Integrating Hurricane Resilient Technologies into Creole Traditional Architecture. A Case Study in the Archipelago of San Andres, Providencia & Santa Catalina, Colombia.

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CONTENTS

ABSTRACT

The Colombian islands of San Andres, Providencia and Santa Catalina, located in the southwestern Caribbean region, have recently been affected by the latest hurricanes, with repercussions on different scales and aspects such as population, environment and infrastructure. Due to the lack of national regulations for the construction of houses resistant to these phenomena, the housing sector in particular, has suffered serious damage, putting at risk, mainly, the traditional architecture of the Archipelago. This architecture, considered Colombian heritage and protected by different national laws, has been influenced by the Caribbean architecture known as Creole, which evolved and adapted to the different conditions of the Caribbean region, historically prone to hurricanes. Following Hurricane Iota in 2020, which destroyed the majority of the infrastructure of Providencia and Santa Catalina islands and a minor portion of San Andres, the Colombian government proposed and built prototypes for the reconstruction of the Archipelago, which were taken as a case study. Based on this, the lack of nationally protected traditional/creole characteristics and techniques in these prototypes was highlighted. Considering the characteristics of Creole architecture, national and international regulations on hurricane resistance, and the national law protecting the traditional patrimony of the Archipelago, this document aims to propose a housing prototype that integrates the mentioned variables, in addition to contributing to historical research on the Creole legacy at the national and international levels.

Key Words: Creole Architecture, Archipelago of San Andres, Providencia and Santa Catalina, Colombian Patrimony, Hurricane, Hurricane-Resistant Arquitecture, Regulations.

Las islas colombianas de San Andrés, Providencia y Santa Catalina, situadas en el suroeste de la región Caribe, se han visto afectadas recientemente por los últimos huracanes, con repercusiones en diferentes escalas y aspectos como la población, medio ambiente e infraestructura. Debido a la falta de regulaciones nacionales para la construcción de casas resistentes a estos fenómenos, el sector de la vivienda en particular, ha sufrido graves daños, poniendo en riesgo, principalmente, a la arquitectura tradicional del Archipiélago. Esta arquitectura, considerada patrimonio colombiano, y además protegida por diferentes leyes nacionales, ha sido influenciada por la arquitectura caribeña conocida como Creole, la cual evolucionó y se adaptó a las diferentes condiciones de la región Caribe, históricamente propensa a huracanes. Tras el paso del Huracán Iota en 2020, que destruyó la mayor parte de la infraestructura de las islas de Providencia y Santa Catalina y una porción menor de San Andrés, el gobierno colombiano propuso y construyó prototipos para la reconstrucción del Archipiélago, los cuales fueron tomados como caso de estudio. A partir de esto, se puso en evidencia la carencia de características y técnicas tradicionales/creole protegidas a nivel nacional en dichos prototipos. Teniendo en cuenta las características de la arquitectura Creole, la normatividad nacional e internacional sobre resistencia a huracanes, y la ley nacional de protección al patrimonio tradicional del Archipiélago, este documento pretende proponer un prototipo de vivienda que integre las variables mencionadas, además de contribuir a la investigación histórica sobre el legado Creole a nivel nacional e internacional.

Palabras Clave: Arquitectura Creole, Archipiélago de San Andrés, Providencia y Santa Catalina, Patrimonio Colombiano, Huracán, Arquitectura Resistente a Huracanes, Regulaciones.

01

INTRODUCTION

1.1. Framework

The Caribbean region has always been affected by the natural phenomenon of hurricanes. Concurrently, the architectural landscape of this area, recognized as "Creole," has forged its identity, consolidating and evolving in response to the hurricane phenomenon, climatic conditions, and the social dynamics unique to the diverse countries within the Caribbean. This unique architectural heritage has permeated the Archipelago of San Andres, Providencia, and Santa Catalina, becoming recognized in Colombia as "Caribbean/Island architecture" rather than "Creole architecture." Intriguingly, this distinction arises from the absence of literature or studies in the country that interconnect these two architectural styles.

Historically, the Archipelago, situated in the Caribbean region, remained somewhat insulated from the devastating impacts of hurricanes, as their trajectories typically bypassed this area. However, in recent years, exacerbated by the effects of climate change, the Archipelago has experienced an increased vulnerability to these natural disasters. The devastating Hurricane Iota in November 2020, reaching a formidable Category 4 as it passed close to the islands, marked a turning point. This cyclone affected 98% of the infrastructure in Providencia and Santa Catalina islands and significantly impacted San Andres. In response, the government initiated a comprehensive action plan involving the reconstruction of houses, implementing four prototypes specifically designed to withstand Category 4 hurricanes with winds exceeding 250 km/h. One significant issue concerning these prototypes revolved around their construction materials, which diverged from the traditional architecture of the island, going against different Colombian laws that protect this tangible and intangible heritage, which represents the history and identity of the island.. On the other hand, due to the choice of poor-quality materials, they started to show some vulnerabilities even before the subsequent category 1 Hurricane Julia hit the region in October 2022.

Compounded by the historical scarcity of tropical cyclones affecting Colombia, national regulations lacked comprehensive information on hurricane-resistant constructions until recent years, when these phenomena became more regular. Consequently, while current standards include annexes addressing hurricane-resistant structures, there remains a notable lack of literature and official information on this specific type of construction.

1.2. Research Question

Considering the evolution of Creole architecture in the Caribbean, along with the historical impact of hurricanes, can this traditional architecture be integrated with hurricane-resistant construction regulations in the Archipelago of San Andres, Providencia & Santa Catalina?

1.3. Methodology

- ***Investigate*** the historical trajectory of Creole architecture in the Caribbean region and the impact of hurricanes in the area over time.

- ***Comprehend*** the adaptations and evolution of Creole architecture in the Archipelago of San Andres, Providencia and Santa Catalina.

- ***Identify*** the impacts that the last hurricanes, Iota and Julia, had on the Archipelago's infrastructure and the architectural response of the government to this catastrophe as a case study.

- ***Analyze*** the characteristics of traditional Creole architecture and their similarities with the characteristics of hurricane-resistant architecture.

- ***Compare*** the construction requirements for hurricane-resistant architecture, focusing on technological, material and architectural/geometrical features, set forth in the various national and international standards, guidelines and codes with the characteristics of the traditional Creole architecture of the Archipelago.

- ***Propose*** a prototype that integrates the characteristics of traditional Creole architecture with hurricane-resistant requirements, focusing on technological, material and architectural/ geometrical features, according to international and national standards, to mitigate the risk of failure in the event of this phenomena or strong winds in the Archipelago, respecting Colombian laws for the conservation of Creole heritage.

1.4. Contributions

Currently, there are no studies in Colombia that relate the architecture of the Archipelago of San Andres, Providencia, and Santa Catalina with Creole architecture developed in the Caribbean region. However, there is clear evidence of the influence that Caribbean architecture, known as Creole, has had on the islands in various common characteristics and construction techniques transmitted from generation to generation. It leads to a lack of understanding of the value of this architecture, not only in terms of aesthetics (including colors and designs) and the importance of its technical development but also in terms of heritage and inheritance, since not knowing the true origin of these practices and decisions, generates a historical gap.

This Caribbean Creole architecture, which later reached the Archipelago, has been conceptualized and developed since at least the 16th century in areas affected by various natural phenomena, being the first one to face hurricanes on the coasts and islands and earthquakes in the inland parts of the continent, evolving and adapting to them.

On the other hand, official national information on hurricane-resistant construction is scarce. The existing information is presented as appendices in a document of recommendations that draws from the NSR-10 (Colombian Seismic Resistant Construction Regulation governing the country) and international literature addressing this architecture for such phenomena. However, there is no specific national guide focusing on hurricanes that takes into account the conditions of the affected regions and integrates the preservation of architectural heritage with hurricane-resistant construction.

That said, the purpose of the thesis is to highlight through a historical analysis the relationship between the Caribbean Creole architecture and the Raizal architecture of the Archipelago, recognizing the latter as Creole architecture, a Colombian heritage. Likewise, to expose the vulnerability of this region to hurricanes and the need to integrate national and international regulations of construction resistant to these phenomena, for the preservation of such Creole architecture, considering also, the national laws that protect it as part of the tangible and intangible heritage of the nation.

1.5. Presentation

This work unfolds in response to the established research question, proposing a narrative structure that facilitates a comprehensive and logical understanding of the topics under consideration.

Chapter 1 provides a general overview of the issues addressed, outlining the methodology employed throughout this document, as well as the scope of the research and its contributions.

Moving to ***Chapter 2***, the concept of hurricanes is explained, along with their characteristics, their impact on the region through the years, and the role of climate change in shaping these phenomena. Additionally, the national and international construction regulations used in this study are elucidated.

Chapter 3 takes a journey through the history and influence of a distinctive type of architecture known as Creole, which emerged and expanded in the Caribbean region as a response to its distinct climatic and social conditions. Subsequently, it focuses on the Archipelago of San Andres, Providencia, and Santa Catalina-the study area for this thesis. It highlights the Archipelago's features and its connection to the term "Creole" in traditional architecture, exalting its main characteristics and its evolution in the islands. Finally, the national laws that protect this architecture as Colombian tangible and intangible heritage are presented.

Chapter 4 presents the different natural hazards affecting the Archipelago and the impact of the recent hurricanes, Iota in 2020 and Julia in 2022, on the infrastructure and population of the Archipelago. It also introduces and explains the case study, one of the strategies implemented by the Colombian government post-Hurricane Iota for the islands' reconstruction. This involves the proposal of four housing prototypes, their comparison with historic Creole planimetry, and an evaluation of their performance both in the aftermath and during Hurricane Julia two years later.

On this basis, ***Chapter 5*** exposes the weaknesses of wood architecture in the face of strong winds or hurricanes, and the common architectural design strategies along with the best practice for technological construction between Creole Architecture and hurricane-resistant architecture, and the conception of the structure suitable for addressing hurricane-resistant requirements, being the verifications by structural calculations outside the scope of this thesis. Finally, it presents a comparative matrix between the architectural and technical features of these two different architectures.

Finally, ***Chapter 6*** presents the development of the proposed prototype as a synthesis of the main variables addressed throughout the thesis: traditional Creole architecture, national and international regulations for hurricane resistance and national laws for the protection of this architecture as patrimony. This serves as a reference in future research and studies devoted to the most suitable conception of a building that holds the Creole architectural features and is conceived to be endowed with structural elements and details to satisfy hurricane-resistant requirements.

1.6. Limits of the Research

The research project confronted a significant challenge, relying solely on literary sources as the primary means of information due to the impossibility of conducting on-site fieldwork in the Archipelago. This limitation underscored the difficulty of capturing the dynamic and contextual nature of the built environment through written records alone, emphasizing the need for alternative research methodologies that go beyond traditional sources.

Adding to this constraint was the shortage of national guides and documents on hurricane-resistant construction in the Archipelago, leading to a predominance of international literature on this topic. This highlights the importance of creating resources specific to the local context rather than relying on those from other countries.

The research faces a twofold challenge, marked by the absence of both national and international literature addressing Creole architecture. In the context of Colombian heritage, the lack of local discourse on Creole architecture impedes a comprehensive understanding of the nation's cultural legacy. Initiatives aimed at exploring, documenting, and recognizing indigenous architectural traditions within the broader context of national identity are imperative. Simultaneously, the study encounters a scarcity of international literature specifically focused on this architecture in the Caribbean. The historical gap in coverage by very few authors underscores the need for an expanded scholarly focus. Recognizing the Caribbean's distinctive architectural contributions becomes crucial for fostering a more nuanced comprehension of the cultural and historical influences that have shaped the built environment in the region.

The research encountered a substantial challenge in the presented case study due to the absence of official reports and documents detailing the performance of the government-proposed prototypes before and after Hurricane Julia in 2022, representing a considerable challenge in comprehending the efficacy of these prototypes in mitigating the impact of the hurricane.

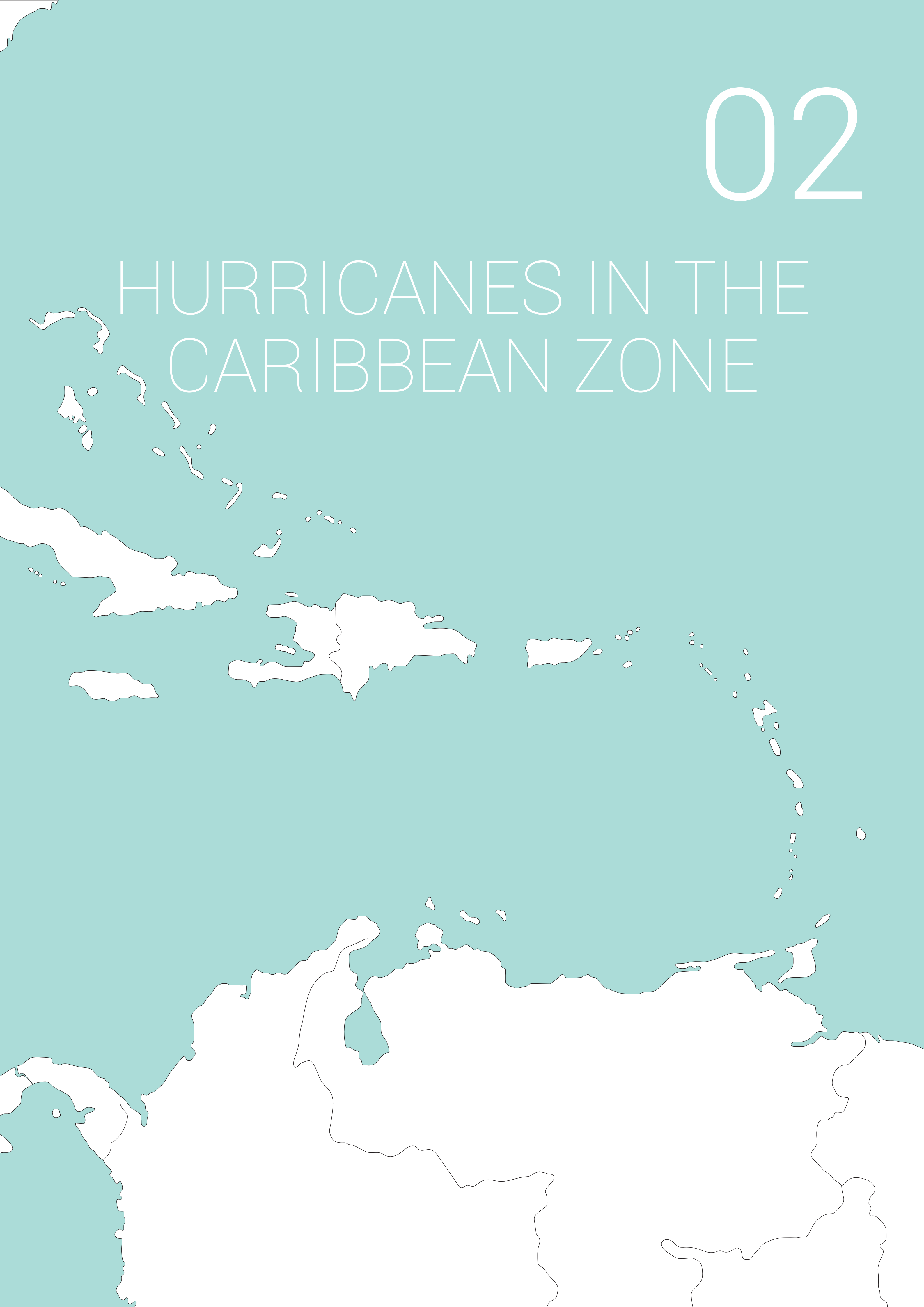
1.7. Next Steps to Develop

In outlining the next steps for development, a twofold approach emerges that intertwines the exploration of Creole architecture as a historical and cultural heritage in both Colombia and the Caribbean. Concurrently, there is a crucial need to address the construction challenges posed by environmental factors, particularly hurricanes, in designated areas. By initiating comprehensive national and international research on Creole architecture, the groundwork is laid for an in-depth understanding of the historical and technical evolution embedded in these architectural practices, and for the development of new literature on the subject.

Simultaneously, as an integral facet of this comprehensive strategy, the formulation of official national documents in Colombia becomes imperative. These documents should specifically focus on guiding the construction of hurricane-resistant infrastructure in regions susceptible to such natural phenomena. By incorporating insights from researched Creole architecture, alongside international best practices for hurricane-resistant construction, into these official guidelines, a balanced integration emerges between preserving cultural heritage and ensuring the resilience of future architectural developments. This dual approach not only contributes to the scholarly discourse on Creole architecture but also provides practical tools for sustainable construction practices, reflecting an integral view for the next steps in architectural development.

02

HURRICANES IN THE CARIBBEAN ZONE



2.1. Hurricanes

As per the World Meteorological Organization (WMO, 2022) and the National Oceanic and Atmospheric Administration (NOAA, 2020), hurricanes, also known generically as tropical cyclones, are weather phenomena characterized by low-pressure systems and organized thunderstorm activity. They originate over tropical or subtropical seas, drawing energy from warm ocean waters. Typically, their diameter ranges from approximately 200 to 500 kilometers, though in some cases, they can expand to a width of up to 1000 kilometers. These tropical cyclones bring about extremely forceful winds, heavy rainfall, towering waves, and, in certain instances, highly destructive storm surges and coastal inundation.

The direction of the winds in a tropical cyclone follows a counterclockwise pattern in the Northern Hemisphere and a clockwise pattern in the Southern Hemisphere. This rotation leads to the development of the distinctive “eye” of the hurricane—a serene and clear central region within the storm. The eyewall, where winds are most intense, surrounds the eye (NOAA, 2020; WMO, 2022).

Hurricanes, typhoons, and cyclones all belong to the same storm category but bear different names based on where they formed. In the North Atlantic and central and eastern North Pacific, these storms are called “hurricanes”, in the western North Pacific “typhoons”, and, in the South Pacific and Indian Ocean “cyclones,” in accordance with NOAA (2020), and WMO (2022).

2.1.1. Hurricanes Classification

Tropical cyclones are classified by their maximum wind speed (Simpson, 1974; NHC, 2012):

Tropical Depression: “A tropical cyclone in which the maximum sustained surface wind speed is 33 knots (62 km/h) or less” (NHC, 2012). It has a closed circulation of wind and is generally the primary stage of a tropical cyclone.

Tropical Storm: “A tropical cyclone in which the maximum sustained surface wind speed between 34-63 knots (63-118 km/h)” (NHC, 2012). At this level, a name is assigned to it, which it retains until the end of the phenomenon; the initial of the name allows us to know how many of the events of the season have reached the level of storm or hurricane, in addition to allowing their differentiation in the long period.

Hurricane: Tropical cyclone with mean maximum sustained winds equal to or greater than 64 knots (>119 km/h) which is the maximum development stage of tropical cyclones. In turn, hurricanes are subdivided into 5 categories, mainly based on sustained wind speed, known as the Saffir-Simpson scale (Simpson, 19741; NHC, 20122). Said classification additionally associates the potential for damage, which is why in this sense they are grouped into Minor Hurricanes (categories 1 and 2) and Major Hurricanes (categories 3 to 5).

“Once a storm escalates to tropical storm-level winds, it is given a name. The names are chosen by an international committee of the World Meteorological Organization (WMO). Names are reused every six years, although the WMO may retire the name of a particularly deadly or costly storm” (NOAA, 2020).

2.1.2. Saffir-Simpson Hurricane Wind Scale (Categories)

The Saffir-Simpson Hurricane Wind Scale is a rating system ranging from 1 to 5, primarily focused on assessing a hurricane's maximum sustained wind speed. It was created in 1971, "by American engineer Herbert Saffir and American meteorologist Robert Simpson (director of the National Hurricane Center from 1968 to 1973)" (Rafferty, 2023).

It's important to note that the Saffir-Simpson Scale evaluates the hurricane's potential for causing property damage based on its wind speed (measured in kilometers per hour) and storm tide (measured in meters). However, it's important to recognize that this scale does not consider other potentially deadly hazards associated with hurricanes, such as storm surges, heavy rainfall leading to flooding, and tornadoes.

Hurricane category, according to the Saffir-Simpson scale (UNGRD, 2021):

CATEGORY	WINDS (km/h)	STORM TIDE (m)	DATA
1	119-153	1.2-1.5	Minimum. Winds could cause some damage: Well-constructed houses could have damage to the frames of the roofing, shingles, vinyl siding, and gutters. Large tree limbs will snap and shallowly planted trees may be torn. Extensive damage to power lines and utility poles will likely result in outages that could last up to several days.
2	154-177	1.6-2.4	Moderate. Dangerous winds could cause extensive damage: Well-constructed houses could suffer major damage to roofs and side walls. Many shallow planted trees will be uprooted or snapped and will block numerous streets. Nearly complete loss of power is expected with outages that could last from several days to weeks.
3	178-208	2.5-3.6	Extensive. Well built homes may incur major damage or removal of the roof covering. Many trees will be torn or snapped, blocking numerous streets. Electricity and water will not be available for several days or weeks after the storm passes.
4	209-251	3.7-5.4	Extreme. Well-constructed houses can suffer severe damage with loss of most of the roof structure and/or exterior walls. Most of the trees will be uprooted or snapped and power poles will be downed. Downed poles and trees will insulate residential areas. Power loss will last for weeks to possibly months. Most of the area will be uninhabitable for weeks or months.
5	>252	>5.5	Catastrophic. A large percentage of the houses are going to be destroyed, with a total collapse of the roof and walls. Downed poles and trees will isolate residential areas. Power loss will last for weeks to possibly months. Most of the area will be uninhabitable for weeks or months.

Table 1. Hurricane Category: Saffir-Simpson scale. Own elaboration based on: UNGRD, (2021).

"Wind speed is just one of many factors that contribute to a hurricane's impact. Other factors include its track (the site where the storm makes landfall), size, storm structure, rainfall amount, duration, and the vulnerability of the area it affects" (C2ES, 2022).

Illustrative Video: Hurricane Wind Damage: Saffir-Simpson Scale (The COMET Program, 2015).

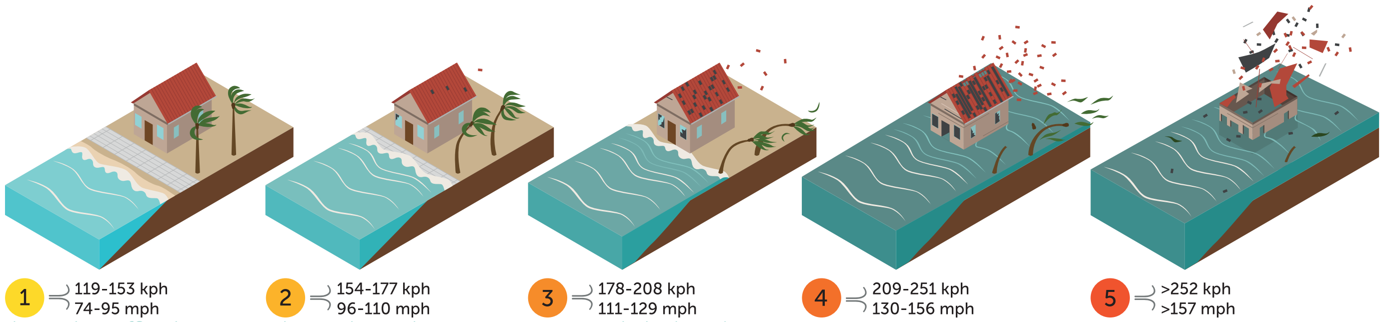


Fig. 1. The Saffir-Simpson scale: Hurricane damage. Source: Revadmin, (2020).

2.2. Climate Change Effects

In the face of ongoing global climate change, the intricate relationship between our warming planet and natural disasters has captured the attention of scientists, policymakers, and the general public. One of the most prominent and concerning aspects of this connection revolves around hurricanes.

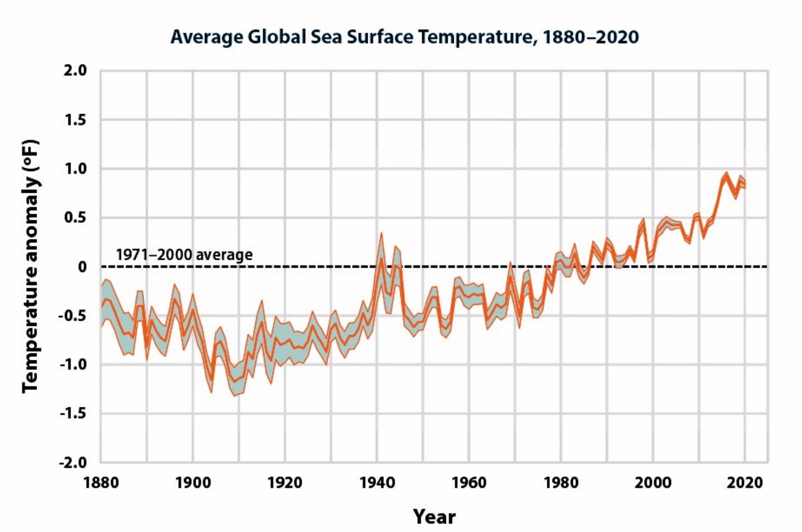
The repercussions of global warming on hurricanes are multifaceted and complex. As the Earth's temperature continues to rise due to human activities, it is becoming increasingly evident that hurricanes are not immune to these changes, allowing them to unleash more intense rainfall, pose a heightened threat of coastal flooding due to surging sea levels and elevate the overall risk associated with these tempestuous cyclones. However, the interaction between global warming and hurricanes is not limited to these immediate impacts. It also extends to the frequency and intensity of these storms (Colbert, 2022).

While some predictions hint at a potential decrease in the overall number of hurricanes on a global scale, others propose that their frequency may remain relatively unchanged. Nevertheless, the critical shift lies in the potential for hurricanes to become more potent when they form. These more intense hurricanes could pose unprecedented challenges in terms of their destructive power and the risks they pose to coastal communities and ecosystems (Colbert, 2022).

Looking back to the 1980s, the hurricane record in the North Atlantic Ocean has borne witness to a more active and formidable period. During this time frame, there has been a discernible increase in both the number of storms and the strength of hurricanes, alongside a notable uptick in the occurrence of hurricanes that undergo rapid intensification. It's important to note that, thus far, many of these alarming trends can be attributed to natural climate variations. However, their implications for the future of hurricane activity in a warming world remain a subject of extensive research and concern (Colbert, 2022).

According to the Center for Climate and Energy Solutions (C2ES), hurricanes are subject to a number of climate change-related influences:

- *Warmer sea surface temperatures* can increase the wind speeds of tropical storms, potentially causing more damage if they make landfall. In the 39 years from 1979 to 2017, the number of large hurricanes increased, while the number of small hurricanes decreased. NOAA predicts an increase in Category 4 and 5 hurricanes, as well as an increase in hurricane wind speeds. Warmer ocean temperatures will also make hurricanes wetter, and storm rainfall is expected to increase by 10-15%. Devastating floods can be triggered by these high-rain hurricanes (C2ES, 2022). Climate change is causing sea surface temperatures to rise around the world, and in the Caribbean and Gulf of Mexico, the water is consistently about 2 degrees Fahrenheit hotter than it was a century ago (NCEI, 2023).



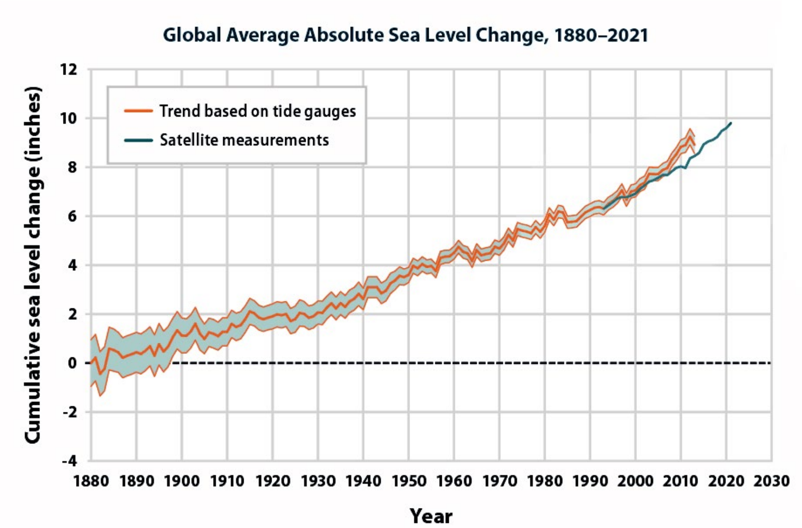
NOTES

"This graph shows how the average surface temperature of the world's oceans has changed since 1880. This graph uses the 1971 to 2000 average as a baseline for depicting change. Choosing a different baseline period would not change the shape of the data over time. The shadded band shows the range of uncertainty in the data, based on the number of measurements collected and the precision of the methods used".

DATA SOURCE
NOAA, 2021

Fig. 2. Own elaboration based on: USEPA, (2021).

- *Sea level rise* is already making coastal storms more destructive, and they are expected to continue to intensify. Global average sea levels have risen more than half a foot since 1900, and are expected to rise 1 to 2.5 feet this century. Coastal areas will be hardest hit. Rising sea levels have increased the risk of coastal flooding and exacerbated the effects of several recent storms. A Hurricane Katrina study estimated that sea-level rise caused flooding 15-60% greater than the 1900 climate (C2ES, 2022).



NOTES

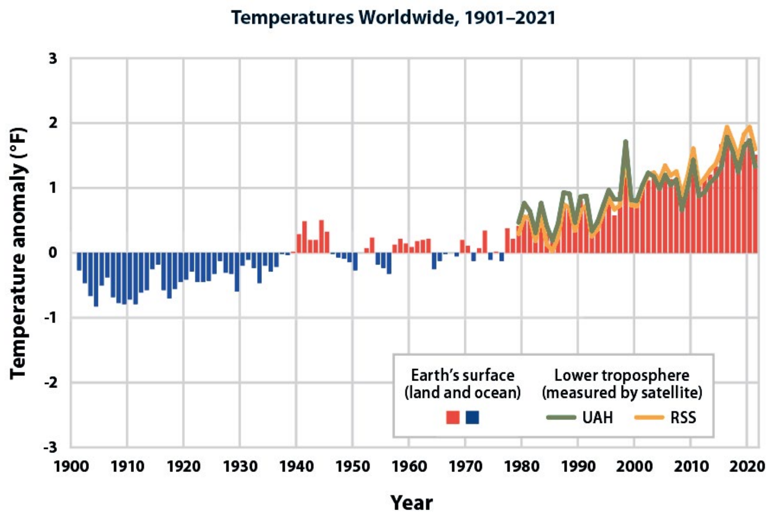
"This graph shows cumulative changes in sea level for the word's oceans since 1880, based on a combination of long-term tide gauge measurements and recent satellite measurements. This figure shows average absolute sea level change, which refers to the height of the ocean surface, regardless of whether nearby land is rising or falling. Satellite data are based solely on measured sea level, while the long-term tide gauge data include a small correction factor because the size and shape of the oceans are changing slowly over time. (On average, the ocean floor has been gradually sinking since the last Ice Age peak, 20.000 years ago.) The shaded band shows the likely range of values, based on the number of measurements collected and the precision of the methods used".

DATA SOURCE
CSIRO, 2017; NOAA, 2022

Fig. 3. Own elaboration based on: USEPA, (2022).

- As the temperature of the Earth changes, so does sea level. Temperature and sea level are linked for two main reasons:
  - Changes in the volume of water and ice on land (namely glaciers and ice sheets) can increase or decrease the volume of water in the ocean.
  - As water warms, it expands slightly—an effect that is cumulative over the entire depth of the oceans (EPA, 2022).

- *Changes in the atmosphere,* such as Arctic warming, may be contributing to other trends seen in hurricane records. Today's hurricanes are moving more slowly than in the past. Although the mechanisms behind this slowdown remain controversial, it is clear that storms are "stalling" and exposing coastal areas to higher rainfall and longer periods of strong wind and storm surges (C2ES, 2022).



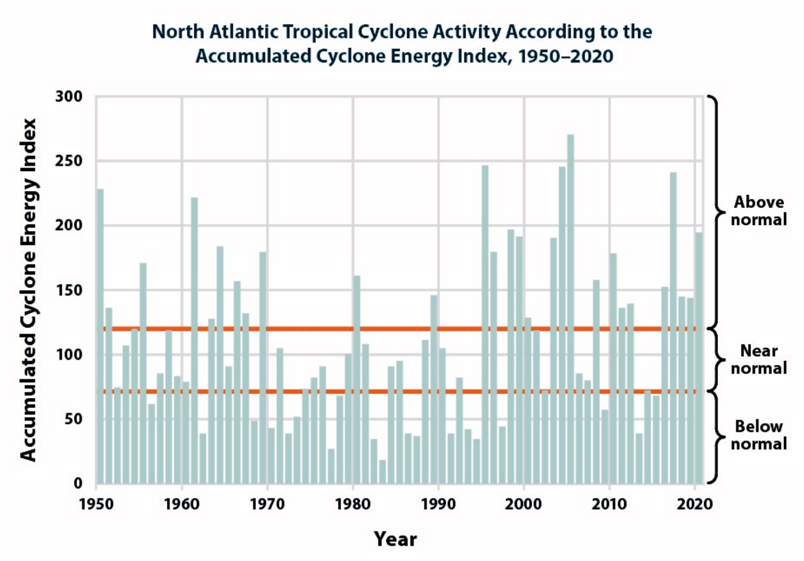
NOTES

"This figure shows how annual average temperatures worldwide have changed since 1901. Surface data come from a combined set of land-based weather stations and sea surface temperature measurements. Satellite measurements cover the lower troposphere, which is the lowest level of the Earth's atmosphere. "UAH" and "RSS" represent two different methods of analyzing the original satellite measurements. This graph uses the 1901-2000 average as a baseline for depicting change. Choosing a different baseline period would not change the shape of the data over time".

DATA SOURCE
NOAA, 2022

Fig. 4. Own elaboration based on: USEPA, (2022).

- *The warming of mid-latitudes may be changing the pattern of tropical storms,* leading to more storms occurring at higher latitudes. A northward bias, where storms reach their greatest intensity, is seen in the Pacific Ocean, but not in the North Atlantic, where hurricanes form that approach the Gulf of Mexico and the East Coast. This shift could put more lives and property at risk, but more research is needed to better understand how hurricane paths may change (C2ES, 2022).



NOTES

"This figure shows total annual Accumulated Cyclone Energy (ACE) Index values, which account for cyclone strength, duration, and frequency, from 1950 through 2020. The National Oceanic and Atmospheric Administration has defined "near normal", "above normal", and "below normal" ranges based on the distribution of ACE Index values over the 30 years from 1981 to 2010".

DATA SOURCE
NOAA, 2021

Fig. 5. Own elaboration based on: USEPA, (2021).

Scientists are currently uncertain whether there will be a change in the number of hurricanes, but they are certain that the intensity and severity of hurricanes will continue to increase.

The intensification of hurricanes leads to greater destruction of infrastructure, houses, and businesses, resulting in a significant rise in the overall cost of hurricanes. The increased risk to human safety is equally distressing since stronger hurricanes provide a greater chance of harm and fatalities (C2ES, 2022). These patterns highlight the critical need for thorough disaster planning, efficient emergency response strategies, and immediate action to combat climate change and lessen the impact of these devastating weather events.

HURRICANE IOTA 2020

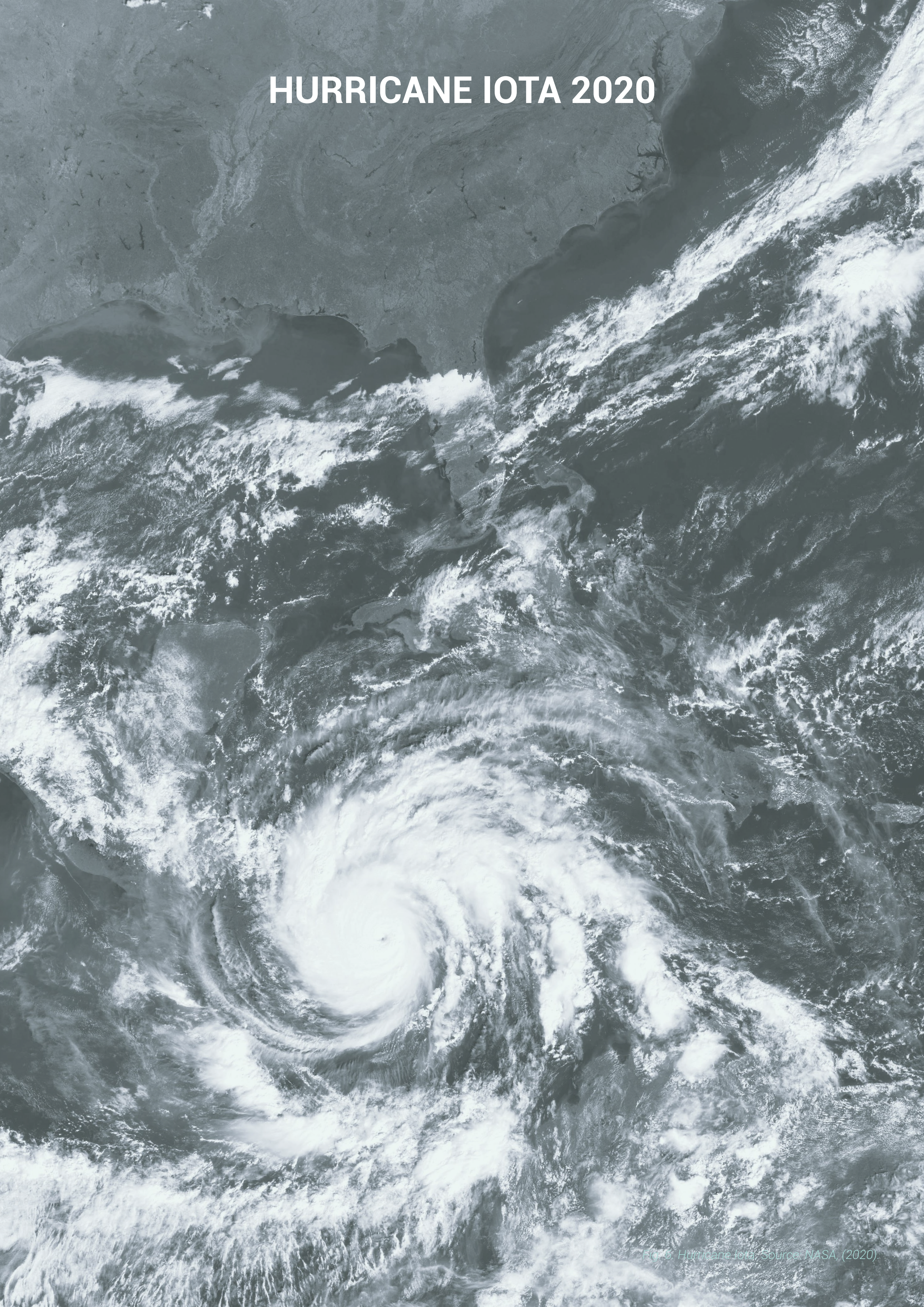


Fig. 6. Hurricane Iota. Source: NASA, (2020).

2.3. Hurricanes through the years: Caribbean Zone

The Caribbean is a geographically and culturally diverse region situated in the northwestern part of the Atlantic Ocean. It is bordered to the north by the Gulf of Mexico and to the south by the northern coasts of South America. The region is renowned for its tropical climate, featuring warm temperatures year-round. However, it is also notorious for its susceptibility to tropical storms and hurricanes, which historically have had a profound impact on the area (Menzies & Ogden, 2023).

This area encompasses coastal regions, nations, and more than 700 islands, islets, reefs, and cays, each with a distinctive character and cultural influence, offering a unique blend of landscapes, cultures, and climates. Some of these islands are the Bahamas, Cuba, Jamaica, Puerto Rico, the Dominican Republic, the Cayman Islands, and the Archipelago of San Andres, Providencia, and Santa Catalina, to name just a few (EMI Global USA, n.d.).

The environment in the Caribbean is exceptionally diverse, including pristine beaches, lush tropical rainforests, vibrant coral reefs, and expansive mangrove ecosystems. This natural richness is coupled with a remarkable variety of architectural styles influenced by the indigenous, European, African, and Asian populations that have shaped the region's history.

Despite its beauty and rich cultural heritage, the Caribbean faces the recurrent challenge of hurricanes (NOAA, n.d.). "Tropical cyclones are like giant engines that use warm, moist air as fuel. That is why they form only over warm ocean waters near the equator. The warm, moist air over the ocean rises upward from near the surface, ... causing an area of lower air pressure below". (NASA, 2019).

"As the warm air continues to rise, the surrounding air swirls in to take its place. As the warmed, moist air rises and cools off, the water in the air forms clouds. The whole system of clouds and wind spins and grows, fed by the ocean's heat and water evaporating from the surface". (NASA, 2019). These contrasts of warm water (about 27°C) and cold air at the surface occur in tropical climates; that is, especially in the Caribbean. For this reason, this region is more sensitive to hurricane formation (Notimérica, 2016).

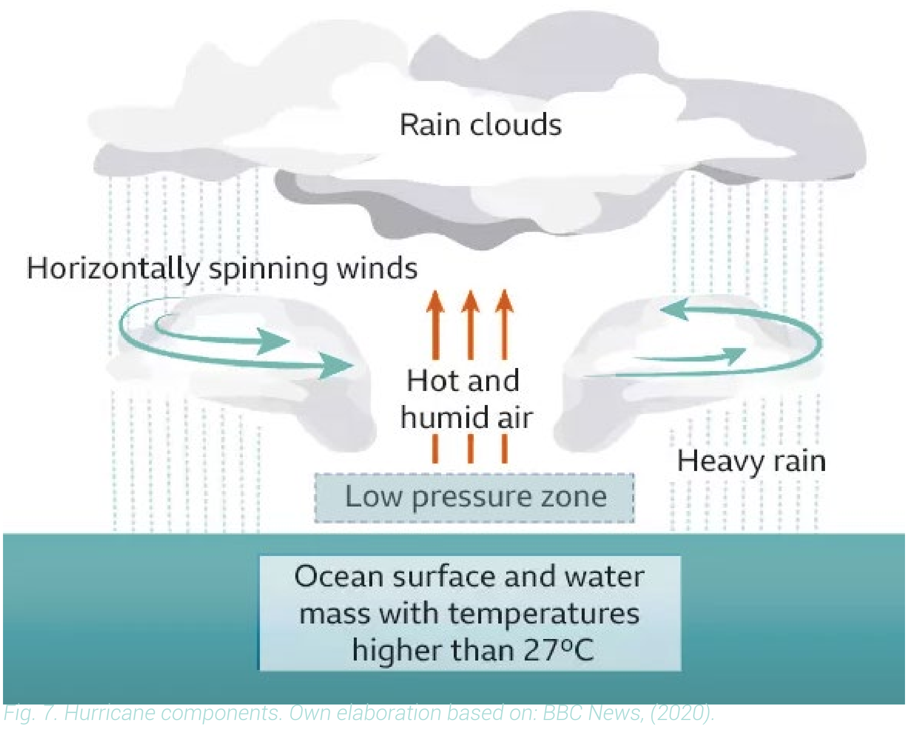


Fig. 7. Hurricane components. Own elaboration based on: BBC News, (2020).

As for the conditions they need to maintain themselves, they are the same as those they need to be created. Hurricanes maintain their maximum power as long as the conditions that feed them exist, that is, over a warm sea. That is why as soon as a hurricane makes landfall it reduces its speed rapidly, since the factors necessary for its subsistence are lost and the friction of the wind against the land surface is greater than on the water, which causes the wind gusts to be reduced (Notimérica, 2016).

Annually, on June 1st, the official hurricane season begins across the Atlantic Ocean, the Caribbean Sea, and the Gulf of Mexico. The season commonly extends until November 30th, a timeline officially established based on historical data, which shows that around 97% of all documented tropical cyclones in history have taken place during this period. However, it's important to note that tropical systems can occasionally develop outside of these designated dates, either before or after the official season (NOAA, 2019).

In recent years, there has been a trend of tropical cyclones forming "prematurely." Indeed, for the past seven consecutive seasons, from 2015 to 2021, tropical cyclones have been documented before the official June 1st start date. As a result, the United States National Hurricane Center (NHC) has now begun to include in its climatology data for the years 1991-2020, and specifically within its annual cycle, the percentage of tropical cyclone occurrences from May through December. Historically, the peak of hurricane activity has typically fallen between mid-August and mid-October, with September 10th being established as the pinnacle of the hurricane season (NHC, n.d.).

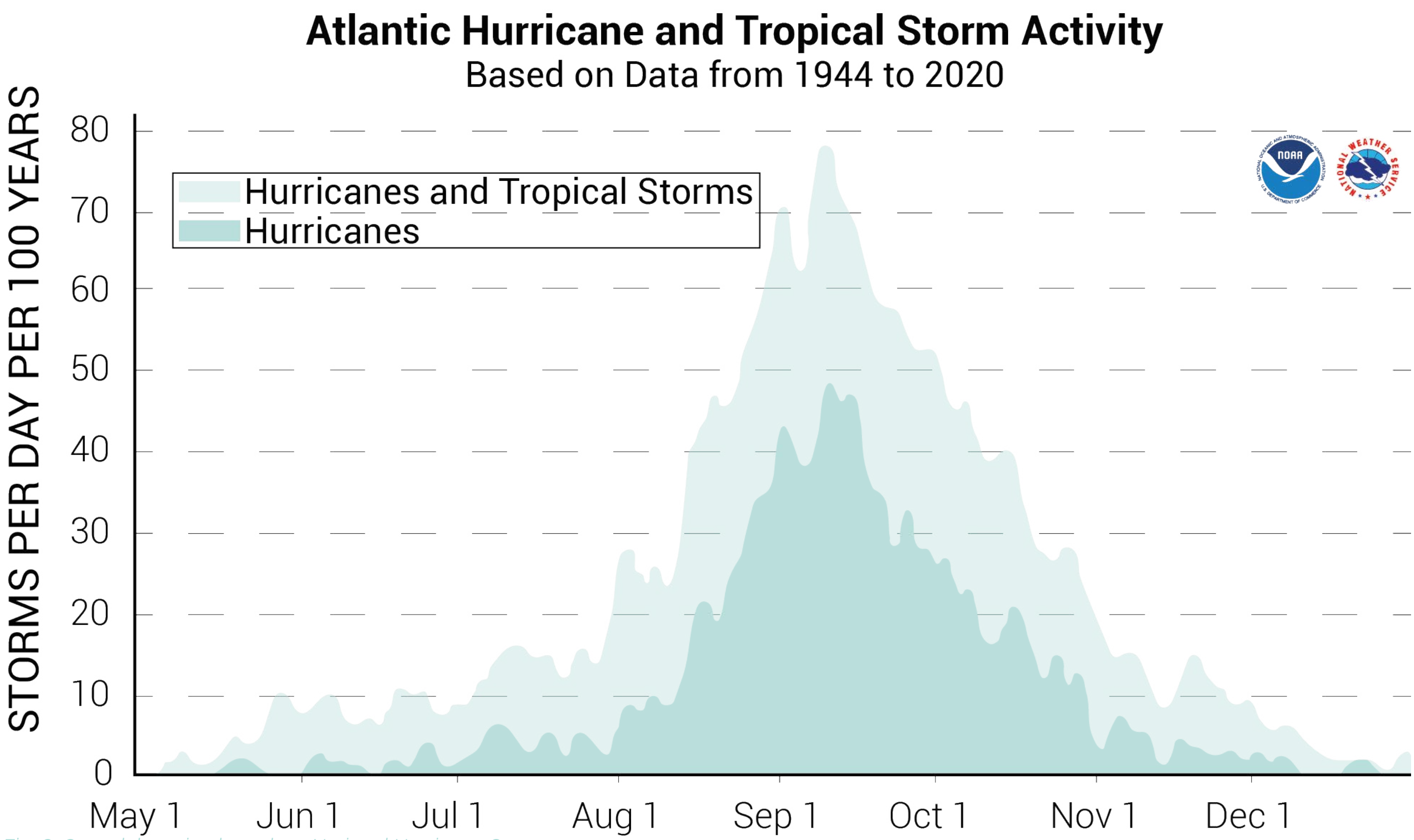


Fig. 8. Own elaboration based on: National Hurricane Center.

The following timeline " Hurricanes in the Caribbean" was compiled from articles with information on each hurricane from the official Wikipedia page:

HURRICANES IN THE CARIBBEAN

Hurricane in Hispaniola, July 1502

Maximum Category: -

Affected zones: Santo Domingo (Hispaniola).

People affected: Approximately 25 ships sank, all crew members perished (around 500 spanish people and an unknown numbers of slaves).

Highest winds: -

Other info: Destroyed completely the city of Santo Domingo, the first american capital founded by Europeans. The city was rebuilt in a new location, on the other side of the Ozama river.

Fig. 9.

The Great Hurricane, October 1780

Maximum Category: Category 4

Affected zones: Lesser Antilles, Puerto Rico, Hispaniola, Bermuda and some U.S. states.

People affected: Approximately 22,000 people died.

Highest winds: 200 mph (325 km/h).

Other info: Often referred to as hurricane "San Calixto" or the "Great Hurricane of the Antilles", it is considered the first hurricane with more fatalities than any other hurricane on record.

Fig. 10.

Hurricane Flora, October 1963

Maximum Category: Category 4

Affected zones: Northern South America, Lesser Antilles, Greater Antilles, Lucayan Archipielago, Bermuda, Eastern Canada.

People affected: Between 7186 and 8000 people died.

Highest winds: Maximum sustained winds of 150 mph (240 km/h) in the Caribbean.

Fig. 11.

Hurricane Gilbert, September 1988

Maximum Category: Category 5

Affected zones: Lesser Antilles, Puerto Rico, Venezuela, Haiti, Dominican Republic, Jamaica, Central America, Yucatán Peninsula, Mexico, Texas, South Central United States, Midwestern United States, Western Canada.

People affected: 318 people died.

Highest winds: 185 mph (295 km/h).

Fig. 15.

Hurricane Joan, October 1988

Maximum Category: Category 4

Affected zones: Windward Islands, ABC islands, Colombia, Venezuela, Costa Rica, Panama, El Salvador, Guatemala, Mexico, Nicaragua.

People affected: Betwen 216-334 people died (as Joan).

Highest winds: Maximum sustained winds of 145 mph (230 km/h) in the Caribbean.

Other info: The storm was renamed Tropical Storm Miriam after moving from Central America into the Pacific, with the system's dissipation occurring southwest of Mexico.

Fig. 16.

Hurricane Georges, September 1998

Maximum Category: Category 4

Affected zones: Leeward Islands, Puerto Rico, Hispaniola, Cuba, Lesser Antilles, Florida Keys, Southeastern Louisiana, Mississippi, Alabama, Florida, Georgia.

People affected: 604 people died, mainly on the island of Hipaniola.

Highest winds: 155 mph (250 km/h).

Other info: Made landfall seven times during its path from the Caribbean Sea to the Gulf of Mexico.

Fig. 17.

HURRICANES IN THE CARIBBEAN

Hurricane Camille, August 1969

Maximum Category: Category 5

Affected zones: Cuba, Yucatán Peninsula, Alabama, Mississippi, Louisiana, Southern United States, Midwestern United States, Eastern Seaboard.

People affected: Approximately 259 people died.

