacity for internal temperature regulation. Research indicates that adobe walls can reduce indoor temperature fluctuations by 4-6 ℃ compared to the exterior, contributing to a more stable environment in extreme climatic conditions, where temperatures can vary from 10 ℃ in winter to 40 ℃ in summer.

Figure 2 illustrates a roofing system combining palm and sheet metal. This system, with a total thickness of approximately 20 cm (15 cm of palm and 5 cm of sheet metal), achieves a reduction in heat transfer of up to 30-40%, based on thermal conductivity measurements (λ) ranging from 0.05 W/m·K for palm to 0.14 W/m·K for steel metal. Additionally, the roof pitch (5 to 20%) promotes natural ventilation, further improving internal conditions during the day.

Figure 3 displays a combination of sillar and block construction, maintaining an appropriate slope in the roofing. Block structures, with an average thermal conductivity of 1.0 W/m·K, can lead to increased internal temperatures if adequate insulation solutions are not implemented. The corrugated sheet metal used in the roofing, although lightweight, has a thermal transmission index that can raise internal temperatures by up to 5 ℃ during hot periods, potentially compromising comfort levels.

The adaptation of designs shown in Figure 4 employs reinforced concrete, a material with a mass of approximately 2400 kg/m³. While its structural strength is superior, the thermal conductivity of concrete (λ = 1.7 W/m·K) is considerably higher than that of traditional materials, suggesting a potential increase in internal temperatures of 3-7 ℃ during heat waves. This highlights the necessity of incorporating complementary insulation strategies, such as using materials with insulating properties to counteract the effects of concrete.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Camargo
Gustavo Diaz Ordaz
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Rió Bravo
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Aldama
Gómez Farías
Xicoténcatl
Tula
Ocampo
González
Antiguo Morelos
Altamira
Nuevo Morelos
El Mante
Tampico
Ciudad Madero
0 15 30 60KM

a)

b) c)

Figure 1. a) the analyzed zones (Source drawn up by the author, based on maps on [16]), and b) indicating the type of housing examined (Source: Photos were taken by the author)

Figure 2. An example of a palm roof covered with sheet metal for enhanced durability. (Source: Photos were taken by the author)

Figure 3. The material combination in traditional housing with an appropriate slope (Source: Photos were taken by the author)

Figure 4. The adapted housing designs incorporating industrial materials (Source: Photos were taken by the author)

3.1. Plant Analysis

After surveying the municipalities shown in Figure 1a, a total of over 580 rural houses were examined using a non-probabilistic sampling method. The municipalities highlighted in gray contained the two selected types of housing, both featuring a rectangular floor plan with dimensions ranging from 6 to 10 meters in length and 4 to 7 meters in depth. In cases where the walls were made of adobe, the average thickness was found to be 45 cm, with some walls reaching up to 60 cm thick. The municipalities marked in pink on the map displayed similar traditional houses (Figure 1a), but these were built using a system based on sillar stone.

In most cases, there was a maximum of one window, and the interior spaces were open without physical divisions. Sanitary facilities were located outside the houses.

It is important to note that while earth construction techniques in South of Tamaulipas are strongly influenced by the Huasteca region, the central and northern parts of the state do not share this cultural heritage. As a result, traditional housing in these areas exhibits distinct characteristics. However, in the southern part of the state, which also falls within the Huasteca zone, we can observe the two housing typologies reported in this paper. This highlights the diversity of architectural practices across the state, reflecting both regional variations and the adaptation of building techniques to local conditions.

Figure 2 features roofs constructed with a bamboo framework, covered with palm to a thickness of 15 to 20 cm. Subsequently, a layer of sheet metal is applied to prevent water penetration. The palm significantly reduces heat transfer, providing greater comfort at the roof level, especially in gabled roofs that retain heat at the highest point.

In Figure 3, the maintained slope of the roof is evident, even with changes in materials, featuring a roof constructed with corrugated sheet metal.

Figure 4 presents roofing solutions employing both corrugated materials and concrete. Notably, the left side of Figure 4 features a reinforced concrete wall system with columns extending to the roof level.