Highest winds: The hurricane's peak 1-minute sustained winds were at a speed of 175 mph (280 km/h).

Other info: Is one of only four Category 5 hurricanes that have made landfall in the continental Unite States (Atlantic Basin).

Fig. 12.

Hurricane Fifi, September 1974

Maximum Category: Category 2

Affected zones: Puerto Rico, Hispaniola, Jamaica, Nicaragua, Honduras, Belize, El Salvador, Guatemala, Mexico, Arizona.

People affected: Around 10000 people died (around 8000 in Honduras).

Highest winds: The hurricane's peak 1-minute sustained winds were at a speed of 110 mph (175 km/h).

Other info: Later known as Hurricane Orlene after regenerating into a new tropical cyclone.

Fig. 13.

Hurricane Allen, August 1980

Maximum Category: Category 5

Affected zones: Lesser Antilles, Puerto Rico, Haiti, Jamaica, Cayman Islands, Yucatán Peninsula, Northern Mexico, Southern Texas.

People affected: Approximately 269 people died.

Highest winds: Achieved sustained winds of 190 mph (305 km/h).

Fig. 14.

Hurricane Mitch, Oct/Nov 1998

Maximum Category: Category 5

Affected zones: Central America (especially Honduras and Nicaragua), Yucatán Peninsula, South Florida, Jamaica, Ireland, United Kingdom.

People affected: At least 22000 people died (caused 11374 fatalities in Central America, including aprox. 7000 in Honduras and 3800 in Nicaragua).

Highest winds: 180 mph (285 km/h).

Other info: It surpassed Hurricane Fifi-Orlene as the deadliest hurricane in Central American history at the time.

Fig. 18.

Hurricane Ivan, September 2004

Maximum Category: Category 5

Affected zones: Windward Islands (especially Grenada), Trinidad and Tobago, Venezuela, Barbados, Jamaica, Hispaniola, Grand Cayman, Cuba, Yucatán Peninsula, Eastern United States, Florida, Alabama, most of the United States Gulf Coast, Canada.

People affected: Approximately 124 people died.

Highest winds: 165 mph (270 km/h).

Fig. 19.

Hurricane Jeanne, September 2004

Maximum Category: Category 3

Affected zones: U.S Virgin Islands, Puerto Rico, Dominican Republic, Haiti, Bahamas, Florida, Eastern United States.

People affected: Approximately 3037 people died.

Highest winds: 120 mph (195 km/h).

Other info: Since Mitch in 1998, it was the deadliest storm to hit the Atlantic basin.

Fig. 20.

HURRICANES IN THE CARIBBEAN

Hurricane Beta, October 2005

Maximum Category: Category 3

Affected zones: San Andrés y Providencia (Colombia), Nicaragua, Honduras.

People affected: Approximately 9 people died.

Highest winds: 121 mph (185 km/h).

Fig. 21.

Hurricane Wilma, October 2005

Maximum Category: Category 5

Affected zones: Jamaica, Puerto Rico, Cuba, Cayman Islands, Central America, Mexico, United States (especially Florida), Bahamas, Bermuda, Nova Scotia, Saint Pierre and Miquelon.

People affected: Approximately 52 people died.

Highest winds: 185 mph (295 km/h).

Other info: Second-most powerful tropical storm ever recorded in the Western Hemisphere and the most intense tropical cyclone ever recorded in the Atlantic basin.

Fig. 22.

Hurricane Felix, September 2007

Maximum Category: Category 5

Affected zones: Trinidad and Tobago, Windward Islands, Venezuela, Leeward Antilles, Aruba, Colombia, Costa Rica, Nicaragua, Honduras, El Salvador, Belize, Guatemala, Mexico.

People affected: Approximately 133 people died.

Highest winds: 175 mph (280 km/h).

Fig. 23.

Hurricane Matthew, Sept/Oct 2016

Maximum Category: Category 5

Affected zones: Windward Islands, Leeward Antilles, Venezuela, Colombia, Greater Antilles, Southeastern United States, Atlantic Canada.

People affected: 603 people died.

Highest winds: 165 mph (270 km/h) in the Caribbean.

Other info: The deadliest Atlantic hurricane since Hurricane Stan in 2005, and the first Category 5 Atlantic hurricane since Felix in 2007.

Fig. 27.

Hurricane Harvey, September 2017

Maximum Category: Category 4

Affected zones: Windward Islands, Suriname, Guyana, Nicaragua, Honduras, Belize, Cayman Islands, Yucatán Peninsula, Southern and Eastern United States (especially Texas and Louisiana).

People affected: Approximately 107 people died.

Highest winds: 130 mph (215 km/h).

Other info: It was the first major hurricane to make landfall in the United States since Wilma in 2005.

Fig. 28.

Hurricane Irma, Aug/Sept 2017

Maximum Category: Category 5

Affected zones: Cape Verde, Leeward Islands, Greater Antilles, Turks and Caicos, Jamaica, The Bahamas, Eastern United States (especially Florida).

People affected: 52 people died directly, 82 people died indirectly (134 total).

Highest winds: 180 mph (285 km/h).

Other info: Was also the third-strongest Atlantic hurricane at landfall ever recorded, just behind the 1935 Labor Day Hurricane and Dorian (2019).

Fig. 29.

HURRICANES IN THE CARIBBEAN

Hurricane Gustav, Aug/Sept 2008

Maximum Category: Category 4

Affected zones: Lesser Antilles, Greater Antilles, United States Gulf Coast, Oklahoma, Arkansas, Tennessee, Missouri, Illinois, Michigan.

People affected: Approximately 153 people died.

Highest winds: 155 mph (250 km/h).

Fig. 24.

Hurricane Irene, August 2011

Maximum Category: Category 3

Affected zones: Hispaniola, Lesser Antilles, Greater Antilles, Turks and Caicos, Bahamas, East Coast of the United States, Vermont, Pennsylvania, Atlantic Canada.

People affected: Approximately 58 people died.

Highest winds: 120 mph (195 km/h).

Fig. 25.

Hurricane Sandy, October 2012

Maximum Category: Category 3

Affected zones: Greater Antilles, Bahamas, most of the eastern United States (especially the coastal Mid-Atlantic States), Bermuda, eastern Canada.

People affected: Approximately 233 people died.

Highest winds: 115 mph (185 km/h).

Other info: Unofficially referred to as Superstorm Sandy. The largest Atlantic hurricane on record as measured by diameter.

Fig. 26.

Hurricane Maria, September 2017

Maximum Category: Category 5

Affected zones: Lesser Antilles (especially Dominica and the U.S. Virgin Islands), Puerto Rico, Dominican Republic, Haiti, Turks and Caicos, The Bahamas, Southeastern United States, Mid-Atlantic States..

People affected: 4725 people died.

Highest winds: 175 mph (280 km/h).

Other info: It is regarded as the worst natural disaster in recorded history to affect Dominica, Saint Croix and Puerto Rico.

Fig. 30.

Hurricane Delta, October 2020

Maximum Category: Category 4

Affected zones: Jamaica, Nicaragua, Cayman Islands, Yucatán Peninsula, Gulf Coast of the United States, Eastern United States.

People affected: Approximately 6 people died.

Highest winds: 140 mph (220 km/h).

Fig. 31.

Hurricane Eta, Oct/Nov 2020

Maximum Category: Category 4

Affected zones: Colombia (San Andres and Providencia), Jamaica, Central America, Cayman Islands, Cuba, The Bahamas, Southeastern United States.

People affected: Approximately 175 people died. >100 people missing.

Highest winds: 150 mph (240 km/h).

Fig. 32.

HURRICANES IN THE CARIBBEAN

Hurricane Iota, November 2020

Maximum Category: Category 5

Affected zones: ABC Islands, Colombia (especially San Andres and Providencia), Jamaica, Central America (particularly Honduras and Nicaragua).

People affected: 84 people died. 41 missing people.

Highest winds: 160 mph (260 km/h).

Other info: Caused significant damage in Central American regions that had already been destroyed by Hurricane Eta two weeks earlier.

Fig. 33.

Hurricane Ian, Sept/oct 2022

Maximum Category: Category 5

Affected zones: Trinidad and Tobago, Venezuela, Colombia, ABC Islands, Jamaica, Cayman Islands, Cuba, Southeast United States (especially Florida and The Carolinas).

People affected: 161 people died. 13 missing people.

Highest winds: 160 mph (260 km/h).

Fig. 34.

Hurricane Julia, October 2022

Maximum Category: Category 1

Affected zones: Trinidad and Tobago, Venezuela, ABC Islands, Colombia, Nicaragua, El Salvador, Honduras, Guatemala, Panama, Mexico.

People affected: 35 people died directly, 54 people died indirectly (89 total).

Highest winds: 85 mph (140 km/h).

Other info: Several days later, Tropical Storm Karl was formed as a result of Julia's residual energy.

Fig. 35.

Physical exposure to cyclones in Latin America and the Caribbean in 2023

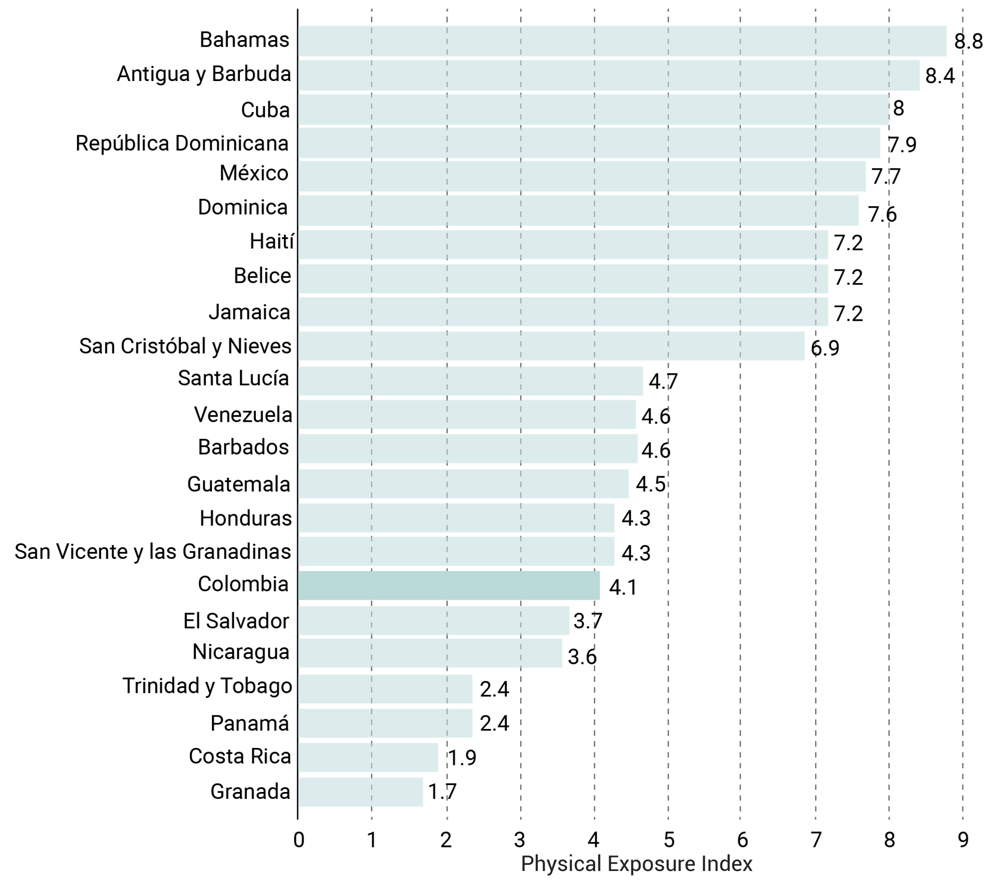


Fig. 36. Own elaboration based on: Statista, (2023).

Records of storms that occurred before 1492 (“discovery” of America) are unavailable due to the absence of documented instances of such phenomena during the pre-Columbian era, and any potential records from that period are lost. The hurricane that struck Hispaniola in 1494 is quite likely the earliest hurricane in the Western Hemisphere to have been observed and reported by Europeans. This is a crucial point in the documentation of meteorological events in the area. However, as moving forward to the year 1500 and beyond, the recorded data clearly illustrates the vulnerability of the Caribbean region to various natural hazards. Tropical cyclones, earthquakes, and volcanic activity become evident as recurring threats, shaping the historical and environmental landscape of the region.

Among these natural hazards, hurricanes have consistently impacted multiple Caribbean states on an annual basis, and they may still be the most prevalent and destructive natural threat that has adversely affected the economies of Caribbean islands for the past 500 years. Tropical cyclones will likely continue to impact several islands each year, influenced by the prevailing storm tracks across the region, geographical characteristics, and orientations of the landmasses.

2.4. National and International Construction Regulations

Due to the impacts that hurricanes have had on infrastructure and constructions in various regions, different countries and organizations have established regulations to ensure they can withstand this type of hazard, thus safeguarding lives to a greater extent.

In the context of construction in Colombia, regulations have historically focused on seismic movements, reflecting the country's geographical characteristics and seismic activity. However, given the increasing incidence and strength of hurricanes in recent years, there has been a recognized need to incorporate specific measures to address this climatic phenomenon. In response to this paradigm shift, appendices to existing documents have been developed, outlining criteria and guidelines aimed at enhancing the resilience of constructions against hurricanes. These appendices, based on international literature, signify the beginning of adapting national regulations to emerging climatic realities.

Given the absence of official documents and guidelines in Colombia specifically addressing issues related to hurricane-resistant construction, a dedicated research initiative, integral to the work presented in this thesis, was undertaken. This investigation primarily drew from international literature, seeking to comprehend the construction criteria employed by countries significantly affected by hurricanes. The goal was to extract insights from established practices that could fortify constructions in the face of these recurrent natural disasters. Additionally, the research delved into guides and codes about wood construction, the primary material in Caribbean architecture. This exploration was crucial as this architecture, known as Creole, has continually adapted and evolved in response to the prevalent hurricane activity in the region. By synthesizing information from international sources and focusing on the unique characteristics of wood construction, the aim is to extract hurrican-resistant requirements as general guideline for the architectural conception of structures in the Colombian context.

National Literature (Colombia):

RESOLUTION NUMBER 0020 OF 2021
“Whereby technical recommendations and guidelines are adopted for the construction of one and two-story houses resistant to winds, hurricanes and earthquakes in the Archipelago of San Andres, Providencia and Santa Catalina”.

The documents entitled "Recommendations and technical guidelines for the construction of one and two story houses resistant to winds, hurricane and earthquake resistant housing in the Archipelago of San Andres, Providencia and Santa Catalina" and "Recommendations for the construction of one and two story housing in wood and encemented bahareque resistant to hurricanes, for the Archipelago of San Andres, Providencia and Santa Catalina, Colombia", are an integral part of this resolution and were developed by the Colombian Association of Seismic Engineering (AIS) according to the Colombian Regulation of Seismic Resistant Construction NSR-10, Title G (For timber structures and guadua structures), after the passage of Hurricane Iota 2020, the highest category hurricane (Category 5) that has passed through the Archipelago since records have been kept.

Codes:

- Asociación Colombiana de Ingeniería Sísmica (2010). Reglamento Colombiano de Construcción Sismo Resistente NSR-10 Tomo 2. Bogota, Colombia: Asociación Colombiana de Ingeniería sísmica.
- Chapter B.6. Wind Forces

Fig. 37.

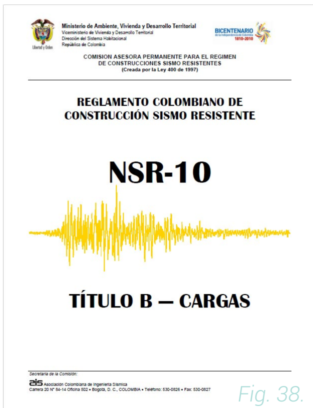
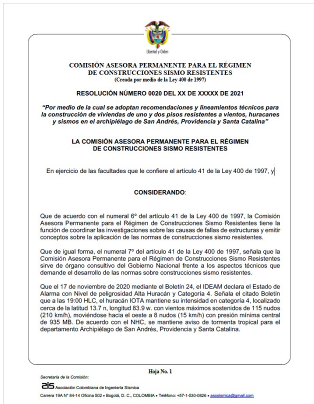


Fig. 38.

Resolution:

- Resolución 0020 de 2021. [Comisión Asesora Permanente para el Régimen de Construcciones Sismo Resistentes.] Por medio de la cual se adoptan recomendaciones y lineamientos técnicos para la construcción de viviendas de uno y dos pisos resistentes a vientos, huracanes y sismos en el archipiélago de San Andrés, Providencia y Santa Catalina. Enero de 2021.


Libertad y Orden

COMISIÓN ASESORA PERMANENTE PARA EL RÉGIMEN DE CONSTRUCCIONES SISMO RESISTENTES
(Creada por medio de la Ley 400 de 1997)

RESOLUCIÓN NÚMERO 0020 DEL XX DE XXXXX DE 2021

"Por medio de la cual se adoptan recomendaciones y lineamientos técnicos para la construcción de viviendas de uno y dos pisos resistentes a vientos, huracanes y sismos en el archipiélago de San Andrés, Providencia y Santa Catalina"

LA COMISIÓN ASESORA PERMANENTE PARA EL RÉGIMEN DE CONSTRUCCIONES SISMO RESISTENTES

En ejercicio de las facultades que le confiere el artículo 41 de la Ley 400 de 1997, y

CONSIDERANDO:

Que de acuerdo con el numeral 6° del artículo 41 de la Ley 400 de 1997, la Comisión Asesora Permanente para el Régimen de Construcciones Sismo Resistentes tiene la función de coordinar las investigaciones sobre las causas de fallas de estructuras y emitir conceptos sobre la aplicación de las normas de construcciones sismo resistentes.

Que de igual forma, el numeral 7° del artículo 41 de la Ley 400 de 1997, señala que la Comisión Asesora Permanente para el Régimen de Construcciones Sismo Resistentes sirve de órgano consultivo del Gobierno Nacional frente a los aspectos técnicos que demande el desarrollo de las normas sobre construcciones sismo resistentes.

Que el 17 de noviembre de 2020 mediante el Boletín 24, el IDEAM declara el Estado de Alarma con Nivel de peligrosidad Alta Huracán y Categoría 4. Señala el citado Boletín que a las 19:00 HLC, el huracán IOTA mantiene su intensidad en categoría 4, localizado cerca de la latitud 13.7 n, longitud 83.9 w. con vientos máximos sostenidos de 115 nudos (210 km/h), moviéndose hacia el oeste a 8 nudos (15 km/h) con presión mínima central de 935 MB. De acuerdo con el NHC, se mantiene aviso de tormenta tropical para el departamento Archipiélago de San Andrés, Providencia y Santa Catalina.

Hoja No. 1

Secretaría de la Comisión:
ais Asociación Colombiana de Ingeniería Sísmica
Carrera 19A N° 84-14 Oficina 502 • Bogotá, D. C., COLOMBIA • Teléfono: +57-1-530-0826 • asosismica@gmail.com

Fig. 39.

Guidelines:

- Asociación Colombiana de Ingeniería sísmica (AIS). (2021). R*ecomendaciones para la construcción de viviendas de uno y dos pisos en madera y bahareque encementado resistentes a huracanes, para el Archipiélago de San Andrés, Providencia y Santa Catalina, Colombia.* Bogotá D.C.

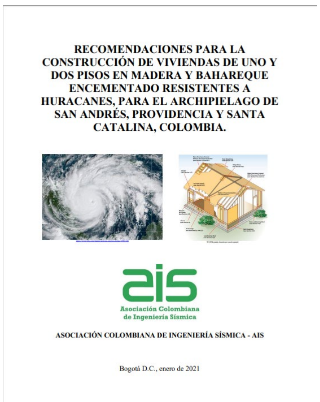


Fig. 40.

International Literature:

Guidelines and Design Manuals:

The United States is renowned for its comprehensive and detailed building codes, making it a benchmark in this field. Specifically, the guide titled **Recommended Residential Construction for Coastal Areas - Building on Strong and Safe Foundations** (Fig. 42) from The Federal Emergency Management Agency (FEMA) of EEUU served as a starting point for the criteria considered in the design and evaluation of foundations discussed later in this thesis.

Habitat for Humanity International (HFHI) is a U.S. non-governmental and nonprofit organization whose purpose is to build simple, decent, and easily maintainable housing for people with limited resources in various countries worldwide. The 1st and 2nd edition of the guideline for the Caribbean **Hurricane Resilient Wooden Houses** (Fig. 43), graphically explains some criteria for the construction and rehabilitation of wood housing in areas vulnerable to hurricanes.

The **Guide to Dominica's Housing Standards** (Fig. 44) was a project developed with the UNDP (United Nations Development Programme) and Engineers Without Borders as a support manual for the safe construction of houses in the face of hurricanes due to their presence on the island of Dominica.

The **Residential Structural Design Guide** (Fig. 45) is a document prepared by Coulbourne Consulting, a sole proprietor structural engineering consultant, and sponsored by the U.S. Department of Housing and Urban Development. It serves as a tool for the design of typical wood-framed houses. However, its information can be applied in other contexts and locations. It is expected to be helpful in gaining a better understanding and perception of houses as structural systems.

The information found in these guidelines, complemented with other national and international guides, was implemented as part of the bases for the criteria hurricane-resistant requirements outlined in the matrix found in the following chapters. Some specific categories developed with this information were: plan geometry, foundation, walls and roof, divided in different sub-categories to specify and organize dimensions, specifications and materials per each one.

- Federal Emergency Management Agency. (FEMA P-550). (2009). ***Recommended Residential Construction for Coastal Areas - Building on Strong and Safe Foundations.*** (Second Edition). https://www.fema.gov/sites/default/files/documents/fema_p550-recommended-residential-construction-coastal-areas_0.pdf

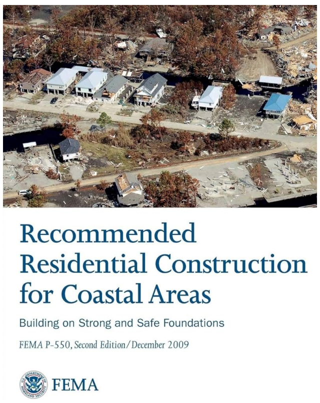


Fig. 41.

- Habitat for Humanity International (HFHI). Regional area office for Latin America and the Caribbean. (BRACED). (2018). ***HURRICANE RESILIENT WOODEN HOUSES (safer building and retrofitting guidelines).*** (Second Edition). https://sheltercluster.s3.eu-central-1.amazonaws.com/public/docs/c/20180927_HURRICANE%20RESILIENT%20WOODEN%20HOUSES_Dominica_web-compressed.pdf?VersionId=Z1c8XEsUeWnssDY4T8nzEh_.JXAzYQEz

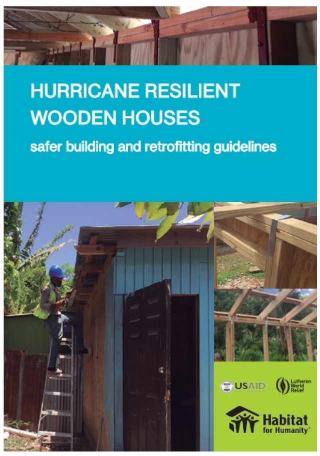


Fig. 42.

• UNDP and Engineers Without Borders. (2018). ***Guide to Dominica's Housing Standards.***
https://www.undp.org/barbados/publications/guide-dominicas-housing-standards

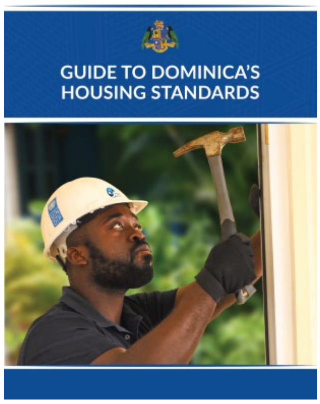


Fig. 43.

• Coulbourne Consulting. (U.S. Department of Housing and Urban Development Office of Policy Development and Research). (2017). ***Residential Structure Design Guide.*** (Second Edition).
https://www.huduser.gov/publications/pdf/residential.pdf

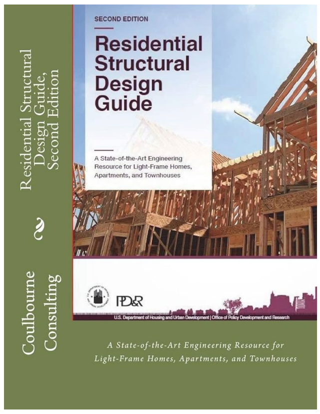


Fig. 44.

Codes and Standards:

In addition to the guidelines mentioned above, it is important to highlight the existence of several internationally recognized codes and standards for the design of timber buildings and the evaluation of wind action on various structures. These codes and standards, originating in the United States and Europe, have played a fundamental role in establishing technical guidelines and safety criteria that have been adopted as a reference by numerous countries around the world.

• International Coode Council, INC. (2023). ***Florida Building Code.*** (Eighth edition).
https://codes.iccsafe.org/content/FLRC2023P1

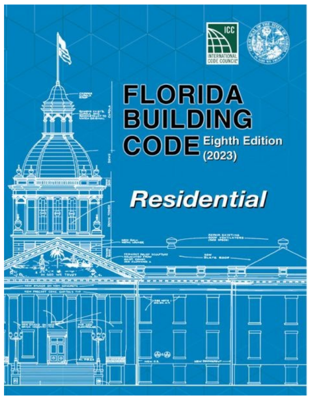


Fig. 45.

• American Wood Council. (2018). National Design Specification for Wood Construction. American National Standard Institute. https://www.plib.org/staging/wp-content/uploads/2020/09/AWC-NDS2018.pdf

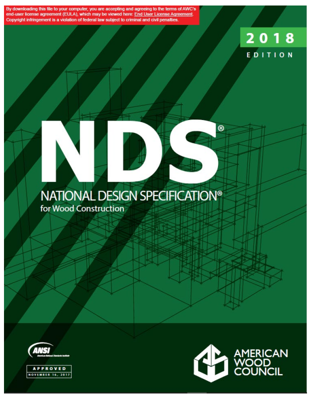


Fig. 46.

- EUROPEAN COMMITTEE FOR STANDARDIZATION. (1991). Eurocode 1: Actions on structures - Part 1-4: General actions -Wind actions. Brussels, Belgium. https://www.phd.eng.br/wp-content/uploads/2015/12/en.1991.1.4.2005.pdf

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 1991-1-4:2005+A1

April 2010

ICS 91.010.30

Supersedes ENV 1991-2-4:1995
Incorporating corrigendum January 2010

English version

Eurocode 1: Actions on structures - Part 1-4: General actions - Wind actions

Eurocode 1: - Actions sur les structures - Partie 1-4: Actions générales - Actions du vent

Eurocode 1: Einwirkungen auf Tragwerke - Teil 1-4: Allgemeine Einwirkungen - Windlasten

This European Standard was approved by CEN on 4 June 2004.

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Ref. No. EN 1991-1-4:2005: E

Fig. 47.

- EUROPEAN COMMITTEE FOR STANDARDIZATION. (1995). Eurocode 5: Design of timber structures - Part 1-1: General - Common rules and rules for buildings. Brussels, Belgium. https://www.phd.eng.br/wp-content/uploads/2015/12/en.1995.1.1.2004.pdf

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EUROPÄISCHE NORM

EN 1995-1-1:2004+A1

June 2008

ICS 91.010.30; 91.080.20

Incorporating corrigendum June 2006
Supersedes ENV 1995-1-1:1993

English version

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Fig. 48.

Conclusion

Hurricanes have left a profound imprint on life in the Caribbean regions they affect, significantly influencing political, social, scientific, cultural, and architectural aspects. Beyond their immediate impact, these natural phenomena have prompted communities to make crucial decisions for their survival and sustainable development.

The need to manage and mitigate hurricane-related risks, has led to the implementation of stringent regulations, especially in construction. These measures aim not only to minimize damage during hurricanes but also to promote the adoption of more resilient and sustainable construction practices over the long term. In the fields of architecture, design, and construction, the focus extends beyond mere material resistance to the forces of hurricanes, emphasizing the preservation of life and the ability to adapt to social and cultural dynamics. This has led to a holistic approach in shaping structures that withstand natural forces while contributing to the overall resilience of communities and the safeguarding of their cultural identity.

Additionally, the impact of hurricanes is further complicated by climate change, increasing the frequency and intensity of these phenomena. This connection to human activities underscores the urgent need to address the fundamental causes of climate change. In this context, informed and sustainable decision-making becomes imperative to ensure a more resilient future for the affected Caribbean regions and worldwide.

03

CREOLE ARCHITECTURE IN THE ARCHIPELAGO OF SAN ANDRES, PROVIDENCIA & SANTA CATALINA

3.1. Influences and Origin of Creole in the Caribbean

The term Creole, derived from the Portuguese "crioulo", began to be used in the 15th century with the arrival of Europeans and African slaves to the American continent to refer to the children of slaves or indigenous and Europeans born in the "new" continent (Edwards, 1994).

This mixture of cultures gave rise to a series of traditions and dynamics that spread through migrations and trade in the different areas of the Caribbean, influencing different fields.
In the sphere of architecture, the difference in climate conditions and indigenous knowledge represented variations in both materiality and design, preserving basic characteristics of the so-called Creole architecture, described by Edwards as follows:

> *... historically related family of* **architectural forms** *characterized by a* **distinctive geometric pattern** *— a European-derived* **rectangular core** *that is* **partially or fully surrounded by peripheral spaces** *that are always more narrow than the central areas and that* **includes at least one full-length front gallery or open loggia.**
>
> (Edwards, 1994, p.157)

Creole architecture in the Caribbean serves as a testament to the necessity of adapting to the challenges posed by the region's hurricane-prone environment, with a strong emphasis on practicality and resilience. In a place where the looming threat of hurricanes is a constant reality, this architectural style not only showcases the aesthetic and cultural diversity of the Caribbean but also provides a practical blueprint for effective environmental adaptation. Over time, Creole architecture has consistently demonstrated the Caribbean communities' ability to thrive amidst an ever-changing and sometimes hostile natural environment. It stands as a living embodiment of their capacity to combine beauty and functionality out of sheer necessity,

---

The following timeline "Origins of Creole" was elaborated from the following two books:

- Edwards, J. (1994). ***The Origins of Creole Architecture.*** The University of Chicago Press on behalf of the Henry Francis du Pont Winterthur Museum, Inc.
- Edwards, J. (2004). ***Creole Architecture: A Comparative Analysis of Upper and Lower Louisiana and Saint Domingue.*** Springer.

Fig. 49. Black Dance. Source: Bridgens, R.

ORIGINS OF CREOLE

XV Century

Use of the term “Creole (Criollo)” derived from Portuguese to refer to children of slaves (African mothers) who where born in their master’s homes.

- **Spanish rural houses** were first coonstructed with open loggias but without complete galleries. These seem to have been included starting towards the **end of the XVI Century.**

XVI Century

- Indirect importation of African slaves into Hispañola began in **1510**, while direct importation (from the coast of Guinea) began in **1517**. If the situation in Hispañola and other Caribbean colonies was similar, slaves had some freedom in the design, construction and modification of their rural houses **until late in the XVII Century**.

- In **Santo Domingo,** during **1510,** “Casa del Almirante”, an Italian Renaissance villa was constructed under Spanish sovereignty. At first it caused a great impact but then it became a model for smaller Spanish colonial plantation houses (country houses) in the 1530’s and thereafter.

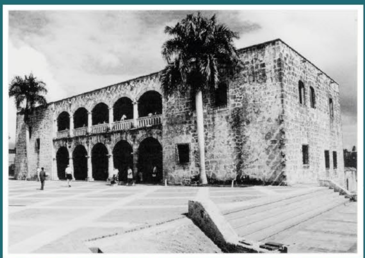


Fig.50. Casa del Almirante, Santo Domingo, built 1510.

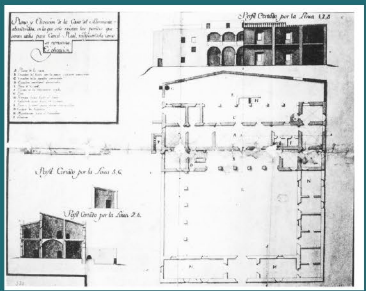


Fig.51. Antonio Abarca Barba, “Plano y Elevacion de la Casa del Almirante,” no. 370, 1770.

- **Middle of XVI Century**: People from **Cap Francois** traded with the Spanish villages of Northen Hispañola and started employing the same constructional methods.

- In the **late XVI Century** and **XVII Century,** West Africans (particularly Mande-speaking building specialists), lançados (Portuguese mariners gone native), and their progeny—creolized Luso-Africans— offered a complete architectural knowledge to European dealers. The trading network spread over the Atlantic, first into **Portuguese Pernambuco and Bahia,** and shortly after that, into the **old Spanish Caribbean.**

XVII Century

- During the second wave of Spanish settlement on **Hispañola** in the **XVI and XVII centuries,** cantilevered upper-story balconies and the ground-floor covered sidewalk passages were introduced from **Iberian** domestic vernacular architecture.

- In the villages on towns of coastal **Veracruz, Mexico**, as well as the early settlement of **St. Augustine, Florida,** Creole domestic architecture that was brought with the first waves of permanent settlement to *tierra firme* was used.

-By the **middle of the XVII Century**, Creole architecture appeared in **Cayenne, Guadeloupe, Saint Domingue, Martinique, and Jamaica,** new French and English territories.

- **Prior to 1655** the sugar colony of **Jamaica** had a well-developed creole architecture.

- In **1655 Jamaica** was invaded by the British who described the Spanish houses with broad galleries, rear cabinete rooms and loggias.

-Almost all houses of **le Cap** during the **XVII and earliest XVIII Century** were made of vegetal materials.

Fig. 52. Guanisnes de palmistes. Sylvin house, Duclos, Haiti.

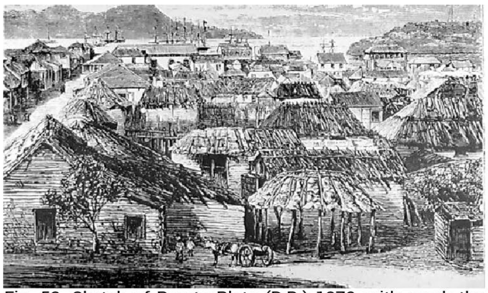


Fig. 53. Sketch of Puerto Plata (D.R.) 1872, with much the same appearence as le Cap in the early 18th century.

ORIGINS OF CREOLE

XVIII Century

The startling parallels between domestic architecture of the Caribbean and Louisiana were noted by travelers during the **XVIII and early XIX** Centuries. Most climatic and environmental characteristics were similar across the two locations, and the architectural adaptations to tropical life that had evolved on the islands were also prefered in the coastal American South:

1. Both in the Greater Antilles and along the coasts of North and Central America, the early Spanish colonial architecture was crucial in the development of local household architectural traditions. Louisiana Creole plantation house and coastal North and South Carolina's Tidewater cottages are the two North American traditions that have drawn the most inspiration from Caribbean Creole architecture.

2. The origins of North American Creole architecture begin much earlier than suggested by many architectural historians.

3. This updated timeline significantly raises the possibility that Caribbean Creole architectural elements were incorporated into existing traditions in the piedmont and upland South before they were widely known. Initially, the Caribbean had a marine and coastal effect in the South, but by the fourth decade of the eighteenth century, elements of Caribbean architecture were actively migrating to the continent's interior.

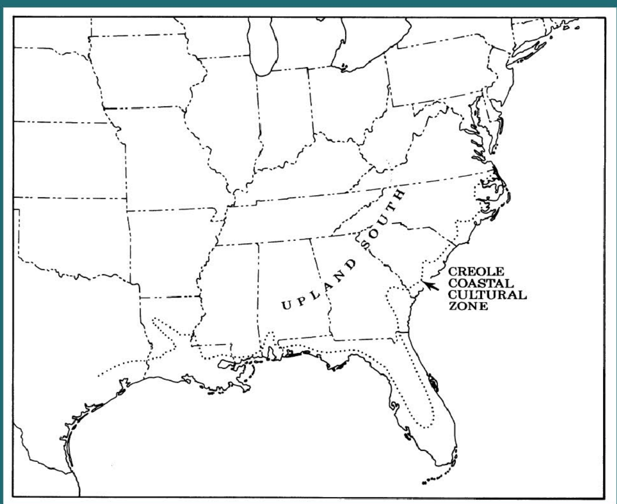


Fig. 54. The Creole coasts of the American Southeast - the zone of greatest Caribbean architectural influence, 1700 - 1770.

- During the colonial period different families of floor plans were included into Louisiana's Creole architecture.

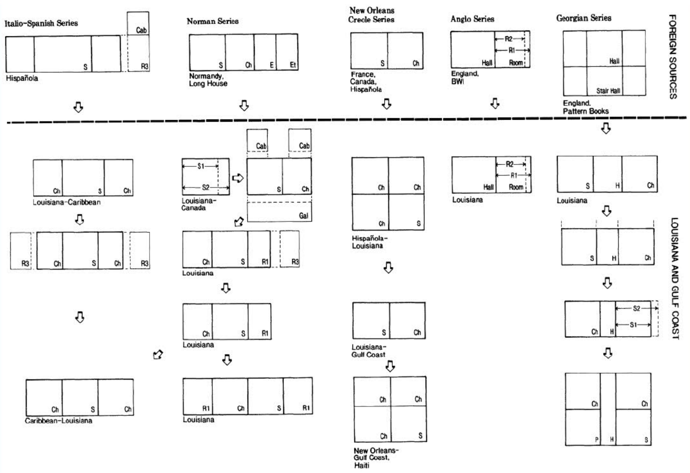


Fig. 55. Base modules of Louisiana Creole vernacular houses and their principal sources.

- **Louisiana** architectural surveys enable the classification of house types.
Norman-plan family of houses: those constructed around an asymmetrical, two-room *salle-et-chambre* core.

The house was also elevated to improve ventilation, and a significant percetage of the floor area was given to open- air spaces. Throughout the **XVIII and XIX Centuries**, the Norman-plan plantation house was being built beside the colonial Louisiana's waterways. Evidenced historical examples were built between around **1710** and the **1820's**. The Norman-plan houses went through four stages of expantion, always keping the asymmetrical Gallic core.

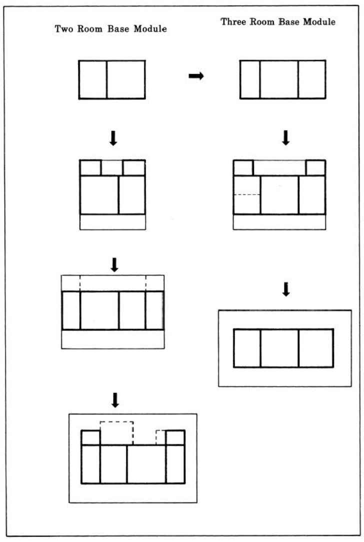


Fig. 56. Evolution of typical eighteenth-century Louisiana Spanish Creole Plans.

- After the multiple fires in the town of **le Cap**, (1688,1694,1734), in **1736** an ordinance was passed requiring masonry or briques *entre poteaux* construction, or *pierre crépie* (plastered stones). Previously, thatched roofs were forbidden in **1721**.

-Spanish family of plans: at least as early as **1726**, raised plantation houses with symmetrical floor plans were being constructed along the **Gulf Coast**.

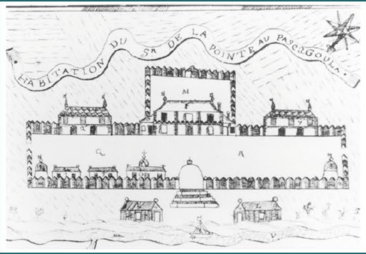


Fig. 57. M. De la Chaise, "Habitation du Sr. de la Pointe au Pascagoula." From M. de la Chaise to Dumont de Montigny, October 30, 1726. (Newberry Library, Chicago.)

- Four geometric elements defined the prototypical first generation of Spanish Caribbean Creole domestic architecture:

1. *Form Class*:
Form Class I, the simplest form, a rectangular module srrounded by a gallery and covered by a flat or pitched roof.
Form Class II, houses with double-pitched roofs.
Form Class III, single-pitch "umbrella roof", covering all core and periferal spaces, generally hipped or sometimes gable-ended.

2. *Base Plan Type*: A three-room base module ora-ganized into a symmetrical tripartite *habitación-sala-habitación* as a core.

3. *Plan Expansion:*
Creole house: Core (base module) with a periphery of narrow spaces such us: galleries and optional loggias, *gabinetes* (corner rooms), and bedrooms.
Proto-Creole house: Renaissance-style in-antis loggia between two gabinetes instead of a front gallery.

4. *Facade Geometry:* First generation Spanish Creole facades were symmetrical or nearly so.

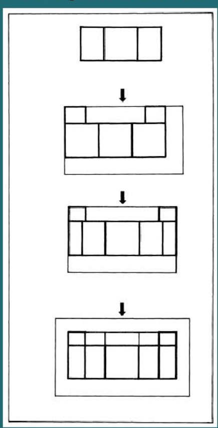


Fig. 58. Evolution of typical eighteenth-century Louisiana Spanish Creole Plans.

- While the asymmetrical Norman base module presents similarities with northwestern France vernacular architecture, the symmetrical Spanish base module does not.

-Desription of **le Cap** by Moreau Saint-Méry, a French creole politician and historian in **1789**: "*The rooms fronting on the street were all square, mea-suring about 15 to 18 French feet, with ceilings 12 or more feet high (Fig.8). By this time gallery fron-ted shed rooms surrounded the rear patios (Fig.9). They were used for kitchens, offices and bedrooms for the African servants. Most patios had a well.*"

-The colony of **Saint Domingue**, especially Cap Francois (**le Cap**) influenced the French Creole architecture on the **Mississippi Gulf Coast**.

At the time of the great migrations from Haiti during the revolutionary period (**1791-1810**), **le Cap** also served as an example for the Creolized cons-tructions of **Mobile and New Orleans.**

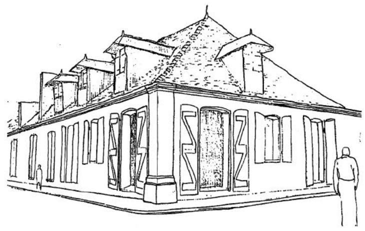


Fig. 59. Maison Basse de type XVIII siècle.

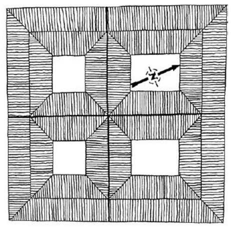


Fig. 60. Plan of block 20-21/E-F, le Cap, ca. 1780.

- **Spanish and French Caribbean town**, and planta-tion architecture on **Hispañola** were inspired by neoclassical ornamental design from the XVIII Century. *It was marked by simplified Tuscan columns and pilasters, and segmental arched door and window tops. Entrances were protected by heavy wooden outer shutters and light wooden inner doors (Fig.10). Jalousies were firsts incorpo-rated on to the inner doors around* **1776**. Around the same period, some of the common French style casement windows started to be replaced by Engli-sh type sliding sash windows.

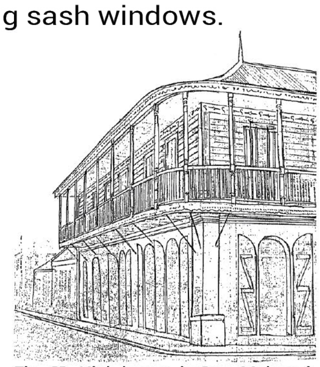


Fig. 61. High house, le Cap. Maison à étage en bordage de planches.

ORIGINS OF CREOLE

Town houses were covered with Normandy or Anjou roof tiles or slates as the colony expanded and maritime transportation from France flourished.
Public buildings around the plazas had arched masonry porticos.

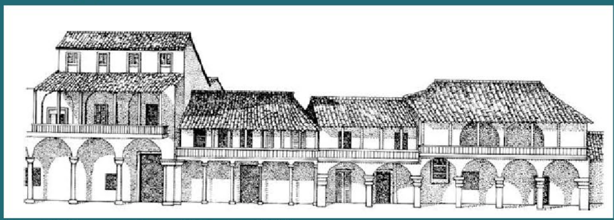


Fig. 62. Havana, Plaza Vieja ca. 1764.

French style king post roof trusses may be seen in the hipped roofs capped with ornamental finials (*épis de faîtage*). (Fig 8 and 10) Balconies that extended over the walkways were a common decoration on buildings. Their balustrades were made of wood or ornamental wrought iron, similar to those found in **New Orleans' French Quarter.**

- Pioneers' cottages in **Louisiana's** Creole history were often built on an asymmetrical two-room unit known as a *salle-et-chambre* (parlor-and-bedroom) cottage. It may be seen in some of the colony's initial designs of small rural houses. A type of typical cottage evolved and spread throughout **southern Louisiana in the XVIII and XIX Centuries.**

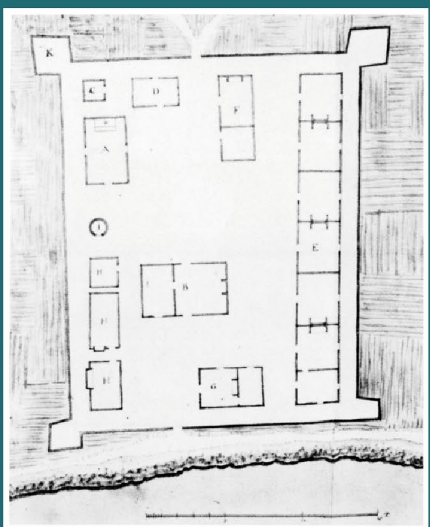


Fig. 63. Ignace François Broutin, "Plan du Fort des Natchitoches," 1732. (A) church; (B) house of the commandant; (C) magazin; (D) warehouse; (E) barracks; (F) guardhouse; (G) house of the keeper of the magazin; (H) kitchen and house for servents; (I) bread oven.

-During the great fires of **1788 and 1794** in **New Orleans,** this city was a colony of Spain, that is why its reconstruction was made under the cultural influence of Spanish Caribbean Creole, resulting in the French Quarter's elimination of the majority of its French architecture.

XIX Century

-**1801-1805:** The term *Creole house* can be found in different journals describing the typical galleried house of planters in **Jamaica.**

- Between **1791-1808**, **Louisiana** had the largest migration of Caribbean inmigrants that were escaping from the revolutionary Saint Domingue and anti-Napoleonic Spanish western Cuba. As late at the 1830's, in Louisiana, these Saint Domingue sugar planters built raised Creole-style plantation houses.

- Around **1808,** after the reconquest of **Pensacola, Florida**, by the Spanish, some modifications in the construction were noted: addition of a small bedroom of one side of the core and insertion of an interior hallway.

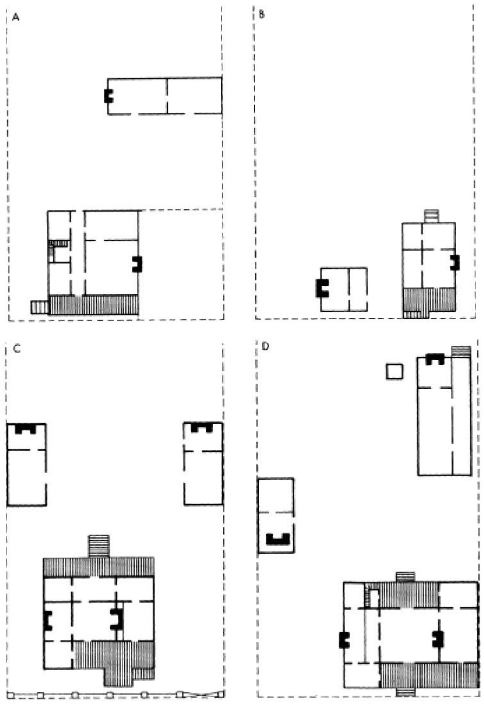


Fig. 64. Rental properties administered by Señor Noriega, Pensacola, Fla., ca. 1808 (properties not contiguous as shown).

- French Creole architecture is still among the most prevalent in the **Gulf Coast** region, having persisted through the **first part of the XIX Century.**

- After multiple catastrophes (earthquakes, XVIII Century; Sackes and fires, 1793; Fire ,1802; earthquake, 1842), **le Cap** was rebuilt each time introducing different modifications. To reinforce the lowest sections of the walls, buttresses were built on post-**1842** houses.

-As a consequence of the significant changes in the houses of **le Cap** due to all the catastrophes, no single architecture persisted throughout its history.

ORIGINS OF CREOLE

- **1859:** The Spanish-plan Creole plantation house was still the most common type of "big house" constructed in affluent and traditional **St. Charles Parish, north of New Orleans.**

Fig. 65. Adrien Persac, Hope Estate plantation house, 1857-61.

- Measured floor plans of houses, the majority of which were built around the **middle of the XIX century**, show how the Creole plan was being adapted to both the older French and the more recently popular Anglo modules. Into the **second half of the XIX century**, in **southern Louisiana**, a similar process was taking place, and the Creole plan there eventually became dominant in both urban and rural regions. Central halls are a modern addition to Louisiana Creole houses of this century.

The Creole plan had an impact on traditional vernacular architecture even in parts of **North America** that had not yet been colonized by the French or the Spanish.

- A review of plans, maps, and prints from the Spanish Greater Antilles reveals that **between the XVI and XIX centuries**, colonial architecture with symmetrical or nearly symmetrical three-room base modules and gabinete-loggia additions gained popularity and spread throughout the **Spanish Americas** at various class and occupational levels.

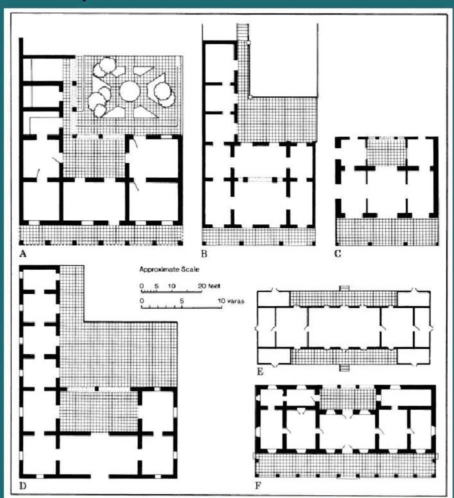


Fig. 66. Spanish Creole Caribbean tripartite house plans, sixteenth-nineteenth centuries. (Drawings, Mary Lee Eggart.) (A) Tlacotalpan, Veracruz, Mex; (B) nineteenth-century house, San Germnán, P.R; (C) "The House where Mila lives," Havana, Cuba, seventeenth century; (D) typical sixteenth-century house plan, Santo Domingo; (E) officer's house, Monti Christi, Dom. Rep., 1757; (F) rural farmhouse, Mariano, Cuba, seventeenth or eighteenth century.

XX Century

- Until the first years of the XX Century, smaller versions of the Norman-plan houses were constructed.

XXI Century

- They are no longer present in le Cap, but they may still be seen in colonial Havana plazas from the middle of the eighteenth century, including the plaza vieja.

Fig. 67. Note. Own elaboration.

- "Casa del Almirante" constructed in 1510 - Santo Domingo.

Fig. 68. Casa del Almirante, Santo Domingo.

For the realization of the timeline, an investigation of existing literature on the origins and influence of Creole architecture in the Caribbean was carried out, where it became evident the existence of historical gaps that prevent a continuous and clear understanding that relates each evolutionary step of this architecture. However, the organization of the existing information in a chronological manner allows for a clearer understanding of the origins and evolution of this architecture, allowing conclusions to be drawn.

Despite the diversity in cultures and political landscapes, the concept of the Creole house rapidly permeated throughout the Caribbean and the southern coasts of the United States. During an era marked by migration and travel, the facades of these houses served as easily recognizable and replicable references, making the exterior designs more prominent in imitation than the complex interior spaces. The latter, however, holds a deeper connection with the growth of families and the dynamics within them.

While certain facets of Creole architecture remained consistent across various regions, a fascinating tapestry of variations emerged due to the rich exchange of cultural influences. These variations gave rise to unique interpretations of the basic concept of the Creole house, whose characteristics were adapted to the environment and the different social and cultural dynamics of each area. Some of these features remained as common points linked to the vulnerability of the areas to hurricanes: elevating the house off the ground to prevent flooding and moisture, and to allow the storage of various supplies and shelter for animals; a rectangular layout surrounded by galleries that served as a transition space between the interior and exterior of the house; gable roofs that assisted in regulating internal temperature and collecting rainwater; and the use of high-density woods for house construction because of their durability, acting as waterproof and sun-resistant materials.

In conclusion, the Creole house concept, with its remarkable adaptability and enduring appeal, has transcended the boundaries of diverse cultures and political landscapes in the Caribbean and the southern United States. This enduring legacy is a testament to the intricate blend of cultures and the resilience of architectural traditions, reflecting the dynamic evolution of the Creole house concept over time. On the other hand, the evolution of Creole architecture in the Caribbean stands as a vivid illustration of how the architecture of a place is intricately woven into the fabric of its unique circumstances. Shaped by the persistent challenges posed by multiple hurricanes over centuries, Creole architecture emerged as a resilient response to the climatic conditions of the region.

3.1.1. Historical Planimetry Examples of Creole Architecture

The emergence of Creole houses unfolds concurrently in diverse Caribbean regions, revealing shared techniques and knowledge rooted in a common history, notably influenced by African experiences. This parallel development underscores the interconnectedness of these architectural traditions.

“In comparing the plans and other architectural features of the colonial houses of the Spanish Caribbean, their French and English derivatives in the Antilles, and the Creole cottages of the Coast and Chesapeake Tidewater, one cannot help but be impressed with the similarities” (Edwards, 1994).

The following planimetries are examples of the architecture developed in North America in the states that have a coastline on the Gulf of Mexico and a direct relationship with the Caribbean.

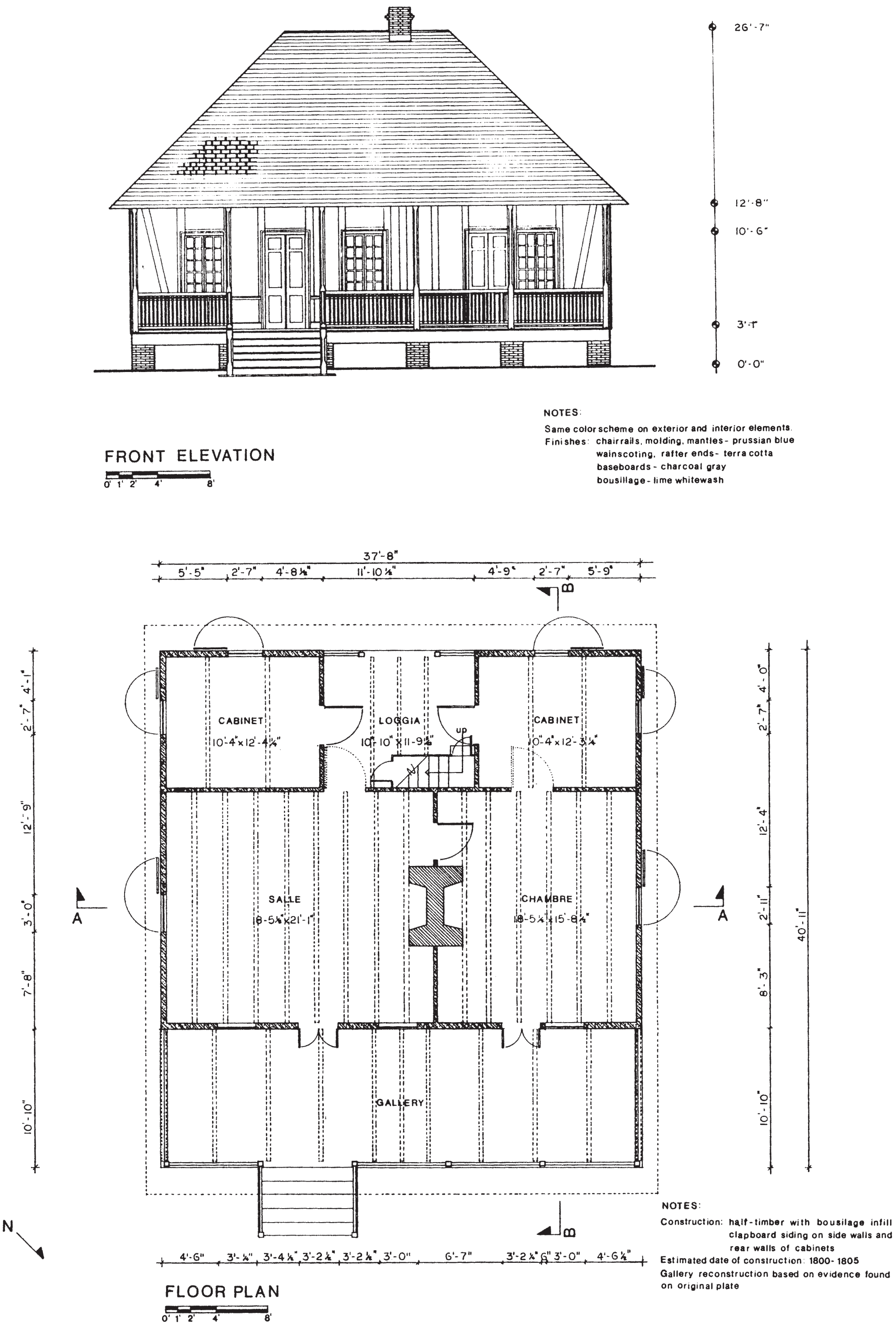


Fig. 69. Kleinpeter-Knox house, Baton Rouge, ca. 1800. Source: Edwards, J. (1994).

Edwards (1994), described the Standard cottage that spread throughout southern Louisiana in the eighteenth and early nineteenth centuries as follows:

- Built in bonne charpente (“proper” mortise-and-tenoned timber frames).
- Elevated house frames a foot or more above the damp soils on cypress blocks or brick piers.
- Core of rooms with a full-length front gallery.
- Presence of rear cabinet-loggia range (small rooms on the rear corners of the house separated by an open or enclosed loggia), called the ‘ti’ (petite) galerie.

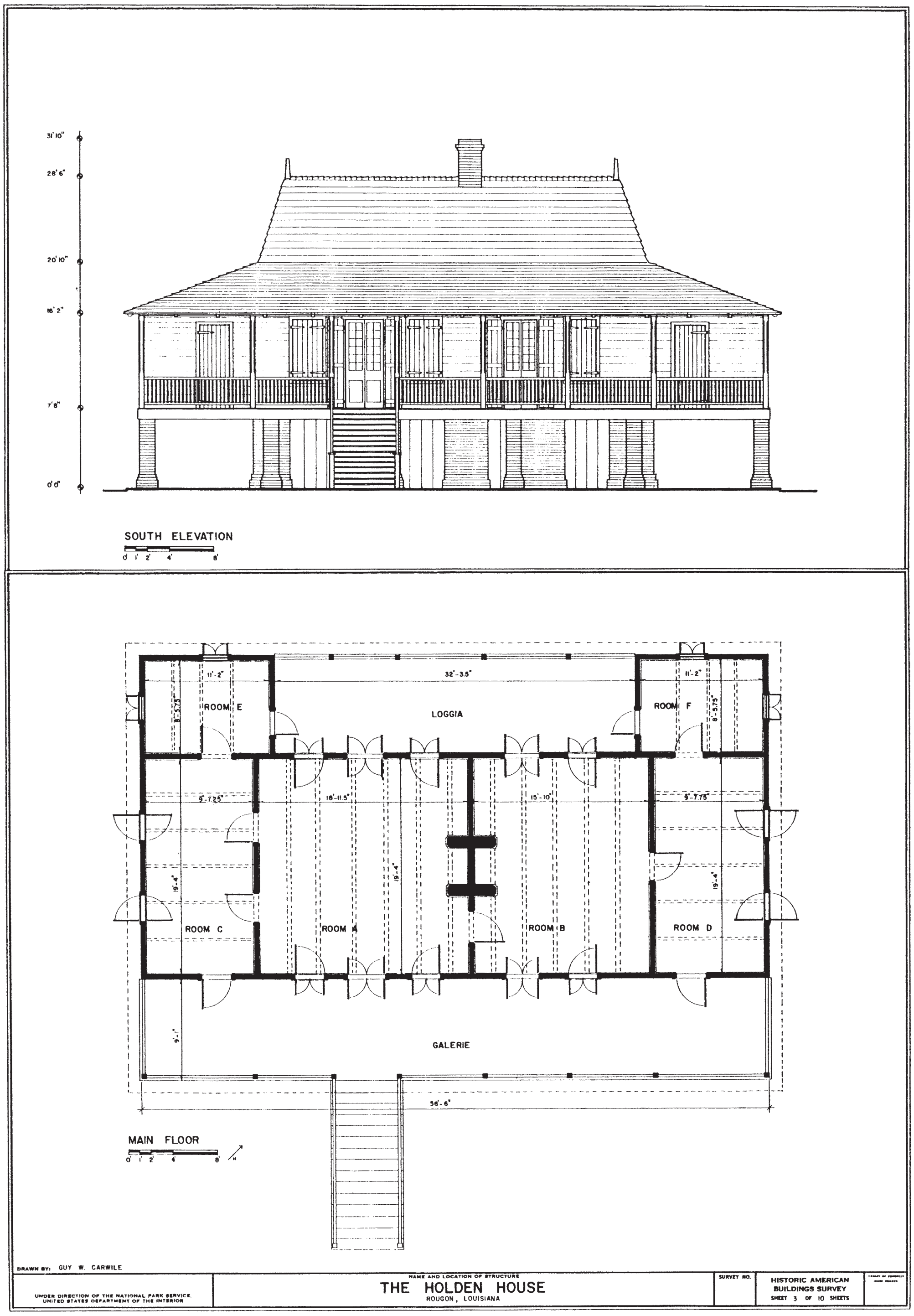


Fig. 70. Holden house, Pointe Coupee Parish. Source: Edwards, J., (1994).

Edwards (1994), described the Norman-plan plantation house constructed along the waterways of colonial Louisiana throughout the eighteenth and well into the nineteenth century as follows:

- Norman-plan family of houses: Houses laid out around an asymmetrical, two-room salle-et-chambre core.
- Expanded three-room plan: bedrooms on either side of the parlor were of different widths, reflecting the differing statuses of master bedroom and children's bedroom.
- Rural salle-et-chambre pattern expanded to a cottage surrounded by gallery spaces.
- Capped with a distinctive double-pitched roof, usually hipped but sometimes gabled.
- Large proportion of the floor space was devoted to open-air rooms.
- Elevated house to enhance air flow (Edwards, 1994).
- Presence of a full-length front gallery and loggia between two corner rooms (Edwards, 1994).

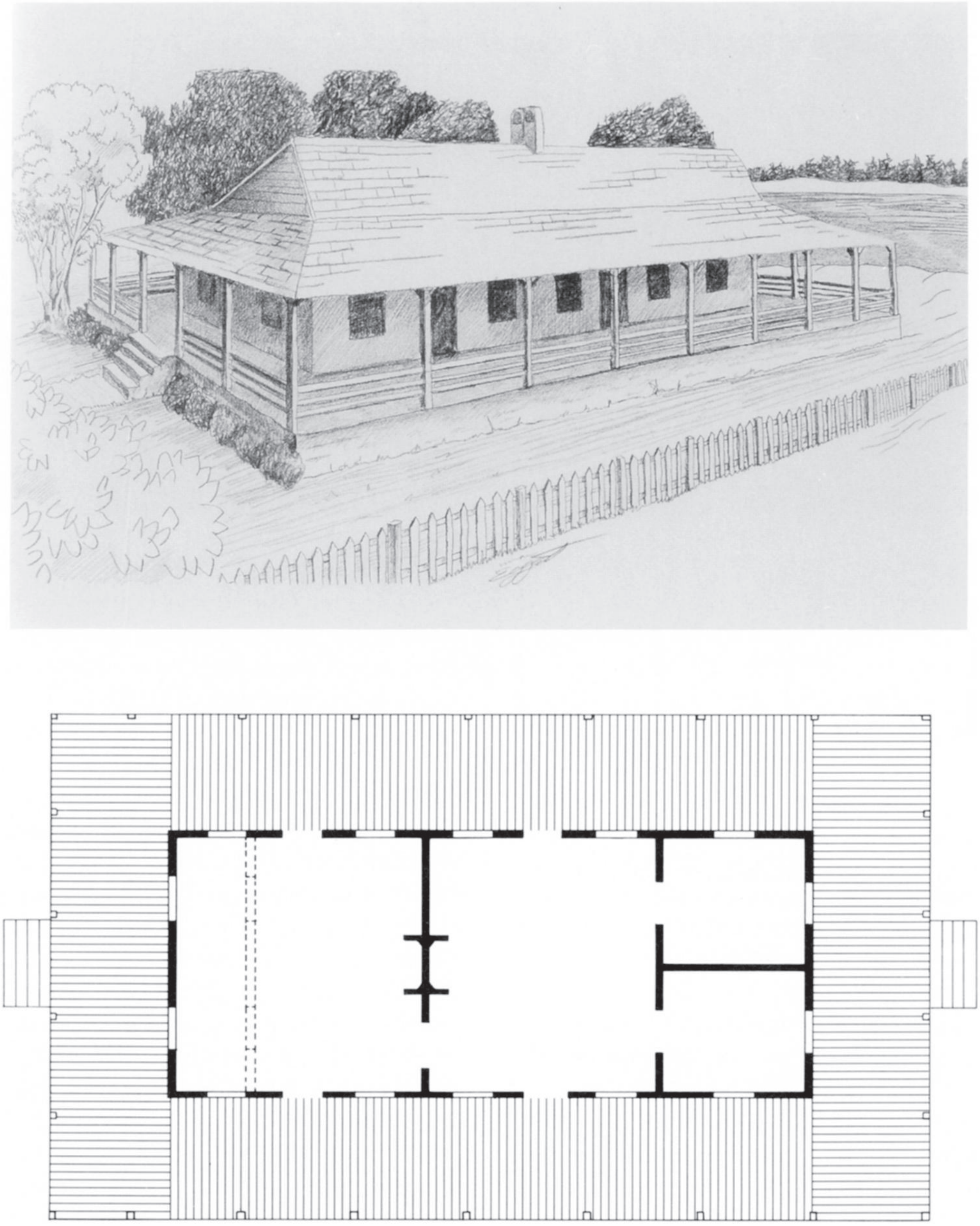


Fig. 72. House of the Commandant, Baton Rouge, 1848. Source: Edwards, J., (1994).

Edwards (1994), described the Spanish commandant's house in Baton Rouge - eighteenth century as follows:

- Three rooms, a large central salle with bedrooms of different widths on either side, and the larger bedroom heated by a fire-place.
- The smaller bedroom was often partitioned transversely to create children's bedrooms, unheated except in the largest houses.
- Presence of gallery surrounding the house.

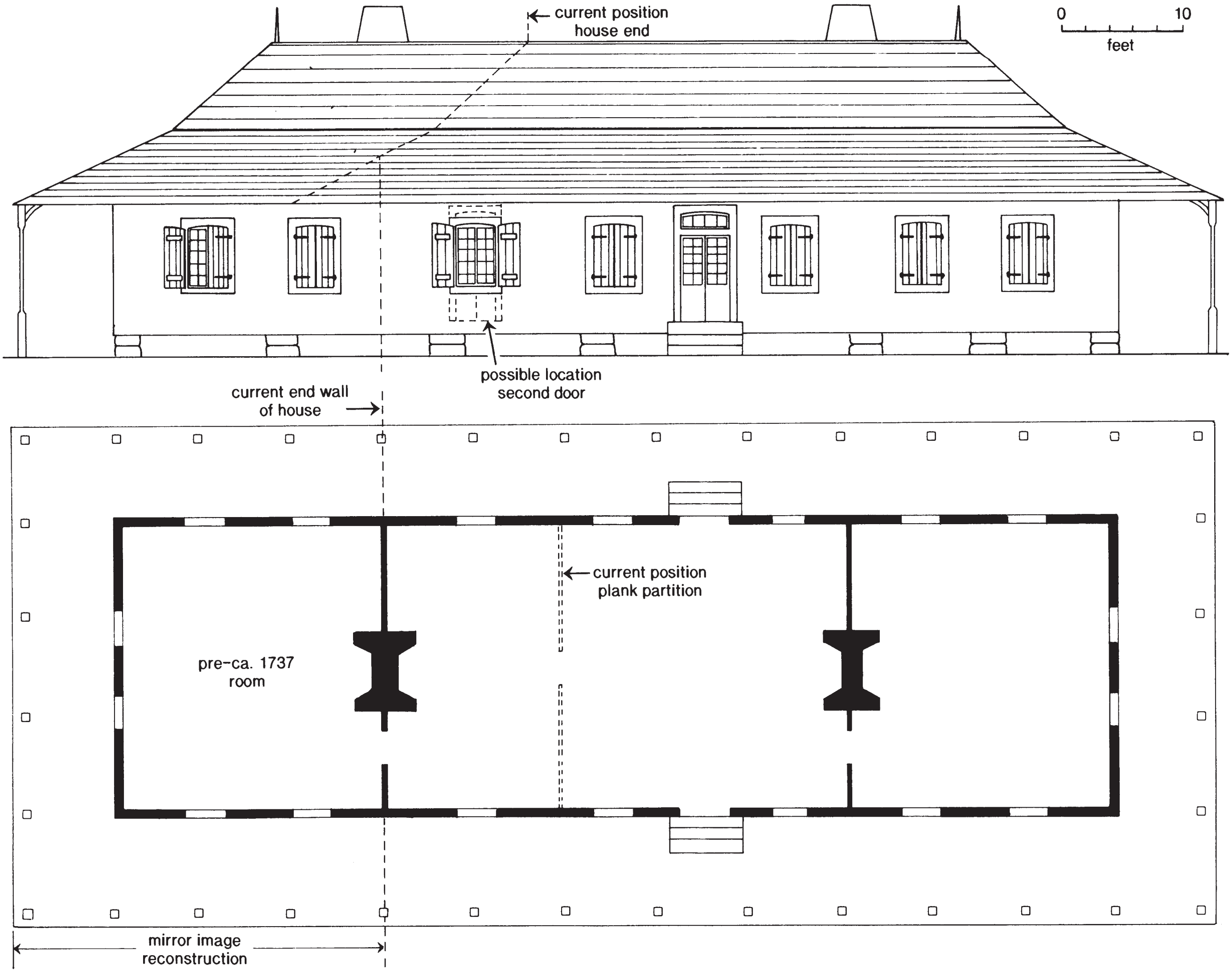


Fig. 73. Nicholas LaCour plantation house, originally from Coupée Parish, La., ca. 1733. Source: Edwards, J., (1994).

Edwards (1994), described another historically significant Louisiana house that illustrates something of the complexities of plan development in colonial buildings as follows:

-Asymmetrical plan with unusually large room.
- The high quality of carpentry of its timber frame speaks to a French colonial genesis prior to 1765.
- Originally it was built as a larger Spanish tripartite-plan structure.
- The original central salon was gigantic-38 by 24 feet-sufficiently long that it was later divided into two substantial rooms with a plank partition.
- One of the original 22-foot-long end rooms was removed, transforming the building into a standard Louisiana three-room Norman plan.

3.2. The Archipelago

Geography:
The Archipelago of San Andres, Providencia, and Santa Catalina, nestled in the crystal clear waters of the Caribbean Sea, is a captivating group of islands that holds a unique place within Colombia. This remarkable ensemble of islands, adorned with lush landscapes and surrounded by azure waters- often referred to as "'the sea of 7 colors"- represents the sole department of Colombia without any continental territory. These islands, along with their neighboring cays and islets, are settled on a volcanic platform in the southwest Caribbean, approximately 110 kilometers off the coast of Nicaragua and 720 kilometers to the northwest of Colombia's mainland. This geographical isolation has not only shaped the natural beauty of the Archipelago but has also contributed to the development of a distinct cultural tapestry, where Afro-Caribbean, Indigenous, and European influences converge, creating a vibrant mosaic of traditions, languages, and culinary delights that reflect the rich cultural heritage of the islands (PROCOLOMBIA, n.d.).

Fig. 73. Territorial map of the Archipelago. Source: Gov. Archipiélago de Providencia y Santa Catalina.

The Archipelago encompasses a vast expanse of 350,000 square kilometers, positioned to the northwest of Colombia, between latitudes 12° 35′ 37″ and 14° 42′ north, and longitudes 81° 40′ 49″ and 81° 43′ 13″ west. It graces the central-western region of the Antilles Sea, which places Colombia in maritime proximity to several nations, including the Dominican Republic, Jamaica, Costa Rica, Nicaragua, and Honduras. Despite its considerable maritime territory, the Archipelago's landmass is relatively modest, spanning just 52.5 square kilometers (sanandres.gov, n.d.). However, it stands as the smallest department in Colombia, boasting the highest population density in the country, with an astonishing 1603.5 residents per square kilometer (contraloriasai.gov, 2011). This unique demographic concentration underscores the significance of the Archipelago within Colombia's cultural and economic landscape.

	Area (km^2)	Population (2023)	Density	Maximum elevation
San Andrés	27	65.663	1.123,18 hab/km^2	85 m.a.s.l
Providencia	17			550 m.a.s.l
Santa Catalina	1			133 m.a.s.l

Table. 2. Archipelago Data. Own elaboration based on: Gov. Archipiélago de San Andres, Providencia y Santa Catalina.

Topography:
The Archipelago showcases a captivating topographical diversity. Comprising a group of islands, cays, and islets, this Colombian territory presents a striking blend of geological formations. San Andres, the largest of the islands, boasts gently undulating hills and picturesque coastlines, while Providencia, its neighbor to the north, stands in stark contrast with its rugged, volcanic peaks that dominate the landscape. These volcanic origins contribute to the island's unique terrain and stunning views. Santa Catalina, although smaller in size, shares the volcanic heritage and offers its distinct topographical character (Martinez, 2019). Coral reef cays with beautiful white sand beaches, swaying coconut palms, and thriving marine life surround the Archipelago, contributes to the beauty of the landscape. This diverse topography shapes rich ecosystems that influence various gastronomic and, by extension, cultural variances.

Climate conditions:
The Archipelago of San Andres, Providencia, and Santa Catalina features a distinctive climate marked by consistently high temperatures, boasting an annual average of 27.3°C. This warm climate can be attributed to the Archipelago's location within the intertropical zone. The region experiences distinct rainy seasons, starting in May, peaking in October and November, and concluding in December. The northern trade winds have a role in these periods of excessive precipitation. During these months, approximately 80% of the annual rainfall accumulates, with an average of 1,700 mm. The interplay of steady winds and elevated temperatures characterizes the area's climate as warm and semi-humid, creating a unique and inviting environment (sanandres.gov, n.d.).

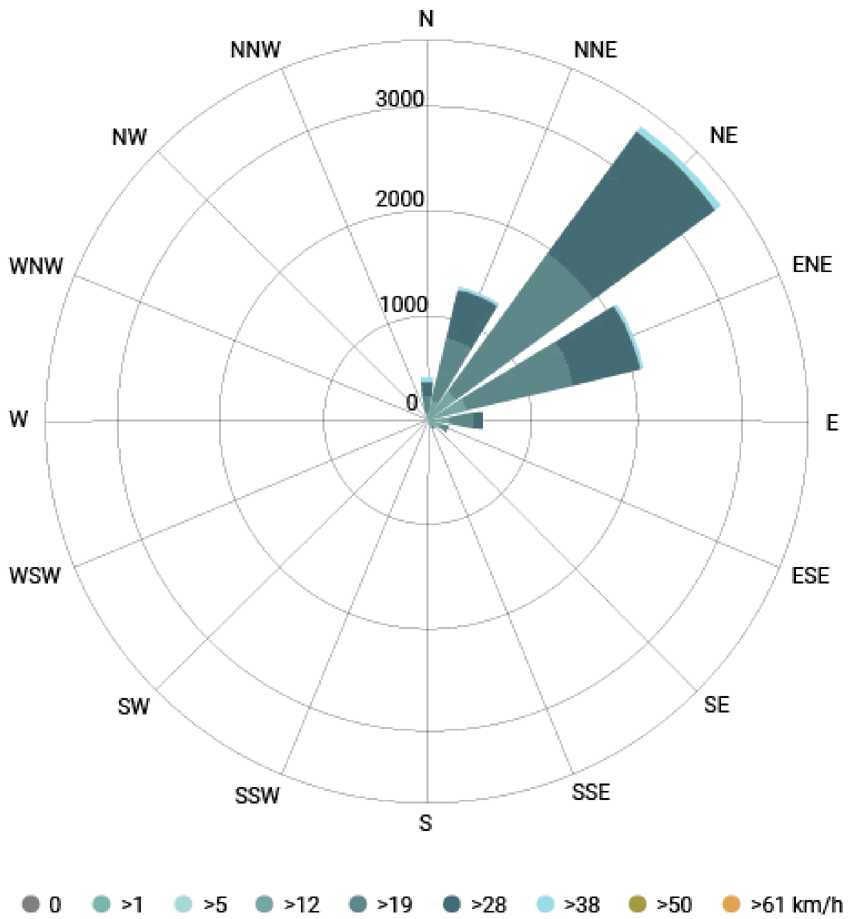


Fig. 74. Wind Rose for the Archipelago. Own elaboration based on: Meteoblue.

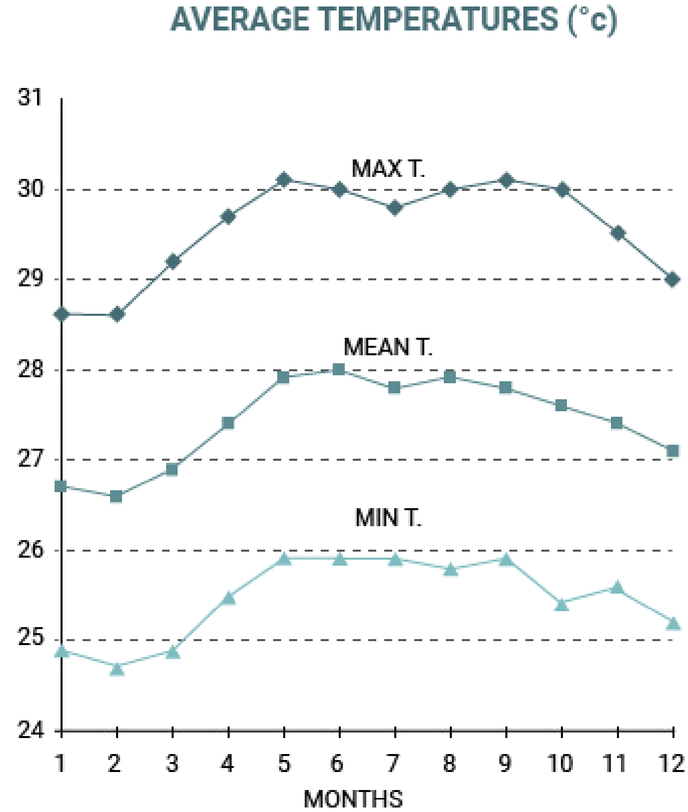


Fig. 75. Own elaboration based on: IDEAM, (2000).

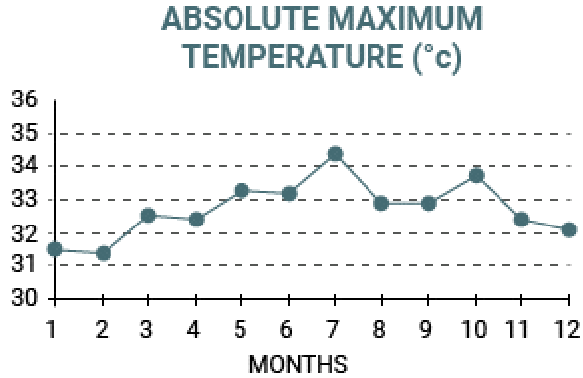


Fig. 76. Own elaboration based on: IDEAM, (2000).

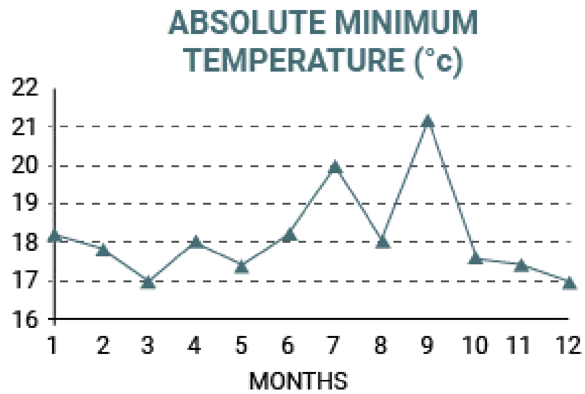


Fig. 77. Own elaboration based on: IDEAM, (2000).

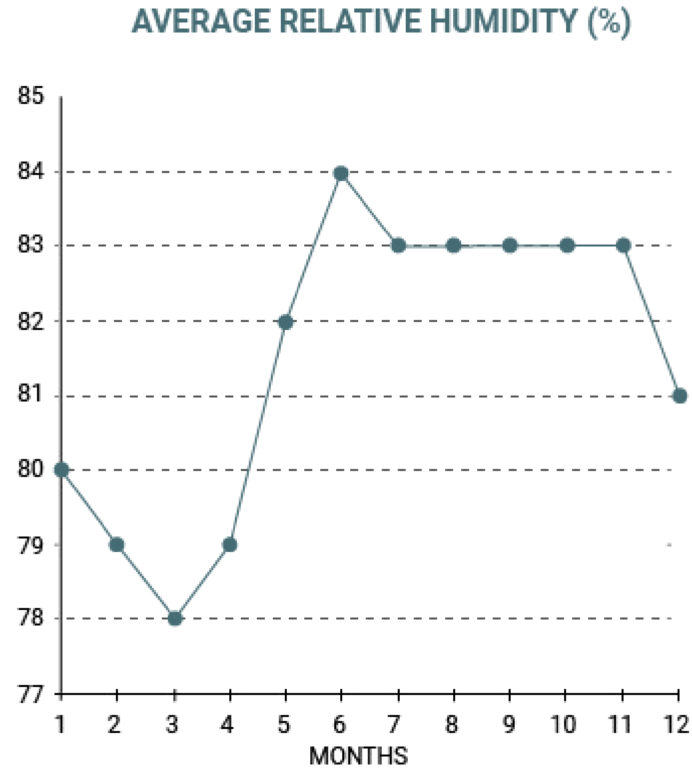


Fig. 78. Own elaboration based on: IDEAM, (2000).

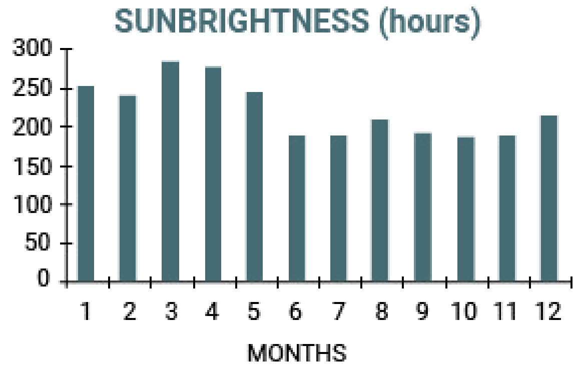


Fig. 79. Own elaboration based on: IDEAM, (2000).

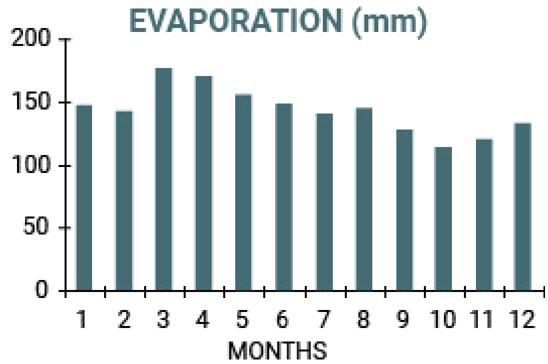


Fig. 80. Own elaboration based on: IDEAM, (2000).

Economy:

The economy of the Archipelago primarily relies on tourism and trade. Agriculture and subsistence fishing are complementary to these activities but are insufficient to supply the requirements of the islands. Consequently, a significant portion of daily consumables, catering to both the local population and tourists, must be imported from the mainland. The primary agricultural product that was commercially exploited in the Archipelago was coconut. Additionally, avocados, sugarcane, mangoes, oranges, yams, noni, and cassava were produced. However, these agricultural productions have steadily declined over the years due to soil degradation and increased urbanization in various areas (sanandres.gov, n.d.).

3.3. Relation with “Creole”
3.3.1. Influences and Origin of Creole in the Archipelago

Due to its strategic geographic location in the Caribbean, the Archipelago of San Andres, Providencia, and Santa Catalina has been influenced by the different cultures and traditions that have spread around it since many centuries ago. Although these cultural exchanges began around the 16th century with the first arrival of Europeans and Africans to the islands, it was not until the 19th century that, due to its economic development, Creole architecture began to take shape and evolve into what we know today, fostering a sense of community and identity among the island's inhabitants, as they collectively built and adapted structures to withstand the challenges posed by the Caribbean's unique environment. This architectural style became a symbol of solidarity and resilience for the people of the Archipelago.

Nevertheless, it is important to highlight that in Colombia, this architectural style is known as Caribbean or islander, rather than Creole, primarily due to the limited research and literature on the subject in the country. This situation reflects a context of misinformation since the descent and characteristics that arrived in the Archipelago from the Caribbean imply that this architecture should indeed be considered Creole.

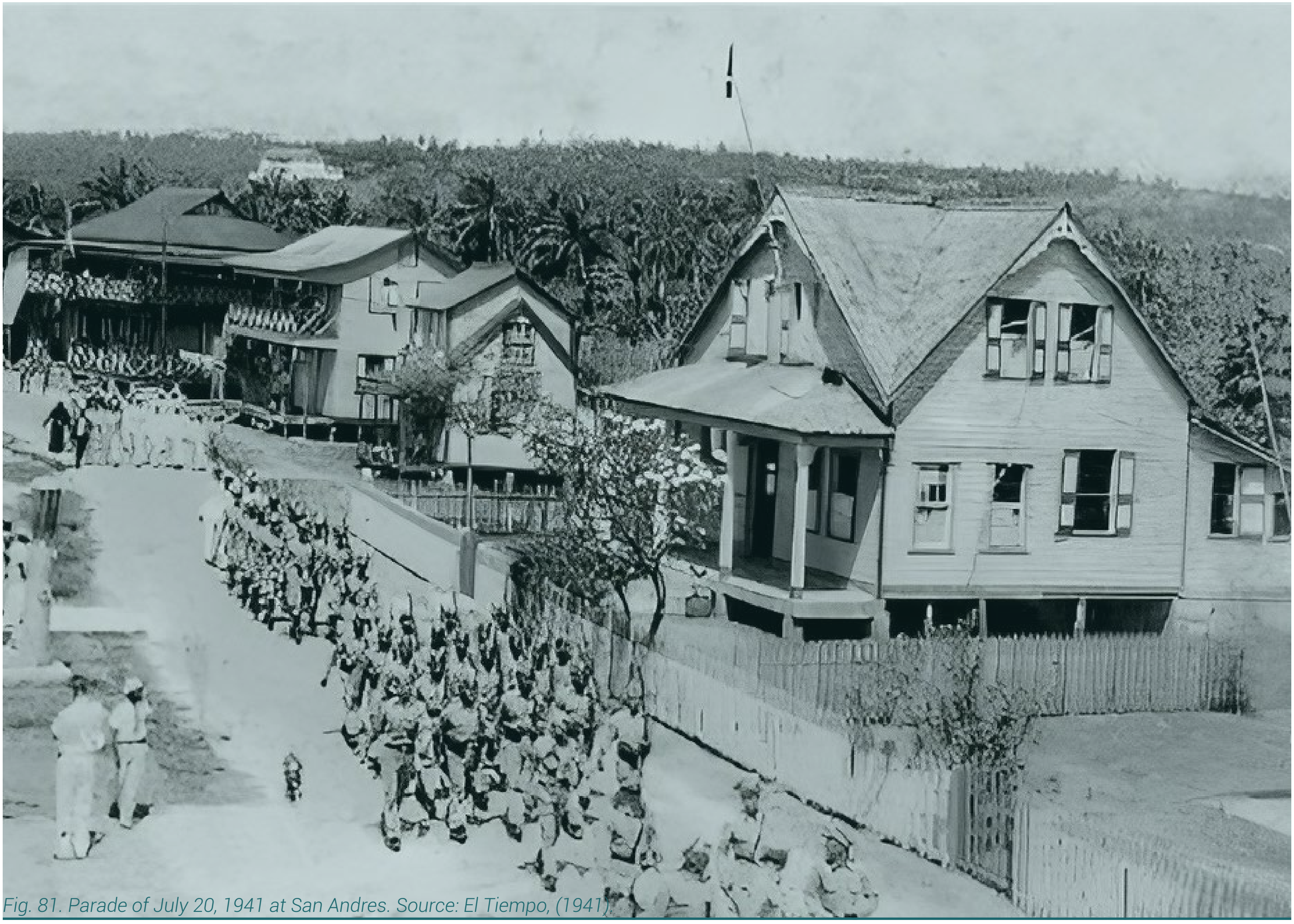


Fig. 81. Parade of July 20, 1941 at San Andres. Source: El Tiempo, (1941).

The following timeline “Influences and Origin of Creole in the Archipelago” was elaborated from the following two books:

- Edwards, J. (1991). ***The Evolution of a Vernacular Tradition.*** Vernacular Architecture Forum.
- Sanchez, C. (2004). ***La Casa Isleña: Patrimonio Cultural de San Andrés.*** Bogotá, Colombia: Universidad Nacional.

INFLUENCES AND ORIGIN OF CREOLE IN THE ARCHIPELAGO

XVI Century

Map evidence has shown that during **1527–1529,** Mosquitios, native people from the **Central American coast** visited the Archipielago.

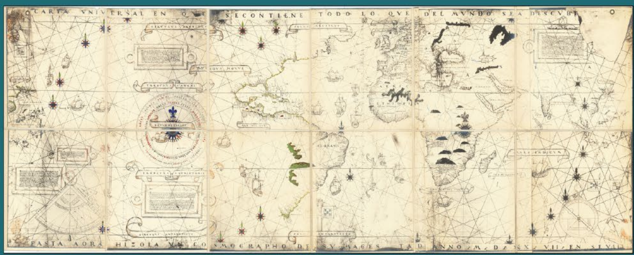


Fig. 82. 1527 Ribeiro Planisphere.

XVII Century

- The first Dutch and English sailors, settlers and adventurers arrived in **San Andrés**, but it was **in Providencia and Santa Catalina** where the first settlements were built by English-speaking planters and their slaves between **1627** and **1629**.

- Its original names were Henrietta (San Andrés) and Providence (Providencia and Santa Catalina).

- As part of the economic and political fights against the Spanish empire, the islands were initially fortified Protestant commercial and military bases, which made **the Caribbean** a conflictive and unstable regional scenario. They were soon transformed into plantations that relied on black slave labor from **Jamaica and other Antillean islands**.

- The Spanish colonial government attempted to occupy the islands in **1641** with expeditions sent from **Cartagena and Panama**, having **Providencia and Santa Catalina** as their main objective.

- The **second half of the XVII century** was marked by sporadic occupations by **English and Spanish**, during which the islands alternated between serving as pirate havens and bases for corsair operations against the major **Atlantic ports**.

- At the **end of the XVII and early XVIII centuries**, San Andres was abandoned for some years.

Fig. 83.1696 Danckerts Map of Florida, the West Indies, and the Caribbean.

XVIII Century

- After the archipelago was abandoned by Spanish soldiers, cotton planters from **Jamaica, the Cayman Islands, and other English-speaking parts of the western Caribbean** began settling there in the **middle of the XVIII century**.

- The presence of English traders and colonist families with their slaves persisted into the **1780s**.

- During the **previous centuries**, the islands changed hands several times between **England and Spain**, with Spain finally keeping them with the signing of the *Treaty of London* in **1786**.

- **Since 1788**, the Archipelago had begun to have closer economic and legal relations with the **Neo-Granadine territory**.

XIX Century

- In **1803**, the Viceroyalty of **New Granada** integrated the islands into its administration and legal-political control.

- The islands were notable for their prolific agricultural and marine production in the **final decades of Spanish colonial control**. With a variety of freshwater sources and abundant timber reserves, the islands' way of life was centered on the exploitation of slaves, particularly in the context of the plantation hacienda system.
They were linked to **Jamaica** for supply and trade, and for the sale of cotton in the **western Caribbean**. The islands were more integrated to the **Anglo-Saxon** economic life in the **Caribbean**, including **British Honduras** and the **Mosquito Coast**, than to **New Granada**.

- By **1810**, there were 1640 people living and working on the archipelago, including both free people and slaves. 850 slaves lived on San Andrés, according to O'Neille (Spanish colonial governor of the Archipelago -1790).

- After the war of Independence against **Spain**, and by local decision, the islands joined **Gran Colombia** in **1822**, to become part of **Colombia.**

Fig. 84. Gran Colombia, 1822.

- During the greater **Caribbean's** time of cultural and economic development in the **XIX century**, **San Andrés** demonstrated a cultural and commercial connection with this region. The wooden architecture that emerged in the **Caribbean** reflects the fact that the region as a whole was open to Victorian concepts.

-North Americans started to interact with the Caribbean; most of **San Andres'** agricultural output was sent to American markets. The islanders frequently visited **England** and the **United States**, and they maintained connections with **Bocas del Toro and Kingston in Jamaica**.

- Many violent slave revolts were happening during the **first half of the XIX century**, but it was not until **1853** that a local American missionary organized the emancipation in **San Andres** pressuring the planters to free their slaves, three years after the slave emancipation was proclaimed in **Colombia (1850)**.

Due to the lack of labor after the freeing of slaves, cotton plantations went bankrupt and many planters decided to leave the island, selling or distributing their land to the former slaves.

- Numerous planters had started to grow coconuts as a secondary source of revenue **around 1850**. The slaves started clearing their newly obtained lands and growing coconuts as soon as slave liberation was finished. By **1856**, **San Andres** was a frequent port of call for American captains seeking to purchase coconuts.

- Around **1860**, the base module for **San Andres** started as a two-room, hall-and-parlor-plan cottage of modest proportions and an extended kitchen.

Fig. 85. Type b2 core cottage with MF1 rear kitchen shed expansion, San Andrés Island.

Fig. 86. ML1 cottage windows in the gables. Note extended kitchen shed.

- After **1870** , the coconut business was bringing a lot of money into the economy, making it possible for succesfull farmers to build a comfortable wooden cottage, with two approaches to the problem of expation: (1) *Internal modular expantion* and (2) *external modular expansion.*

Fig. 87. Type d3 cottage with MLC1 full second story with piazza. An increasingly popular house type in San Andrés.

-Plan types become more complex as a result of *internal modular expansion*. Two distinct lineages of internal expansion were adopted on **San Andres**. Each started with the fundamental Type B asymmetrical "room-and-hall" plan.

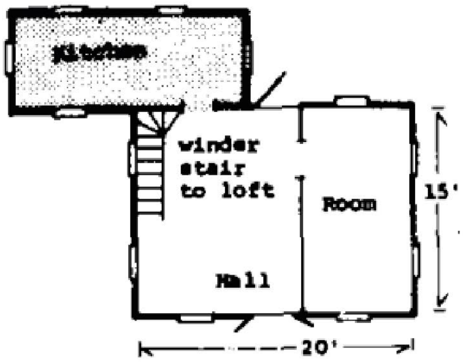


Fig. 88. Type b1.

The original hall was divided into a front hall and a smaller back dining room to start the first stage of expansion.The original bedroom was similarly divided, becoming a four-square foundation module, while the main cottage continued to grow. Houses with six or more rooms and a rectangular core eventually developed. Out of Type b, smaller plans also developed.

On the basis of two geometric principles—symmetry and axiality—four facade classes were established by observing the base module as it developed through various stages and plans.

Fig. 89. Type f1 four-room cottage with MF1 and MLB1-S expansion, San Andrés Island.

-Expansion is at the very core of vernacular architecture, especially in environments of fast economic growth, however, Internal expansion had limitations. In the hot, humid tropics, for instance, tightly contained rectangular house modules were relatively poorly adapted. Once built, a rectangular home was difficult to enlarge. After this, a completely different strategy for cottage expansion was implemented: *external modular expansion.*

Levels of modular expansion can be used to describe the process of external extension. Modular levels are independent of the internal plan types. No matter how simple or complex a module's interior floor layout, it is considered a "zero-expanded" cottage if there are no outward extensions. A new method of exterior modular expansion—*loft expansion*—was also being used as the modular cottage was entirely surrounded with piazzas and sheds. Making the loft more habitable was a big challenge for tropical vernacular architecture. The loft, with its steeply pitched ceiling, offered possibilities for use.

A new "double wall-plate" cottage design was created, in which the front and rear walls' parapet heights were increased above the wall plates. Such walls increased the loft's height by one or more feet, which was enough to allow someone to walk and stand below the collar beams that strengthened the rafters.

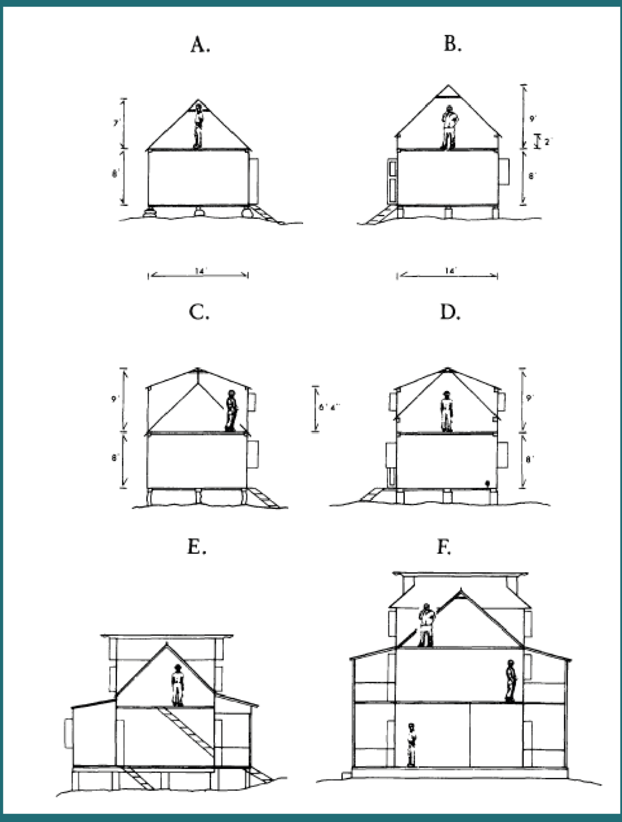


Fig. 90. The relations between loft types and roof types, as seen in section views. A. low-loft MLA0 cottage; B. double-wall-plate (parapeted) cottage, MLB0; C. pack saddle expansion, MLA1-P; D. shed-roof cottage, MLB1-S; E. MLB1-G "garrer" expansion; F. MLA1-H "hip-and-gable" expansion.

Large "garret" dormers with two windows were added to the roofs **sometime after 1900**. Garrets were used in some houses, although they were never very common. A New England-style shed dormer was also added to several "double wall-plate cottages" around the same period. With only a small "wing roof" on each side to show the original pitch, the "shed-roof dormer" practically covered the whole roof. It was a success, an increasing number of cottages acquired this shed-roof dormer in the **late XIX and early XX centuries**. An average-sized shed-roof dormer might be installed with three or more shuttered windows along the front and back, giving the loft plenty of cross-ventilation.

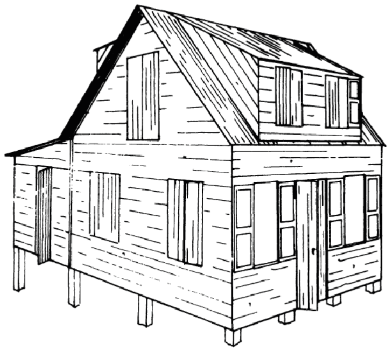


Fig. 91. A new England shed-roof dormer, MLB1-S, added to a type d1 cottage.

- After that, a similar kind of dormer was created to fit the low-loft cottages (without parapet walls). The top of the cottage was covered with a cap known as a "packsaddle dormer". Every type of dormer expansion is independent of every type of modular first-floor expansion.

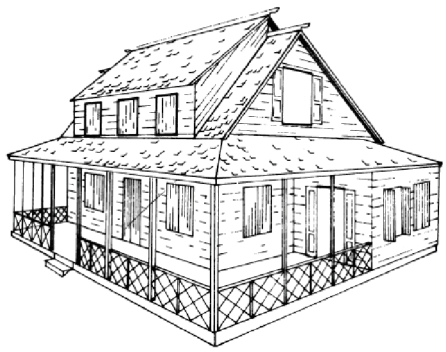


Fig. 92. MF2 packsaddle roof cottage showing access to kitchen shed via side piazza.

- The **San Andres** cottage's shape had to undergo one more innovation to be fully developed. To create an elevated second-floor front (and rear) porch over the first-floor piazza, the packsaddle and shed-roof dormers were moved forward (and back). One or more windows on the façade of the dormer were changed into doors (again improving loft ventilation) and the floor of the loft was extended out to the front piazza and rear shed plates.

The roofs of the piazza and the back shed were combined with the shed's wing roofs and pack-saddle additions. As a result, the front and back of the home featured high porches.

Fig. 93. Type J1 house with an MF2 encircling piazza and MLB2-S shed roof expansion, Sound Bay, San Andrés, 1970.

-A cooking stove was later installed in some of the newly added areas, which marked the start of the *external modular extension* approach. The introduction of cast-iron, wood, and subsequently kerosene cooking stoves around the year **1880** may be considered as the beginning of this innovation.

-The region was impacted by the industrial revolution **(1760-1840)** and the age of innovation in **Europe**. On **San Andrés**, the timber frame construction technique (Ballon Frame), known for its quick construction and low cost, was used.

- **The archipelago** consolidated a culture influenced by the **English Caribbean**, where the original colonization came from, which was reinforced with the arrival of numerous **Jamaicans** in the **first decades of the XIX century,** and later, of inhabitants from the **Cayman Islands**, **between 1830 and 1880**. Their migration was prompted by the need for labor during the construction of the Panama Canal and to care for the fruit plantations.The islands were isolated from the rest of **Colombia** until the **beginning of the XX century** as a result of their geographical position and the internal politics of the country, which explains this influence.

- An architectural revolution occurred along with the social and economic change that was seen in the years that followed. The tiny "room and hall" cottages of **San Andres** had developed into multistory timber-framed plantation houses by **1900**, which were surrounded by galleries and topped with elaborate dormers.