In general, it can be observed that traditional housing in the non-Huastec municipalities of the State of Tamaulipas (central and northern regions) is characterized by the construction of houses made of adobe or stone, featuring a square floor plan. These dwellings are primarily intended for living and sleeping activities, complemented by backyards that accommodate additional services and recreational activities. Adaptations in various areas have maintained a consistent design principle [11]: a square layout, gable roofs, and minimal or no presence of windows, as shown in Figure 5. In addition, thermal properties show improvements in relation to thermal insulation. Table 2 shows thermal properties of the material composition of structural compounds, usually used in traditional houses obtained by the experiment application.

Recovering traditional housing, due to the nature of the architectural construction system, demonstrates possibilities for sustainability, as observed in other areas of the country [12,13].

3.2. Discussion on Thermal Diffusivity and Specific Heat of Construction Materials

Understanding the thermal properties of materials is necessary for the design of energy-efficient buildings. This study evaluated the thermal diffusivity and specific heat of various materials, including different types of adobe and concrete. The following section discusses the results related to these properties.

Table 1 presents the experimentally measured thermal properties of various materials used in traditional houses in Tamaulipas, as assessed during this study for the two housing types analyzed in this paper.

Based on the obtained results and applying the models found in [14], it is observed that the temperature difference exceeds 10 ℃ between the exterior and interior when outside temperatures are high, with a minimum difference of 5 ℃. The behavior visible from the results shown in Table 1 indicates that, when combined with the thicknesses of the construction elements (a minimum of 40cm for walls and up to 80cm, and roofs with a thickness of up to 20cm), there is a high level of comfort for the occupants.

Thermal properties of materials measured during the study are directly linked to the performance of traditional homes in Tamaulipas. These properties—such as thermal conductivity, diffusivity, and specific heat—explain the capacity of materials like adobe and palm to regulate internal temperatures effectively. For instance, the lower thermal diffusivity and higher specific heat of adobe compared to concrete result in more stable indoor temperatures, aligning with the observations of reduced temperature fluctuations in traditional homes. This connection underscores the importance of material properties in determining the thermal comfort and energy efficiency of the housing types analyzed.

3.2.1. Thermal Diffusivity

Thermal diffusivity, measured in mm^2/s, indicates the rate at which heat propagates through a material. In this analysis, concrete exhibits a value of 0.947 mm^2/s, surpassing that of adobe materials. Compact clay adobe and stabilized adobe show diffusivities of 0.314 mm^2/s and 0.317 mm^2/s, respectively, while traditional adobe has a value of 0.275 mm^2/s, and palm roofing presents a value of 0.297 mm^2/s.

These results indicate that while concrete allows for rapid heat propagation, adobe materials respond more gradually to thermal changes. This characteristic may be advantageous in climates where a more gradual thermal regulation is desired, minimizing abrupt temperature fluctuations in interior spaces.

3.2.2. Specific Heat

Specific heat, measured in MJ/m^3K, is essential for assessing a material's capacity to store thermal energy. Concrete exhibits a specific heat of 1.298 MJ/m^3K, while adobe materials show higher values, with stabilized adobe reaching 1.920 MJ/m^3K and compact clay adobe at 1.569 MJ/m^3K. The palm roofing has a lower specific heat of 0.442 MJ/m^3K.

In Figure 6, we find the results for applications of properties in Table 1, for the expected temperatures for the 3 materials: Concrete, Compact clay from San Carlos, and Adobe from Jaumave Material, according to the theoretical model [14].

The three materials (concrete, adobe from Jaumave, and compact clay from San Carlos) exhibit significant differences in their thermal response. Concrete has the highest thermal inertia, reaching its peak temperature (33.33 ℃) hours after the ambient temperature peak, making it ideal for slowly releasing heat and mitigating thermal fluctuations (if needed). Adobe shows a more moderate response, with lower thermal amplitude than concrete and a maximum temperature of 28.55 ℃, making it suitable for warm, dry climates. Compact clay, on the other hand, has the smallest daily thermal variation, reflecting its excellent insulation capacity and thermal stability, making it ideal for regions with extreme temperatures. These differences show the potential of concrete for thermal storage, adobe for thermal moderation, and compact clay for insulation in various climatic applications.