XX Century

- **Early in the XX century**, full, two-story homes gained popularity. Certain cottage types may occasionally be expanded to produce a new one. Due to this, the stairs leading to the second level were occasionally located outdoors, on the side piazza.

-Another strategy for vertical expansion has gained popularity **during the course of the XX century.** The entire house may be mounted eight feet above the ground with ease because all of the houses in this style were built on piers. After that, walls might be built in the spaces between the pillars to create a finished basement, or "bottom house". These spaces were used for work or additional living space in rural areas, for commercial uses in urban areas, or for rental properties.

Thus, the use of these numerous techniques for vertical extension enables the construction of three-story homes. This method of expansion even applies to modest-sized homes.

Fig. 94. Two-story I house with encircling MF2/MLB2 piazzas. Note stairway location on side piazzas.

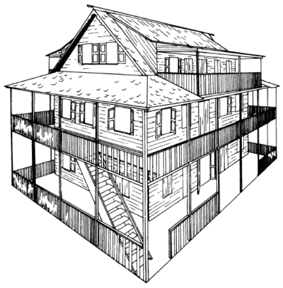


Fig. 95. Fully expanded shed-roof house wiith MF2, MB2, and ML2-S expansions. Note typical stairway location (stairway to second flooor may be located on front piazza).

-In the **early 1900s**, the islands were progressively integrated into **Colombia** in a process known as Colombianization. Since the archipelago was seen as outside the Hispanic, Catholic, and white political project that the Andean elites were interested in, the Colombian state attempted to change its culture and society, which had an impact on many of the dynamics that had previously existed in relation to the rest of the Caribbean, creating new cultural traditions.

- In **1928** the Esguerra-Bárcenas Treaty, a pact between **Colombia** and **Nicaragua** was signed. In accordance with the conditions of this agreement, Nicaragua acknowledged Colombia's sovereignty over the **Archipelago** while Colombia acknowledged Nicaragua's sovereignty over the **Coast of Mosquitos**. After the local forests had been cut down and replaced with coconut groves, fustic cedar, pine, and hardwoods were imported from Nicaragua's Mosquito Coast as construction materials, a situation that lasted until the signing of the treaty.

INFLUENCES AND ORIGIN OF CREOLE IN THE ARCHIPELAGO

- Beginning in the **1950s**, a more accelerated period of transformations took place with the use of new materials introduced to the island, such as cement, blocks, slabs, tiles and steels.

Fig. 96. E. Corpus's house.

Fig. 97. P. Coulson's house.

- The dwellings are consolidated in a clear process of evolution, developing an urban character by keeping the facing and profile of the road, with a noticeable presence of the sidewalk. The preservation of the family house on the second floor and the existence of commercial use on the first floor is another indicator of the urban sector.

These houses have two stories, a clear connection between the gallery or corridor and the main road, a round-top roof with a hipped roof, and an imported window with a fixed portion on top and a moveable portion below.

Fig. 98. D. Gallardo's house.

- The declaration of **San Andres** as a free port by President Gustavo Rojas Pinilla in **1953** began a process of change that included, in addition to the massive emigration of Colombians from the mainland to the islands, the dispossession and land speculation of the Raizal islanders, discrimination, displacement and acculturation.

XXI Century

Currently, in the sectors of Northend, La Loma, San Luis and on the Circunvalar road, there are some representative houses of the traditional architecture of San Andrés due to the use of wood and new systems that were adapted to the particular conditions of the climate, geography, culture and landscape of the island.

Northend: This sector has undergone the most significant changes. The majority of the houses still have a direct relationship with the courtyard, and other elements of the landscape. Although a third of the residences are mixed-use, containing commercial space, housing is the primary and predominant use.

Fig. 99.
Northend.
Omar Manuel Levur's house.

Fig. 100.
Northend.
Ayolin Pombo Jame's house.

La Loma: The courtyard, together with other elements of the surroundings, continues to hold the highest significance. Greenery and trees are very important. The houses were mostly obtained through inheritance. Construction dates: 50% in the first half of the 20th century and 10% in the previous century.

Fig. 101.
Loma and Circunvalar.
Cecilia Lever's house.

Fig. 102.
Loma and Circunvalar.
Mark Bent's house.

San Luis: The V-top is the most typical roof style in this area, therefore more than a third of houses have gabled roofs. A little over half of the houses have two stories. The majority of them are still being used as residences.

Fig. 103.
San Luis.
Alarico Escalona Hall's house.

Fig. 104.
San Luis.
Carmen Rankin de Hall's house.

The present-day islanders represent a diverse blend of Africans, Europeans, Caribbean individuals from various areas, Asians, and an increasing number of mainland Colombians. Among these islanders, the Creole language endures, serving as a testament to their commitment to preserving their distinct culture, which draws inspiration from their historical roots as former English colonies, their African ancestral heritage, and their connections—with the Caribbean initially and subsequently with Colombia.

The architectonic dynamic witnessed in the interactions among the numerous constituent elements of the San Andres tradition is the result of a complex and fragmented evolutionary process, marked by incremental changes and diverse influences, gradually shaped the intricate web of relationships and cultural elements that define the tradition.

More than 40% of the traditional houses were built between 1901 and 1950.

10.72% were built before 1900.

7.25% were built between 1981 and 1994.

San Andres island possesses a tangible treasure of:

370 heritage-listed properties

being

345 constructed using wood as the primary building material

The vast majority of the traditional houses inhabited today:

67% were inherited

65% have been occupied by raizales and their families

(Sanchez, 2004)

3.3.2. Characteristics of Creole Architecture in the Archipelago

The architectural traditions of San Andres are a testament to the profound influence of its unique natural hazards. In the face of tropical storms, rising sea levels, and other environmental challenges, the raizales, the native inhabitants of the islands, have developed construction practices that prioritize safety and resilience.

Historically, the construction of houses in San Andres was a community effort, involving the skills of local carpenters and builders of goletas (small sailboats). This collaborative approach to construction further emphasizes the sense of community and shared responsibility that defines the island's culture (Sánchez, 2022).

In conclusion, the creole architectural traditions have not only adapted to their geographical context but have also become a cherished cultural heritage, distinctively representing the island's identity within Colombia. The Northend, La Loma and San Luis sectors are living testimonies of the island's culturally rich construction practices and characteristics, which will be further elucidated in the sections below.

Orientation
- The road as an area of heritage value is the space along which the buildings are located. The main facades are oriented parallel to the road or facing the sea (Mosquera, 2014).
- The longest façade is designed east-west, since the main winds (trade winds) come from the northeast (Mosquera; Calderón, 2022).

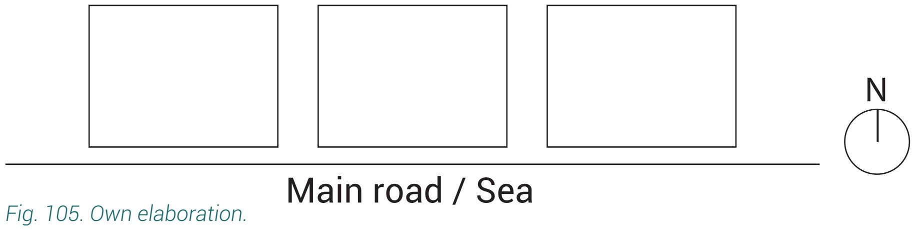


Fig. 105. Own elaboration.

Clusters
- There are clusters by sets in the sectors (direct relation with the road) and in the subsectors (relation with secondary roads forming interior sets) (Sánchez, 2022).
- These clusters can be of family and neighborhood type, and arise in order to share the yard, fruit trees, well, cistern and cemetery. This depends on family ties and traditional occupation of different sectors (Sánchez, 2022). These types of spaces are protected by the Colombian Law 1324 of 2021, mentioned before.
- Open courtyards and few interior divisions to encourage the creation and strengthening of these family and neighborhood ties (Sánchez, 2022).
- The courtyard also contains: the vegetable garden area, the children's play area, the cistern for rainwater storage and, at the back of the property, when its dimensions allow it, the area for the animals (Sánchez, 2022).

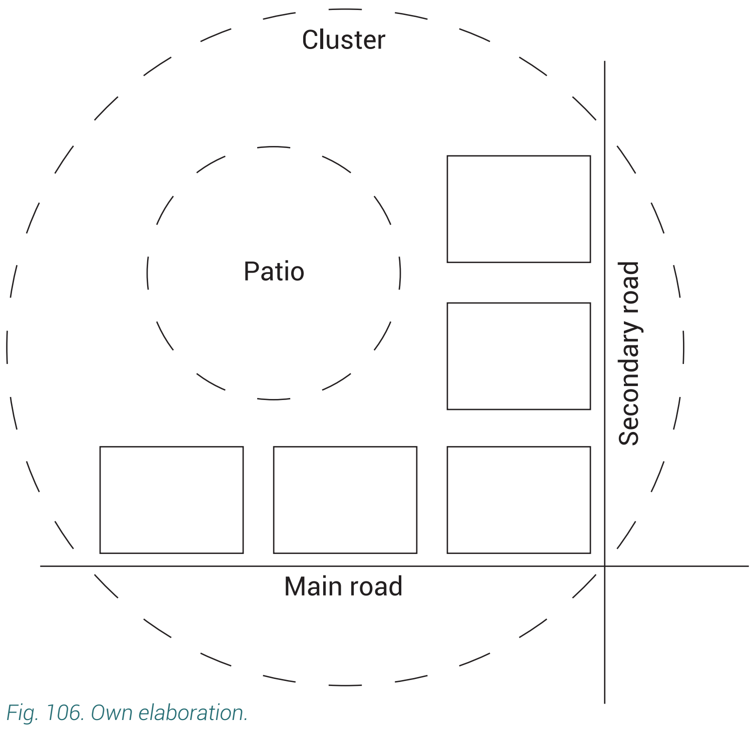


Fig. 106. Own elaboration.

Plan distribution
Definition of first Creole houses in San Andres: Basic rectangular hut or a rectangular-shaped case with a gabled roof and shuttered windows.

- First constructed around an asymmetrical two-room core. Then symmetrical plans started to be constructed (Edwards, 1991).
- Base module in San Andres started as a two-room cottage of modest proportions and an extended kitchen (Edwards, 1991).
- Addition of an interior central hallway (Edwards, 1991).

- Service units such as bathrooms and kitchens were separated from the living areas for reasons of space, sanitation and safety (related with fire) (Edwards, 1991).
- From this point on, a marked division between public spaces (living rooms, kitchen) and private spaces (bedrooms) begins to emerge (Edwards, 1991).
- Core (base module) with a periphery of narrow spaces: galleries and optional loggias (Edwards, 1991).
- Plan types became more complex as a result of internal modular expansion that started with the asymmetrical two-room plan (Edwards, 1991).

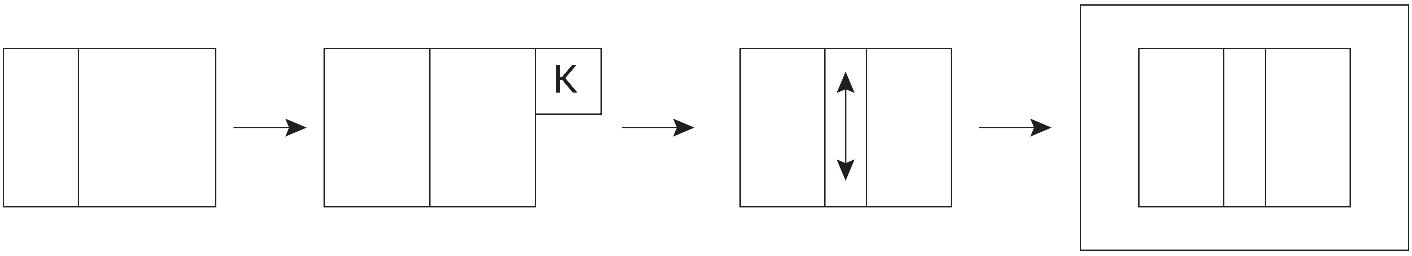


Fig. 107. Own elaboration.

Expansions

Typical family house: The house would be extended either horizontally or vertically, creating a new floor or a new living area in response to a growing family's needs. The tiny "room and hall" (base module) cottages developed into multi storey timber-framed houses surrounded by galleries.

- From the base module, the expansion of the house is presented; the family grows, the house grows (Sánchez, 2022).
- Expansion towards the front, the eaves are projected on the facade of the longest side, and a new space is generated, the piazza (galleries) (Sánchez, 2022).
- As it expands vertically, with another floor, the balcony appears. First at the front, on the longest facade and then on the sides (Sánchez, 2022).
- Vertical expansion, the loft gains height and for this reason it becomes more habitable and new spaces are created (Edwards, 1991).
- The different techniques for vertical expansion enables the construction of three storey houses (Edwards, 1991).
- Currently, preservation of the family house on the second floor and the existence of commercial use on the first floor (Sánchez, 2004).

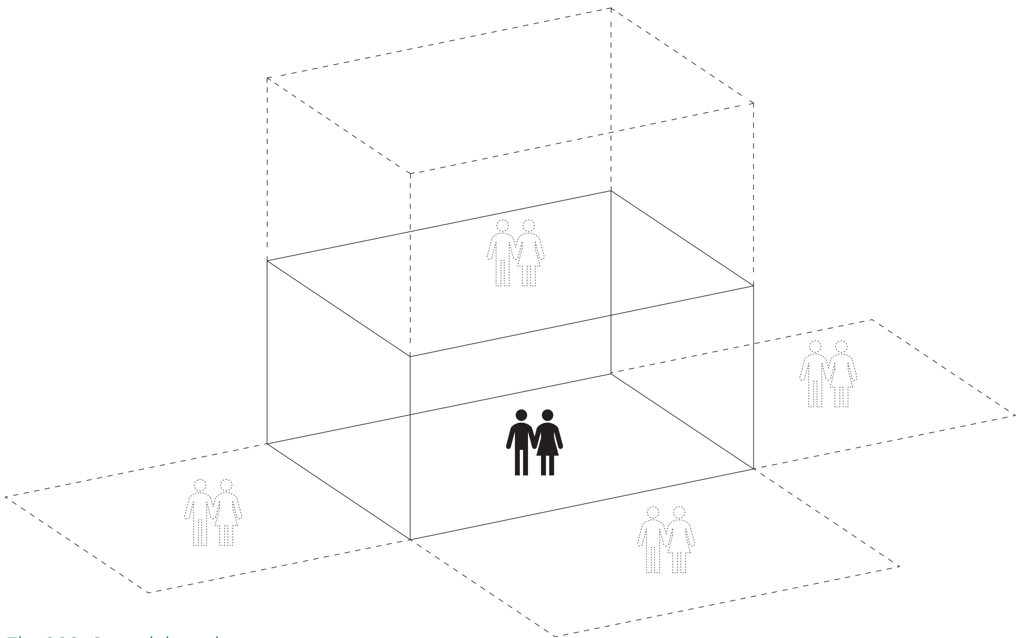


Fig. 108. Own elaboration.

Elevated foundation

- Piles of approximately 0.6 to 1.2 meters high above the ground, built in wood or stone and then in concrete (Ruiz, 2013).
- The house is sometimes raised to a greater height to generate a space between the floor and the living area that can be used for different purposes: as a storage room, kitchen, workshop or commerce (Ruiz, 2013).
- Elevation of the houses allowing ventilation for the purpose of dissipating (avoid) the humidity of the soil and cooling the external surface of the ground floor system (Ruiz, 2013).

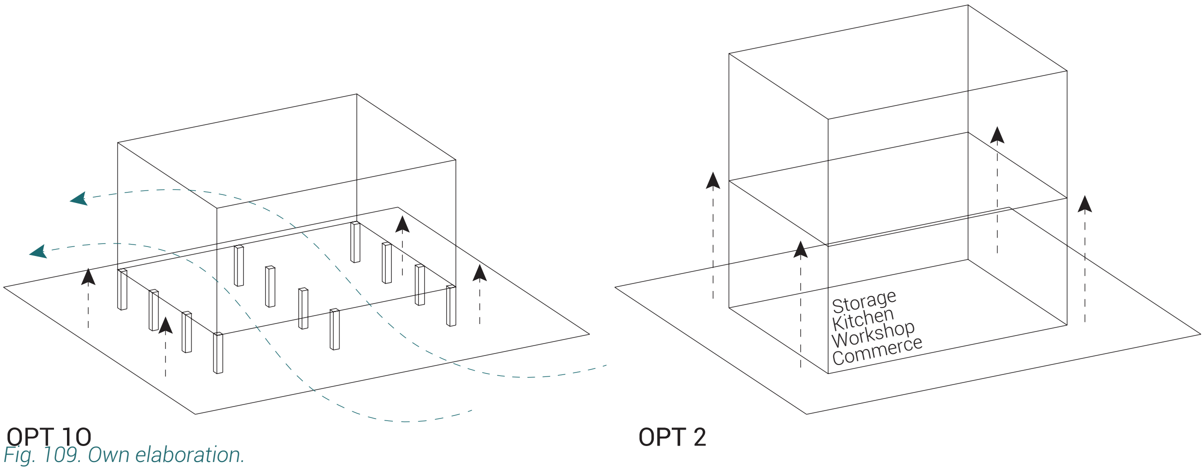


Fig. 109. Own elaboration.

Use of wood: Structure and Cladding

- Use of woods such as pine, teak and mangrove for the construction of houses due to their physical-mechanical properties (resistance to salinity, premature rotting and fungal attack caused by humidity, even without prior immunization treatments) (Ruiz, 2013).
- Ideal sizes. Large sections of very high quality species. They were not cut prematurely and allowed just drying times before working, ensuring optimal results in terms of stability and durability (Ruiz, 2013).
- Simplicity in operation and maintenance (Ruiz, 2013).
- Periodic varnishing or painting to promote preservation (Ruiz, 2013).

Structure: Platform Frame

- Initially the balloon frame, “the studs (vertical members) extend the full height of the building” (Britannica, 2009), was used. This “eventually evolved into a stronger method that relied on shorter lengths of lumber” (Osborn, 2020): platform frame, which consists of raising the structure floor by floor, so that the floor slab interrupts the continuity of the columns between the first and second floors (each floor is framed separately) (Pablo, 2016).

In this way, the subfloor transmits its loads axially and not eccentrically as in the case of the Balloon Frame (Pablo, 2016). “The frame can be built very quickly, and when sheathed, it takes on the structural qualities of a stiff, solid box” (Osborn, 2020). This structure is composed of modular elements, such as beams and columns, which offer some flexibility. This allows the structure to absorb and redistribute forces generated by seismic vibrations or strong winds associated with hurricanes (Pablo, 2016).

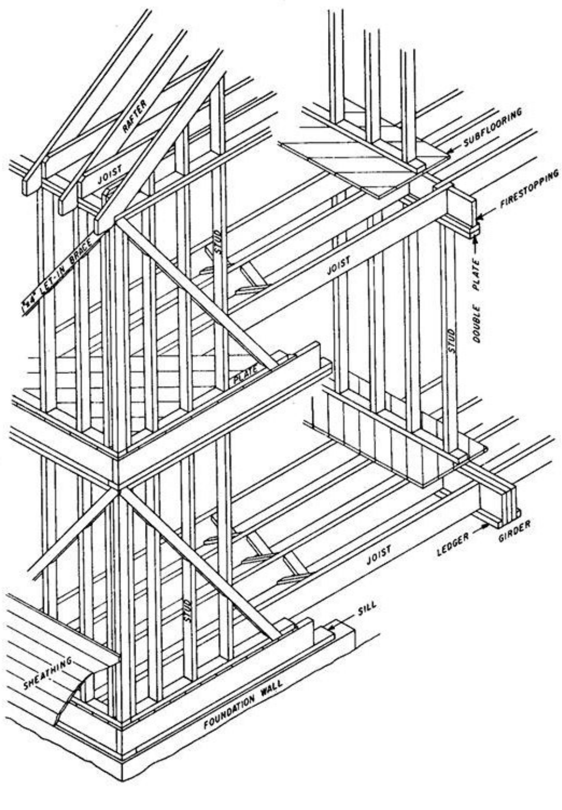


Fig. 110. Platform Frame. Source: Pablo, (2015).

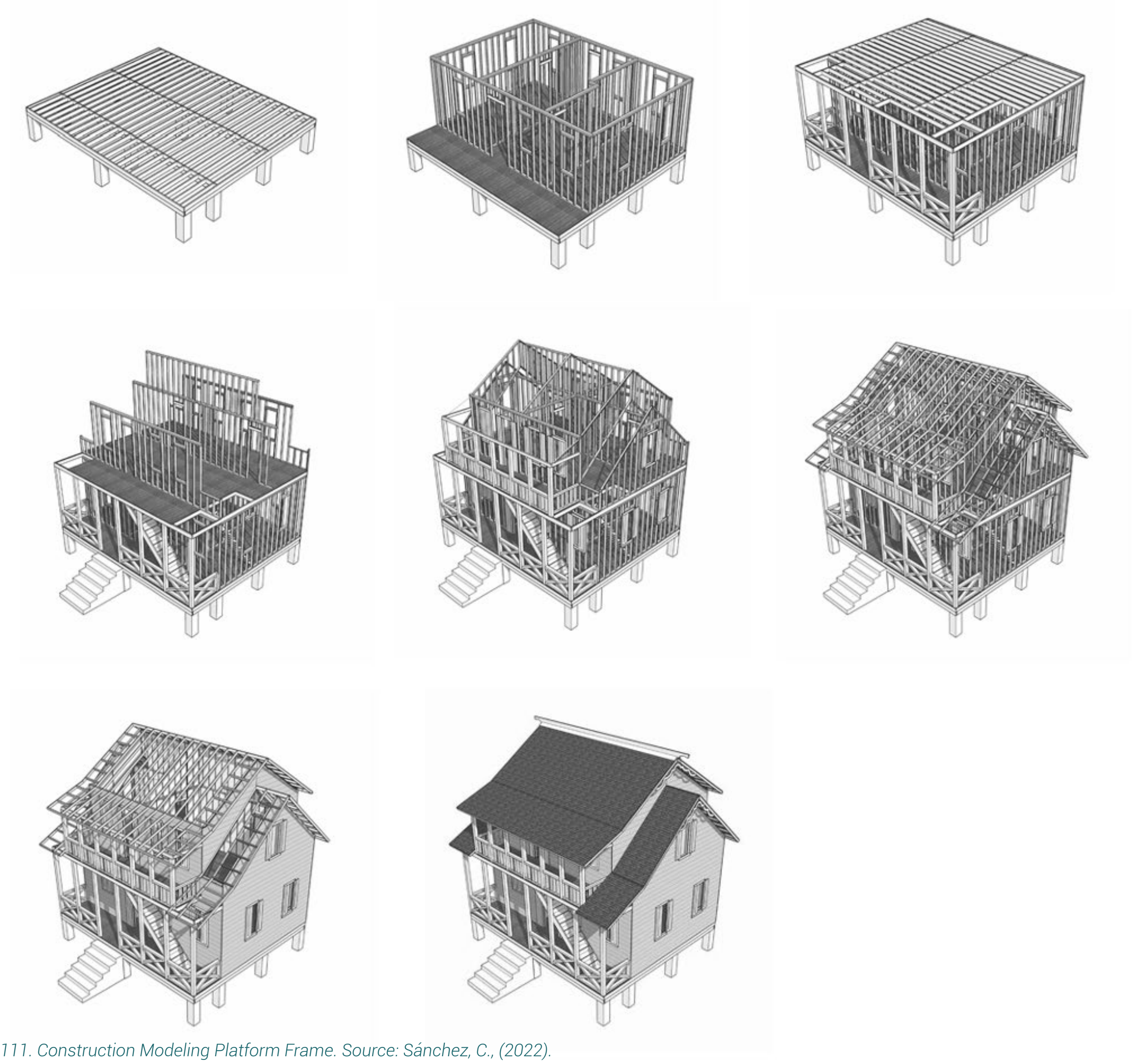


Fig. 111. Construction Modeling Platform Frame. Source: Sánchez, C., (2022).

Cladding: Tongue and groove

- Building construction based on a simple system called tongue and groove (Rae, 2016) where its basic principle of tabs and channels at the end of slats and sections joined horizontally, allowed a high percentage of houses to be built in a simple, very fast and economical way in terms of parts and transportation costs. The constructions reached a structural solidity, capable of withstanding strong winds, storms and tropical storms (Ruiz, 2013).
- For the facade cladding, smooth wood strips were also used without any type of channels (like those used in the tongue and groove technique), attached with screws to the wooden frame of the walls (Ruiz, 2013).

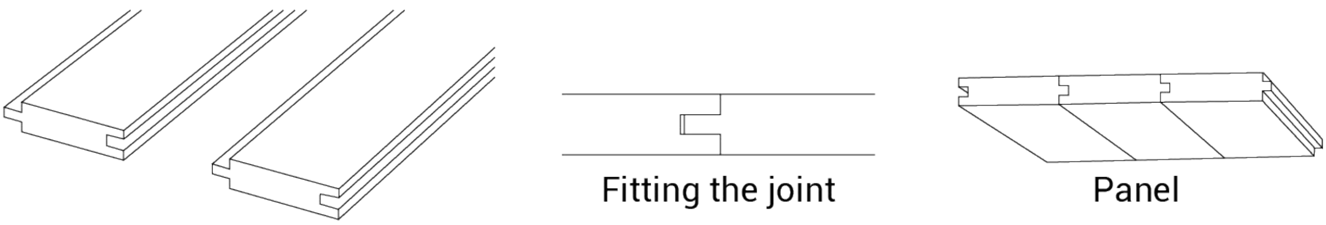


Fig. 112. Own elaboration based on: Rae, A., (2016).

Water storage

- Wooden barrel used as a water reservoir that was later replaced by the cement cistern for rainwater storage (Sánchez, 2022).

Fig. 113. Water barrel in Sarie Bay - San Andres.
Source: Sánchez, C., (2004).

Roof

- Types of roofs:

The majority (74.5%) of the traditional houses in San Andrés have a gable roof with an elongated rectangular base. In this typology, there are variants in the roof finish, as well as in the roof breaks and in the eaves (Sánchez, 2022).

  - Shed roof: The volume of the elongated attic has breaks in the front and rear roofs, and win dows appear on the longer facade (Sánchez, 2022).
  - Darma: The attic volume, also elongated, in addition to the breaks in the front and rear roofs, has windows and a door leading to the balcony on the longer facade. The eaves project over the balcony (Sánchez, 2022).
  - Garat: The attic seems to protrude from the roof. The breaks in the roof finish are perpendicu lar to the facade and it has a window at the front (Sánchez, 2022).

For the Caribbean, the shed roof, darma and garat types had already been used. However, it can be affirmed that the V-top is a variant specific to San Andres. The largest number of houses (42.03%) corresponds to this type (Sánchez, 2022). (See Fig. 114. Types of Roof)

  - V-top: The break in the front eave is projected over the balcony and the uniqueness of the side facade is emphasized. For shed roof, 24.06 %; darma, 4.64 %; garat: 3.77 % (Sánchez, 2022).
  - Round top: Houses with an almost square plan and a hipped roof. This shape may have the eaves projected around the entire volume. They correspond to 20% (Sánchez, 2022).

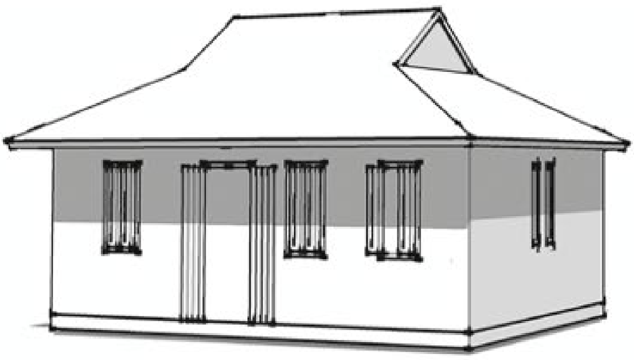
- The front and back of the houses started to feature high porches when the roofs of the piazza and the back shed were combined with the shed's wing roofs and pack-saddle additions (Edwards, 1991).
- Roof at different heights (Edwards, 1991).
- Large "garret" dormers with two windows were added to the roofs after 1900. They were used in some houses but were not very common (Edwards, 1991).
- Irregular slopes of the roofing material, including eaves at different angles (Sánchez, 2022).

Shed Roof

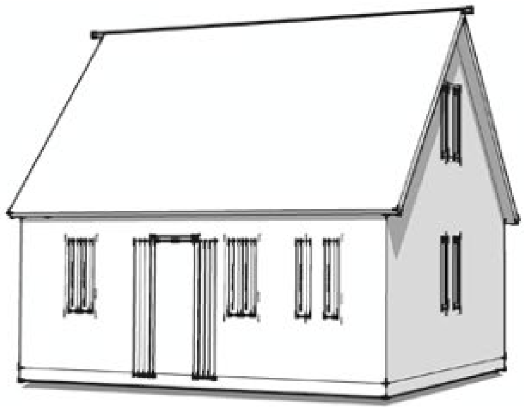
Darma Roof

Garat Roof

V-top Roof



Round Top Roof



Basic Roof

Fig. 114. Types of Roof. Source: Sánchez, C., (2022).

Details

- Railings
    - Used in galleries and balconies (Somerson, 2020).
    - Balustrades made of wood or ornamental wrought iron (Saldarriaga & Fonseca, 1985).
- Windows, doors and shutters
    - Location of doors and windows on the side facades, which are adjusted to the direction of the winds (Sánchez, 2022).
    - Entrances protected by heavy wooden outer shutters and light wooden inner doors (Somerson, 2020).
    - Jalousies incorporated after on inner doors.
    - Use of lattices at the top of doors and windows in exterior walls (Somerson, 1994).
- Roof
    - Side trims on the roof (Saldarriaga & Fonseca, 1985).

Railings

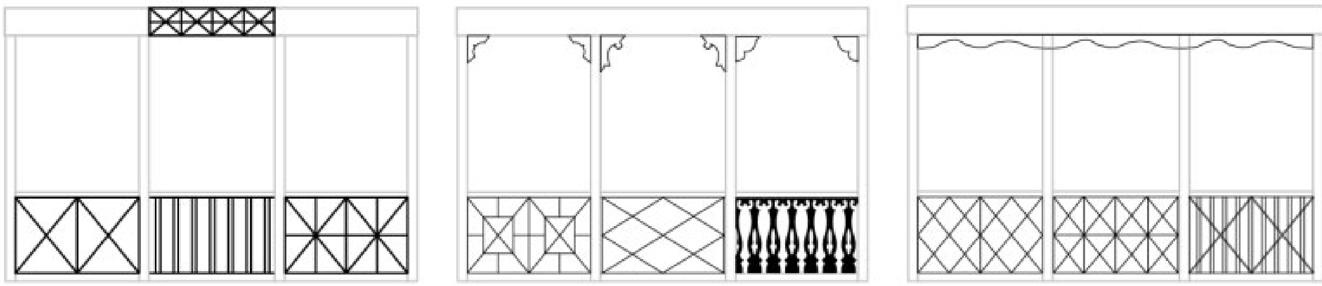


Fig. 115. Source: Saldarriaga, A; Fonseca, L., (1985).

Doors & Windows

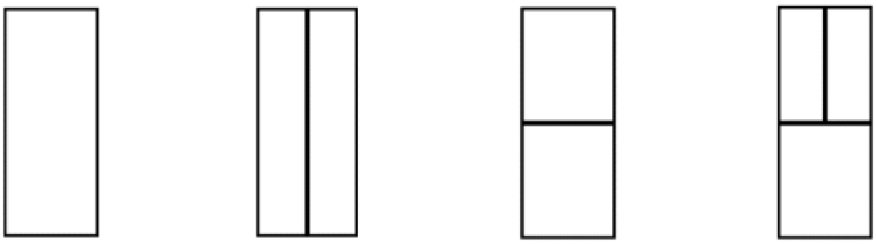


Fig. 116. Source: Saldarriaga, A; Fonseca, L., (1985).

Fig. 117. Source: Saldarriaga, A; Fonseca, L., (1985).

Roof

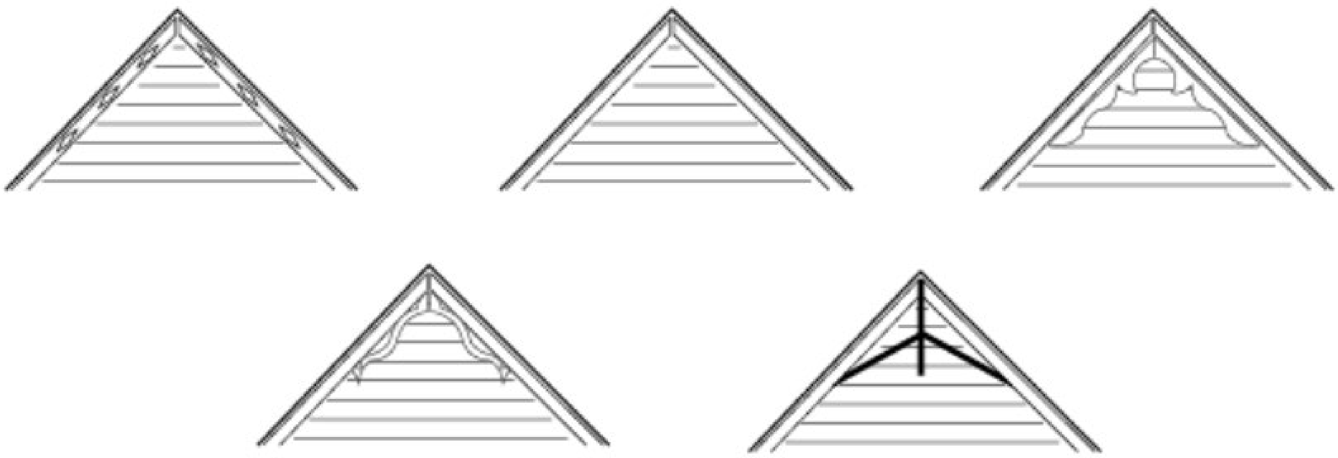


Fig. 118. Source: Saldarriaga, A; Fonseca, L., (1985).

3.3.3. Evolution of Creole Architectural Typologies in the Archipelago

To obtain a comprehensive understanding of the geometric and spatial evolution of the houses of the Archipelago of San Andres, Providencia, and Santa Catalina, a more detailed examination of the architectural chronology is necessary. This involves scrutinizing the intricacies of house typologies over time. Through the analysis of detailed planimetry, encompassing both external expansion and internal modifications, the configuration of these houses can be systematically traced, providing a step-by-step elucidation of their development.

This analytical approach allows observers to trace the gradual growth and transformation of these architectural structures, thus shedding light on the inventive adaptability of local builders and inhabitants. The result is an enriched understanding of Creole architecture in the Archipelago. It becomes clear how these houses have evolved to become emblematic symbols of cultural resilience, especially in the unique and challenging context of the Caribbean.

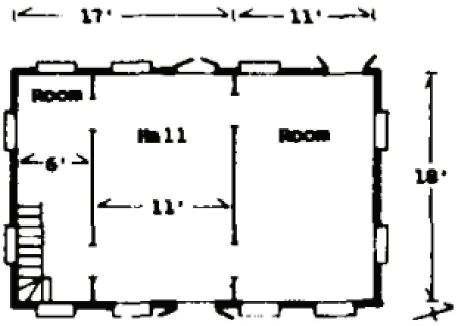
> *The* ***architectonic dynamic*** *expressed in the* ***relationships among the various components*** *of the* **San Andres tradition** *resulted from a piecemeal* ***evolutionary process.*** *Though established as* ***part of*** *a* ***unique historical and evolutionary sequence****, and though* ***modified by conditions of climate and siting****, the components function synchronically as* ***part of*** *a totally* ***integrated grammatical system****-a living cultural tradition.*
>
> (Edwards, 1991, p.86)

The following scheme "Evolution of Dwelling Types in San Andres" was elaborated from the following two books:

- Edwards, J. (1991). ***The Evolution of a Vernacular Tradition.*** Vernacular Architecture Forum.
- Fonseca & Saldarriaga. (1985). ***Vivienda en madera San Andrés y Providencia.*** Bogotá D.C., Colombia. Ediciones Proa.

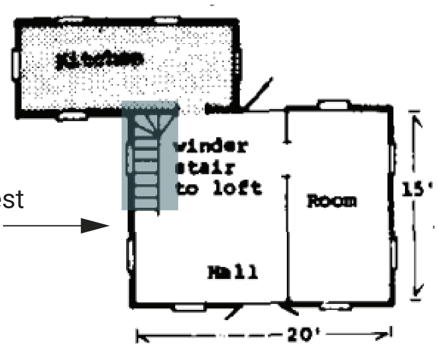
EVOLUTION OF DWELLING TYPES IN SAN ANDRES

Possible diffusion



Type h1
Addition of an extra bedroom on the opposite side of the hall from the "room", creating a plan with three full-depth rooms *en suite*.

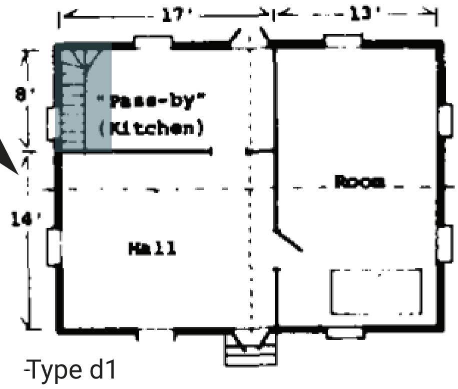
Diffusion from West Indies



Type b1

Plan I (Type B): Basic asymmetrical "room-and-hall".

Internal expansion



Type d1
Segmentation of the original hall into a front hall and a smaller rear dinning room.

4 TYPES OF FACADES - Under the principles of symmetry and axiality

Symmetrical facade: balanced upon a center line

Asymmetrical facade: one opening (usually the door) adjusted from six to eighteen inches to the right or left of the center line.

Axial Facade: door in the middle of the facade, balanced by equal numbers of windows (or doors and windows) on either side.

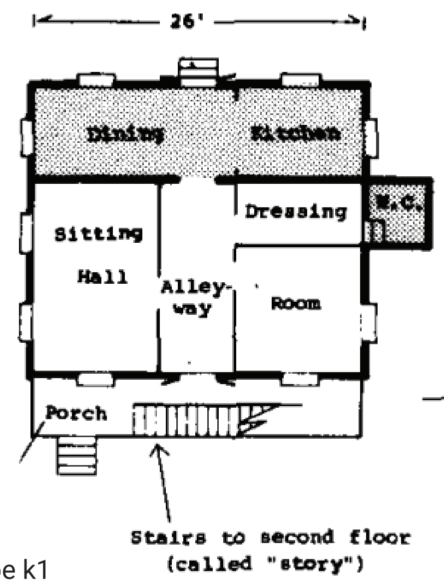
Nonaxial facade: even number of openings, with none on the midline of the facade.
Any combination of the four geometric possibilities was acceptable:

Facade Class	Axiality	Symmetry
1	yes	yes
2	yes	no
3	no	yes
4	no	no

Possible diffusion

Stimulus Diffusion

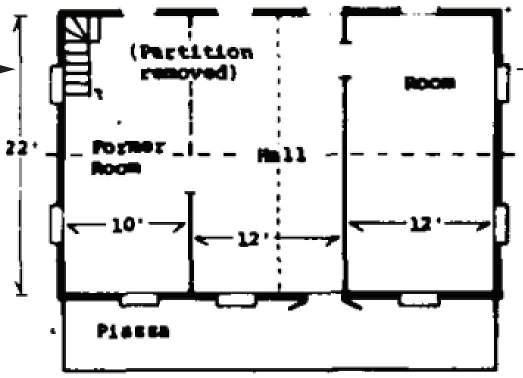
from United Sates



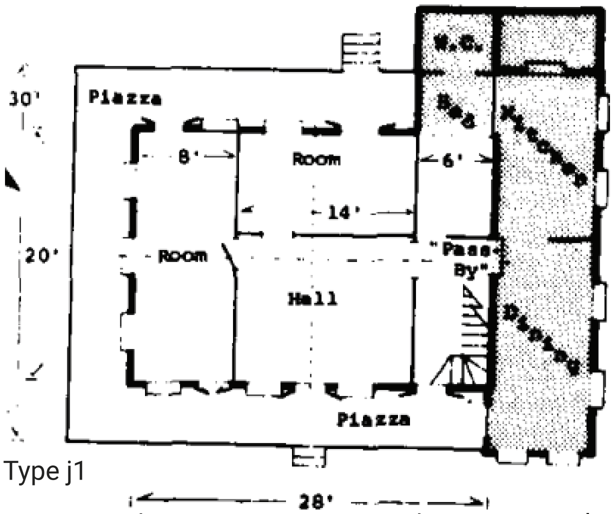
Type k1

Symmetrical central hall-plan introduced with a two-story I house.

Access to the loft traditionally via a winder stair placed inside a rear corner of the core module.

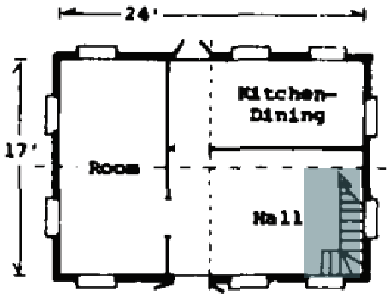


Type h3

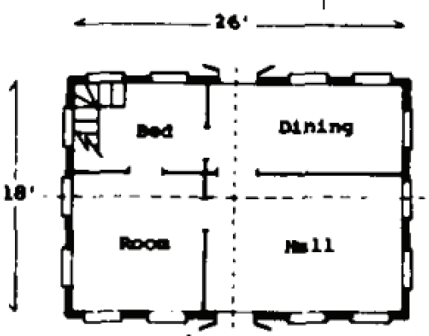


Type j1

Houses with six or more rooms within a rectangular core evolved.



Type d4



Type f1

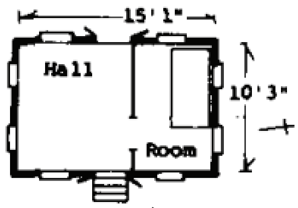
Original bedroom similarly bifurcated, creating a four-square base module.

External expansion

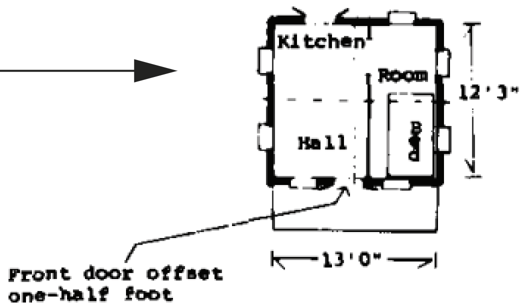
Through the addition of an outside encircling gallery placed around the bedrooms and across the rear of the building.

Smaller two-room houses (Type b-1, b-2) and a single-room plan (Type a1), represent a kind of devolutionary lineage.

Type b- consisted of a room-and-hall module with a narrow bedroom, limiting the room to a single bed.

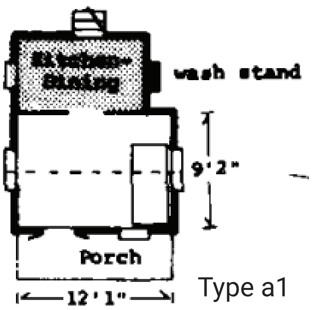


Type b-1



Type b-2

Possible diffusion



Type a1

Fig. 119. Own elaboration based on: Edwards, J., (1991).

EVOLUTION OF DWELLING TYPES IN SAN ANDRES

External expansion

Levels of modular expansion / External expansion

Expansion elements of each successive modular level are dependent upon the prior existence of those of an inferior level.

MFO
A rectangular core cottage without external additions.

M: A basic, core cottage module.
0: Unexpanded.
F: On the first floor.

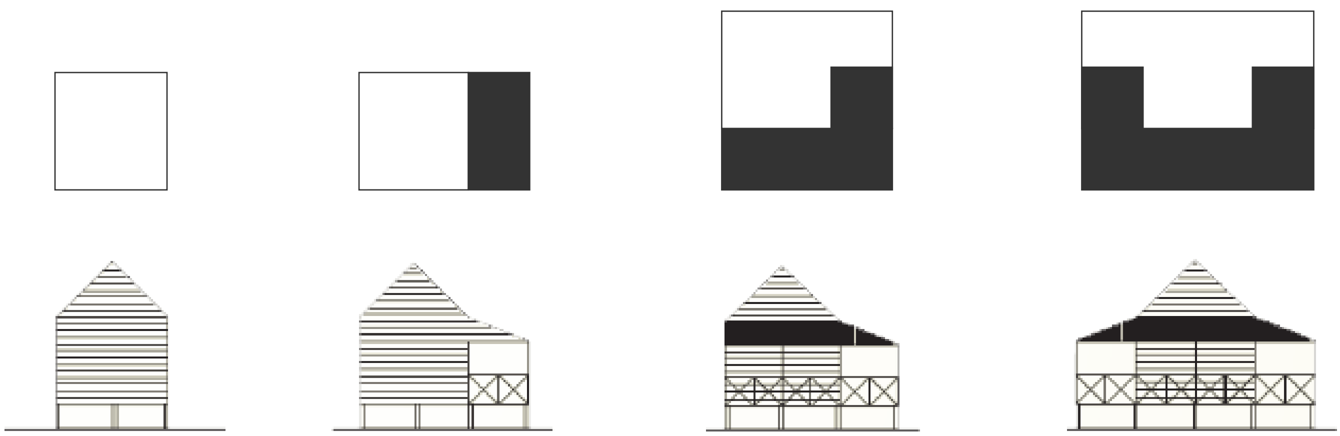
MF1
A cottage with any combination of a full-length front veranda and a full-width rear shed.

MF2
At least one side piazza , dependent on the prior existence of a front piazza.

Side piazzas may be added simultaneously in any specific building.

Once side piazzas have been added to the base module, they can be enclosed and turned into extra bedrooms.

MF3
Addition of an outside encircling gallery placed around the bedrooms and perhaps across the rear of the building as well.

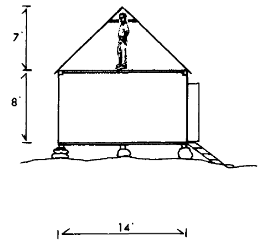


Loft expansion

(All forms of dormer expansion are independent of all forms of first-floor modular expansion).

Euro- American vernacular traditions

MLA0

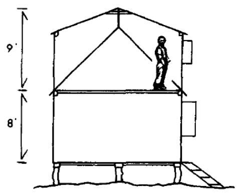


A

Unexpanded "low-loft" cottage. The rafters rested directly on the same wall plates that supported the ceiling joists.

Cap called a "**packsaddle dormer**" was placed across the entire top of the cottage.

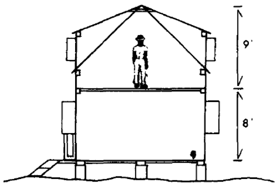
(MLA1-P)



C

New England-style shed dormer was added to **MLB0** "double wall- plate cottages".

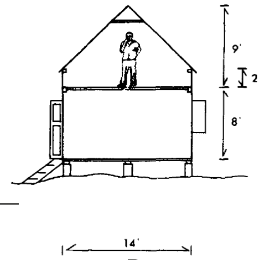
MLB1- S



D

(B class [double wall plate], modular loft expansion level 1, **shed-roof** form).

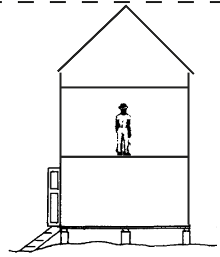
MLB0



B

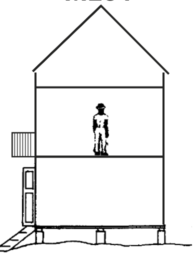
"Double wall-plate" cottage: parapet walls extended the height of the front and back walls above the wall plates. (sufficient to permit a person to walk).

MLC0



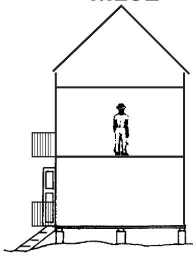
Full two- story house

MLC1



Built with a full-width second-story piazza.

MLC2



An MF2+ML1C house with an encircling gallery on both the first and second floors.

Final innovations:

-Forward and backward extension of the packsaddle and shed-roof dormers to provide an elevated second-floor front (and rear) porch over the first-floor piazza.

- Extension of The loft floor out to the front piazza and rear shed plates, and one or more windows on the face of the dormer turned into doors (enhancing loft ventilation).

-Integration of the Shed wing roofs and packsaddle expansions with the roofs of the piazza and the rear shed.

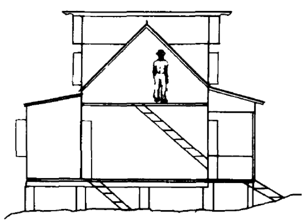
MLA1-G or MLB1

Two-window **"garret"** dormers that capped the entire roof or garret form. Garrets became unpopular.

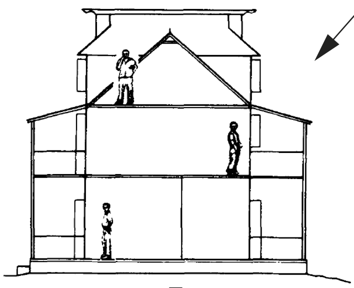
MLA1- H or MLB1-H

Taller "**hip-and-gable garrets**".

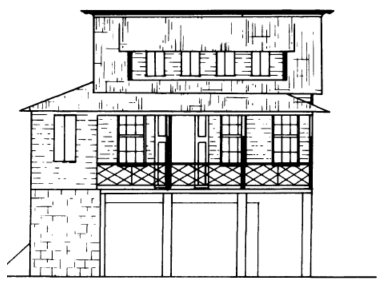
Creation of the **"bottom house"** by raising the entire house by tall posts.



E



F



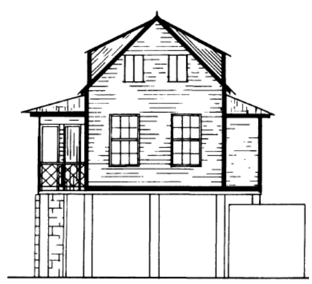


Fig. 120. Own elaboration based on: Edwards, J., (1991).

In addition to the internal and external expansions, another important aspect in the configuration of the house that underwent modifications over time was the kitchen. Given that the predominant material of the house was wood, this was originally situated outdoors as a sort of fire pit but was subsequently relocated inside, when the firesides turned into stoves and stopped being a fire threat for the house.

For the Raizal culture, this space transcended its basic functionality to serve as a gathering place for the communities that value their strong social bonds and intergenerational dialogue —a topic that will be explored in greater detail later on.

The importance of the traditional kitchen as a catalyst for cultural expressions

Around meal preparation, kitchens unite not just small families but also extended families, neighborhoods, towns, and entire communities. With wild animals, vegetables, and the produced and domesticated biodiversity on a limited portion of land, kitchens reflect a significant connection to the biological richness of the surrounding area.

Based on the research outlined in the book "Land & Sea," three areas stand out in the Archipelago's traditional kitchens: *the grung, the yard, and the fireside:*

The grung:
The most significant subsistence crops are grown on the grung (ground). It is typically found in locations that are suitable for this purpose among the dry forest, some distance away from residential areas. Many of them belong to the people who cultivate them, but those who lack property or have only tiny or inappropriate parcels for planting sometimes borrow land in exchange for a portion of the harvest. Despite the recent decline in agriculture, many people still keep their farms. In the past, women actively attended the grung, but today it is mostly a male domain because only few women work these lands (MinCultura, 2016).

Fig. 121. The grung. Own elaboration based on: Cátedra Raizal (2020).

The yard:
The area that surrounds the house, the yard, serves as a significant area for social gatherings and is also where certain subsistence crops are grown. In this regard, the yard serves two crucial functions for the Archipelago's traditional kitchens (MinCultura, 2016):

1. Food production using a variety of herbs, fruit trees, and minor crops grown primarily by women in their backyards.The majority of the aromatic and medicinal herbs and spices that are cultivated here are species that are not found in the grung. Here, you may also find a lot of ornamental plants (MinCultura, 2016).

2. Serve as a venue for gatherings of friends and family, which are frequently centered around food. The patios of island houses typically include one or more large trees that provide consi derable shade, where people gather to engage in domestic tasks or to chat while cooking with friends or family. People keep their fireside in the yard, which was formerly an outdoor kitchen but is now typically just a fire pit constructed with a few stones on the ground or on a metal barrel used to transport gasoline (MinCultura, 2016).

The yard is a common space shared among families and/or neighbors. It is cared mostly by women, but some men also help, and some of them are knowledgeable about the plants grown there and their functions (MinCultura, 2016).

It should be noted that this space, which has largely shaped the way the Raizal community relates to each other, is protected in Colombia by **Law 2134 of 2021, Article 1, Paragraph 2°**: The green spaces or communal or family yards or 'the yard' or 'di yaad' are fundamental sociability spaces of the Raizal culture that surround the buildings of the traditional architecture of the islands, are an integral part of the traditional architectural ensemble of the Raizal People of the Archipelago and contain vegetation, trees, orchards and other elements of ornamental, environmental, food and nutritional security, landscape and spiritual value, important elements for the preservation of the Seaflower Biosphere Reserve (Ley 2134, 2021).

Fig. 122. The yard. Own elaboration based on: Koene, T.

The fireside:

In order to reduce the smoke inside the homes and the possibility of a fire, which was high given that the traditional architecture is made of wood, the fireside, the place for the fire, for decades was located in outdoor kitchens near the houses added as a component of the courtyard.

The women's primary area of responsibility was the fireside, where they cooked both daily and special meals. In general, all islanders owned one since they were the main place for meal preparation. However, the sophistication of these external kitchens with their firesides varied depending on the economic standing of the families, which also dictated the construction of the space, the type of utensils and tools, and the products they had to prepare (MinCultura, 2016).

Even though modern electric or gas stoves inside the home have taken the place of outdoor kitchens, which require more work and are more difficult to use, wood stoves have survived to this day. This is possibly because there is such a strong tradition of cooking on them that it is almost forbidden to prepare some recipes without using firewood. For this reason, in almost all the patios of the houses it is possible to find the fireplaces on the floor, which are used when there is a need (MinCultura, 2016).

Fig. 123. The fireside. Own elaboration based on: Ministerio de Cultura, (2016).

*"The **island's traditional cuisine** is composed of a large amount of **knowledge and flavors** that have been **passed down from generation to generation** over the years, generating feelings of **identity, belonging and historical continuity** in these communities"*

(Ministerio de Cultura, 2016, p. 19).

Conclusion

The island's resources have played an important role in the evolution of architecture and cultural dynamics. Considering the fertile soils and abundant raw materials, the houses constructed from mangrove wood served as multifunctional spaces, offering not only rest and gatherings but also places of work. In the surrounding land, families engaged in collaborative efforts to cultivate various herbs, fruit trees, and small crops, which would be used later for preparing their traditional dishes.

Currently, the primary factor driving the expansion of houses has changed, resulting from both new needs and globalization. Unlike in the past, where the expansion was mainly to accommodate new family members, nowadays, the economy plays a central role in this transformation. While there has always been a work component within the domestic sphere, as mentioned before, previously linked to agriculture, it has evolved into other types of employment that are still carried out within the house. Consequently, new spaces have emerged to meet these economic demands.

3.4. Creole Architecture in the Archipelago as Colombian Patrimony

Vernacular architecture is a fundamental element of the identity of the Raizal people of the Archipelago. This architectural expression is not only a reflection of their history but also a testimony of the evolution of this community, from the smaller modest houses to the multi-story buildings that have emerged over the decades. Each structure tells a unique story, marking the passage of time and the constant adaptation of Raizal architecture to the changing needs of the community.

This architectural style reflects a balance with the environment, maintaining a harmonious relationship between the interior and exterior throughout all its spaces. From the most intimate rooms inside the house to the galleries that eventually lead to the courtyard, becoming a sacred space of gathering and exchange, where families congregate, stories are shared, and traditions are kept alive. It is a testament to how this architecture merges with the daily life of the whole community, providing an environment that facilitates human connections and the preservation of their cultural heritage.

Raizal architecture is much more than a constructive expression, it's a reflection of a culture rooted in the land and the hearts of its people. It is a way of living and coexisting that has been passed down through generations, a tangible manifestation of the community's identity and values. Every detail, from the choice of materials to the layout of the spaces, bears the imprint of a rich and complex history woven with the multiple interactions that characterize life in the Archipelago.

Given the significant importance of this architectural expression, **Law 47 of 1993** was enacted, whereby special rules were issued for the organization and operation of the Archipelago Department of San Andres, Providencia, and Santa Catalina as an act of preservation and respect for the cultural heritage of this department. In **Chapter VIII**: On the protection of the cultural heritage:
Article 51: On the conservation of native architecture. The construction of real estate in the Archipelago Department of San Andres, Providencia, and Santa Catalina shall be carried out preserving the native architecture of the department (Law 47, 1993).

After the passage of Hurricane Iota in the Archipelago in 2020, it was necessary to draft new laws for the conservation of this culture and their heritage, which reinforce and expand those already set out in the current constitution, for example **Law 2134 of 2021**: By which the tangible and intangible cultural heritage of the nation of the Raizal people of the Archipelago of San Andrés, Providencia and Santa Catalina is recognized, it is proposed the development of the corresponding studies to make the corresponding declarations, according to the procedures in force and other provisions are issued:
Article 1: Recognize as Intangible Cultural Heritage of the Nation the wisdom, ancestral knowledge, traditional techniques and cultural practices in their coexistence with the sea and the traditional architecture of the Raizal people of the Archipelago of San Andres, Providencia and Santa Catalina.

In Chapter II. Various dispositions:
Article 7°. Authorization. Authorize the National Government so that, through the Ministry of Culture in coordination with other competent entities, it may carry out the following actions:
(d) Encourage the management and transmission of the practices, knowledge and techniques of the traditional builders of the Archipelago, to favor generational relay and guarantee the permanence of this activity and its economic sustainability in order to ensure the preservation of the ancestral raizal activity in the islands as a cultural identity that endures through time.

Article 13. Local and departmental technical capacities shall be strengthened for the management of incentives to the owners of properties that manifest the attributes of the architecture of cultural interest of the Archipelago, who invest in the recovery and new construction of these properties and in the promotion of the trades and cultural practices related to the cultural heritage.
Paragraph. New constructions for housing that are part of government programs and that are carried out within the territory of the Archipelago shall be promoted, which must include the attributes of housing of cultural interest for the Archipelago:

a) Traditional construction techniques.
b) Incentive to lower costs for the use of wood.
c) Spatiality and formal elements of the region.
d) Protection of the natural heritage.

These protection laws are a constant reminder of the importance of preserving the traditional architectural heritage and ancestral knowledge of the Raizal community. They were enacted in response to the gradual loss of these elements over time. Factors such as industrialization and the introduction of new construction materials, such as cement and brick, have contributed to the partial or complete disappearance of ancient customs, such as the use of wood in construction. The enactment of these laws serves as a guide that leads to the conservation and respect of an invaluable architectural heritage, a legacy shared by the Raizal community.

04

AFFECTATIONS AFTER RECENT HURRICANES IN THE ARCHIPELAGO AND CASE STUDY

4.1. Hazards in the Archipelago

Colombia, situated in the northwest of South America, is characterized by its vulnerability to a diverse array of natural hazards, encompassing both hydro-meteorological events such as floods, droughts, and storms, as well as geophysical occurrences like earthquakes and volcanic eruptions (World Bank Group, 2021). Among this assortment of potential risks, the islands of San Andres, Providencia, and Santa Catalina are particularly vulnerable. These Caribbean islands, known for their natural beauty and vibrant communities, are situated in a region prone to severe weather conditions. This includes the possibility of powerful tidal waves, destructive winds, and heavy rainfall (Minambiente & Invemar, 2014).

These weather events are intensified by the warm waters of the Caribbean. Among these atmospheric phenomena, hurricanes and tropical storms stand out as the most significant threats, putting both human lives and property at risk. The unique geographical context of these islands, coupled with the prevailing weather conditions, underscores the importance of understanding and mitigating these risks. Weather patterns, such as heavy rainfall and sea-level fluctuations, can disrupt daily life, infrastructure, and the socioeconomic fabric of these island communities. Thus, efforts to fortify resilience and ensure the safety and prosperity of the residents and visitors to the islands of San Andres, Providencia, and Santa Catalina take on heightened significance.

According to the Disaster prevention and attention booklet (sanandres.gov & UNGRD, 2012), the Archipelago is susceptible to several natural hazards, including:

Hurricanes and Tropical Storms: The islands are located in a hurricane-prone region, making them vulnerable to the destructive forces of these phenoma. These weather systems bring strong winds, heavy rainfall, storm surges, and tidal waves that can cause significant damage to infrastructure and pose risks to human lives (sanandres.gov & UNGRD, 2012).

Tidal Waves and Storm Surges: The islands are at risk of experiencing these, especially during hurricanes and tropical storms. These phenomena can lead to coastal flooding, erosion, and damage to waterfront properties (sanandres.gov & UNGRD, 2012).

Heavy Rainfall and Flooding: The Archipelago can experience heavy rainfall, particularly during the rainy season, which may lead to flooding in low-lying areas. Flooding can disrupt daily life, damage houses, and affect transportation (sanandres.gov & UNGRD, 2012).

Earthquakes: While not as common as some other hazards, earthquakes can occur in the region due to its proximity to tectonic plate boundaries. These seismic events can potentially result in structural damage (sanandres.gov & UNGRD, 2012).

Volcanic Activity: While volcanic activity is not currently a major hazard, the islands of San Andres and Providencia have volcanic origins, and there is a potential for future volcanic activity that could impact the region (sanandres.gov & UNGRD, 2012).

Fires: In Providencia, where abundant natural vegetation thrives, the risk of natural fires becomes a relevant concern. The island's lush ecosystems, including forests and dense greenery, are susceptible to wildfires, particularly during dry spells or prolonged periods of low rainfall (sanandres.gov & UNGRD, 2012).

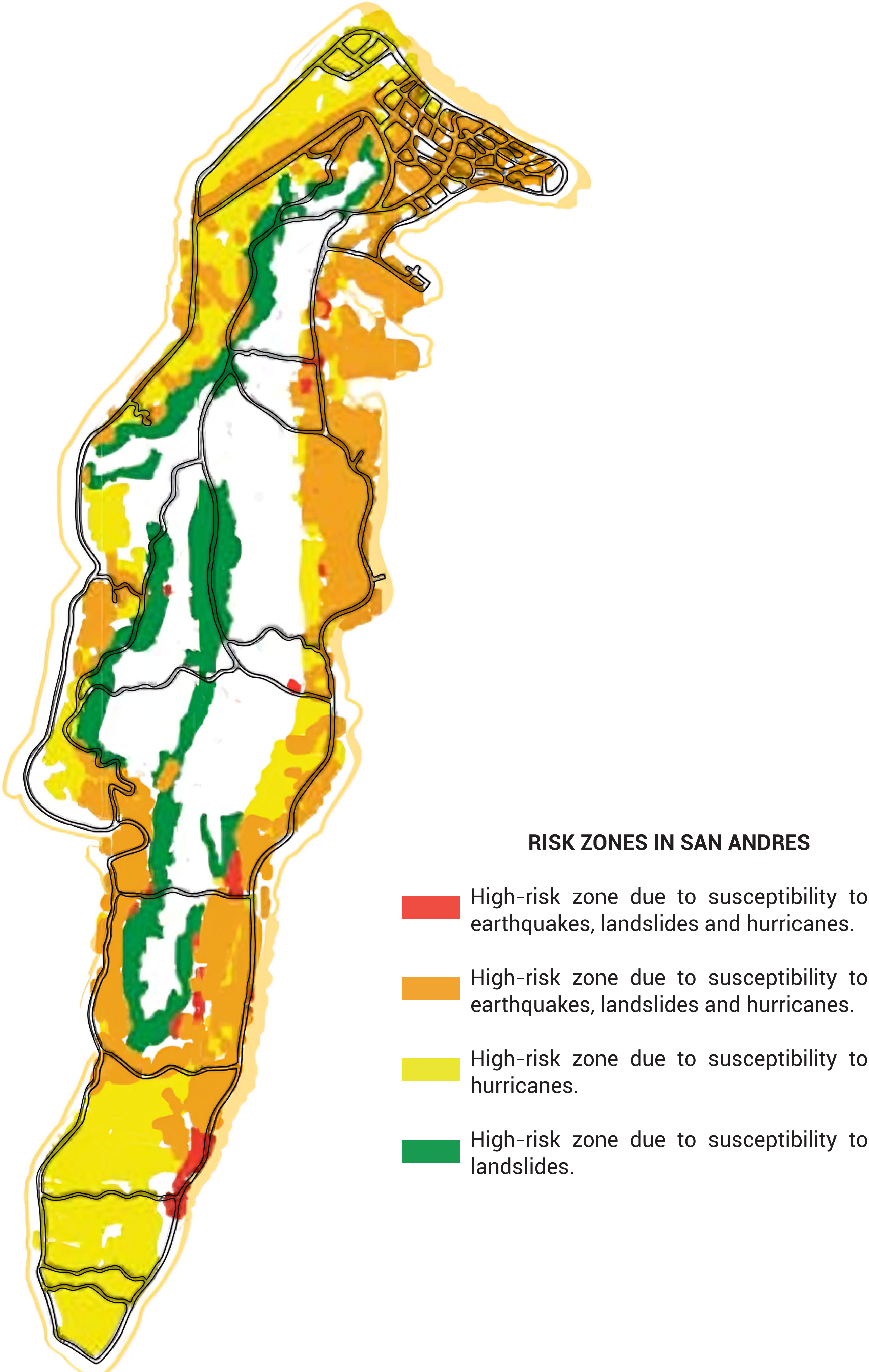


Fig. 124. Map of risk zones in San Andres. Source: Gov. de San Andres Islas; UNGRD, (2012).

4.1.1. Recent High-Impact Hurricanes in the Archipelago

As previously mentioned, due to its geographic location, Colombia is particularly vulnerable to the various hazards that occur in the Caribbean, such as hurricanes. The entire country can be impacted indirectly by these phenomena through increased rainfall and strong winds. However, their presence over the Caribbean Sea poses a direct threat to the departments along the Atlantic coast: La Guajira, Bolívar, Magdalena, Atlántico, Córdoba, Cesar, Sucre, and Córdoba, as well as the insular region in the Archipelago of San Andres, Providencia, and Santa Catalina (UNGRD, 2022).

Although measuring the intensity of hurricane activity is important, it's necessary to emphasize that the number of cyclones isn't the most relevant aspect. Rather, the areas where these cyclones are most likely to form and the possible paths they may take should be the primary topics of concern (UNGRD, 2022).

Furthermore, the increased frequency and severity of hurricanes in the Caribbean region have raised concerns about the long-term resilience of Colombia's coastal areas. As climate change continues to influence weather patterns, the potential for more frequent and intense hurricanes becomes a growing threat. For example, the Archipelago had not been hit by a devastating catastrophe that would destroy it, which is why its housing and heritage had remained untouched. This situation changed in recent years after the passage of hurricanes Eta and Iota in 2020 where 98% of the infrastructure of Providencia and Santa Catalina was destroyed, as well as a smaller part of the island of San Andres (Cruz Roja Colombiana, 2020).

Some of the main causes of the damage caused by Hurricane Iota were (AIS, 2021):

- Poor resistance of walls to lateral loads.
- Inadequate connection between structural elements.
- Inadequate connection between walls and foundations.
- Inadequate connection between walls and roof.
- Absence of a resistant diaphragm at the roof level.

Fig. 125. Source: EFE, Castaneda, M., (2021).

Basic Wind Speed in Colombia:

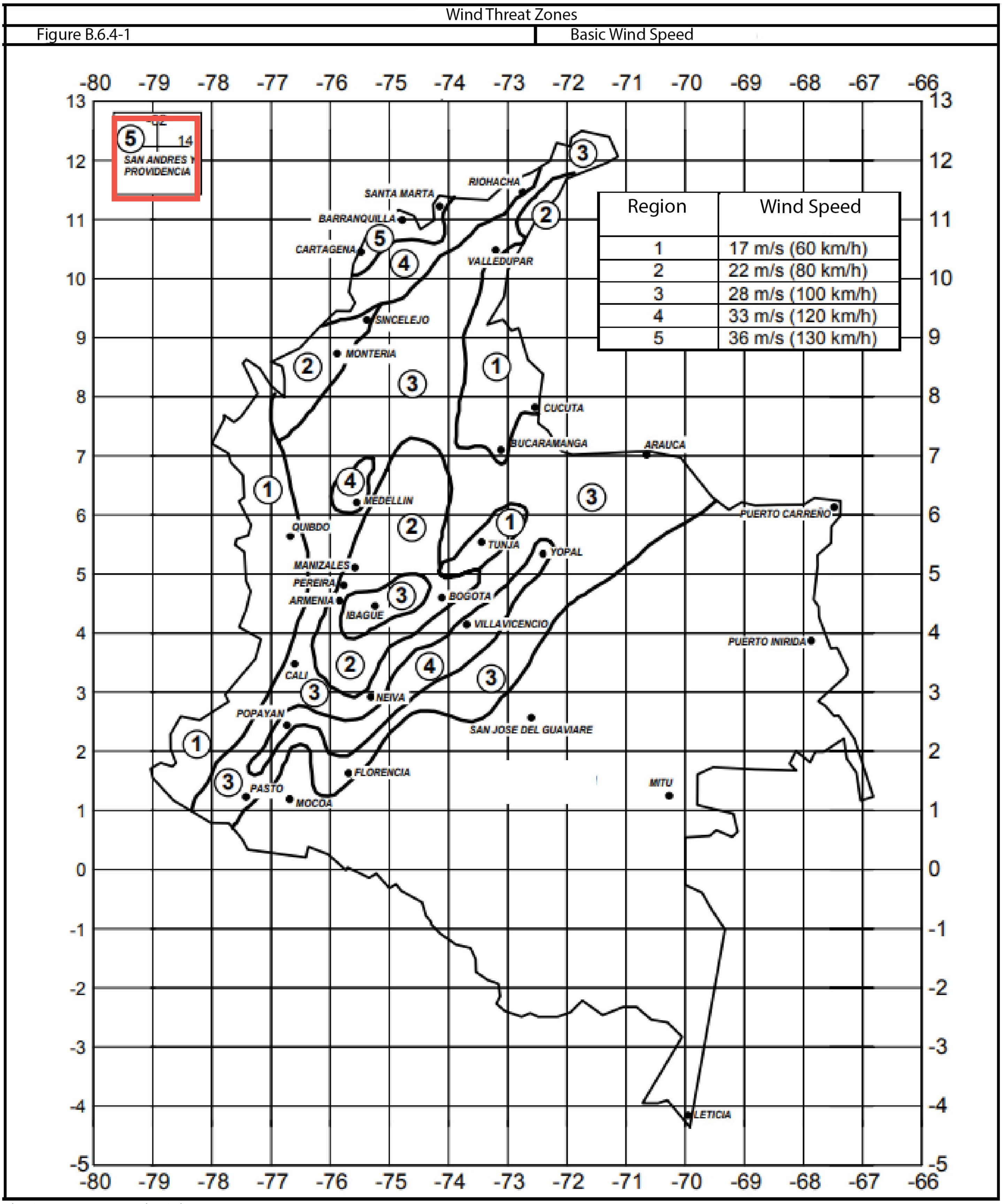


Fig. 126. Source: AIS, (2010).

- Special Wind Regions - The basic wind speed shown in fig. B.6.4-1 can be adjusted by the respective authority in case of higher local wind speeds (AIS, 2010). Taking this into account, according to the official records of the Colombian entity IDEAM (Institute of Hydrology, Meteorology and Environmental Studies), of hurricanes that have impacted the Archipelago, the highest wind recorded (Iota 2020) is 250 km/h (155 mph).

4.1.1.1. Hurricane Iota (2020)

The 2020 Atlantic hurricane season was exceptionally active, marked by the formation of tropical cyclones at a record pace. It stands as the most active season in recorded history. Thirteen out of the 30 named storms this year escalated to hurricane strength.

On November 2, 2020, the National Hurricane Center reported that Hurricane ETA had reached Category 4, impacting the Archipelago of San Andres, Providencia, and Santa Catalina, as well as Cartagena and a significant portion of the Colombian Caribbean. Subsequently, on November 15, just as the Archipelago was recovering from ETA's impacts, Hurricane Iota escalated to Category 4 and headed towards Providencia Island. Thus, on November 16 and 17, Iota became the first Category 5 hurricane to affect Colombia (Transparencia por Colombia, 2022).

On November 17, the Municipal Government of Providencia and Santa Catalina declared a State of Emergency through Decree 123 of 2020. On November 18, 2020, the National Government modified the emergency declaration issued by the Archipelago's Governor, elevating it to a national disaster status due to the magnitude and impact of this second natural disaster, especially on the infrastructure of Providencia and Santa Catalina Islands. The Presidency issued Decree 1472 of 2020, "Declaring the Existence of a Disaster Situation in the Department of Archipelago of San Andres, Providencia, and Santa Catalina". This decree led to the modification of some measures previously taken by the local government to address the impacts of the disaster: It extended the disaster declaration for an additional 12 months, and it designated the National Unit for Disaster Risk Management as the entity responsible for the Specific Action Plan (PAE) and its proper coordination with the National Disaster Risk Management System (Transparencia por Colombia, 2022).

San Andres was severely affected by Hurricane Iota, primarily in the southern part of the island. The ring road was destroyed, hundreds of palm trees and trees fell, some houses were left without roofs with leaks, while others were completely destroyed. In the case of Providencia and Santa Catalina, situated approximately 93 km from San Andres, the hurricane passed within proximity at less than 12 km, with wind speeds reaching a staggering 250 km/h. The devastation was profound, with an estimated 98% of the island's infrastructure left in ruins, affecting more than 6000 residents (Ordóñez, 2021).

According to data provided by the Ministry of Housing, following Hurricane Iota, there was a need for extensive housing reconstruction efforts. Specifically, 1787 houses required attention, including repairs to 877 existing structures and construction of 910 new houses (Redacción Colombia, 2021).

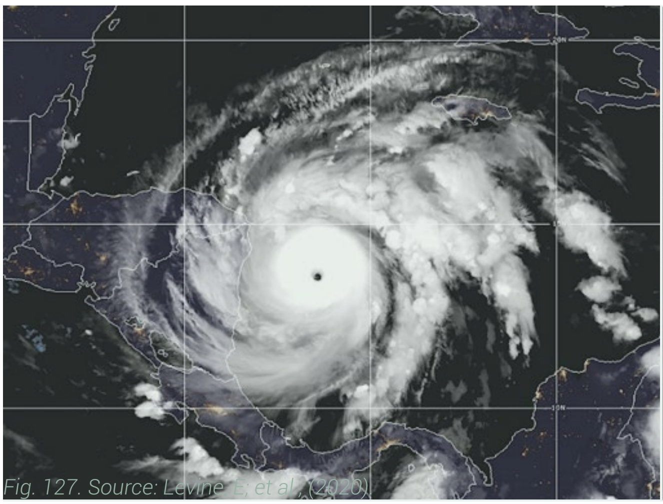


Fig. 127. Source: Levine, E. et al. (2020).

Fig. 128. Trajectory Hurricane Iota. Source: Conagua, (2020).

4.1.1.2. Hurricane Julia (2022)

The 2022 Atlantic hurricane season marked an event within the annual tropical cyclone formation cycle. It notably stood out as the least active season since 2015, following a series of seasons characterized by above-average activity from 2016 to 2021.

Hurricane Julia, a deadly tropical cyclone, wrought significant devastation in Central America in October 2022 as a Category 1 hurricane. On October 7, the phenomenon was officially classified as a tropical depression while near the Venezuelan coastline. Within a few hours, the westward-moving depression traversed the Paraguaná Peninsula and the Guajira Peninsula in Colombia after. During this period, a vigorous burst of deep convection emerged near the depression's center, and its central banding features improved, resulting in its rapid intensification into Tropical Storm Julia. Later that afternoon, the storm began to strengthen further as it advanced through the warm southwest Caribbean, benefiting from a moist atmospheric environment with low wind shear (National Hurricane Center, 2022).

On October 9, the National Hurricane Center declared Julia a Category 1 hurricane. This development put the Archipelago of San Andres, Providencia, and Santa Catalina, along with the maritime areas of the Colombian Caribbean, on high alert. The center of Hurricane Julia passed just south of San Andres Island as it gained hurricane strength to the east of Nicaragua (National Hurricane Center, 2022).

Colombia's disaster management agency, UNGRD, reported that the rainfall associated with Julia had a devastating impact on the seven municipalities of Riohacha, Uribia, Albania, Hatonuevo, Distracción, Dibulla, and Maicao in La Guajira. This calamity left 48387 people from 9819 families affected, resulting in the destruction of 174 houses and damage to 5247 residences, as well as a health center (Davies, 2022).

A report issued by the same organization showed that both islands experienced the impact of flooding, structural roof collapses, and falling of utility poles and substantial trees, along with other material damages. The impact that the tropical storm and Hurricane Julia had on the Archipelago was as follows (UNGRD, 2022):

- San Andres: 2 people with minor injuries, 123 families (492 individuals) affected, 121 houses damaged, and 2 houses destroyed.
- Providencia: reports of 4 families (16 individuals) affected, 4 houses, 3 roads, and one healthcare center affected.

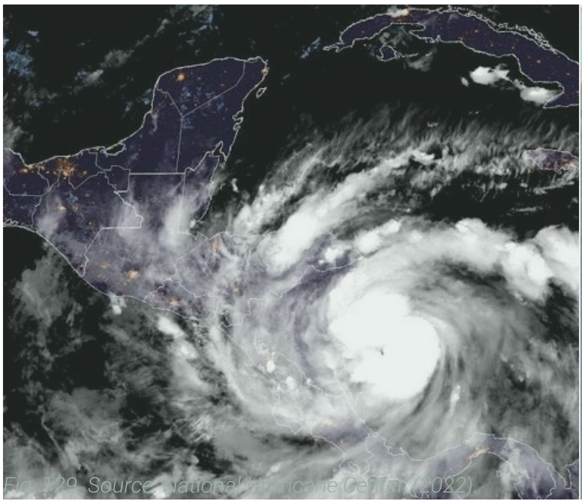


Fig. 129. Source: National Hurricane Center, (2022).

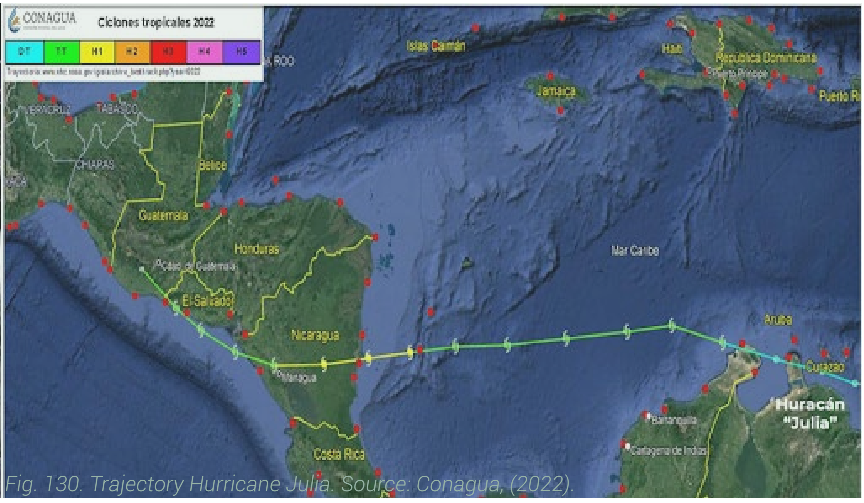


Fig. 130. Trajectory Hurricane Julia. Source: Conagua, (2022).

4.2. Case Study: Government Housing Typologies for the Inhabitants Affected due to Hurricane Iota of the Caribbean Islands of Providencia and Santa Catalina

Every Colombian department and municipality employs technical and urban planning tools like the Territorial Development Plan (PDT) and the Territorial Ordering Plan (POT), each with specific timeframes of four and twelve years, respectively.

Considering that the Colombian Caribbean, specifically the Archipelago, is located in a vulnerable zone prone to natural disasters like hurricanes, these documents should ideally contain information that enables proper response to an emergency. However, according to the document "*Citizen diagnosis of the reconstruction process of the Archipelago of San Andres, Providencia and Santa Catalina*", it was observed that the San Andres Departmental Development Plan 2020-2024, "All for a New Beginning," lacks guidelines for addressing hurricane-related disasters. The primary action outlined in this plan regarding risk management focuses solely on strengthening the fire department. This absence of a hurricane disaster component was noted in 2014. Likewise, the Providencia Municipal Development Plan 2020-2024, "United for Social Work," while emphasizing studies to understand disaster risks and the reinforcement of response capabilities, does not specifically approach hurricane disaster management, exposing the community (Transparencia por Colombia, 2022).

On the other hand, for various emergencies that may arise, plans and protocols are proposed to address the needs of the affected community. Law 1523 of 2012 establishes three specific processes for responding adequately to such circumstances (Transparencia por Colombia, 2022):

1. Declaration of the emergency.
2. Establishment of a Specific Action Plan (PAE).
3. Application of the special regime for disaster and public calamity situations.

After the devastating impact of Hurricane Iota 2020 on the Archipelago of San Andres, Providencia, and Santa Catalina, and following the decrees issued by the country's government, the Presidency and other entities proposed a 100-day plan for the assistance and reconstruction of the islands which was set to begin in January 1, 2021 and conclude by April 10, 2021 (UNGRD, 2021). According to Transparencia por Colombia (2022), the National Unit for Disaster Risk Management (UNGRD) and the Presidency established a plan with three key phases:

1. Distribution of tents, food, and water.
2. Repair of water and energy infrastructure.
3. Housing reconstruction process.

According to the document "Minutes of the final design consultation table 2021," the National Government, in collaboration with the Reconstruction Management and the Ministry of Housing, City, and Territory, undertook a mandate to prioritize social dialogue and empower the community in the decision-making process. This initiative involved conducting 20 working sessions, including technical meetings, community engagement forums, and meetings with social leaders and ethnic organizations (raizales), with the active participation of more than 500 individuals (Findeter, 2023). On January 1, 2021, the initiative to construct four housing typologies "resistant to a category 4 hurricane", led by the Ministry of Housing, City, and Territory, was set in motion. The Ministry requested help from the Territorial Development Banking institution, Findeter (non-local corporation), to provide technical assistance for the construction and reconstruction of these dwellings and to take on the oversight of other disaster-related projects on the island (Findeter, 2022).

4.2.1. Selected Prototypes

According to information found in Findeter's official web site:
Based on the Damage Assessment and Needs Analysis (EDAN) conducted by UNGRD and the Providencia Municipality, a total of 1838 projects have been commissioned. Among these, 1076 involve the construction of new houses, while 762 entail repair and renovation work (Findeter, 2022).

Of the houses built by Findeter, there are two types: 737 lot-fitted houses and 330 shelter-type houses, the latter being the 4 types presented in this thesis (Findeter, 2022).

The three types of housing interventions: repair, lot-adjusted and shelter comply with Colombian seismic resistance standards NSR-10 (Findeter, 2022).

Some common characteristics of this type of housing are (Findeter, 2022):
- Pile foundations with ballast.
- Steel elements that make up the structure (columns, mezzanines, beams and roofs) are galvanized to prevent corrosion processes.
- Connections of metallic structure elements by means of structural bolts.
- Houses designed to withstand winds of 250 km/h.
- Weight: 75 tons.
- Ramps to facilitate access for people with reduced mobility.

The 330 shelter-type houses are located in different sectors of the island of Providencia and Santa Catalina (Findeter, 2022):

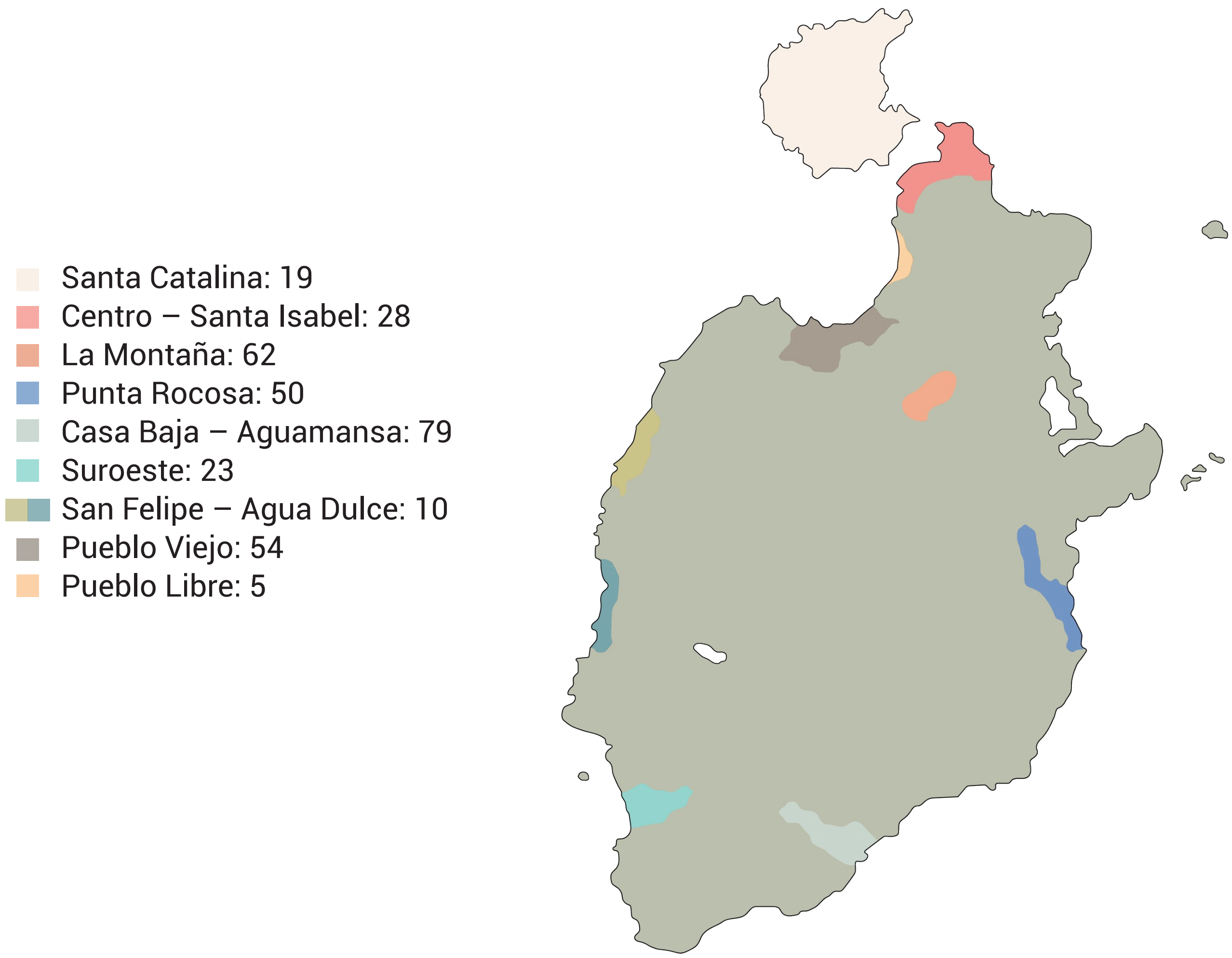


Fig. 131. Islas de Providencia y Santa Catalina. Own elaboration based: on SHADOWXFOX.

Prototype 1

Ground Floor Plan

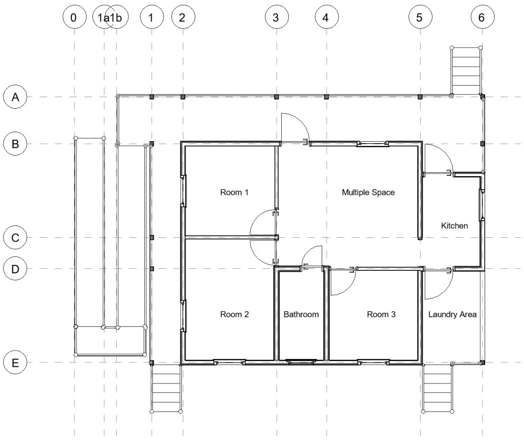


Fig. 132. Own elaboration based on: Findeter, (2021).

3D

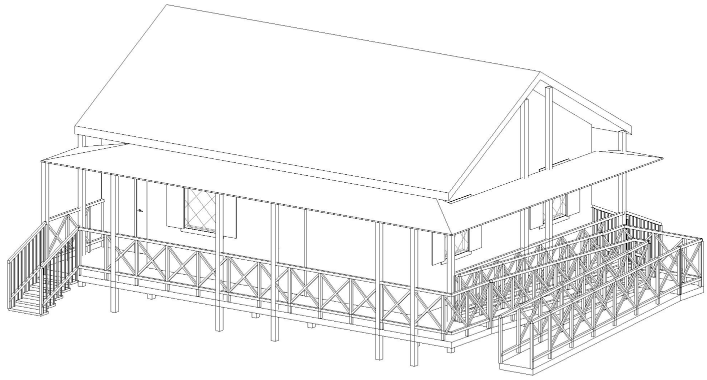


Fig. 133. Own elaboration based on: Findeter, (2021).

Render

Fig. 134. Source: Ministerion de Vivienda, (2021).

Number of bedrooms: 3
Divided Bathroom: No

Areas:

- Bathroom: 4.03 m2
- Kitchen: 5.3 m2
- Laundry area (external): 5.55 m2
- Room 1: 8.25 m2
- Room 2: 11.01 m2
- Room 3: 8.14 m2
- Multiple space: 17.26 m2
- Internal total area (without walls): 53.99 m2
- Galleries: 26.97 m2
- Ramp: 13.42 m2
- Stairs: 4.37 m2
- Total constructed area: 26.97 + 67.47 + 13.42 + 4.37 = 107.86 m2

Floor elevation: 0.66 m
Roof slope (principal roof): 56%
Maximum high: 4.74 m
Foundation depth: 1m

Prototype 2

Ground Floor Plan

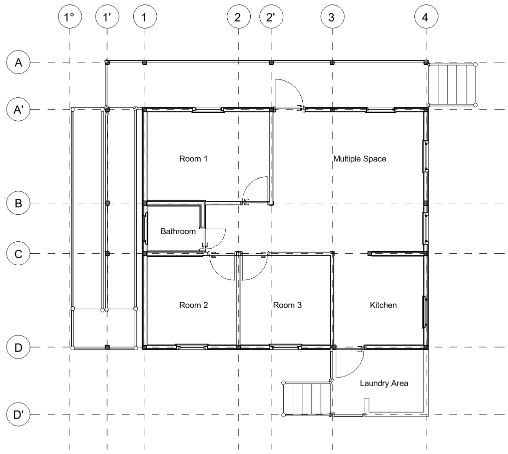


Fig. 135. Own elaboration based on: Findeter, (2021).

3D

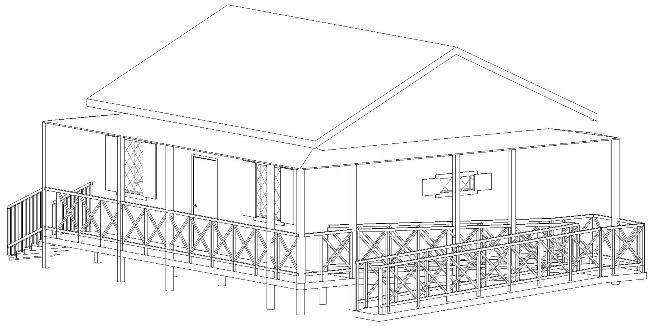


Fig. 136. Own elaboration based on: Findeter, (2021).

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Fig. 137. Source: Ministerion de Vivienda, (2021).

Number of bedrooms: 3
Divided bathroom: Yes

Areas:

- Bathroom: 2.43 m2
- Kitchen: 8.21 m2
- Laundry area (external): 3.5 m2
- Room 1: 11. 2 m2
- Room 2: 8.19 m2
- Room 3: 8.32 m2
- Multiple space + hall: 24.9 m2
- Internal total area (without walls): 63.25 m2
- Galleries: 18.28 m2
- Ramp: 15.92 m2
- Stairs: 3.53m2
- Total constructed area: 18.28 + 77.84 + 15.92 + 3.53 = 115.57 m2

Floor elevation: 0.66 m
Roof slope (principal roof): 46.6%
Maximum high: 4.74 m
Foundation depth: 1m

Prototype 3

Ground Floor Plan

Fig. 138. Own elaboration based on: Findeter, (2021).

3D

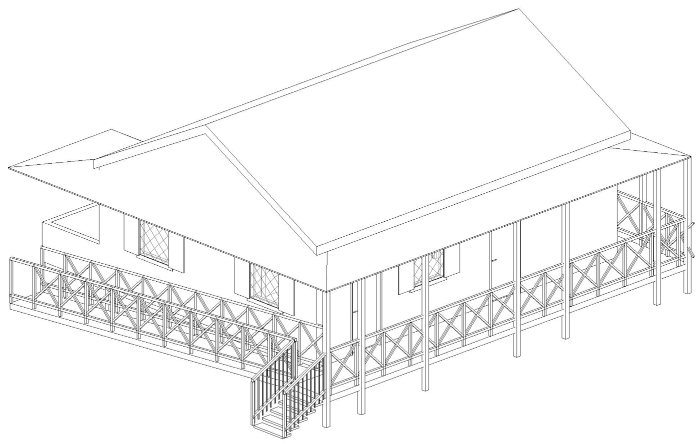

Fig. 139. Own elaboration based on: Findeter, (2021).

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Fig. 140. Source: Ministerion de Vivienda, (2021).

Number of bedrooms: 3
Divided bathroom: No

Areas:

Bathroom: 4.02 m2
Kitchen: 6 m2
Laundry area (external): 5.92 m2
Room 1: 8.25 m2
Room 2: 11.01 m2
Room 3: 8.14 m2
Multiple space + entrance space: 23.2 m2
Internal total area (without walls): 60.62 m2
Galleries: 24.31 m2
Ramp: 9.86 m2
Stairs: 3.36 m2
Total constructed area: 24.31 + 72.42 + 9.86 + 3.36 = 109.95 m2

Floor elevation: 0.66 m
Roof slope (principal roof): 58%
Maximum high: 4.81 m
Foundation depth: 1m

Prototype 4

Ground Floor Plan

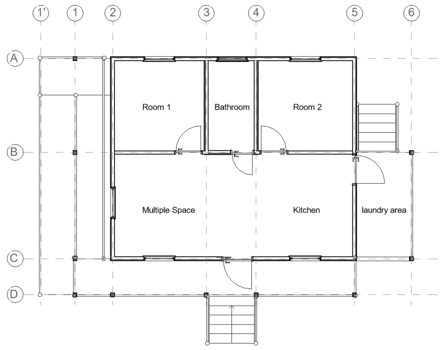

Fig. 141. Own elaboration based on: Findeter, (2021).

3D

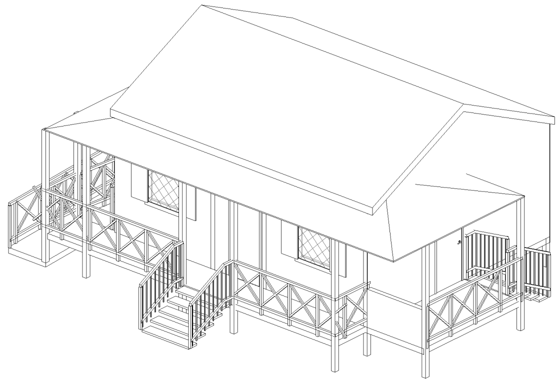

Fig. 142. Own elaboration based on: Findeter, (2021).

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Fig. 143. Source: Ministerion de Vivienda, (2021).

Number of bedrooms: 2
Divided bathroom: No

Areas:

- Bathroom: 4.21 m2
- Kitchen: 9.92 m2
- Laundry area (external): 5.86 m2
- Room 1: 8.28 m2
- Room 2: 8.71 m2
- Multiple space: 14.66 m2
- Internal total area (without walls): 45.78 m2
- Galleries: 10.3 m2
- Ramp: 14.46 m2
- Stairs: 4.4 m2
- Total constructed area: 10.3 + 57.51 + 14.46 + 4.4 = 86.67 m2

Floor elevation: 0.66 m
Roof slope (principal roof): 56%
Maximum high: 5.03 m
Foundation depth: 1m

4.2.2. Comparative Analysis: Historic Creole Planimetry and Prototypes Planimetry

Prototype N° 1 | 2

Plan

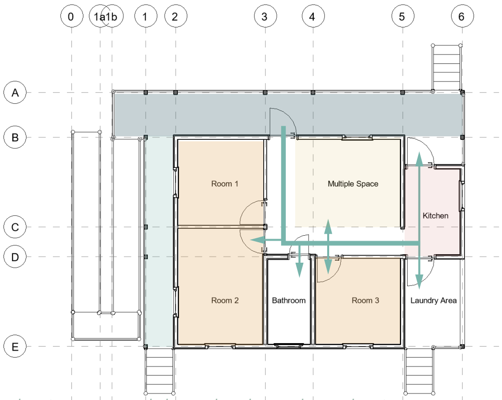


Fig. 144. Own elaboration based on Fig. 132

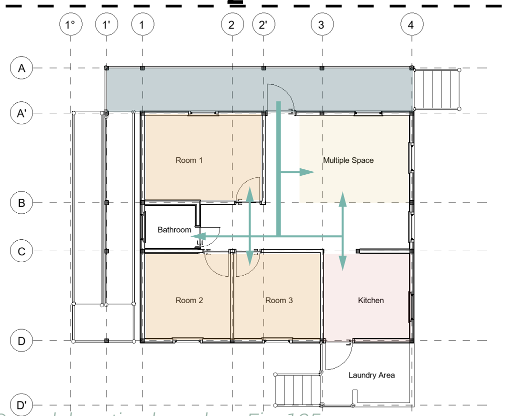


Fig. 148. Own elaboration based on: Fig. 135

Facade

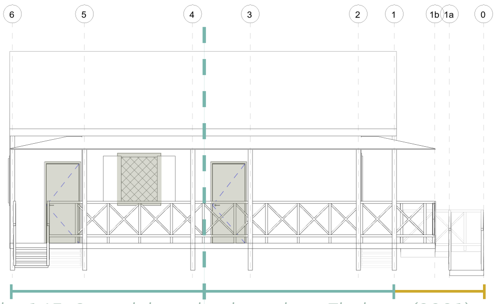


Fig. 145. Own elaboration based on: Findeter, (2021).

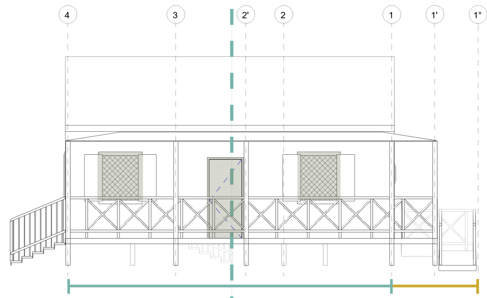


Fig. 149. Own elaboration based on: Findeter, (2021).

3D

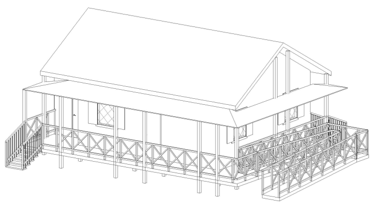


Fig. 146. Own elaboration based on: Findeter, (2021).

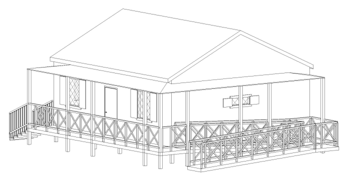
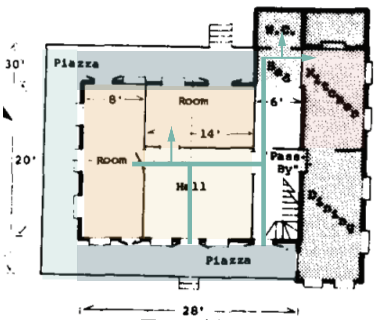


Fig. 150. Own elaboration based on: Findeter, (2021).

Similar plan typology



Type j1

Fig. 147. Own elaboration based on: Edwards, J., (1991).

Not similarities found

Prototype N°	1	2
Facade – Symmetry	No	No
Facade – Axiality	No	No
Facade – Class	4	4
Modular expansion	MF2	MF1
Loft typology	No	No

Legend: Yes; No; Axes; Front/rear Veranda; Side piazza; Hall / Multiple space

3

Fig. 151. Own elaboration based on: Fig. 138.

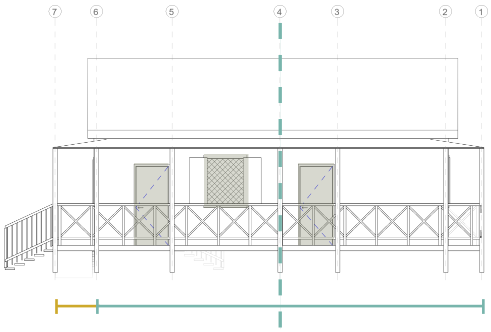


Fig. 152. Own elaboration based on: Findeter, (2021).

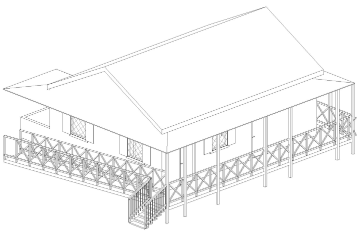


Fig. 153. Own elaboration based on: Findeter, (2021).

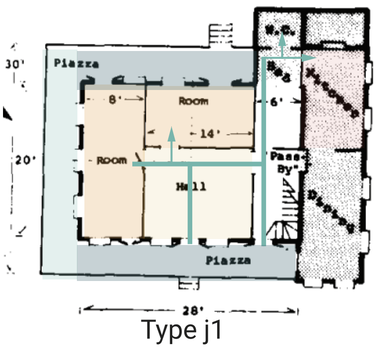


Fig. 154. Own elaboration based on: Edwards, J., (1991).

4

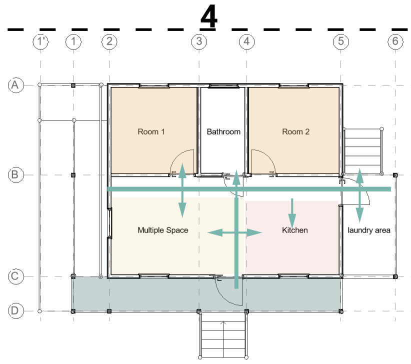


Fig. 155. Own elaboration based on: Fig. 141.