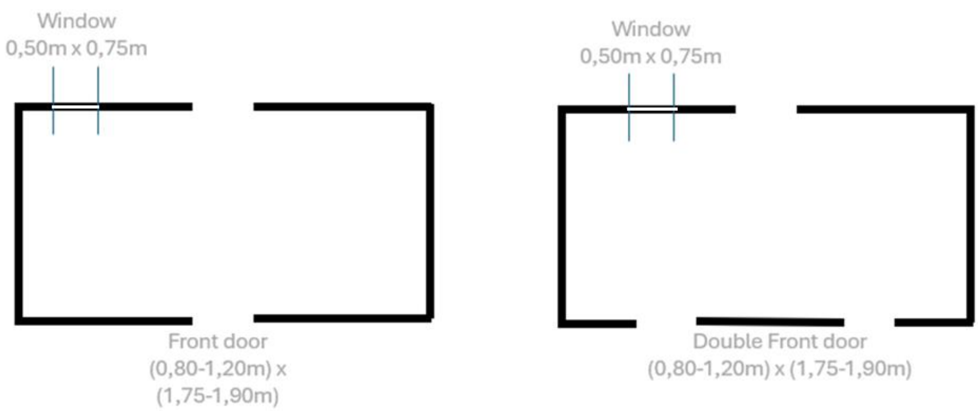

Figure 5. The average plans in traditional house in Tamaulipas. Source: drawn up by the author

Table 2. Thermal properties found for the material composition of structural compounds in traditional house obtained by the experimental application.

Material	Thermal Diffusivity (mm^2/s)	Thermal Resistivity (℃ cm/W)	Thermal Conductivity (W/m K)	Specific Heat (MJ/m^3K)
Compact Clay Adobe	0.314	203	0.492	1.569
Stabilized Adobe	0.317	164.3	0.609	1.920
Traditional Adobe	0.275	233.0	0.429	1.559
Palm Roof	0.297	761.4	0.131	0.442
Concrete [1]	0.947	40.70	2.411	1.298

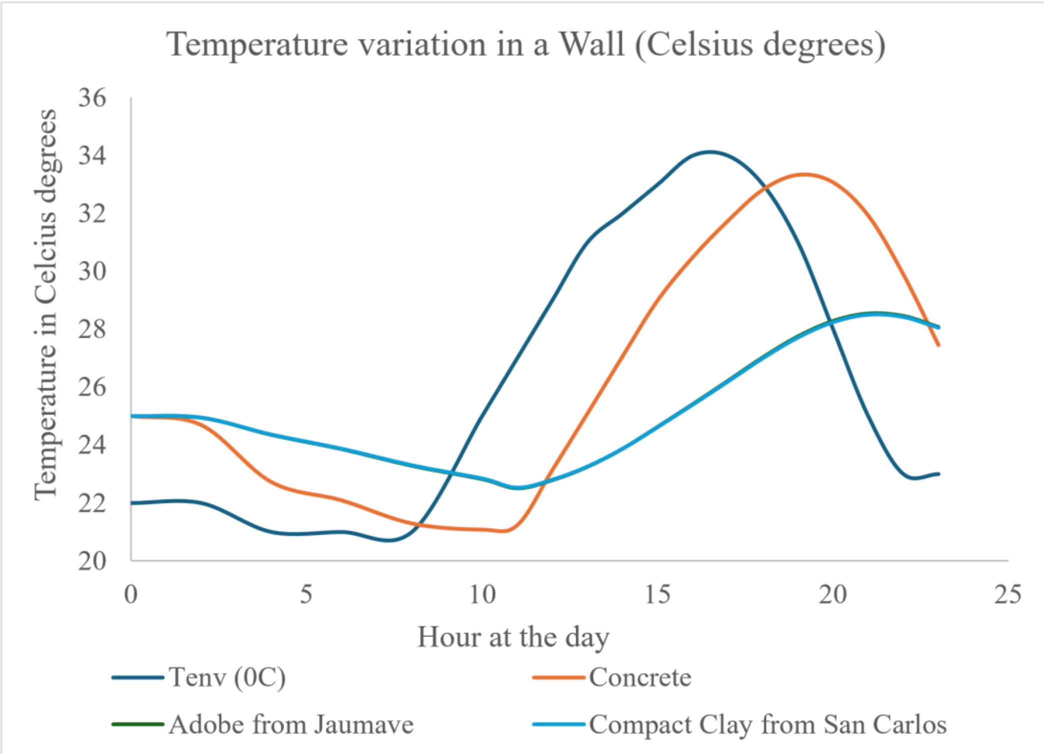

Figure 6. Results of model application applied to the results obtained with three materials

3.3. Sustainability implications

The study on the sustainable thermal performance of traditional earth housing in Tamaulipas is deeply aligned with several Sustainable Development Goals (SDGs), highlighting its relevance in terms of sustainability, climate adaptation, and poverty alleviation.