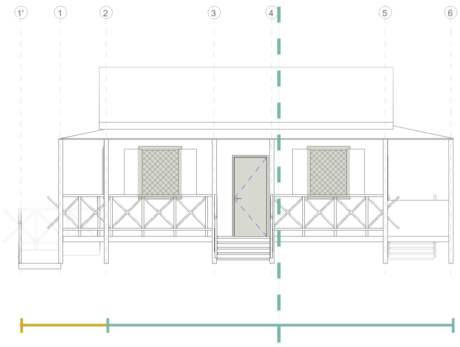


Fig. 156. Own elaboration based on: Findeter, (2021).

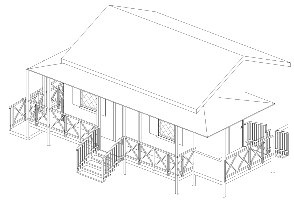


Fig. 157. Own elaboration based on: Findeter, (2021).

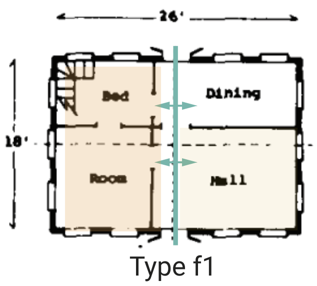


Fig. 158. Own elaboration based on: Edwards, J., (1991).

3	4
●	●
●	●
4	4
MF2	MF1
●	●

Rooms — Openings — Ramp

Kitchen — Reference measurement

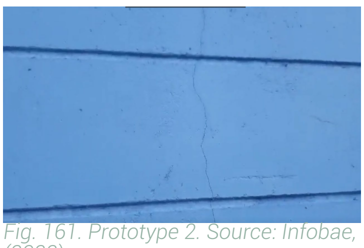
The thorough analysis of the spatial distribution of architectural typologies developed by Findeter, incorporating planimetry extracted from historical texts and documents detailed in **Section 3.3.3. Evolution of Creole Architectural Typologies in the Archipelago**, reveals intriguing parallels and resemblances between these contemporary structures and Creole architecture. Notable similarities manifest in plan type, facade design, and modular expansion, underscoring the enduring influence of historical documentation on shaping present-day architectural expressions. This examination highlights the significance of historical records in comprehending the evolution and adaptation of architecture.

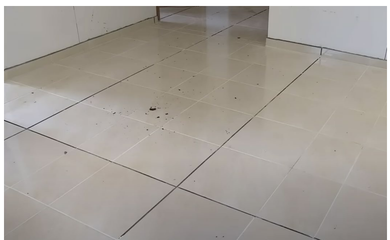
4.2.3. Prototypes Performance before Hurricane Julia 2022

The proposal and implementation of the housing typologies envisioned for the recovery of the Archipelago of San Andres, Providencia, and Santa Catalina following the passage of Hurricane Iota in 2020 have been a contentious topic that has caused various controversies for different reasons, including construction timelines, costs, drainage issues, material quality, among others.

Emphasizing materiality, after the analysis of the island's tangible and intangible heritage, taking into account the characteristics of the Creole typology, wood, recognized as the main material for this architecture, was not used as the principal structural material of construction of these proposed prototypes, being employed only for railings, doors and shutters. This questions not only the quality of the materials used, as mentioned in the first paragraph, but also its selection, based on the fact that construction on the islands must preserve the native architecture of the department (Law 47, 1993), as well as their traditional construction techniques (Law 2134, 2021).

Likewise, although the prototypes were designed and built in accordance with current national standards, mainly NSR-10, in addition to promising to withstand category 4 hurricanes, less than two months after receiving the houses during 2021 and before Hurricane Julia hit the area in October 2022, they began to present common failures in most of the wooden parts: railings, doors and shutters, as well as in the mortar coatings of the walls. This caused not only the benefited community to request the entities in charge the revision or replacement of certain materials in some housing typologies, but also raised doubts about the durability of their houses in the face of another catastrophic event and their long-term maintenance, assuming that possible failures caused by a hurricane would be mainly the responsibility of the selection of poor quality materials rather than a design problem.

Damage Description	Prototype Damage Image
• Moisture and cracks in mortar coatings (Cambio, 2022) (Caracol, 2022) (Infobae, 2022).	 Fig. 159. Prototype 4. Source: Findeter, (2022).  Fig. 160. Prototype 2. Source: Noticias Caracol, (2022).  Fig. 161. Prototype 2. Source: Infobae, (2022).

Damage Description	Prototype Damage Image
• Moisture and mold in wooden shutters (Cambio, 2022).	 Fig. 162. Prototype 2. Source: Findeter, (2022).
• Wood rotting on handrails (Caracol, 2022).	 Fig. 163. Prototype 2. Source: Noticias Caracol, (2022).  Fig. 164. Prototype 2. Source: Noticias Caracol, (2022).
• Detachment of anchors due to wood rotting (Caracol, 2022).	 Fig. 165. Prototype 2. Source: Noticias Caracol, (2022).
• Inadequate closing of shutters, allowing water and wind infiltration (Cambio, 2022).	 Fig. 166. Prototype 1. Source: Findeter, (2022).
• Internal tile expansion (Caracol, 2022).	 Fig. 167. Prototype 2. Source: Noticias Caracol, (2022).

The images used to create the table above were taken from videos of reports presented by the community and media on the internet.

4.2.4. Affectations after Hurricane Julia 2022

After the passage of Hurricane Julia, a Category 1 hurricane on October 9, 2022, public complaints were made by the population of the Archipelago and journalists through various media about the failures in the houses. However, there are no official documents published by the Colombian government or by the entities in charge of the reconstruction to support these complaints. Among the most relevant general complaints made by the population, there were roofs blown off, damage to the ceiling, damage to walls and flooded foundations (Noticias Uno, 2022). It is important to highlight that some of the damage to roofs was caused by the lack of safety strategies at the construction site in an area prone to high winds. It should be noted that Hurricane Julia caused more damage to San Andres than to Providencia and Santa Catalina due to the trajectory of the hurricane.

Fig. 168. Roof damage due to a hurricane. Source: Findeter, (2022).

The roof of a house that was under construction and was not yet anchored to the structure of the house was affected. (Findeter, 2022)

Conclusion

According to the **Section 2.1.2. Saffir-Simpson Hurricane Wind Scale**, a Category 1 hurricane affectation is minimum: “Winds could cause some damage: Well-constructed houses could have damage to the frames of the roofing, shingles, vinyl siding, and gutters” (UNGRD, 2021). However, it should be noted that the issues with these houses were reported even before Hurricane Julia struck, just two months after their construction, condemned the typologies to be at a disadvantage in the face of a hurricane of any category. It's important to also acknowledge that according to this wind scale, each cyclone category carries the potential for infrastructure damage, regardless of its construction quality. Specifically, in the case of the four prototypes, it can be used as an example that the poor quality of materials (meaning poor mechanical properties), more than certain design decisions, can lead to a poor performance of the house in the face of these catastrophes.

With information obtained from Findeter and public complaints from the population, it was concluded that the main damages and failures were evidenced in the roofs and related parts such as the ceilings, which are understood to be the weakest part of the constructed houses in the context of hurricanes due to stresses. Considering also the evidence of damage prior to Hurricane Julia, cracks in walls signify weak points within the walls that can potentiate failures in more advanced hurricane situations. Likewise, damage to the wood of window and door frames and shutters is understood as a threat in the event of winds and rains, since they no longer fulfill their function of protection.

Each failure in the different parts of the house due to poor quality materials represents the weakening of the house to resist any type of natural hazard, in this case, hurricanes, putting at risk the lives of its inhabitants and failing to fulfill its purpose of acting as a shelter for them.

Considering the prototypes, a wide variety of materials such as fiber cement, steel and mortar coating are used in their construction. It is important to note that these were built by an external entity contracted by the government, so there is a notable absence of adoption of heritage construction techniques, including the use of wood, which is the primary material in these methods. Wood is not only valued for its tradition and cultural significance but also for its properties that have been tested over the years, demonstrating resilience in the face of challenges such as hurricanes (Ruiz, 2013).

By incorporating hurricane resistance regulations and considering other essential context-specific factors, such as Creole architecture, it becomes feasible to propose an appropriate architectural conception of structures that not only enhance the safety of their occupants but also offer comfort and adaptability to their social dynamics, while respecting their cultural heritage in terms of construction techniques and use of materials.

05

HURRICANE-RESISTANT ARCHITECTURE

5.1. Wood as a Construction Material and its Properties

As mentioned in the last chapter, wood as a construction material has played an important role in the development of the Archipelago's infrastructure, both because of the wide availability of this resource on the islands and because of its physical and mechanical properties that make it stand out as a construction material.

Wood is an anisotropic material, which means that some of the physical and mechanical properties are not the same in all directions passing through a given point, vary depending on the direction in which the stress is applied (Xunta de Galicia, n.d.). Therefore, when defining its mechanical properties, it is crucial to always differentiate between the direction perpendicular and the direction parallel to the fiber. This fact constitutes the main difference in behavior compared to other materials used in structures such as steel and concrete (AITIM, n.d).

This material has the best performance when forces are applied parallel to the fibers.

<u>Mechanical properties:</u>

- **Compressive strength:** Wood is subjected to compressive stress when it is subjected to two forces or loads of opposite direction that tend to deform it by crushing (Gobierno de Canarias, 2016). Higher resistance when the forces are applied in a direction parallel to the fibers (Ochoa, 2023).

- **Bending strength:** Wood is subjected to bending stress when it receives forces or loads that tend to flex it (Gobierno de Canarias, 2016). Higher resistance when the forces are applied in a direction perpendicular to the fibers (Ochoa, 2023).

- **Tensile strength:** Wood is subjected to tensile stress when two forces or loads of opposite direction are applied, which tend to deform it by elongation (Gobierno de Canarias, 2016). Higher resistance when the forces are applied in a direction parallel to the fibers (Ochoa, 2023).

- **Elasticity:** The most common varieties of wood used in the construction industry, can develop a wide elastic range in their mechanical response. They can be deformed and subsequently return to its original state without suffering significant structural damage, guaranteeing adaptability in the face of variations in temperature and loads, without compromising the integrity of the element (Emedec, 2023). The modulus of elasticity indicates the stiffness of a material: the stiffer a material is, the higher its modulus of elasticity (Xometry, 2023).

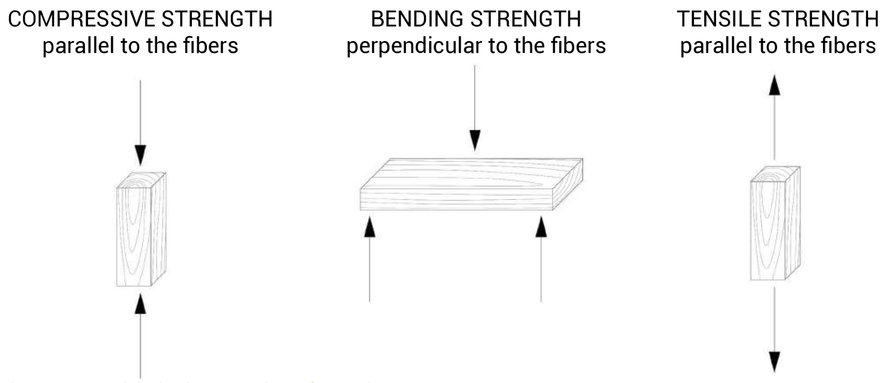


Fig. 169. Mechanical properties of wood. Source: Luengo, M.

Physical properties:

- Density: It is the ratio of its weight to its volume (Xunta de Galicia, n.d.). Varies among different wood species. Factors such as climatic conditions influence the density of a particular tree. For example, faster growing timbers tend to be lighter (Emedec, 2023).

All materials have different mechanical and physical properties, performing in different ways:

	Compressive Strength (N/mm^2)	Bending Strength (N/mm^2)	Tensile Strength (N/mm^2)	Modulus of Elasticity (kg/cm^2)	Density (kg/m^3)
Softwood (Pine)	17,56 - 25,50	27,46 - 32,36	74,53 - 78,45	90000 - 110000	500 - 571
Concrete	19,61 - 34,32	0,39 - 5,39	2,94 - 5,88	215000 - 390000	2200 - 2400
Steel	333,43 - 480,53	245,17 - 441,30	549,17 - 706,08	2100000	2240 - 2400

Table. 3. Mechanical and physical properties of wood. Own elaboration based on: IMZA, (2023); Construaprende, (2009); Woodiswood, (2022); Galistar, (2016); NRMCA, (2020).

Compression strength in wood is low compared to other building materials use for building structures, for example, concrete and steel. Bending and tensile strengths in wood have a better performance in comparisson with concrete but not with steel. The modulus of elasticity of wood is the lowest compared to the other two materials, as well as the density, being the lightest and most elastic of the three materials shown.

Sustainability and Environmental Aspects
It is a renewable and energy-efficient resource as its production and processing requires significantly less energy than other building materials such as steel or concrete (Emedec, 2023).

Thermal insulation: Timber is a natural thermal insulator due to having air pockets within its cellular structure (CGB, 2021). “Softwood has about 10 times the thermal insulating ability of concrete and masonry, and 400 times that of solid steel” (naturally:wood, 2022). However, although it is a decent insulator compared with this materials, it is rather a poor insulation compared to other types of wall insulation. In addition, lightweight wood framing methods allow easy installation of additional fibre or foil insulation (FTMA New Zeland, 2016).

5.2. Weaknesses of a Wooden House in the Event of High Winds or Hurricanes

Given the Archipelago's susceptibility to hurricanes and high winds, wooden constructions in the area pose challenges in terms of their resilience to these forces. Some weaknesses that can be evidenced are:

One of the critical points is in the roofs, which are particularly vulnerable to the onslaught of high winds. During severe storms, these roofs can suffer considerable damage, weakening, or even detaching, exposing the house to destruction by heavy rains and high winds.

Another weakness occurs at the joints between the walls and the floor. As wood expands and contracts due to variations in humidity and temperature, it can weaken these structural connections over time. This factor increases the risk of displacement, partial collapse or overturning during extreme weather events such as hurricanes, which generate considerable lateral forces on the structure. This situation may change depending on the material used for the floor and foundation related with the timber structure, and how the connections are made.

The vulnerability of not treated wood to moisture is another concern. In island environments, where exposure to water is frequent, wood can deteriorate rapidly, compromising its structural integrity and increasing the likelihood of significant damage in the event of a hurricane.

In this context, the importance of good anchorage cannot be underestimated. A solid and adequate anchorage between the different parts of the house is essential to resist the extreme forces generated by hurricanes. Not only does it contribute to structural cohesion, preventing displacement or separation of parts, but it also efficiently distributes wind-generated loads, providing a more effective defense against adverse weather elements.

Fig. 170. House affected by hurricanes Eta and Iota 2020. Source: ONG Manos Unidas, (2020).

Fig. 171. House affected by hurricane Eta. Source: AFP, (2020).

It is important to highlight that there is not enough information available regarding the performance of Creole architecture in the face of hurricanes. As a result, some weaknesses in its construction techniques remain unknown, preventing the assertion that this architecture is entirely resistant to such events. However, there is evidence of traditional houses in the Archipelago that have stood for centuries, even after facing these phenomena on multiple occasions. These houses exhibit all the characteristics that classify them as part of the heritage of Creole architecture.

Patrimonial houses in the island of San Andres (constructed since the XIX century)

Fig. 172. Houses of heritage value in San Andres. Source: Sánchez, (2004). Map source: San Andres Planning Department, POT San Andres, scale 1:20.000, 2002

● Patrimonial houses in the island of San Andres


Fig. 173. Carmelicia Forbes's House. Source: Sánchez, (2004).


Fig. 174. Luis Archbolds's House. Source: Sánchez, (2004).


Fig. 175. Island House Museum. Source: San Andres Travel, (2022).

5.3. Common Design Strategies between Creole Architecture and Hurricane-Resistant Regulations

Considering the standards and guidelines cited in the previous chapters, some similarities can be identified between the characteristics of hurricane-resistant timber construction and some traditional Creole design strategies, knowing that these have been the product of experience gained through trial and error following unpredictable environmental events, evolving to become increasingly resistant.

This method of construction, rooted in the practical wisdom of the communities, emphasizes the importance of learning from direct interaction with the environment and adapting structures accordingly. This process of constant adaptation underscores the flexibility and resilience inherent in traditional Creole design strategies, while highlighting the contemporary relevance of these practices in creating houses capable of withstanding hurricanes and other climatic challenges.

Characteristics:

- Building Geometry
- Elevated Foundation
- Shutters
- Roof Structure: Trusses
- Roof Slope
- Roof Division

Fig. 176. Creole House in San Andres. Source: UFF.

- ## Building Geometry

Plan: A circular, square or rectangular plan should preferably be developed, as it allows for easy circulation of the wind around the building, preventing it from exerting pressure on only one side, and helping to alleviate hurricane or wind loads.

The illustrations below highlight safe, robust building shapes that are resilient (✓), that is, inherently able to withstand many of the forces that impact them, versus shapes that may be more susceptible to damage (✗) when impacted by events such as hurricanes and earthquakes (PAHO; WHO, 2021).

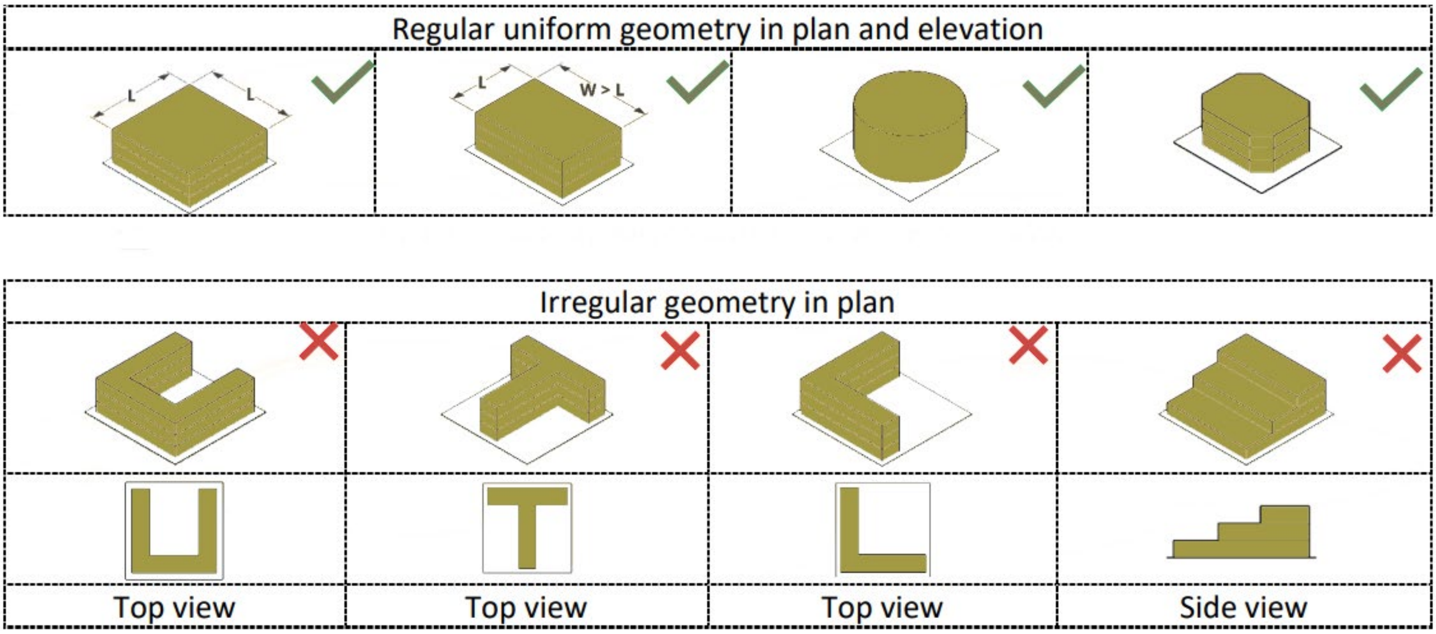


Fig. 177. Irregular plan geometries are more prone to damage. Source: PAHO; WHO., (2021).

- ## Elevated Foundation

Homes in flood-prone areas should be elevated to minimize potential flooding. Raised houses are more likely to survive floods, hurricanes, and other storms because ground-level water passes under the house (HFHI, 2018). Likewise, the elevation of the houses allows ventilation for the purpose of dissipating (avoid) the humidity of the soil and cooling the external surface of the ground floor system (Ruiz, 2013). Likewise, there are potential drawbacks associated with this choice, as it may not be suitable for use in locations characterized by swift water currents, ice flows, or rapid movement of debris or erosion, unless specific precautions are implemented. Additionally, factors such as wind forces, seismic risks, and potential alterations to the building design need to be taken into account (FEMA, n.d.).

Likewise, it is important to keep in mind that the flood baseline (BFE), a value that helps identify the flood risk in a certain area, as determined by the Federal Emergency Management Agency (FEMA) in the U.S., is unknown in some countries, thus, it is not possible to identify how much the construction should be elevated in every area (FEMA, n.d.).

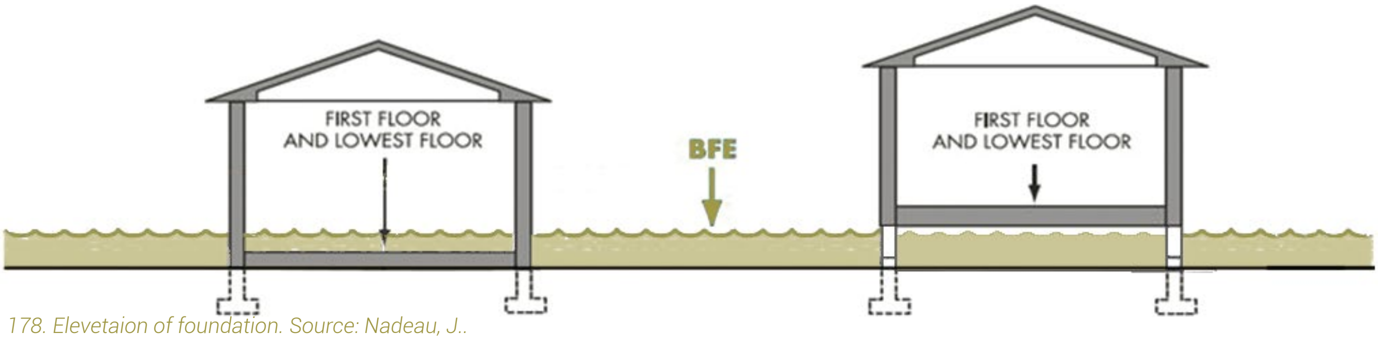


Fig. 178. Elevetaion of foundation. Source: Nadeau, J..

- **Shutters**

Considering that initially traditional Creole architecture didn't use glass for window enclosures, wooden shutters were implemented as protective strategies due to the exposure of the house interior to winds and rain. Currently, the use of glass in windows has been implemented, so it is important that these shutters cover them completely and are properly anchored to the wall, so they will adequately protect against possible projectiles that may impact the house (FEMA, 2017).
In storm conditions, characterized by high wind speeds and rain, potential window damage may arise when wind loads surpass the window's design limits. This damage could lead to heightened internal wind-induced pressure, elevating uplift forces on the building roof. Additionally, rain intrusion into the building during storms has the potential to cause damage to the building's interior (Moravej et al, 2016).

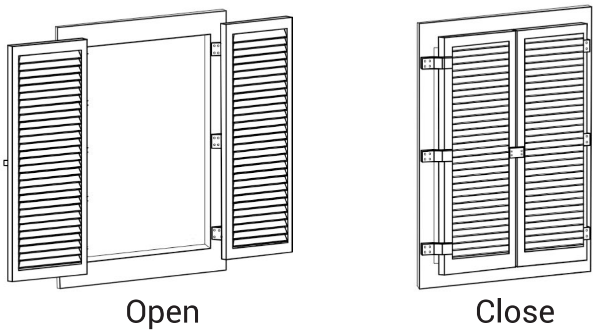


Fig. 179. Window shutters. Own elaboration based on Croci North America, (2023).

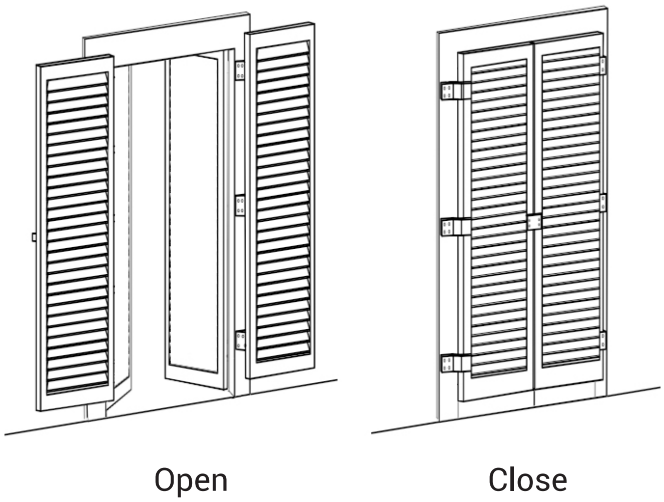


Fig. 180. Door shutter. Own elaboration based on: Fig. 173.

- **Roof Slope**

To gain strength, in the gable roof, the gable end wall must be properly braced. It must resist some forces through its connection strength and bracing lumber as uplift and downward pressures from the roof, and, horizontal pressure and suction forces on the wall (Energy.gov, 2012).

Roof slope: Roofs with lower slopes tend to create greater uplift forces in high winds. Whereas, with steeply pitched roofs, they create a wall or sail effect on which wind loads act (Holder, 2022). To lessen the effects of uplift forces on the roof, the roof pitch should be between 25° and 40°. The best roof pitch angle is 30° (UNDP & EWB, 2018).

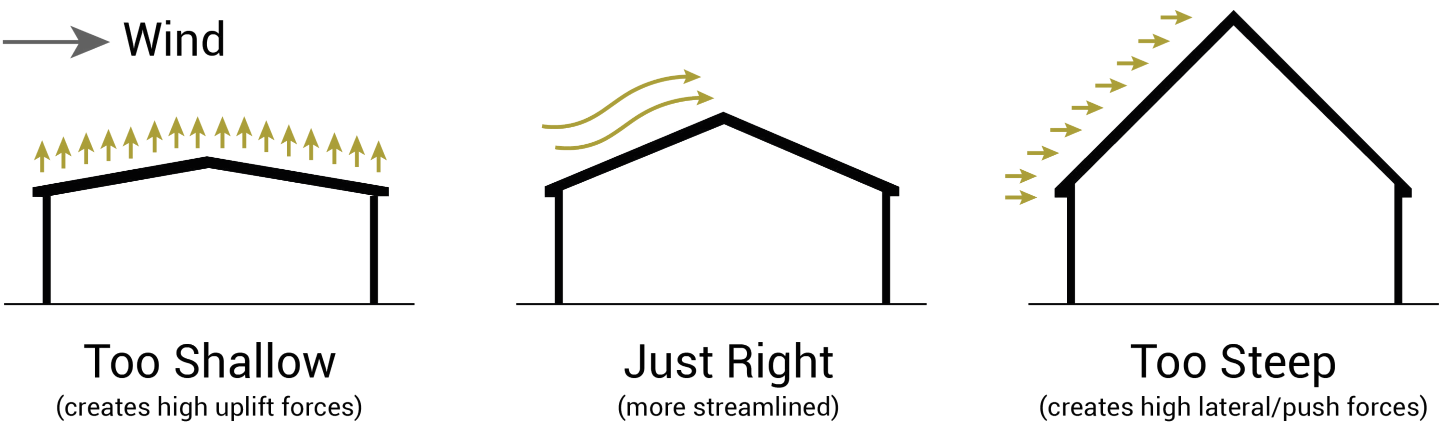


Fig. 181. Roof pitches and their implications for wind forces. Source: MyPDH, (2022).

- **Wooden Roof Structure**

Structure made of wood stripes (rafters and purlins) that join the double tie beams through reinforcements and screws (López, 2022), acting as a single structural element resisting the various external forces acting on the roof, in this case, high winds. These elements can be complemented with wood trusses, which are flexible for shear and torsion forces. This implies that a standard truss, even without additional reinforcement for strength, possesses sufficient resilience to flex slightly and return to its original position without causing damage to the roof above. This flexibility allows roofs to adapt to high winds, preventing the breakage that might occur in more rigid structures (trussbuilders, 2021). Their triangular shape is also crucial to their structural integrity, as it effectively distributes these forces. Likewise, by arranging the truss elements in triangular patterns, the design maximizes their load-bearing capacity with minimal use of materials (DaBella, 2023).

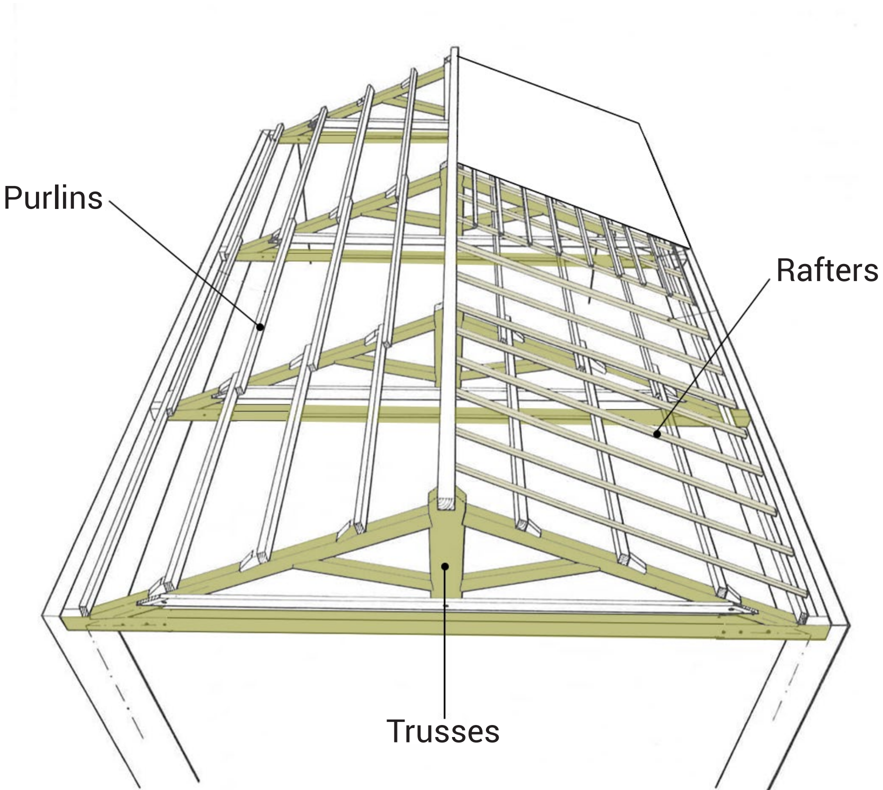


Fig. 182. Parts of wooden roof structure. Source: Tecnologias de la madera, (2021).

- **Roof Division**

Since overhangs experience high wind pressures, the roof of the galleries must remain separate from the structure rather than an extension of the main building. Short overhangs should be used to avoid wind uplift (UNDP & EWB, 2018).

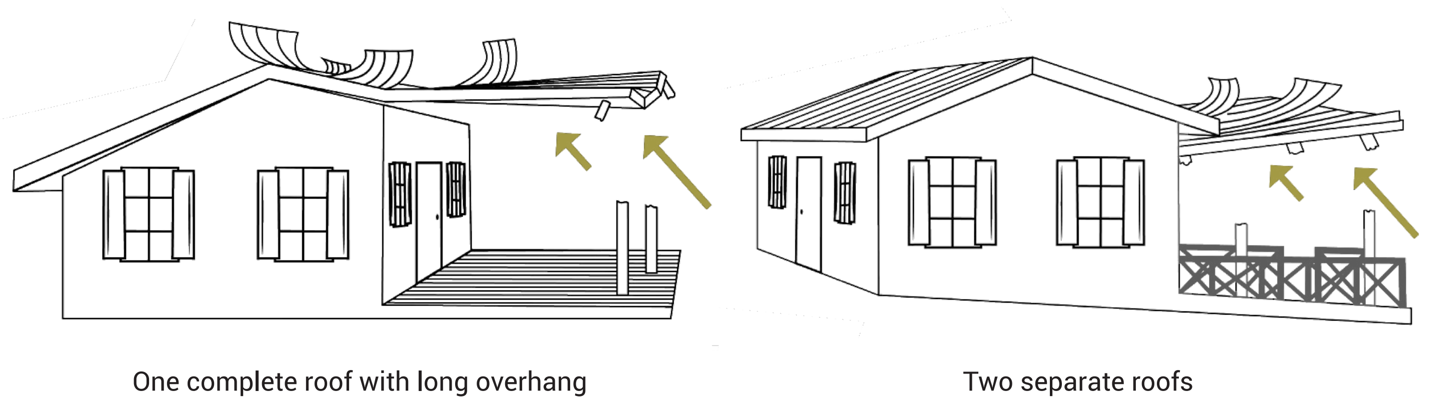


Fig. 183. Roof uplift due tu winds. Source: UNDP; Engineers Without Borders, (2018).

5.3. Comparative Matrix: Creole and Traditional Architecture & Hurricane-Resistant Architecture According to National and International Literature

In today's dynamic architectural landscape, the pursuit of resilient, environmentally conscious, and culturally rooted housing solutions has become essential. In this era of shifting climate patterns and a heightened focus on sustainable living, it is crucial to assess the intersection of two distinct yet interrelated variables in the Archipelago: Creole and traditional architecture and hurricane-resistant architecture, while always keeping in mind the persuit of a sustainable design.

Creole architecture offers functional adaptability. It reflects the traditions, materials, and spatial strategies that have evolved over centuries to harmonize with local climates and withstand the challenges posed by nature, including hurricanes.

Concurrently, the intensification of hurricane activity underscores the pressing need for housing that can endure the formidable forces of these natural disasters. This requires a thorough understanding of the specific prerequisites for an appropriate architectural conception that hurricane-resistant housing must meet to ensure the safety and well-being of its occupants.

Moreover, as the world grapples with the imperative to mitigate the environmental impact of human habitation, sustainable housing emerges as a promising solution. One of the important points is the use of sustainable materials for its construction, in this case wood, which presents a good performance in its useful life, besides being a material known and managed by the community for years.

In light of these considerations, this comparative analysis aims to explore the intricate relationship between Creole architecture and hurricane-resistant housing requirements, in search of a sustainable design conception and materiality. By scrutinizing these variables and their intersection, it is intended to establish a comprehensive evaluative framework for the proposal, envisioning housing solutions that seamlessly merge tradition, resilience, and sustainability. The ensuing matrix will serve as a valuable tool, offering insights into the synthesis of these critical aspects in the pursuit of housing that is both culturally rooted and prepared for the challenges of a changing world.

It is important to note that this matrix has been made with national, but mainly international literature due to the scarcity of hurricane resistant construction regulations in Colombia.

It is also important to highlight that some of these international regulations have been annexed in new national resolutions that complement existing laws, and have also been approved by the national government for implementation in the Archipelago. For this reason, the adoption of these regulations does not go against Colombian laws that protect the traditional construction techniques of the Raizales in the islands.

				Creole and traditional		Hurricanes Resistance according to National and International Literature (AIS, FEMA, UNPD, HFHI., etc)
LOCATION	Specifications		1	Principal facade parallel to the street or the sea (Mosquera, 2014).		-
			2	Houses with the longest side oriented east-west, since the main winds come from the northeast (Sánchez, 2022).		-
			3	Some houses surrounded by green areas (Sánchez, 2004).	5	When houses are surrounded by green areas, vegetation (trees) should be located at a distance greater than their height to prevent them from falling on the house due to strong winds. Likewise, care should be taken with loose branches that may impact the house (HFHI, 2018).
			4	Houses that form groups among neighbors to share a courtyard, fruit trees, a well, cistern, cemetery, garden and play area (Sánchez, 2022).		-
				-	6	Constructions should be kept away from slopes and water sources to prevent landslides and flooding (HFHI, 2018). Avoid locating close to the coastline to prevent storm surge effects (AIS, 2021).
				-	7	Avoid building foundations on backfill material to prevent the house from collapsing due to a slide (HFHI, 2018).
				-	8	Avoid building on the top of a mountain due to strong winds (HFHI, 2018).
PLAN	Shape / Dimensions		9	Plan geometry: square/rectangular shape (Ruiz, 2013).	13	Simple, compact, symmetrical shapes: Circular shape could be the best option, also square or rectangular shape (HFHI, 2018).
			10	Dimensions of dominant geometrical plan: length:width ratio = 5:7 aprox (Edwards, 1991).	14	Maximum favorable length:width ratio = 1:3. (UNDP, 2018) Aspect ratio in plan 1.0 ≤ L/W ≤ 2.4. (AIS, 2021)
	Specifications		11	Internal division between the private and public (Edwards, 1991), strengthen the resistance of the walls to horizontal forces, increasing their stiffness.	15	The building must have a configuration of internal walls in each direction of the plan, to strengthen the resistance of the walls the wind forces applied on the structure (AIS, 2021).
			12	Internal and external expansion related to family growth (Sánchez, 2004).		-
FOUNDATION	Shape / Dimensions / Measurements	Footing	16	Isolated triangular or oval-shaped footing pointing seaward, to facilitate the dynamic flow of water, reducing the erosion effect in case of swells and waves (Somerson, 2020).	20	A square-shaped rigid isolated footing designed to resist bending moments generated by eccentric loads or lateral forces. In addition to supporting vertical loads, these footings also provide stability and resistance to moments or torsion applied to the structure (gecopre, 2023).
				-	21	Footings have to be located no less than 920 mm into solid ground (UNDP, 2018).
				-	22	Minimum size (width x depth) according to soil (Caribank, 2018): **Clay:** 760 x 300 mm. **Rock or compacted granular soil:** 600 x 275 mm.
						3 options: a) Columns / b) Blocks / c) Piles
		Vertical Element		-	23	**a) Columns:** Minimum size (a x b) for square foundation columns according to house height (Caribank, 2018): **1)** Less than 3 m high: 200 x 200 mm. **2)** 3 to 3.65 m high: 250 x 250 mm. **3)** 3.65 to 4.3 m high: 300 x 300 mm.
			17	Piles between 600 and 1200 mm high approximately above the ground (Ruiz, 2013).	24	**b) Blocks:** Minimum size (a x b) for square concrete block: 200 x 200 mm thick (Caribank, 2018). Should be at least 3 rows of blocks to protect it from rain and soil moisture (at least 600 mm above the ground) (HFHI, 2018).
				-	25	**c) Piles:** Minimum diameter size for timber piles: 304.8 mm. This size satisfies the bending requirements under erosion conditions (FEMA, 2009).
		Beams		-	26	Tie beams between footings are required: 200 x 300 mm (UNDP, 2018).
				-	27	**Continuous beam foundation:** Size (w x h) for continuous beam foundation**:** 200 mm x 150 mm. Stirrup longitudinal steel: 4 No. 3, No. 2 at 200 mm. Steel for wall anchorage: No. 3 (AIS, 2021).
	Joints / Bracing			-	28	Anchoring between wooden structure and the foundation system are required (HFHI, 2018).
		Vertical Element		-	29	**b) Blocks:** When using foundations blocks base plate, the connection has to be tied with washer and nut to fasten the wooden structure onto the foundation, and made out of steel rebar. The base plate is bolted to the foundation every 975 mm (HFHI, 2018).
				-	30	**c) Piles:** The base plate is bolted to the foundation every 800 mm with washer and nut (HFHI, 2018). For higher piles, the foundation design may include diagonal bracing to stiffen the pile foundation in one or more directions (FEMA, 2009).
	Specifications			-	31	Open foundations are often recommended (instead of solid wall, crawlspace, slab, or shallow foundations), allowing water to pass beneath the elevated building through the foundation reducing lateral flood loads on the structure (FEMA, 2009).
				-	32	Elevate the lowest horizontal structural member of the floor assembly to be at least 304.8 mm above the Base Flood Elevation (UNDP, 2018).
			18	Continuous columns from foundation to roof beams (Mosquera, 2014).	33	Continuous columns and metal strapping from roof trusses to foundation helps maintain structural stability (deltechomes, 2021).
	Materials		19	Wood or stone in the traditional models built between 1890 and 1950, and reinforced concrete in the houses recently built on the Archipielago (Sánchez, 2004).	34	Should be constructed with flood-resistant materials, and must be heavy to resist lift wind force (FEMA, 2009). Ex: Reinforced concrete

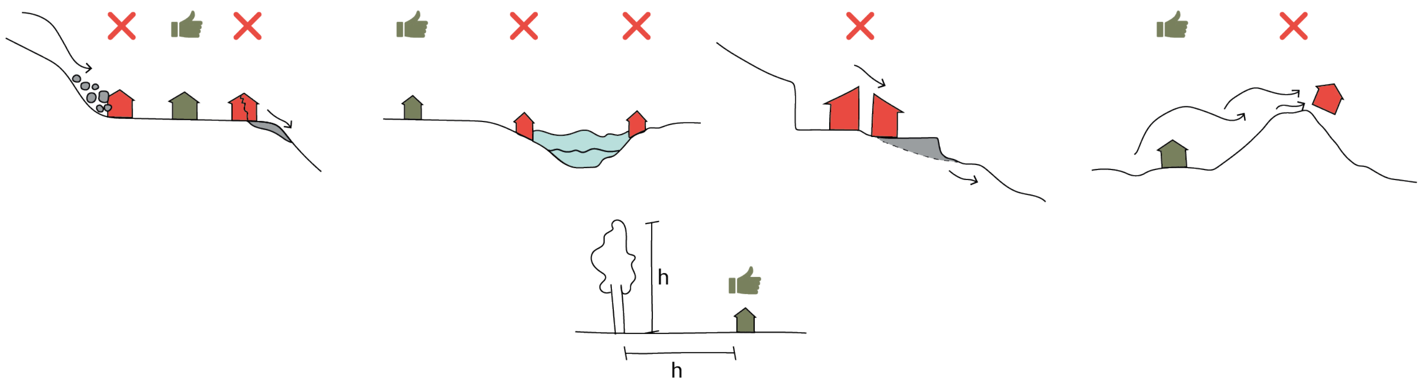


Fig. 184. Safe location. Own elaboration based on: HFHI, (2018).

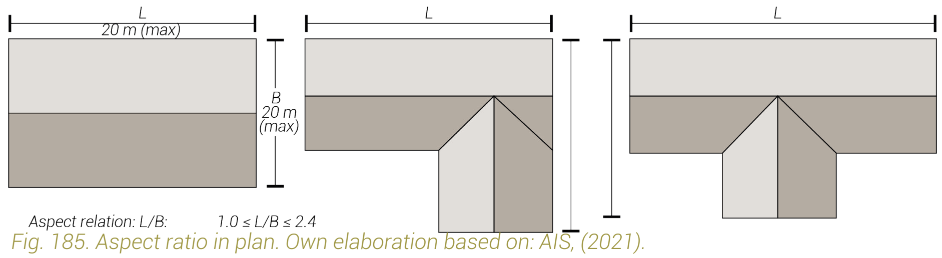


Fig. 185. Aspect ratio in plan. Own elaboration based on: AIS, (2021).

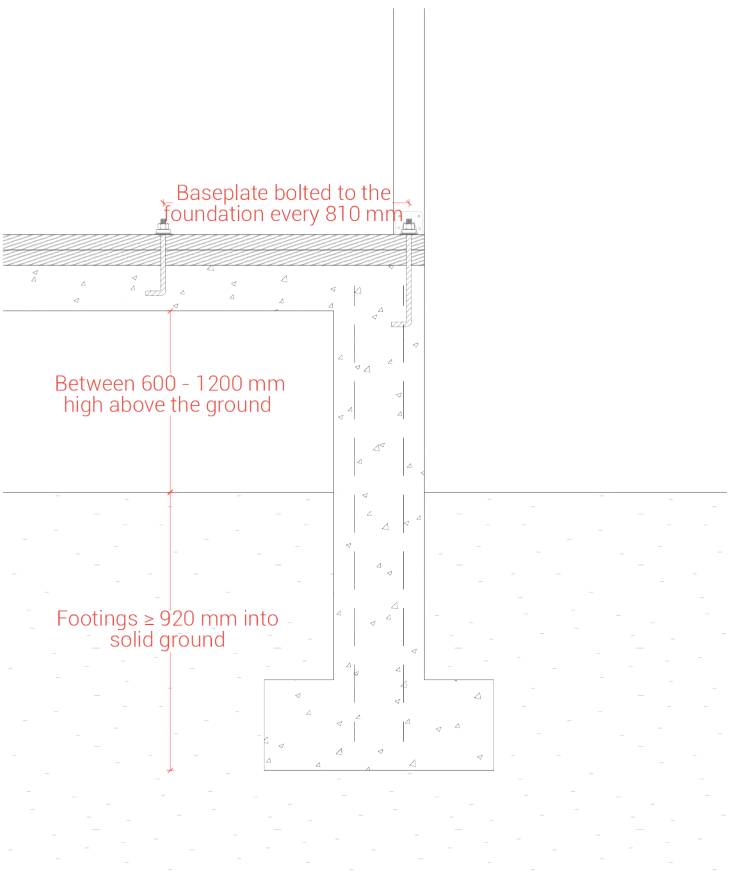


Fig. 186. Foundation dimensions. Own elaboration based on Ruiz, (2013); UNDP, (2018); HFHI, (2018).

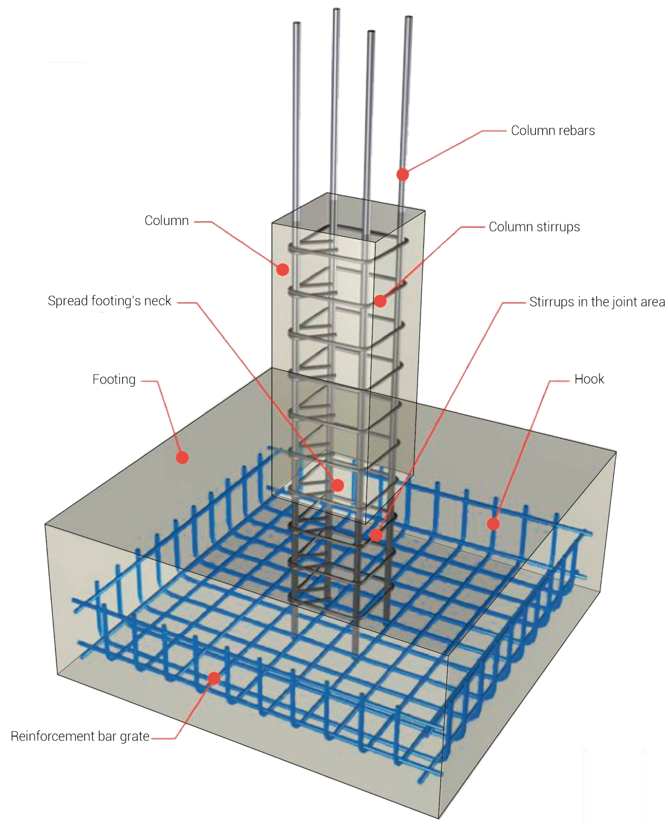


Fig. 187. Isolated footing. Own elaboration based on: MMDELAMORA, (2017).

WALLS	Shape / Dimensions / Measurements	Posts / stud	35	Standardization in cutting and dimensions of wood pieces: 50.8 x 101.6 mm (Sánchez, 2022).	42	**Timber dimension:** 50.8 x 101.6 mm (UNDP, 2018).
		Wallplate / baseplate			43	**Timber dimension:** two of 50.8 x 101.6 mm or one of 101.6 x 101.6 mm (Double wallplate and baseplate) (UNDP, 2018).
		Bracing			44	**Timber dimension:** 50.8 x 101.6 mm (UNDP, 2018).
		Cladding	36	Sawn wooden planks for cladding: 12.7 mm thick, 220 mm width, 3 m lenght (Sánchez, 2004).	45	**Boards used as cladding:** Thickness: 12 mm for walls and 9 mm for decks. Guadua mat boards: Thickness: 17 mm (AIS, 2021). Five Ply 15.88 mm sheathing used in other cases (deltechomes, 2021).
	Joints / Bracing	Joints wall-foundation		-	46	Use of stainless steel bolts and threaded rods for the connection of the walls to the foundation (AIS, 2021).
				-	47	**Connections baseplate with foundation:** To prevent the wind forces lifting up the entire building or blowing it over. **1.** If there are rebars, bend them and reinforce the joint with some nails in both directions. **2.** If there are no rebars, use hurricane metal straps fastened with screws. **3.** If the wall is being constructed, use J bolt with washer and nut to tie the baseplate to the foundation every 810 mm (HFHI, 2018).
		Joints wooden frame	37	In the 19th century, within creole structures in the United States, the mortise and tenon technique was employed to secure wallplates to the upper sections of the posts (Edwards, 2006).	48	**Connections posts/stud with wallplate/baseplate:** Screws to connect posts with wallplate/baseplate. To reinforce the connections the strongest option is to use hurricane straps that go under the baseplate (HFHI, 2018).
				-	49	**Walls with openings:** Double wallplate, strong connection of each upright, double uprights at openings, brace to a strong node (HFHI, 2018).
				-	50	**Corners:** Connect uprights and wallplates, and uprights of the corners with hurricane straps (HFHI, 2018).
		Joints wall-roof		-	51	Two connections to be considered between rafters or trusses to a wallplate supported by vertical posts: **1.** Between plate and posts using metal straps. **2.** Between rafter and plate, required hurricane straps (UNDP, 2018).
		Bracing		-	52	Ensure rigid and strong walls. Brace every wall in both directions at 45°, no less than 30°, or more than 60°, to avoid racking. The strongest bracing is created by nailing timber and galvanized steel straps (HFHI, 2018).
				-	53	Walls should be braced across corners at plate level and at both corners of each wall (UNDP, 2018).
		Cladding		-	54	In case of using cladding boards: nails every 100 mm at the edges; nails every 150 mm in intermediate areas (AIS, 2021).
	Specifications	Wooden frame	38	Wooden column and beam system before XIX century. After, balloon frame and platform frame techniques started to be used (Sánchez, 2022).	55	**Different wood construction systems as:** Post and beam, wood blocks, SIP panels, CLT (Cross Laminated Timber) and timber framing (Platform or Balloon Frame) (EcoHabitar,2021). Platform frame technique is the most common wooden construction observed in wood hurricane-resistant construction regulations.
		Cladding	39	Tongue and groove technique for external cladding (Sánchez, 2004).	56	Tongue and groove technique for external cladding (IFRC, 2013).
				-	57	Timber shear walls should be located parallel to the wind direction (UNDP, 2018).
				-	58	Wood must be dry, with a moisture content of less than 19%, preferably in equilibrium with the humidity of the site (AIS, 2021).
	Materials		40	Pine, teak and mangrove, the last when it could still be extracted and used (Ruiz, 2013).	59	Use of any type of structural wood, the use of coniferous wood is recommended because of its easy handling due to its low weight. Ex: Caribbean Pine, Patula Pine, Radiata Pine, Southern Yellow Pine (AIS, 2021).
			41	Tongue and groove wood siding coated with white lime (López, 2022).	60	**Boards used as cladding:** plywood and OSB boards and laminated guadua mat boards. All should be manufactured with phenolic type adhesive, which is more resistant to saline environments (AIS, 2021). Five Ply 15.88 mm plywood sheathing used instead of OSB on exterior walls, roof and floor strengthens the home and prevents flying debris from penetrating the structure (deltechomes, 2021).
OPENINGS	Shape / Dimensions / Measurements		61	Vertically elongated openings (Sánchez, 2022).	66	Large openings. They may require stronger members such as engineered wood beams, hot-rolled steel, or flitch plate beams (HUD, 2017).
	Joints / Bracing			-		49
	Specifications	Windows	62	Windows with no glass (Somerson, 2020). Or imported window with a fixed top part and a movable bottom part (Sánchez, 2004).	67	Reinforced windows with impact glass to prevent wind and water from entering the house (deltechomes, 2021).
		Shutters	63	**Exterior doors and windows:** Double shutter opening outwards. **Interior doors:** Single doors. (Somerson, 2020)	68	Closing doors and windows with shutters (HFHI, 2018).
		Orientation	64	Windows on the north and side facades are oriented to receive the breezes from the trade winds, which in this region come from the north and east (Sánchez, 2022).	69	Openings facing each other to allow wind flow and avoid internal pressure in case window and door protections fail (HFHI, 2018), also favoring cross ventilation inside the building.
	Materials		65	Wood used for doors, windows, shutters and frames (Somerson, 2020).	70	Wooden shutters for windows, with wood reinforcements or metal slats (HFHI, 2018).

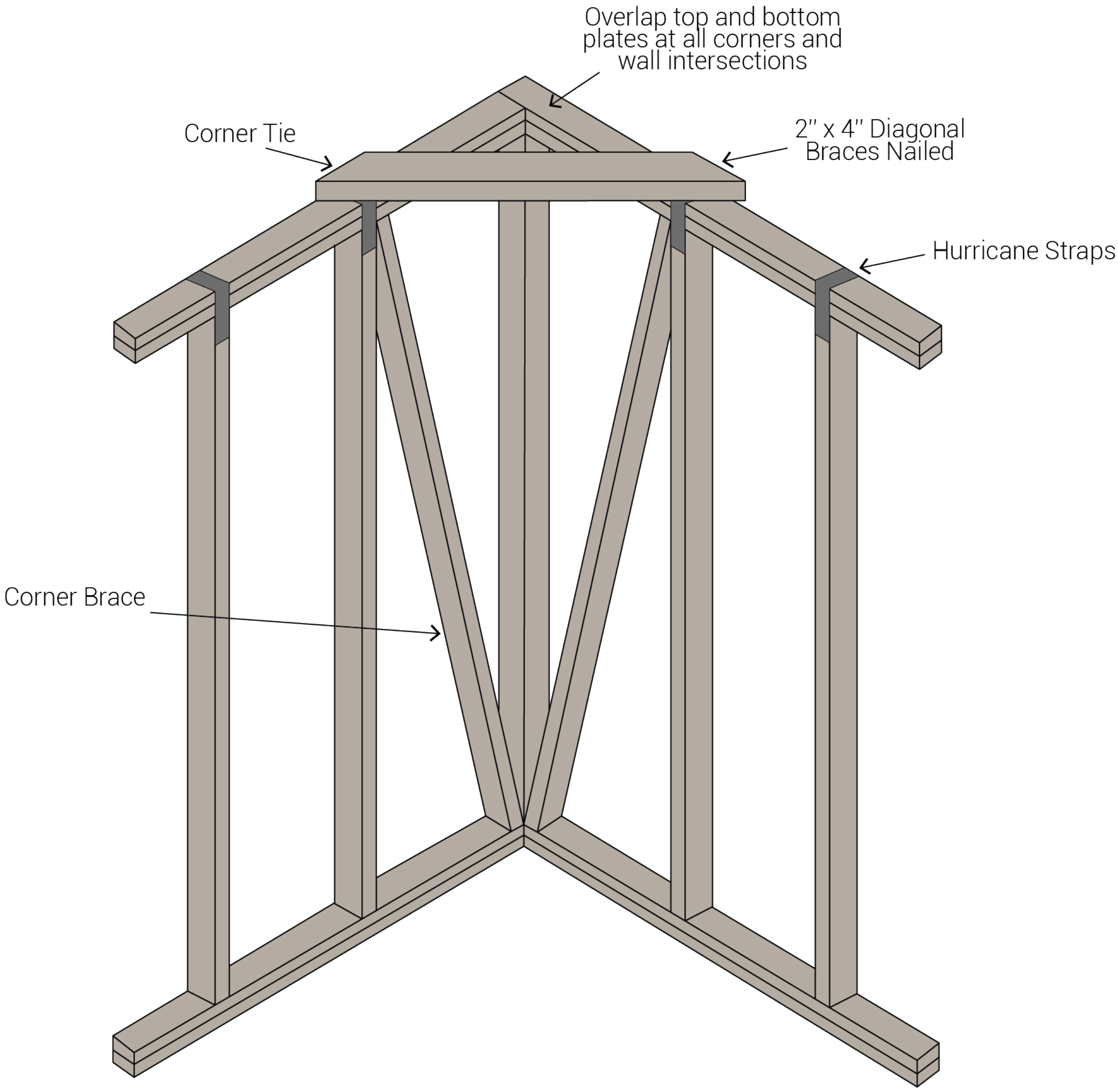


Fig. 188. Timber wall intersections. Own elaboration based on: UNDP; Engineers Without Borders, (2018).

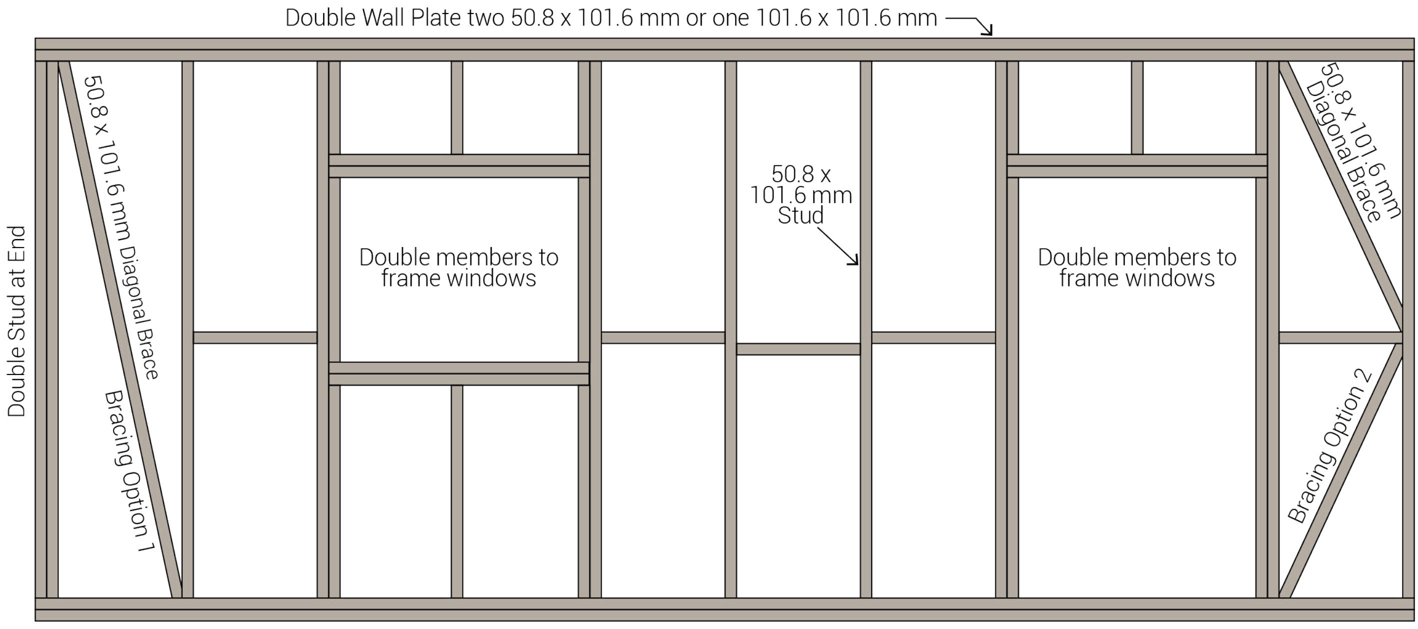


Fig. 189. Timber wall frame. Own elaboration based on: UNDP; Engineers Without Borders, (2018).

ROOF	Shape / Dimensions / Measurements	Structure	71	Types of gable roof: Shed roof, darma, garat, V-top and round top (Somerson, 2020). Slopes according to the direction of the prevailing winds (López, 2022).	81	For the principal roof: Gable roof (two slopes) is a good option but the hipped roof (four slopes) has the strongest shape and is the most aerodynamic (HFHI, 2018).
			72	**Roof angle:** 30° (Somerson, 2020).	82	**Roof angle:** Between 25° and 40°. Best roof angle 30° (HFHI, 2018).
			73	50.8 x 101.6 mm wood pieces placed as joists forming a frame that responded structurally as a whole (Sánchez, 2022).	83	**Minimum Rafter Sizes (UNDP, 2018):** Ridge: 50.8 x 203.2 mm Hip Rafters: 50.8 x 203.2 mm (Hip Roof) Jack Rafters: 50.8 x 152.4 mm (Hip Roof) Common Rafters: 50.8 x 152.4 mm
					84	**Purlins Size (UNDP, 2018):** Purlins: 50.8 x 101.6 mm
					85	50.8 x 101.6 mm collar ties on every rafter (UNDP, 2018).
				-	86	**Rafter** spacing 609.6 mm maximum (UNDP, 2018).
				-	87	**Purlin** spacing 609.6 mm max. Spacing for 50.8 x 101.6 mm purlins (lath) shall be 50.8 mm on centers (UNDP, 2018).
		Sheets / tiles		-	88	Roof galvanized sheeting shall be 24 gauge (0.5 mm) minimum (UNDP, 2018).
				-	89	Roof galvanized sheets should extend 50.8 mm beyond the plank that tops the deck joists at the bottom (IFRC, 2013).
				-	90	The principal roof **overhang** has to be short but long enough to protect the walls from rain. It shall not be more than 460 mm at the eaves (UNDP, 2018).
	Joints / Bracing	Structure	74	Structure made of wood stripes (rafters and purlins) that join the double tie beams through reinforcements and screws, and keep the top in the appropiate gradient (López, 2022).	91	Roof structure composed with **trusses** of strong reinforcements and resistant joints to be able to withstand strong winds. Brace below the roof and between roof trusses (HFHI, 2018).
					92	Screw timbers connecting the rafters to the side of the rafters, not the face (UNDP, 2018).
					93	The screws must go into the purlins at least two inches (UNDP, 2018).
					94	Purlins fixed to the rafters using hurricane straps or screws with plywood (UNDP, 2018).
		Sheets / tiles		-	95	Use of galvanize/ umbrella nail and washer or screw with washer and nut to connect rafters, purlins and sheets. Fold the nails at the end to have more resistance against the wind and place the nail at the highest part of the wave to protect from heavy rains (HFHI, 2018). Self-tapping screws can also be used (UNDP, 2018).
				-	96	**Corrugated galvanized roof sheets:** At ridges, eaves and overhangs screws should be placed every 75 mm. In all other locations, they should be placed every 150 mm (UNDP, 2018).
	Specifications		75	Presence of dormer (Edwards, 1991).	97	Roof dormer has to be braced with steel connectors and strapping to increase its resistance to uplift (BASC, 2022).
			76	Rainwater collection gutters installed around roofs to channel rainwater into cisterns for reuse (Somerson, 2020).	98	Gutters around roofs for rainwater evacuation (HUD, 2017).
			77	Separate roof for the exterior galleries (terrace) (Edwards, 1991).	99	The external corridor or roofed terrace should have a separate roof (HFHI, 2018).
		Sheets / tiles		-	100	Overlapping roof tiles at least 2 1/2 corrugations and screw the overlapping sheet on the sides to prevent water from blowing under the seam (UNDP, 2018).
				-	101	Roof capping should be made from material as strong as the sheeting itself and should be screwed down to the purlin on either side of the ridge, ridgeboard or hip (UNDP, 2018).
				-	102	Driving heads or large washers under the screw heads to prevent the roof sheets from tearing when pulled upwards by high winds (UNDP, 2018).
				-	103	Spaces between sheeting and the wallplate should be closed up to prevent the wind from getting under the sheeting and lifting it. This can be done by nailing a fascia board to the ends of the rafters (UNDP, 2018).
	Materials	Structure	79	Wooden roof structure (Sánchez, 2004).		59
				-	104	Hurricane ties are required and shall be galvanized or stainless steel (UNDP, 2018).
		Sheets / tiles	80	Corrugated zinc or fiber cement roof sheets or natural materials as straw, palm and leaves (traditional models) (Somerson, 2020).	105	Corrugated galvanized roof sheet (UNDP, 2018). Zinc sheet (HFHI, 2018).
GALLERIES AND BALCONIES	Shape / Dimensions / Measurements		106	**Galleries:** Approximately 3 m wide (Edwards, 1994).	109	**Galleries:** Should be kept short, small, and separated from the structure (UNDP, 2018).
	Specifications		107	Surrounded by permeable treated wooden railings (Somerson, 2020).	110	Permeable railings that allow wind flow.
			108	**Balconies:** Appears, first at the front, on the longest façade, then on one side, then on the other (Sánchez, 2022).		-
	Materials			40		-
WATER SUPPPLY	Specifications		111	Some cisterns were semi-buried (Sánchez, 2004). Generally built next to, behind, but also underneath the houses inside the home (Somerson, 2020).	114	Water tank anchored to the ground or secured to a wall to prevent it from becoming a projectile during hurricanes (Rojas, 2021). It should be located as close as possible to the house (SonProject, 2021).
			112	Wooden barrel connected to the roof gutters to collect and store rainwater (Sánchez, 2022).	115	A system of gutters and downspouts directs the rainwater collected by the roof to the storage cistern (Jarrett, 2022).
	Materials		113	Wooden barrel replaced by cement cisterns lined with wood (Sánchez, 2022).	116	They can be built in different materials, however, reinforced concrete is considered best especially for underground cisterns (SonProject, 2021).

Table. 4. Matrix. Own elaboration based on cited references.

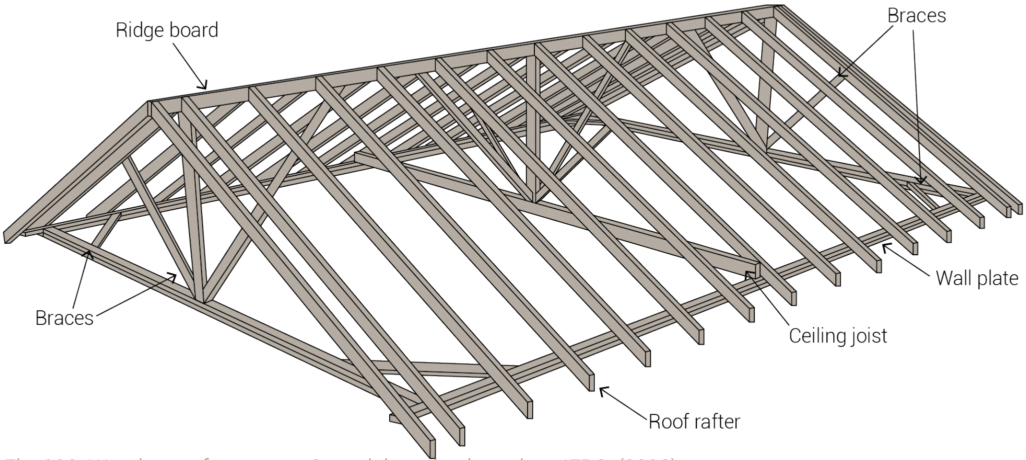


Fig. 190. Wooden roof structure. Own elaboration based on: IFRC, (2013).

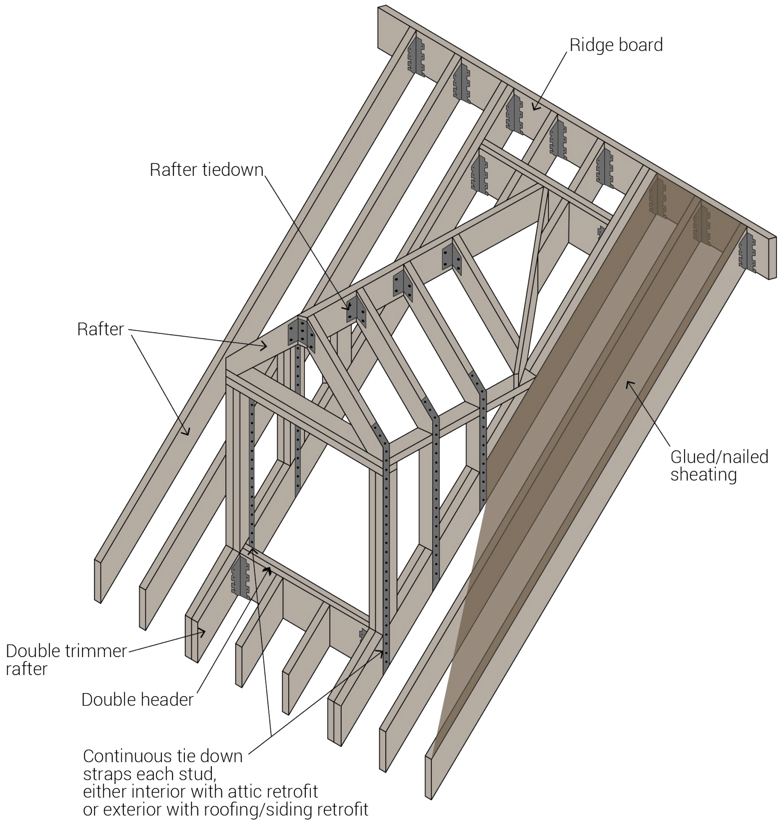


Fig. 191. Dormer structure. Own elaboration based on: EERE, (2022).

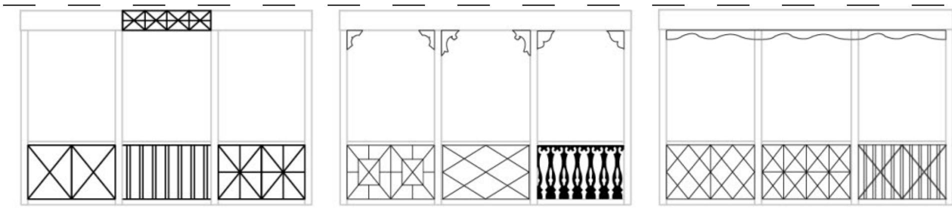


Fig. 192. Source: Saldarriaga, A; Fonseca, L., (1985).

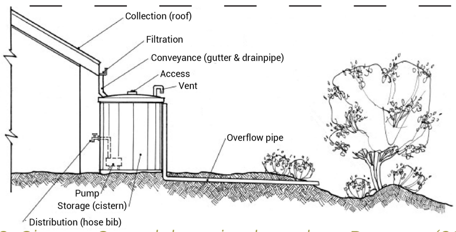


Fig. 193. Cistern. Own elaboration based on: Downey, (2015).

06

PROPOSAL

6.1. Assumptions

Based on the information provided in the previous chapters, the impact of hurricanes on the Caribbean area is exposed, including their influence on local architecture and the international regulations designed to withstand such phenomena. From this, the Archipelago of San Andres, Providencia, and Santa Catalina, is introduced along with its Creole architectural heritage, which exhibits characteristics and construction techniques protected by Colombian law. These show affinity with some hurricane-resistant strategies, forming the basis for the argument regarding the need to return to roots to address the current situation. Further on, it details the significant impact of the most recent hurricanes on the Archipelago, along with how the government responded with architecture detached from heritage.

Thus, from a historical and architectural perspective within the legal framework of the Archipelago's regulations, the need to relate three important variables is highlighted:

1. ***Vulnerability*** *of the area to hurricanes and the need to adhere to regulations for constructions resistant to the phenomenon.*

2. ***Recognition*** *of Creole architecture as a foundational typology and its resilience throughout history to phenomena like hurricanes.*

3. ***Protection*** *of material and immaterial heritage of the root community in terms of construction techniques by national laws.*

6.2. Brief

Generate a prototype that preserves the construction techniques and traditional characteristics of Creole architecture, using wood as the main material, respecting local conservation laws, while adopting international regulations to implement conceptual design solutions that enhance its resilience against strong winds and hurricanes.

HURRICANE RESISTENCE

According to international protocols and manuals

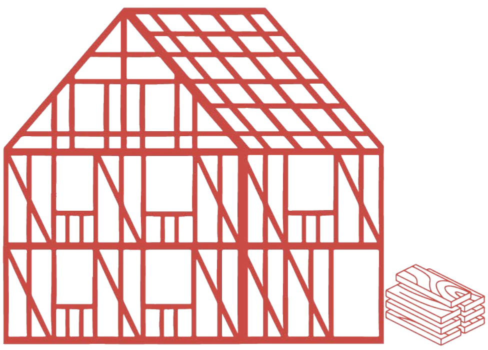
Fig. 194. Own elaboration based on: Nesterenko, R., (2022).

CREOLE ARCHITECTURE

Traditional construction methods and design

Fig. 195. Own elaboration based on: Alaver.

MATERIALITY



Use of wood as the main material

Fig. 196. Own elaboration based on: Dreamstime.

6.3. Design Process

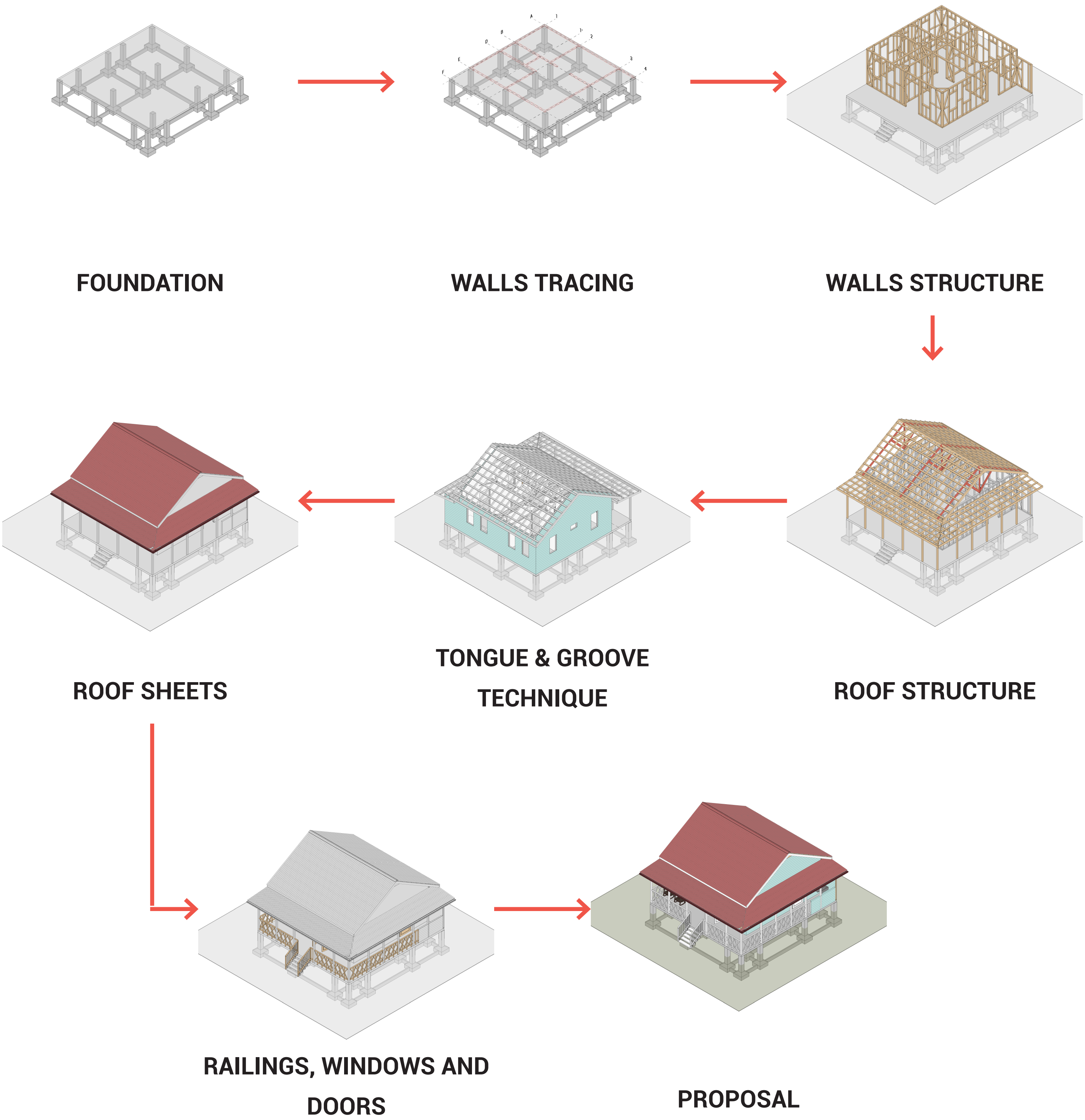
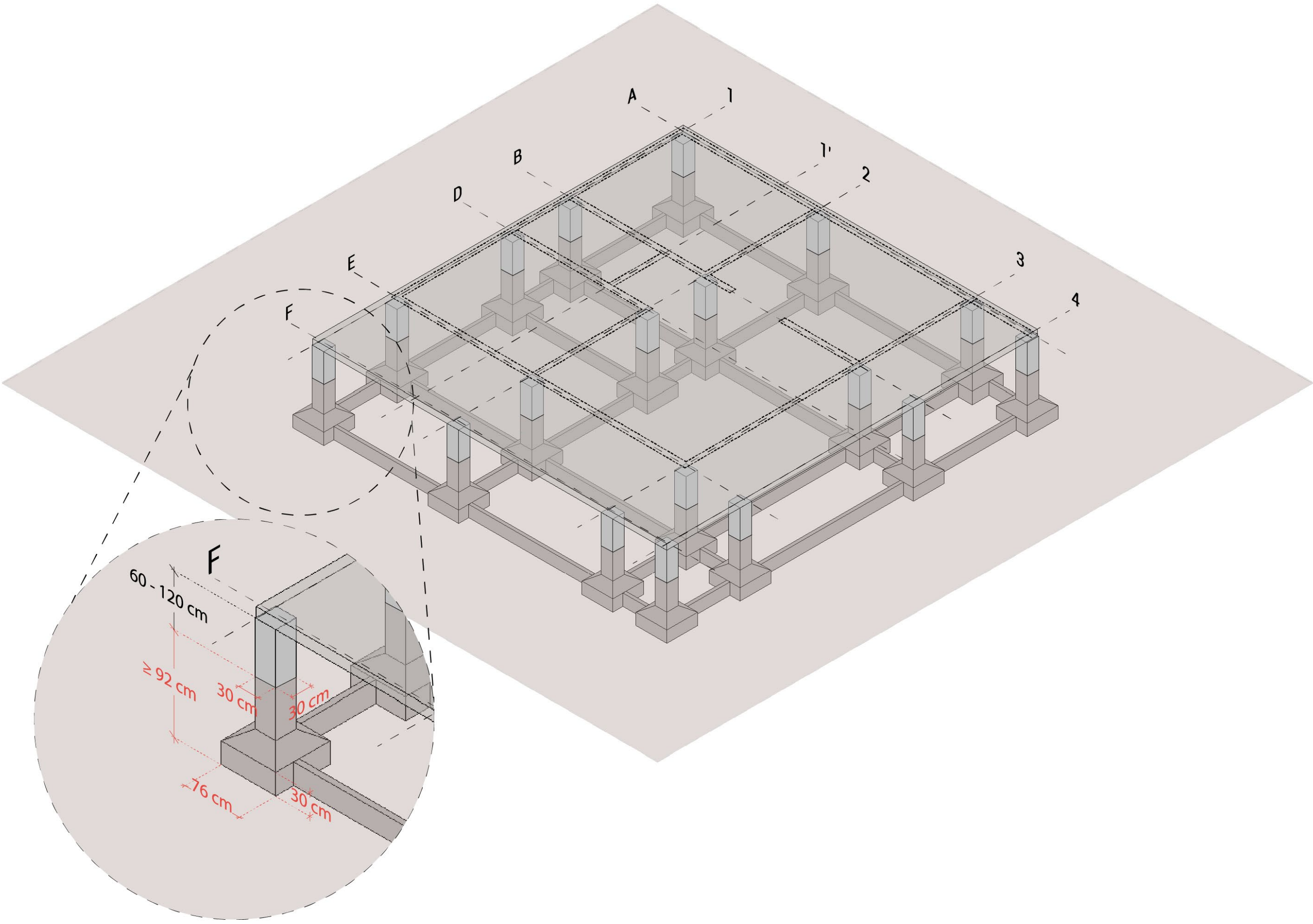


Fig. 197. Design Process. Own elaboration.

The general design process of the proposal is presented to provide a clear and organized approach to it, having extracted the main requirements from each part of the construction process mentioned in the **Section 5.4. Comparative Matrix: Creole and Traditional Architecture & Hurricane-Resistant Architecture According to National and International Literature.**

FOUNDATION & WALLS TRACING

Fig. 198. Foundation. Own elaboration.



CREOLE

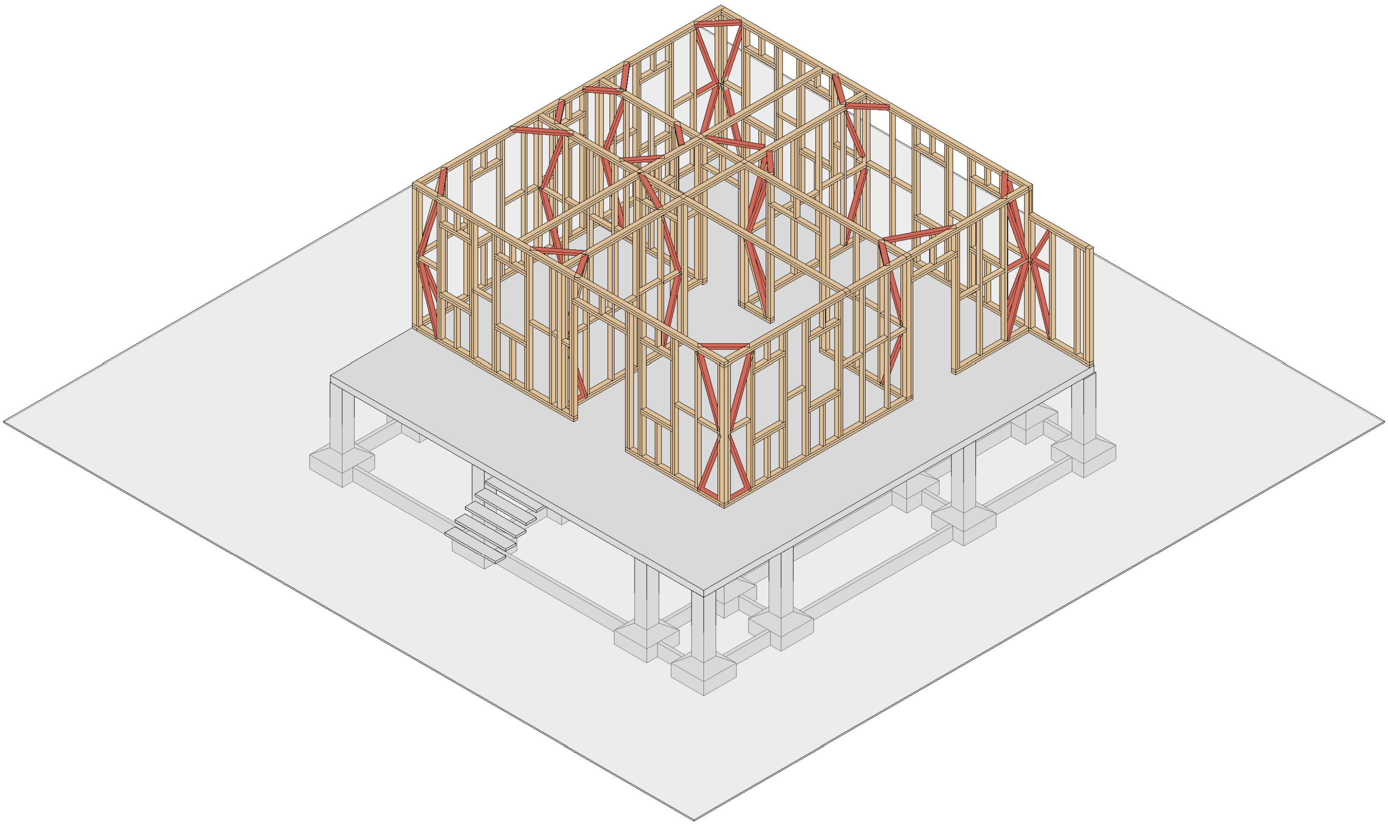
- Piles between 600 and 1200 mm high approximately above the ground (Ruiz, 2013).
- Walls tracing according to the distribution of the internal spaces, considering an approximately 3 m wide galleries (Edwards, 1994).

NATIONAL/INTERNATIONAL REGULATIONS

- Footings located no less than 920 mm into solid ground (UNDP, 2018). 760 x 300 mm (min size: width x depth) for Clay soil (Caribank, 2018).
- Tie beams between footings: 200 x 300 mm (UNDP, 2018).
- Minimum size (a x b) for square columns: 3.65 to 4.3 m high: 300 x 300 mm (Caribank, 2018).
- Should be constructed with flood-resistant and heavy materials to resist lift wind force (FEMA, 2009). Ex: Concrete

WALLS STRUCTURE

Fig. 199. Walls Structure. Own elaboration.



CREOLE

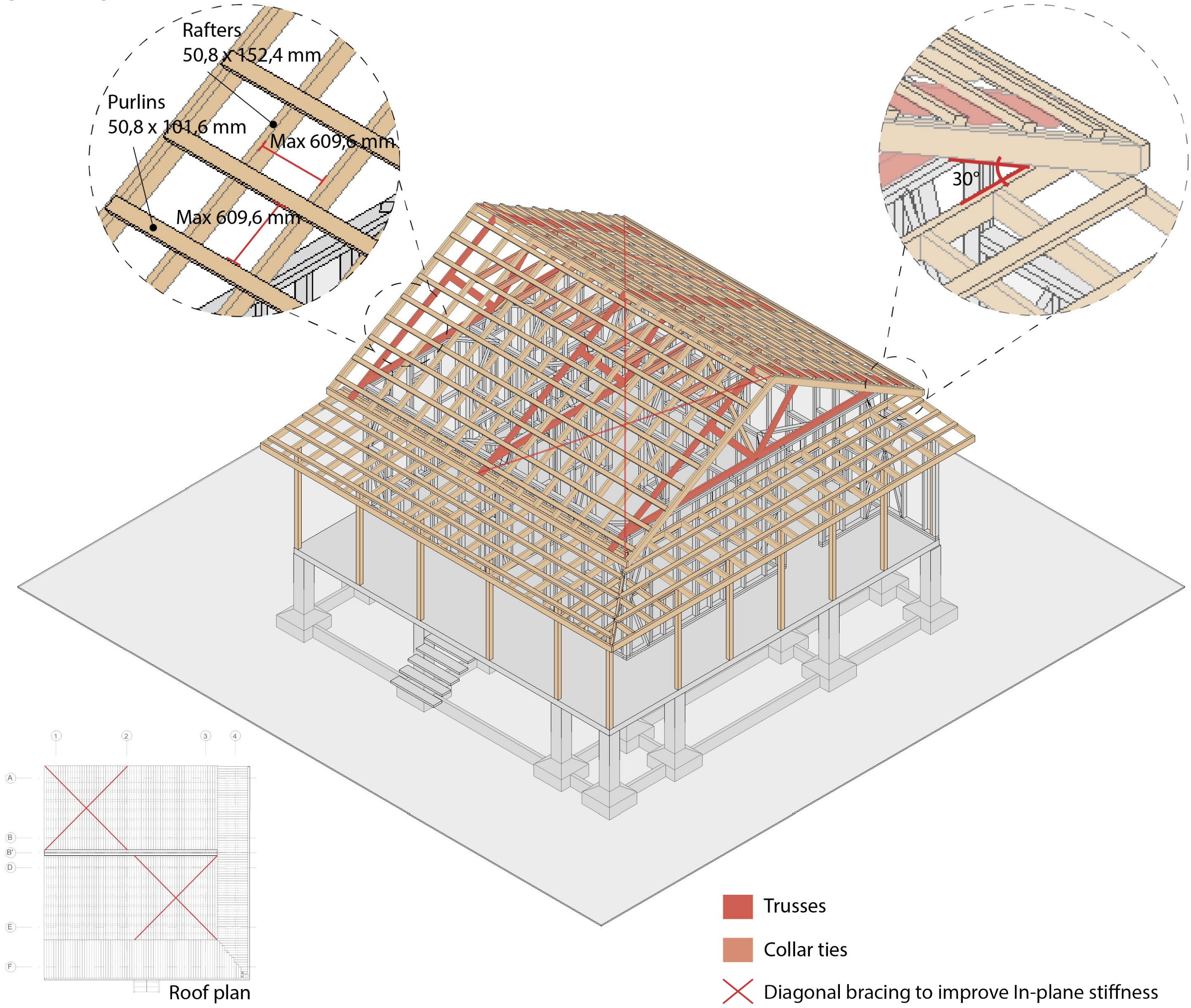
- Platform frame technique (Sánchez, 2022).

NATIONAL/INTERNATIONAL REGULATIONS

- Posts and bracing: Timber dimension: 50.8 x 101.6 mm (UNDP, 2018).
- Wallplate / base plate: Timber dimension: two of 50.8 x 101.6 mm or one of 101.6 x 101.6 mm. (Double wallplate and baseplate) (UNDP, 2018).
- J bolts to anchor the walls to the foundation, connecting the sole plate to the column / pier (UNDP, 2018).
- Brace every wall in both directions at 45°, or between 30° and 60°. Strongest bracing created by nailing timber and galvanized steel straps (Izquierdo, 2018).
- Walls braced across corners at plate level and at both corners of each wall (UNDP, 2018).
- Corners: connect uprights and wallplates, and uprights of the corners with hurricane straps (Izquierdo, 2018).
- Walls with openings: double wallplate, strong connection of each upright, double uprights at openings, brace to a strong node and double base plate anchored to foundation with washer and nut (Izquierdo, 2018).
- Connections stud with wallplate/baseplate: use hurricane straps under the base plate to reinforce the connections (Izquierdo, 2018).

ROOF STRUCTURE

Fig. 200. Design Process. Own elaboration.



CREOLE

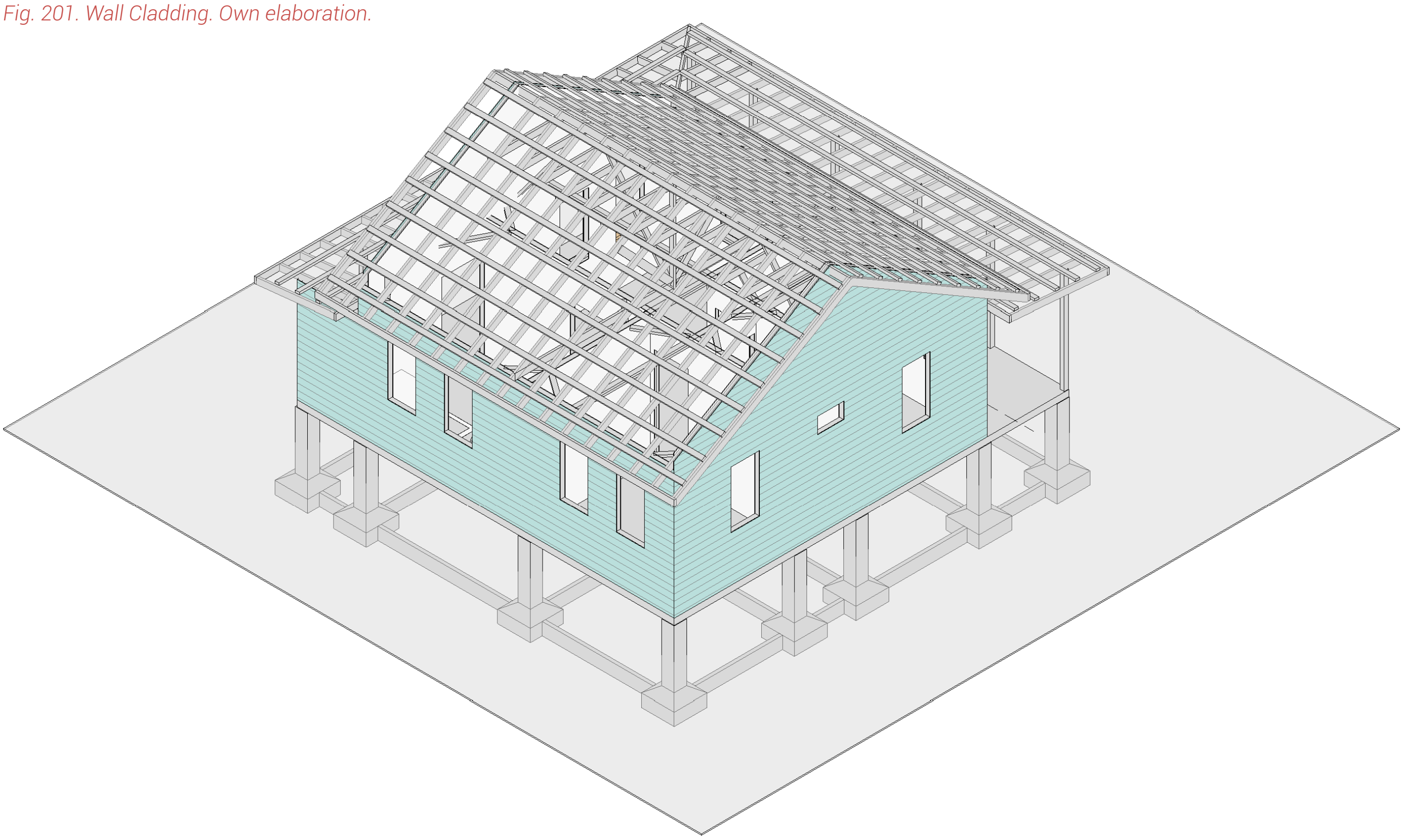
- Gable roof. (Somerson, 2020)
- Structure made of wood stripes (rafters and purlins) that join the double tie beams through reinforcements and screws (López, 2022).
- Separate roof for the exterior galleries (terrace) (Edwards, 1991).

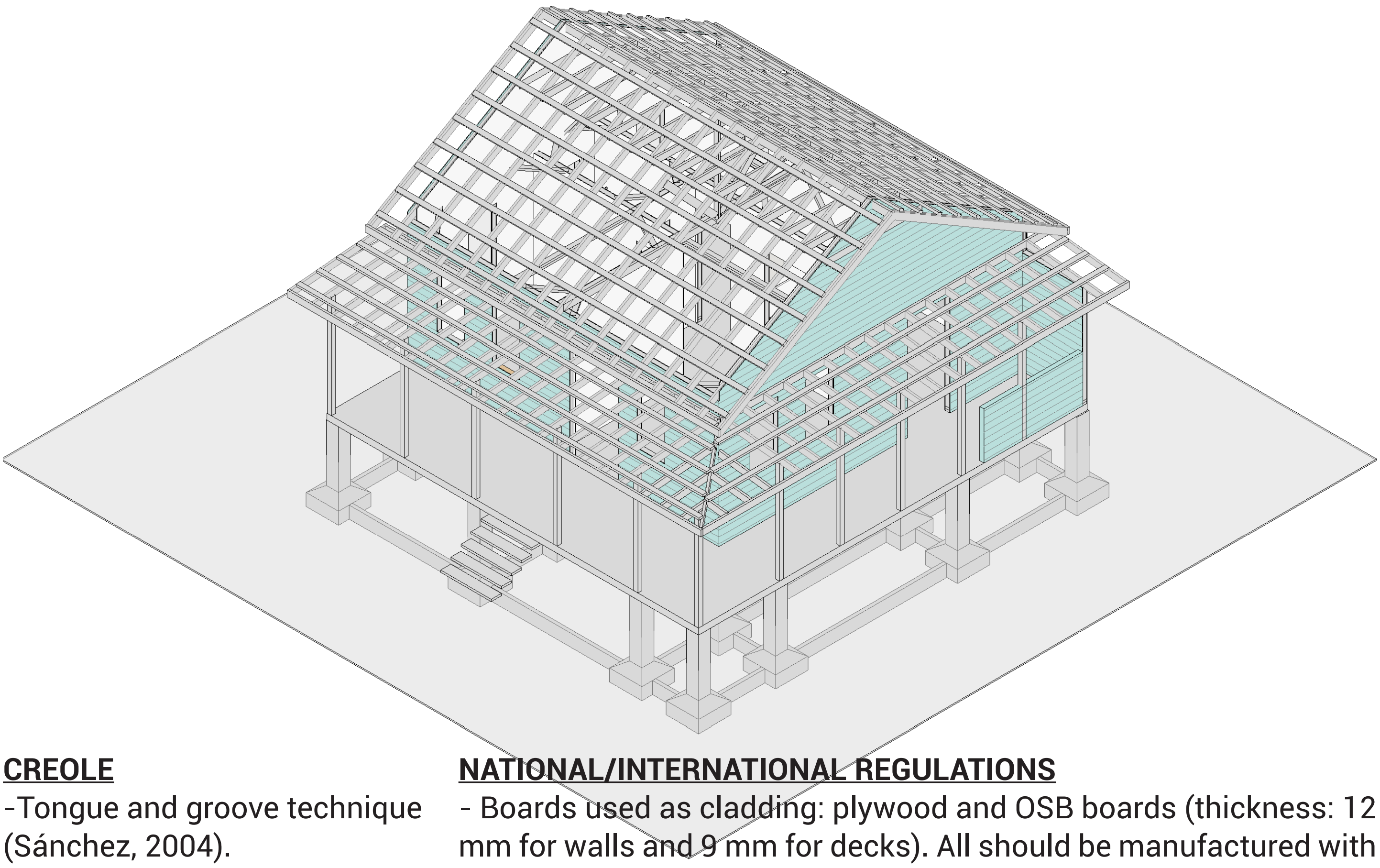
NATIONAL/INTERNATIONAL REGULATIONS

- Roof angle: 30°. (Izquierdo, 2018)
- Minimum Rafter Sizes (UNDP, 2018):
  Ridge: 50.8 x 203.2 mm
  Hip Rafters: 50.8 x 203.2 mm
  Purlins: 50.8 x 152.4 mm
- Rafter spacing 609.6 mm max (UNDP, 2018).
- 50.8 x 101.6 mm collar ties on every rafter (UNDP, 2018).
- Purlin spacing 609.6 mm max. Spacing for 50.8 x 101.6 mm purlins (lath) shall be 2′ on centers and fixed to the rafters using hurricane straps or screws with plywood (UNDP, 2018).
- Roof structure: trusses with strong reinforcements and resistant joints to be able to withstand strong winds. Brace below the roof and between roof trusses (Izquierdo, 2018).
- Principal roof overhang: no more than 46cm at the eaves (UNDP, 2018).

TONGUE AND GROOVE TECHNIQUE

Fig. 201. Wall Cladding. Own elaboration.





CREOLE

-Tongue and groove technique (Sánchez, 2004).

NATIONAL/INTERNATIONAL REGULATIONS

- Boards used as cladding: plywood and OSB boards (thickness: 12 mm for walls and 9 mm for decks). All should be manufactured with phenolic type adhesive, which is more resistant to saline environments (AIS, 2021).

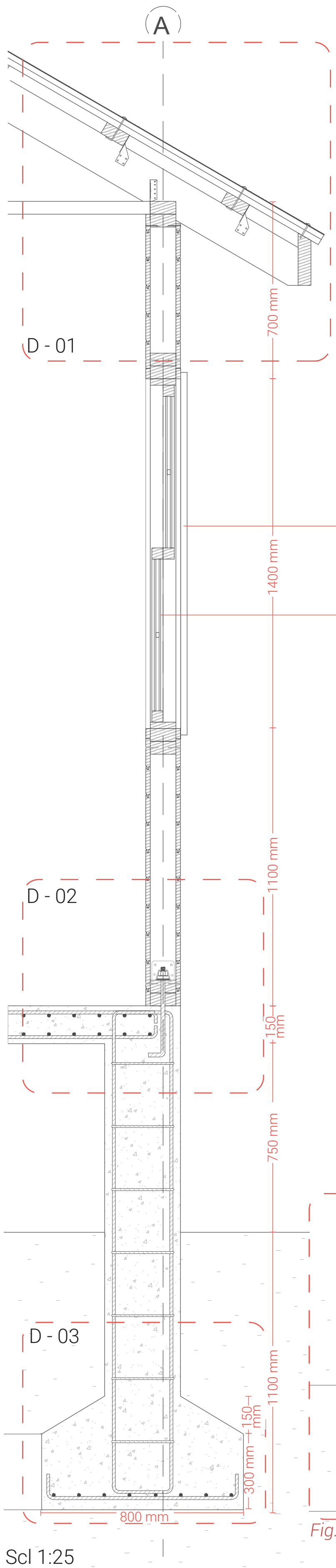


Fig. 202. Facade Detail. Own elaboration.

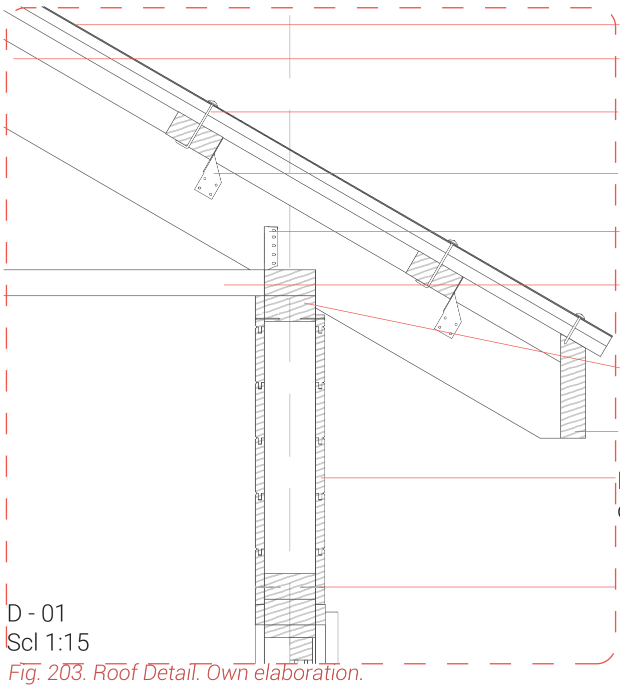


Fig. 203. Roof Detail. Own elaboration.

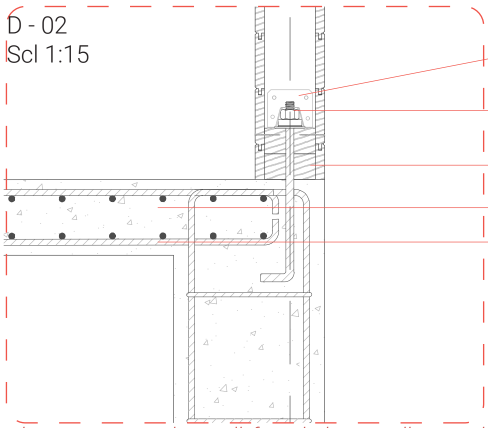


Fig. 204. Connection wall-foundation Detail. Own elaboration.