As an example, Jaumave and San Carlos municipalities show a high poverty level and the requirements of major and better houses [11,15]. This research emphasizes the importance of traditional construction techniques, such as adobe, which promote the use of local and sustainable materials. These practices not only help preserve cultural heritage but also contribute to creating livable and sustainable environments, aligning with the goal of ensuring access to safe and affordable housing.

By demonstrating that adobe houses maintain stable indoor temperatures and reduce energy consumption, the study supports practices that help mitigate climate change. The integration of bioclimatic design strategies enhances the resilience of these homes against extreme climatic events, fostering communities that are better equipped to adapt to climate variability.

Implementing traditional construction methods can be economically viable by using materials near the developed house, providing affordable housing solutions for communities facing poverty. By reducing reliance on artificial climate control and utilizing local resources, these techniques enable families to save on energy and maintenance costs, improving their quality of life and contributing to poverty reduction.

The focus on earth housing in Tamaulipas reflects a model of sustainable development that integrates environmental, economic, and social considerations. The use of local materials, such as earth and plant fibers, not only minimizes the carbon footprint of construction but also promotes the local economy and community well-being.

The benefits for poverty alleviation include energy savings, as traditional homes require less energy to maintain comfortable conditions, leading to lower expenses for occupants. Furthermore, the promotion of traditional construction techniques can generate local employment, strengthening regional economies. The accessibility of local materials makes housing construction more attainable, allowing families in poverty to secure dignified living conditions without relying on external resources.

Assuming an average conventional house in Tamaulipas consumes 301 kWh/month, a reduction in heat transfer through walls made of earth materials could lower energy consumption by 60-90 kWh/month, even with just a 1-2 ℃ decrease in temperature. This assumes the elimination of air conditioning needs, which typically operates 2-3 hours per day during peak temperatures. By reducing both heating and cooling demands, we can significantly improve energy efficiency, leading to a better quality of life, especially in low-income communities. The exact savings will vary based on the local climate, material properties, and household energy usage patterns, with larger savings expected in warmer regions. Thermal properties changes demonstrate the potential of traditional construction techniques to offer sustainable energy solutions in vulnerable communities.

3.4. Use of Bamboo in Improving Earth Houses

Bamboo, known for its mechanical strength and flexibility, offers great potential to complement earth homes in Tamaulipas. This material can be used in various ways:

1. Bamboo can be used as a reinforcing element in adobe walls, improving their ability to withstand seismic loads. Studies conducted in regions such as Chiapas have shown that the use of bamboo framing significantly reduces the risk of cracks and structural collapses.
2. By integrating bamboo panels into roofs and walls, the thermal efficiency of homes can be improved. This is especially useful in extreme climates like that of Tamaulipas, where temperatures can fluctuate drastically between day and night.
3. Bamboo is a renewable resource that grows rapidly and requires minimal maintenance. Its local availability could reduce transportation costs and promote local economies by encouraging its cultivation and processing.

To fully leverage these advantages, specific studies need to be conducted on the adaptation of bamboo in the Tamaulipas context. This would include evaluating its durability against local climatic conditions and its compatibility with traditional construction systems. The incorporation of bamboo could represent a bridge between the traditional and the modern, improving the resilience and sustainability of rural houses.

3.5. Original Contribution and Relevance of the Study

This study provides an original contribution by addressing key gaps in the literature regarding the thermal performance and sustainability of adobe housing in Tamaulipas. While it is widely recognized that adobe structures offer thermal stability, this research goes beyond general observations by providing specific, empirical, and regionally grounded evidence.

Key Contributions:

Empirical Quantification: The research quantifies thermal properties such as thermal conductivity, specific heat, and diffusivity of adobe, concrete, and palm roofing. These data fill a significant gap, as such measurements for materials used in Tamaulipas had not been previously documented.

Context-Specific Analysis: By situating the study in rural communities with high poverty levels, it provides insights into how traditional construction can contribute to affordable, energy-efficient housing, particularly in economically constrained areas.

Comparative Insights: The study compares adobe with other construction materials, highlighting its advantages in maintaining stable indoor temperatures with a lower environmental impact. This establishes adobe as a sustainable alternative to modern construction techniques in similar climatic and socioeconomic contexts.

Policy Implications: By linking findings to the Sustainable Development Goals (SDGs), the study offers actionable insights for policymakers and practitioners. It emphasizes the potential of traditional methods in combating climate change, reducing energy consumption, and improving housing conditions for impoverished communities.

3.6. Final Insights

This study highlights the superior thermal performance of traditional houses in Tamaulipas, particularly those constructed with adobe and stabilized adobe. Measurements revealed that adobe walls effectively reduce temperature fluctuations by 4—6 ℃ compared to modern materials like concrete, contributing to greater indoor comfort and lower energy consumption for climate control. Additionally, the use of palm roofs demonstrated significant insulation properties, reducing heat transfer by up to 40%. These findings confirm that traditional construction techniques and materials can offer viable, sustainable solutions for energy-efficient housing, particularly in rural and economically disadvantaged communities.

The findings align with previous studies emphasizing the thermal efficiency of traditional materials such as adobe and bamboo [19,20], and also underscore the advantages of bioclimatic design and local materials in enhancing the sustainability of rural housing. Furthermore, the results corroborate [20,21], which highlighted the high thermal conductivity of industrial materials like concrete compared to natural alternatives. This study extends the existing body of knowledge by providing specific measurements of thermal properties within the context of rural Tamaulipas, offering localized insights into material performance.

3.7. Research Limitations

Despite its contributions, this research has certain limitations. The sample size of 580 rural houses, while informative, may not fully capture the diversity of construction practices across the region. Analysis of inner temperature was theoretically solved with a model validated for the workgroup over time. Additionally, the scope of the study was limited to thermal performance, leaving structural properties and long-term durability unexamined. Further, the methodological approach relied on data from a specific timeframe, which may not account for seasonal variations in thermal performance. Future research will expand the geographical scope, incorporate longitudinal studies, and explore the integration of modern materials with traditional techniques to develop hybrid solutions for sustainable housing.

4. Conclusions

The results of this research highlight the significant advantages of traditional adobe construction in terms of thermal performance and sustainability, particularly for rural housing in Tamaulipas. The superior thermal properties of adobe, such as its high thermal mass (over 800 kg/m³), contribute to efficient internal temperature regulation, reducing temperature fluctuations by 4-6 ℃ compared to the exterior. These materials not only provide a stable indoor environment but also reduce reliance on artificial heating and cooling systems, leading to lower energy consumption and a smaller environmental footprint for houses.

Despite the prevalence of modern construction methods, this study reaffirms the relevance of traditional techniques, which offer both environmental and economic benefits. The combination of adobe with natural materials such as palm for roofing and adobe walls (with an average thickness of 45 cm), can further improve the performance of these homes in extreme climatic conditions, where temperatures range from 10 ℃ in winter to 40 ℃ in summer. The use of these designs has the potential to reduce energy consumption by 30-40%, as observed in roofing systems using palm and metal. Despite the prevalence of modern construction methods, the study reaffirms the relevance of traditional techniques, which provide environmental and economic benefits.

This study also emphasizes the importance of integrating traditional construction techniques into contemporary design, as it can play a crucial role in achieving the Sustainable Development Goals (SDGs), particularly in mitigating climate change and combating poverty. Adobe residential houses are not only more affordable but also promote the use of local resources, boosting regional economies and reducing transportation costs. Traditional houses can be more cost-effective for low-income communities, with up to a 20-30% reduction in energy costs, which improves the quality of life for residents.

Future research will focus on evaluating hybrid designs that combine traditional and modern materials, such as bamboo, which has mechanical strength and flexibility that can enhance the durability and thermal efficiency of houses. Studies will assess the impact of these hybrid solutions on habitability and occupant comfort under varying climatic conditions, with an emphasis on their applicability in rural communities facing poverty. The findings of this study underscore that the use of adobe and local materials can offer sustainable and cost-effective solutions to improve the resilience and efficiency of rural housing, contributing to climate change adaptation and sustainable development in Tamaulipas and similar regions.

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Conflicts of Interest

The authors declare no conflicts of interest.

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