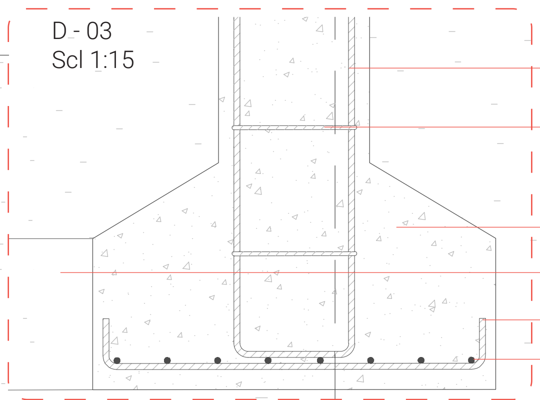
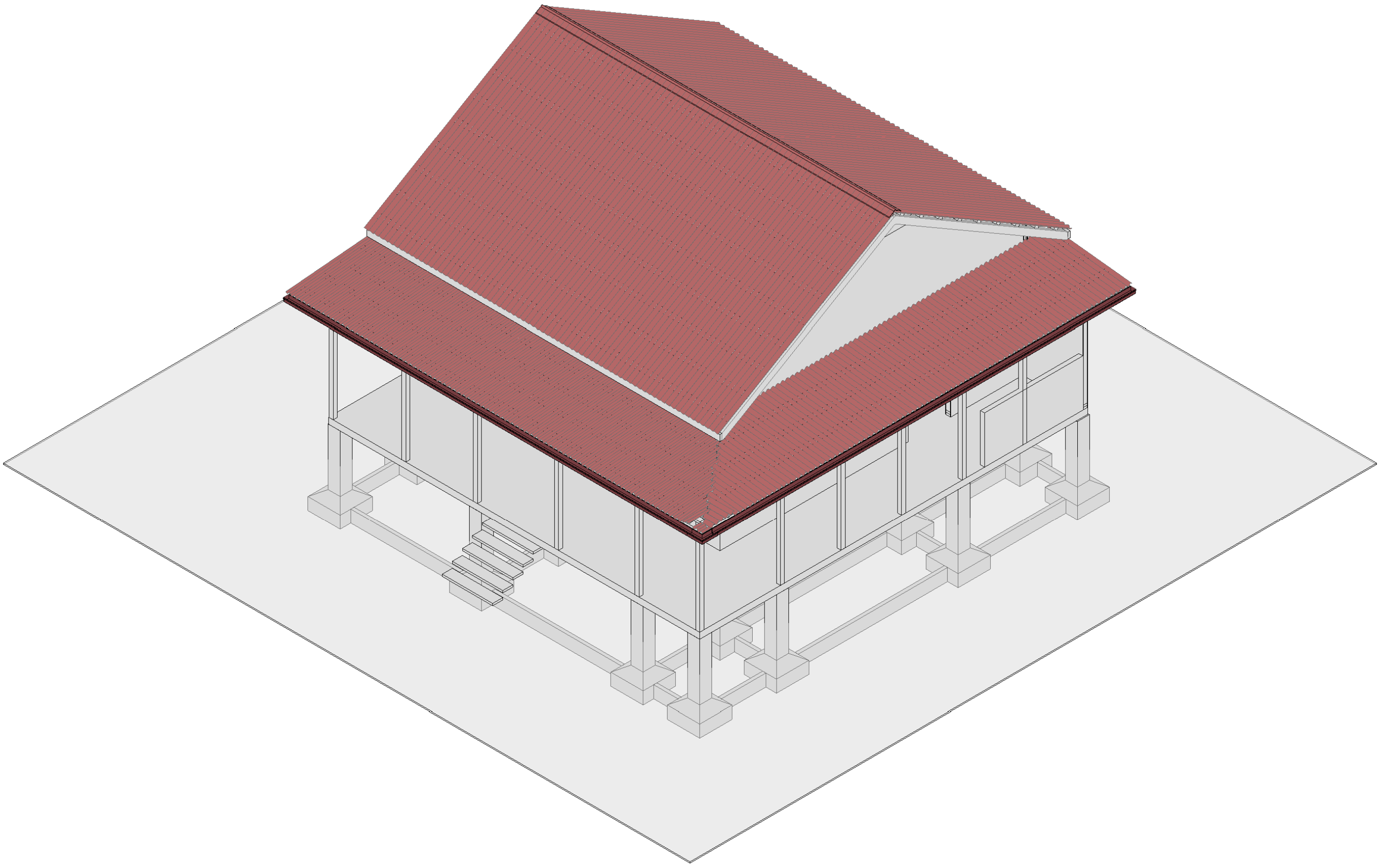


Fig. 205. Footing Detail. Own elaboration.

Note: For more detailed information see Section 5.4. Comparative Matrix: Creole and Traditional Architecture & Hurricane-Resistant Architecture According to National and International Literature.

ROOF SHEETS

Fig. 206. Roof Sheets. Own elaboration.



CREOLE

- Rainwater collection gutters installed around roofs to channel rainwater into cisterns for reuse (Somerson, 2020).

NATIONAL/INTERNATIONAL REGULATIONS

- Roof galvanized sheeting shall be 24 gauge (0.5 mm) minimum (UNDP, 2018).
- Roof galvanized sheets should extend 50.8 mm beyond the plank that tops the deck joists at the bottom (IFRC, 2013).
- Screw timbers connecting the rafters to the side of the rafters, not the face (UNDP, 2018).
- Overlapping roof tiles at least 2 1/2 corrugations and screw the overlapping sheet on the sides to prevent water from blowing under the seam (UNDP, 2018).
- Roof capping should be made from material as strong as the sheeting itself and should be screwed down to the purlin on either side of the ridge, ridgeboard or hip (UNDP, 2018).
- Spaces between sheeting and the wallplate should be closed up to prevent the wind from getting under the sheeting and lifting it. Nail a fascia board to the ends of the rafters (UNDP, 2018).
- Corrugated galvanized roof sheet (UNDP, 2018). Zinc sheet (Izquierdo, 2018).

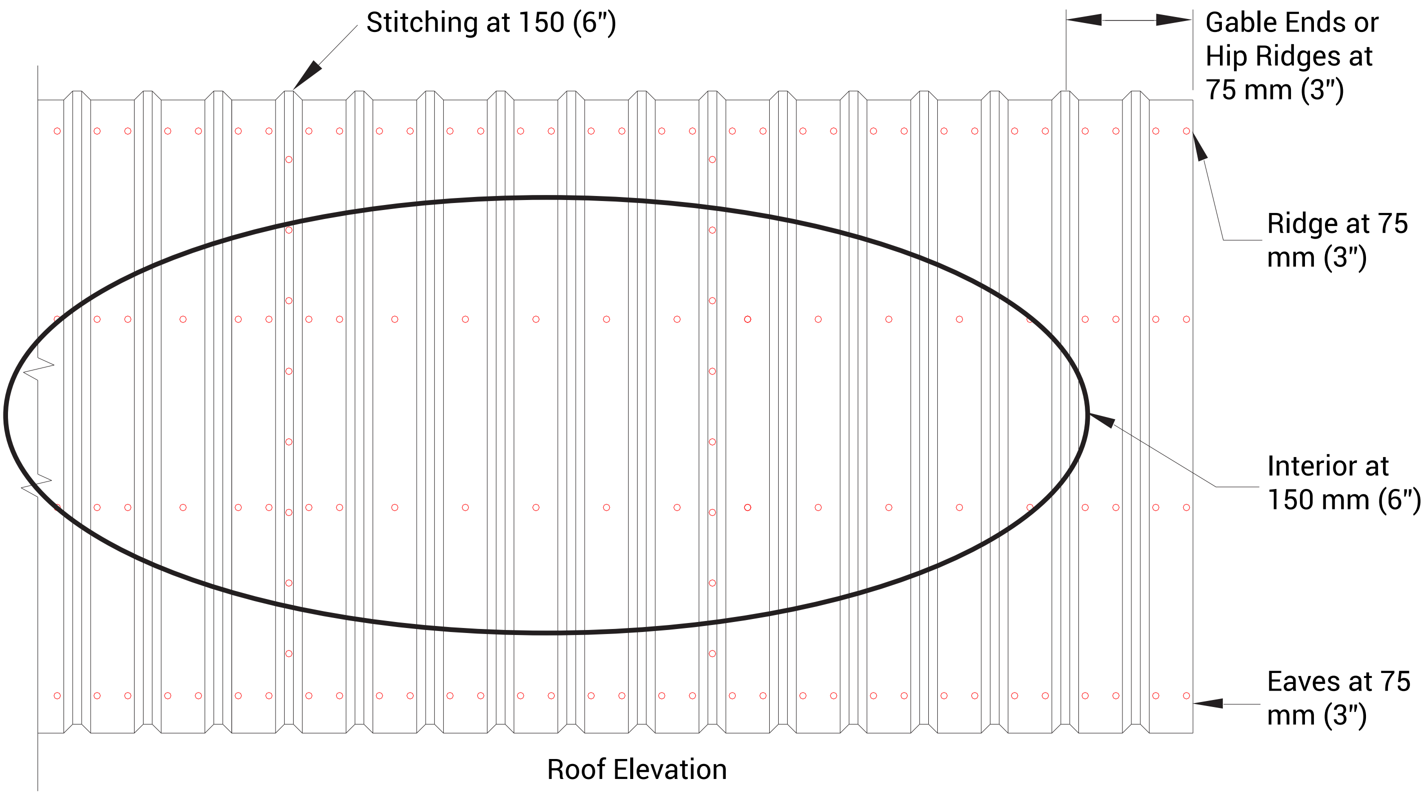


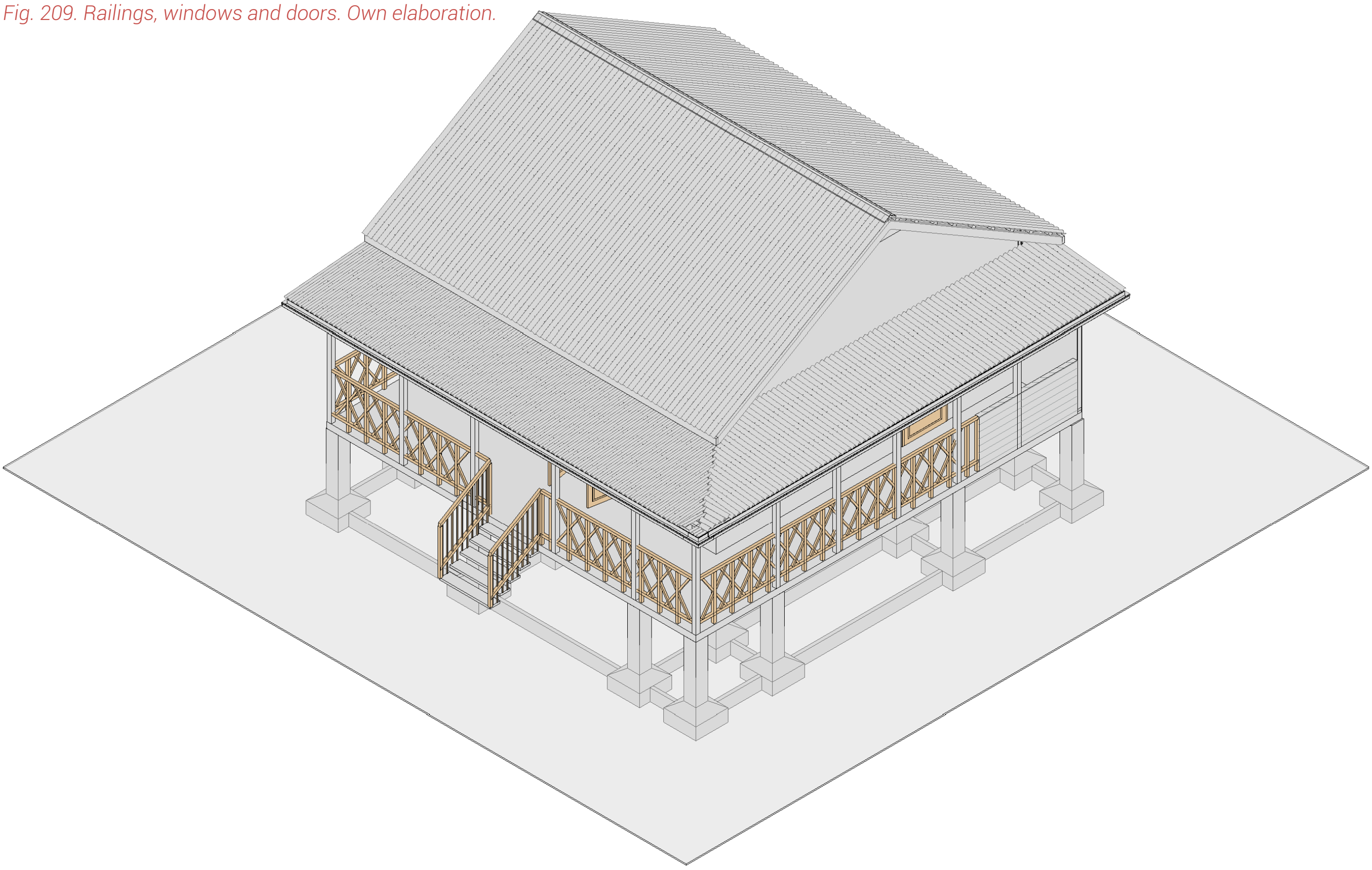
Fig. 207. Sheeting Connection Separation. Own elaboration based on: Caribank, 2018.

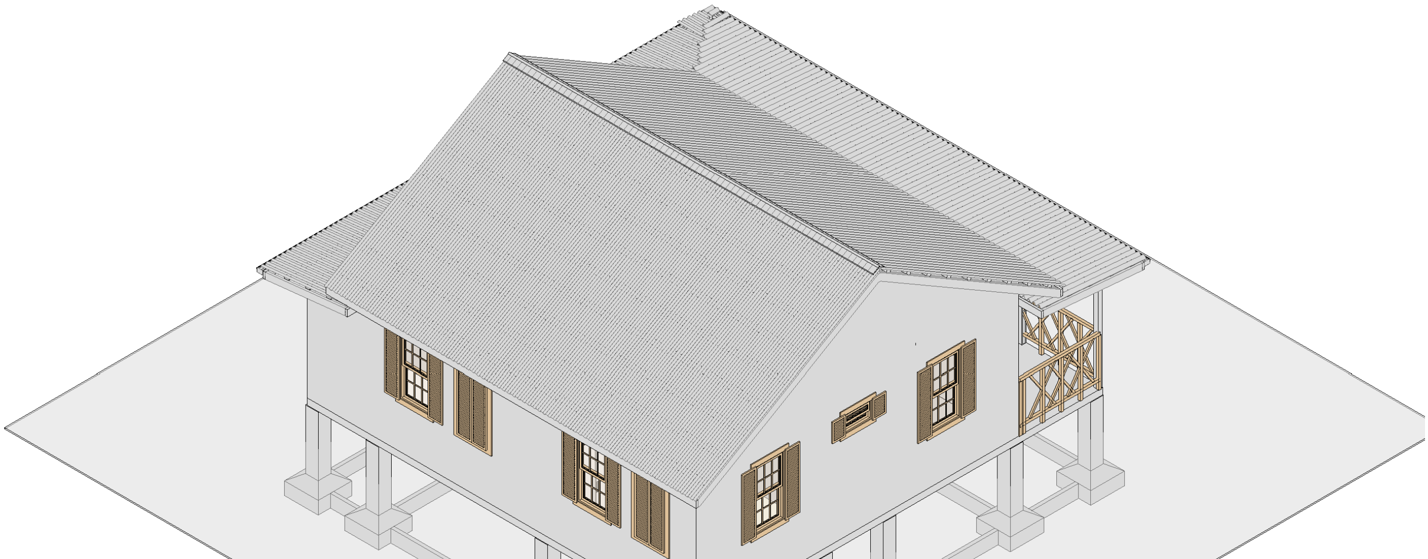
Fig. 208. Sheeting Connection. Own elaboration based on: HFHI, 2018.

RAIN PRECAUTION
1. Overlap at least 2 waves.
2. Nail at the top of the wave to protect the dwelling from rain.
3. Use galvanize/umbrella nails/screw and washer and bend the nails to make more opposition to wind.

RAILINGS, WINDOWS AND DOORS

Fig. 209. Railings, windows and doors. Own elaboration.





CREOLE

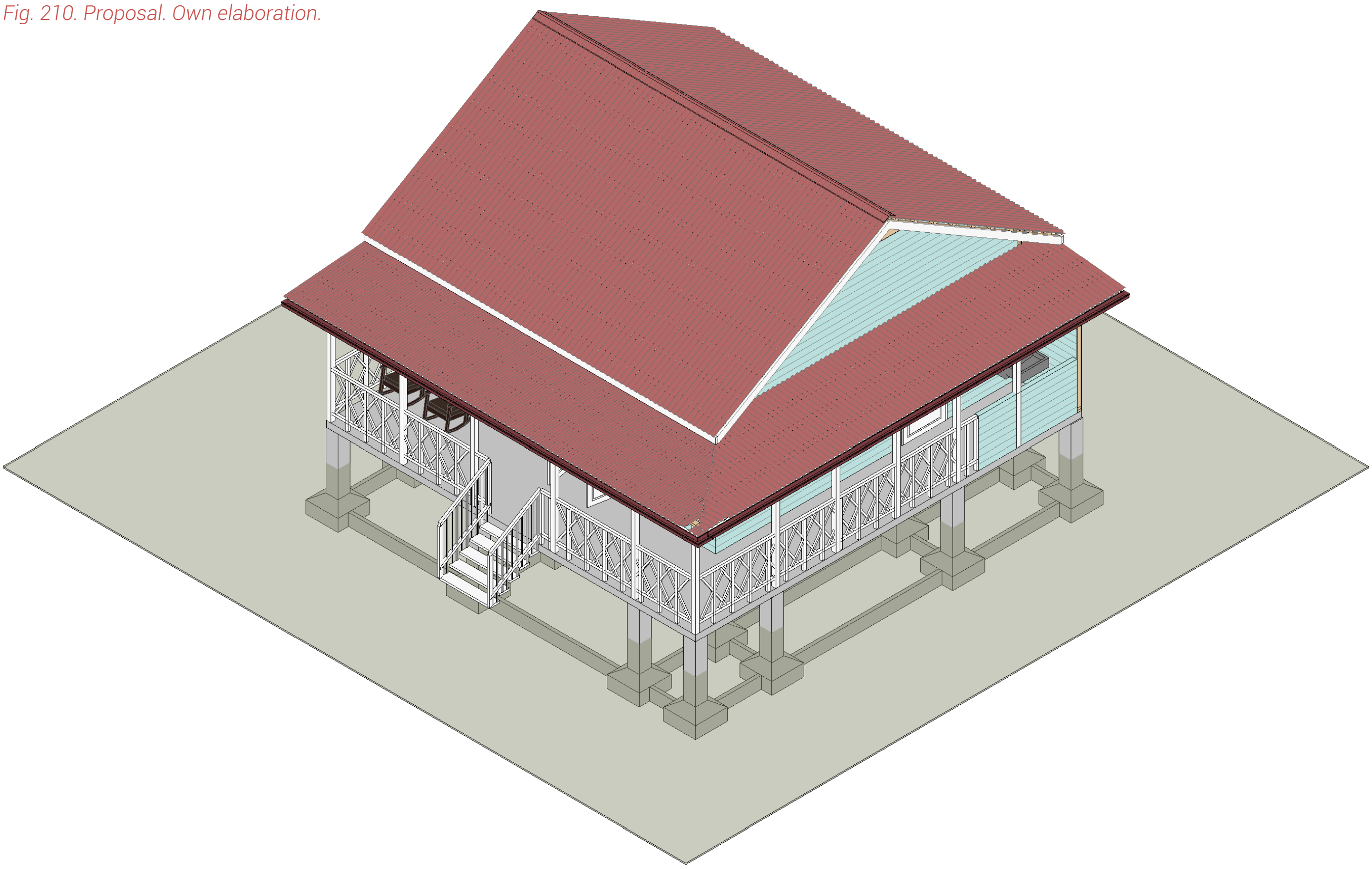
- Windows: fixed top part and a movable bottom part (Sánchez, 2004).
- Permeable treated wooden railings (Somerson, 2020).
- Exterior wooden doors and windows: Double shutter opening outwards. Interior doors: single doors (Somerson, 2020).

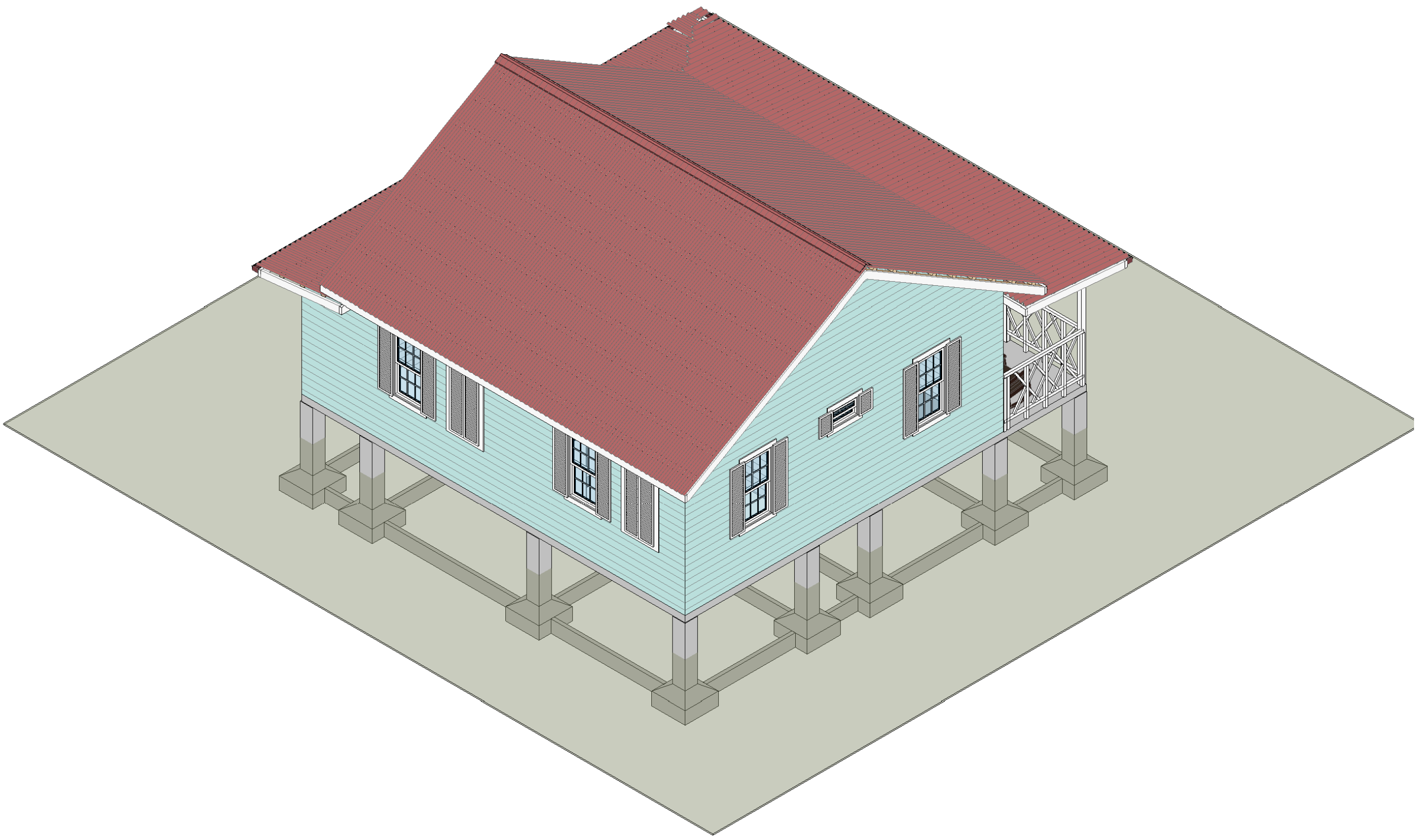
NATIONAL/INTERNATIONAL REGULATIONS

- Reinforced windows with impact glass to prevent wind and water from entering the house (deltechomes, 2021).
- Wood reinforcements or metal slats in shutters (Izquierdo, 2018).

PROPOSAL

Fig. 210. Proposal. Own elaboration.





6.4. Planimetry

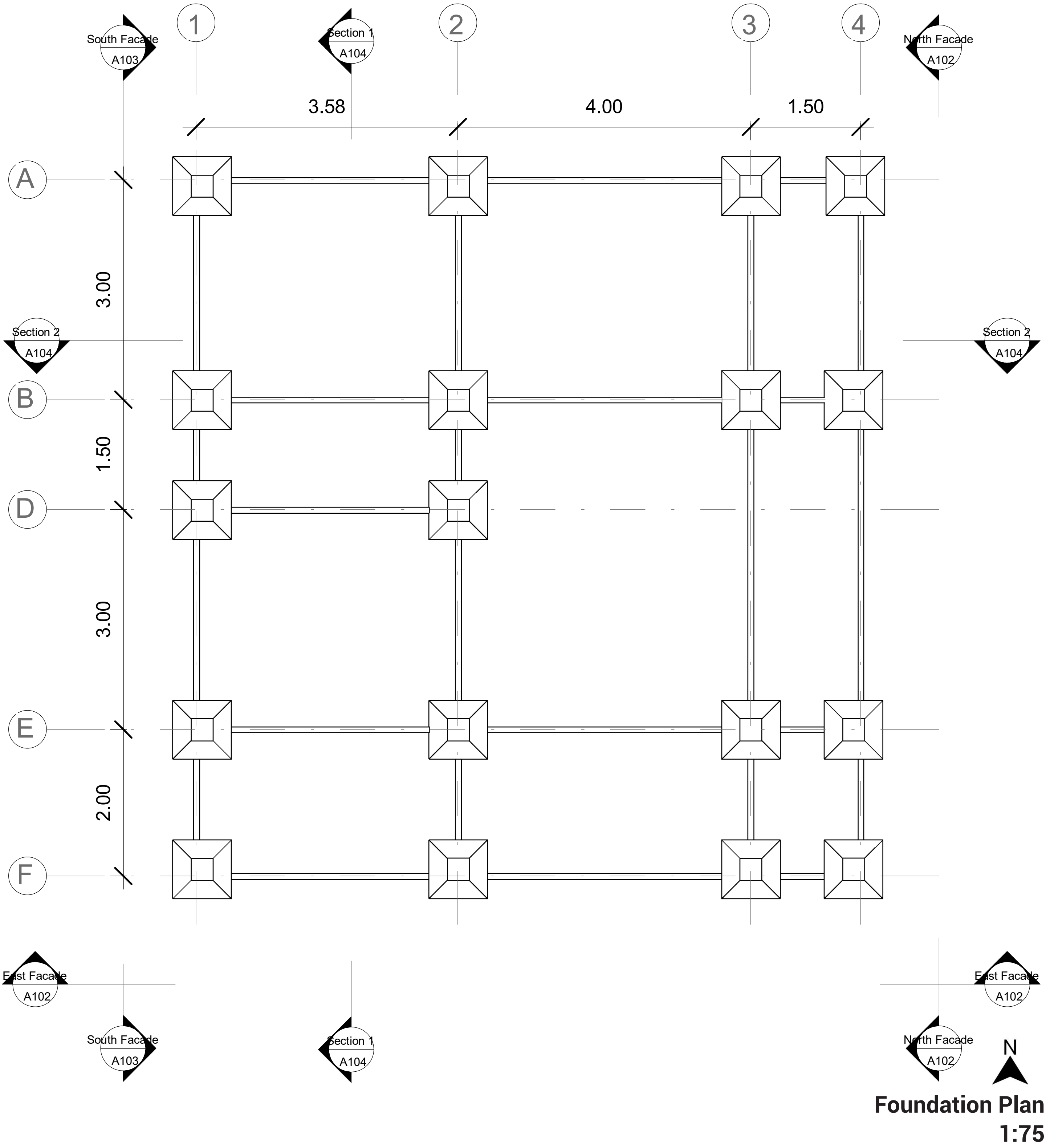


Fig. 211. Foundation Plan. Own elaboration.

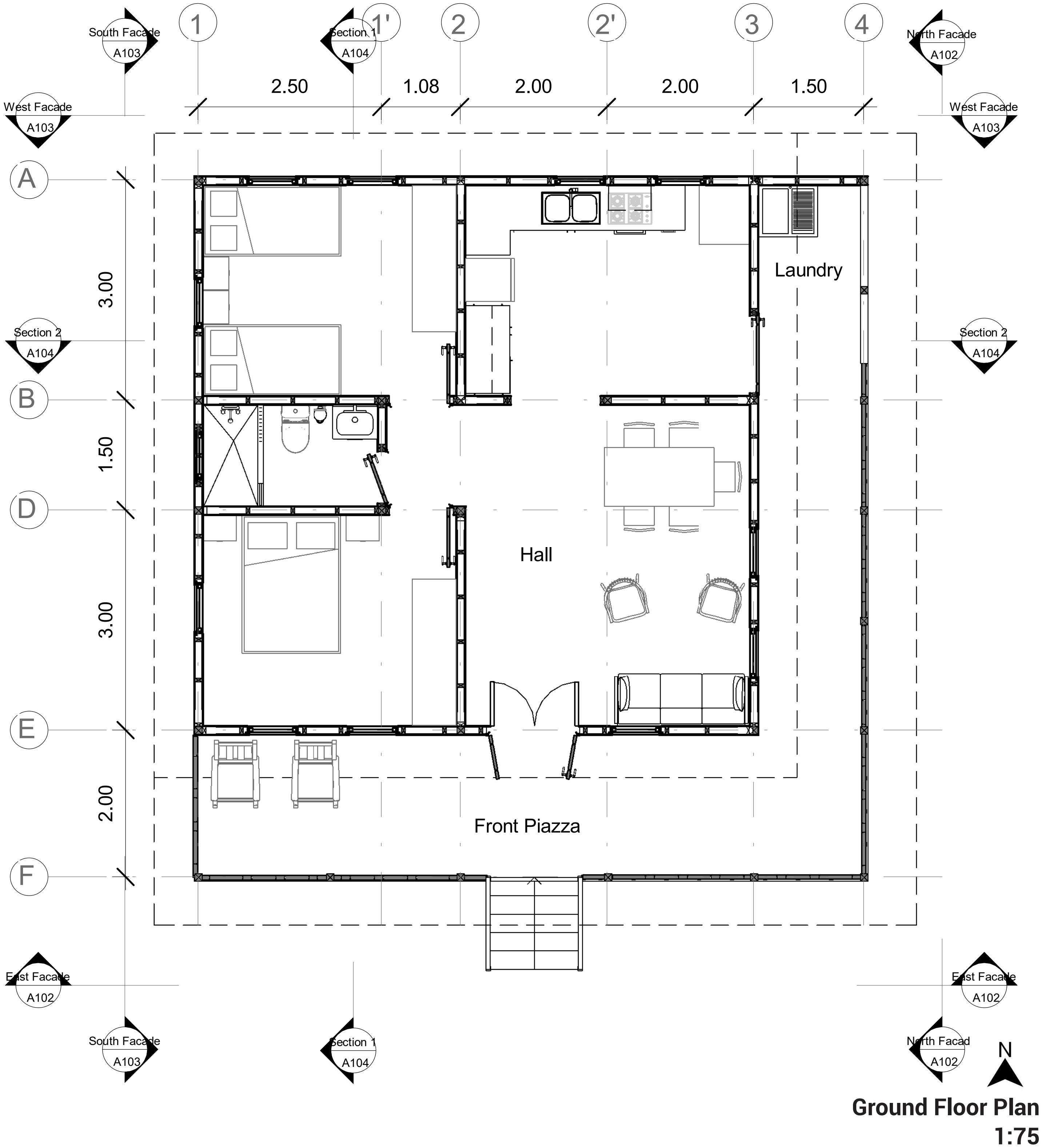


Fig. 212. Ground Floor Plan. Own elaboration.

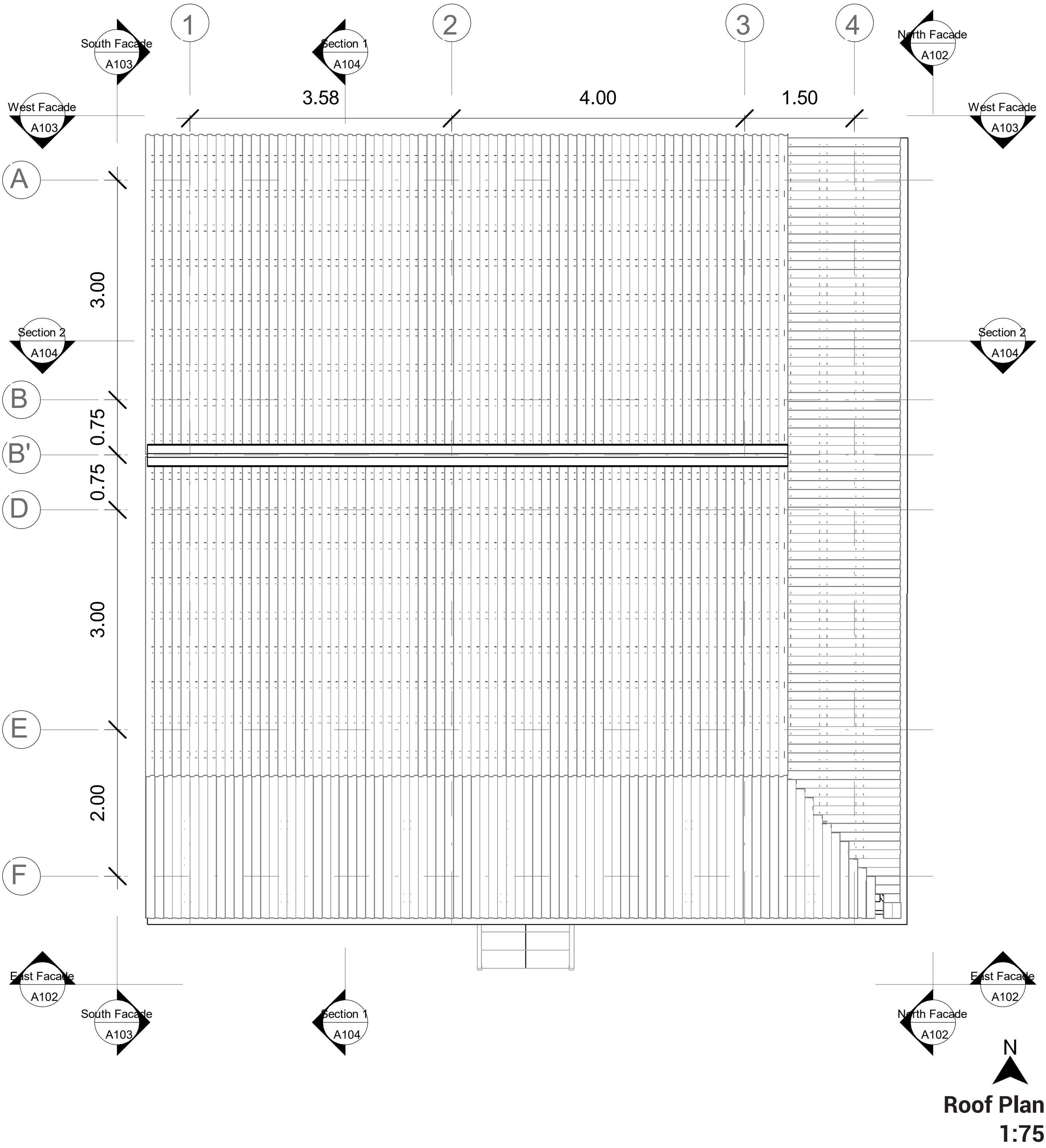


Fig. 213. Roof Plan. Own elaboration.

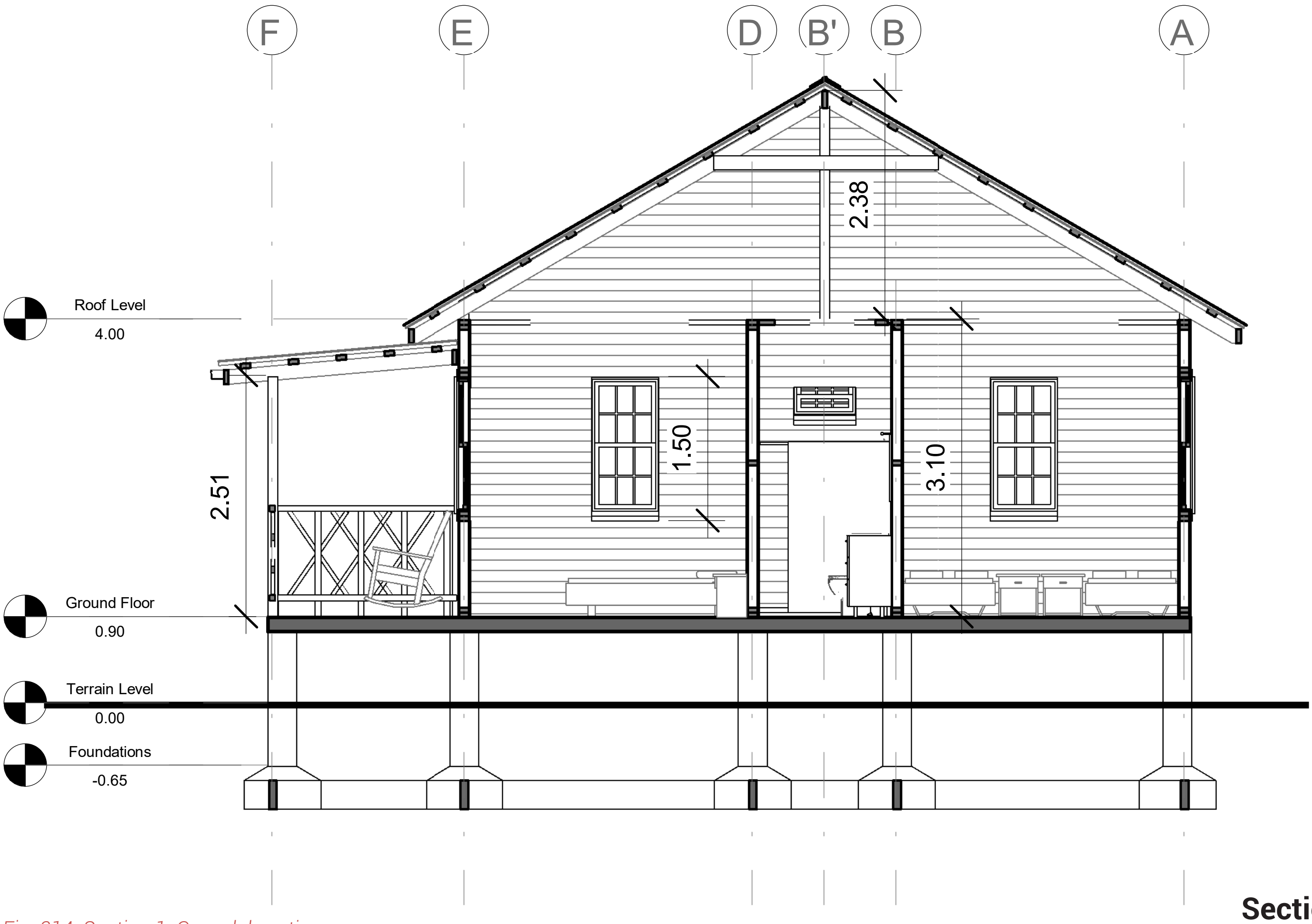


Fig. 214. Section 1. Own elaboration.

Section 1
1:75

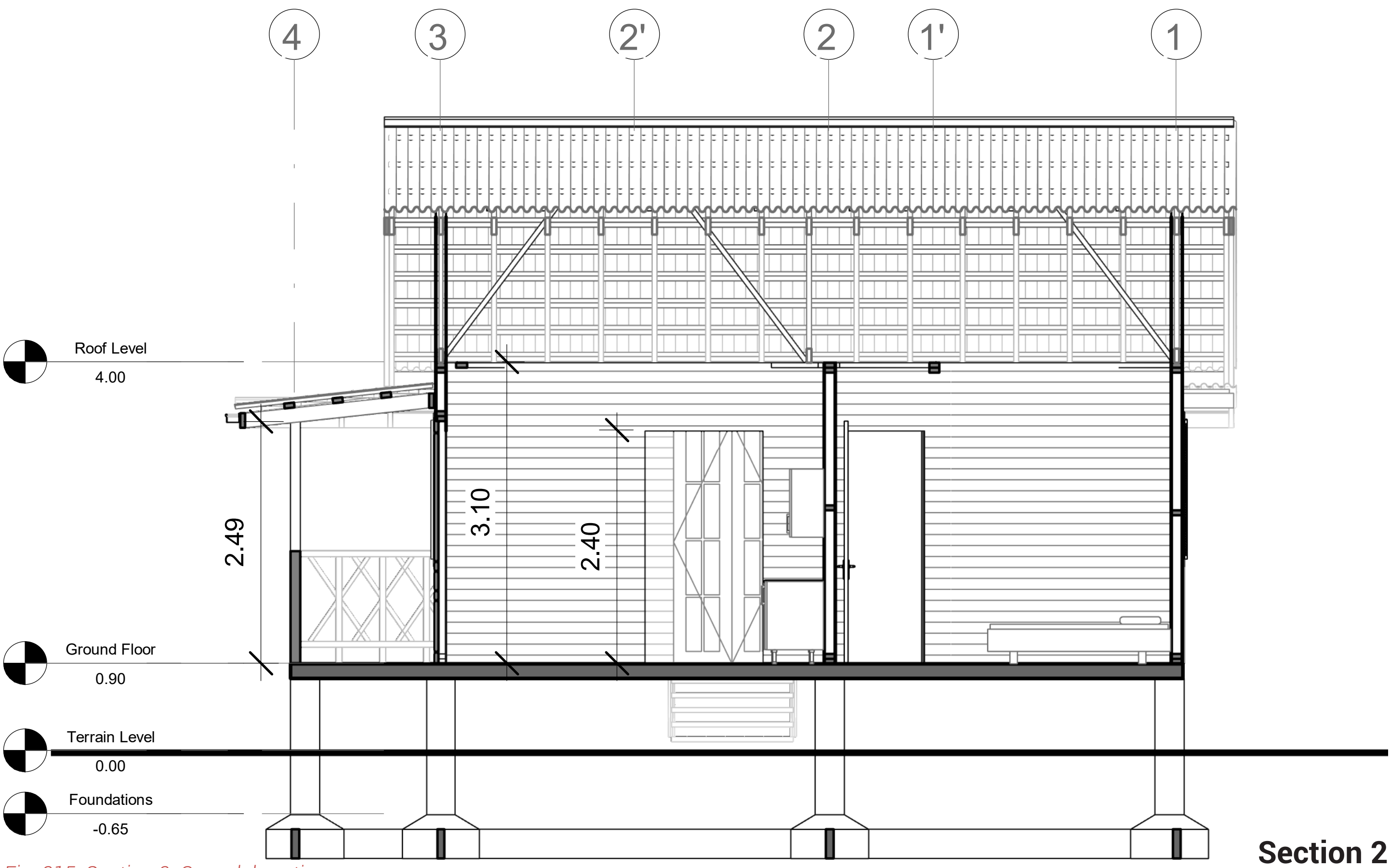


Fig. 215. Section 2. Own elaboration.

Section 2
1:75

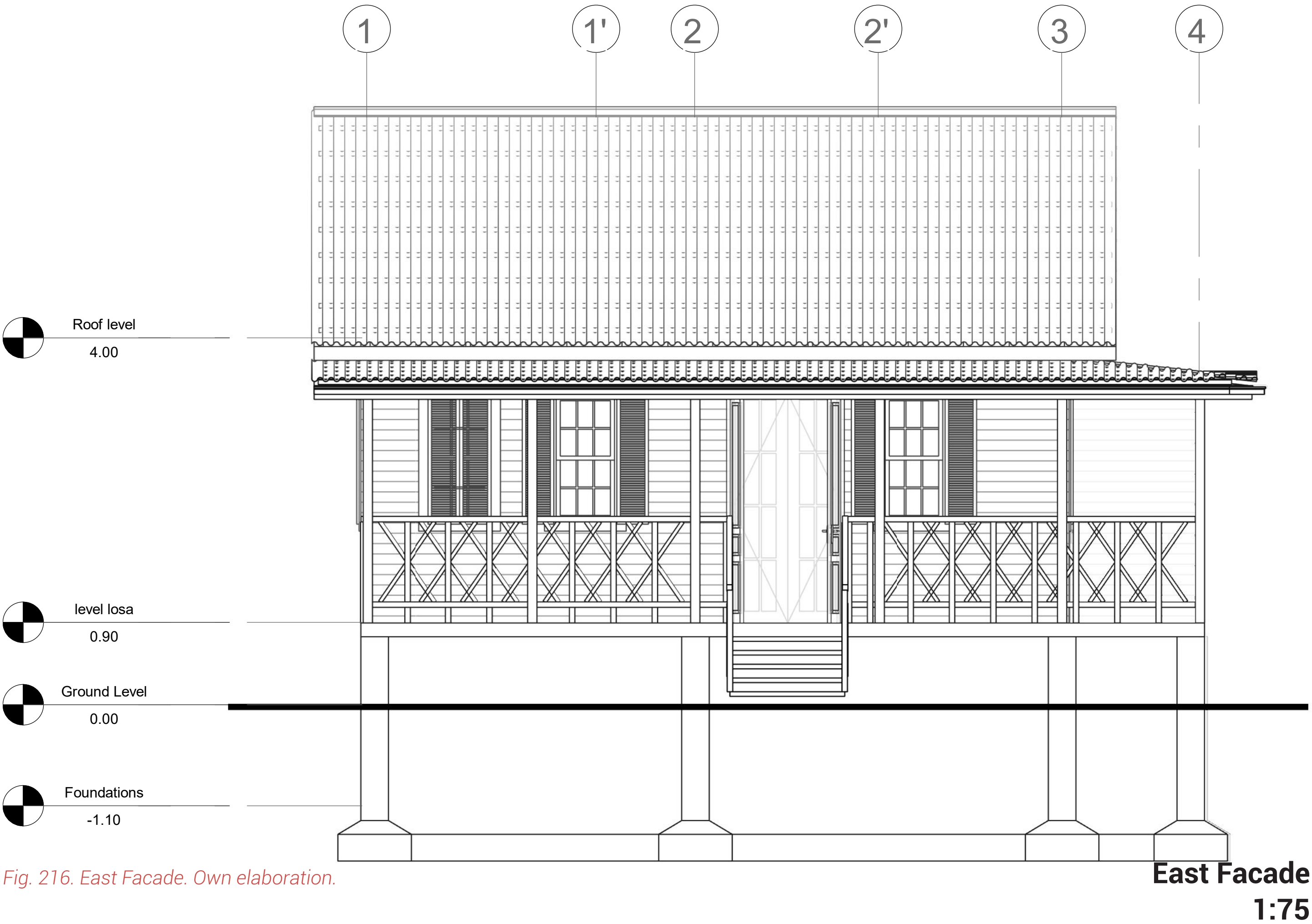


Fig. 216. East Facade. Own elaboration.

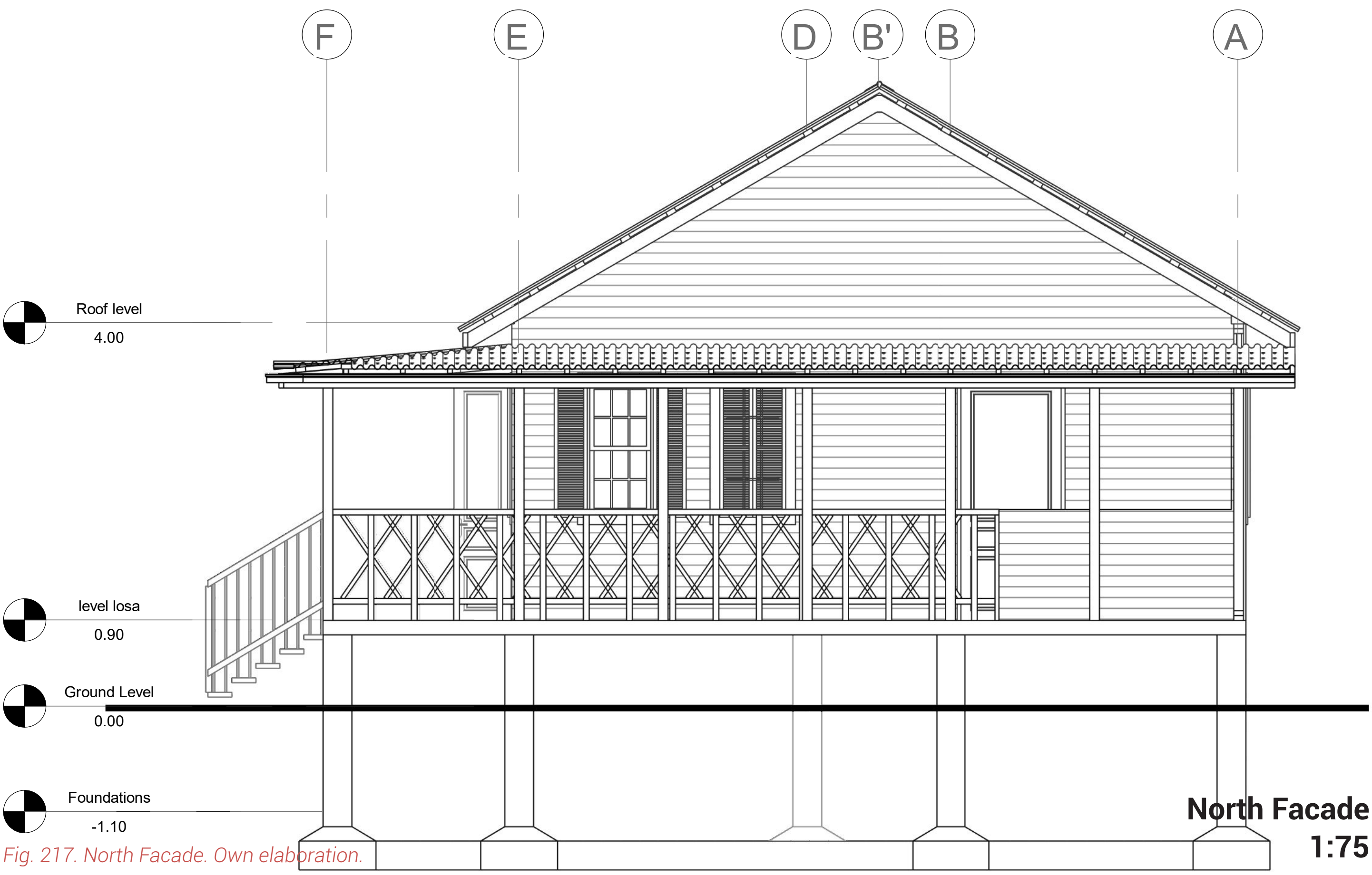


Fig. 217. North Facade. Own elaboration.

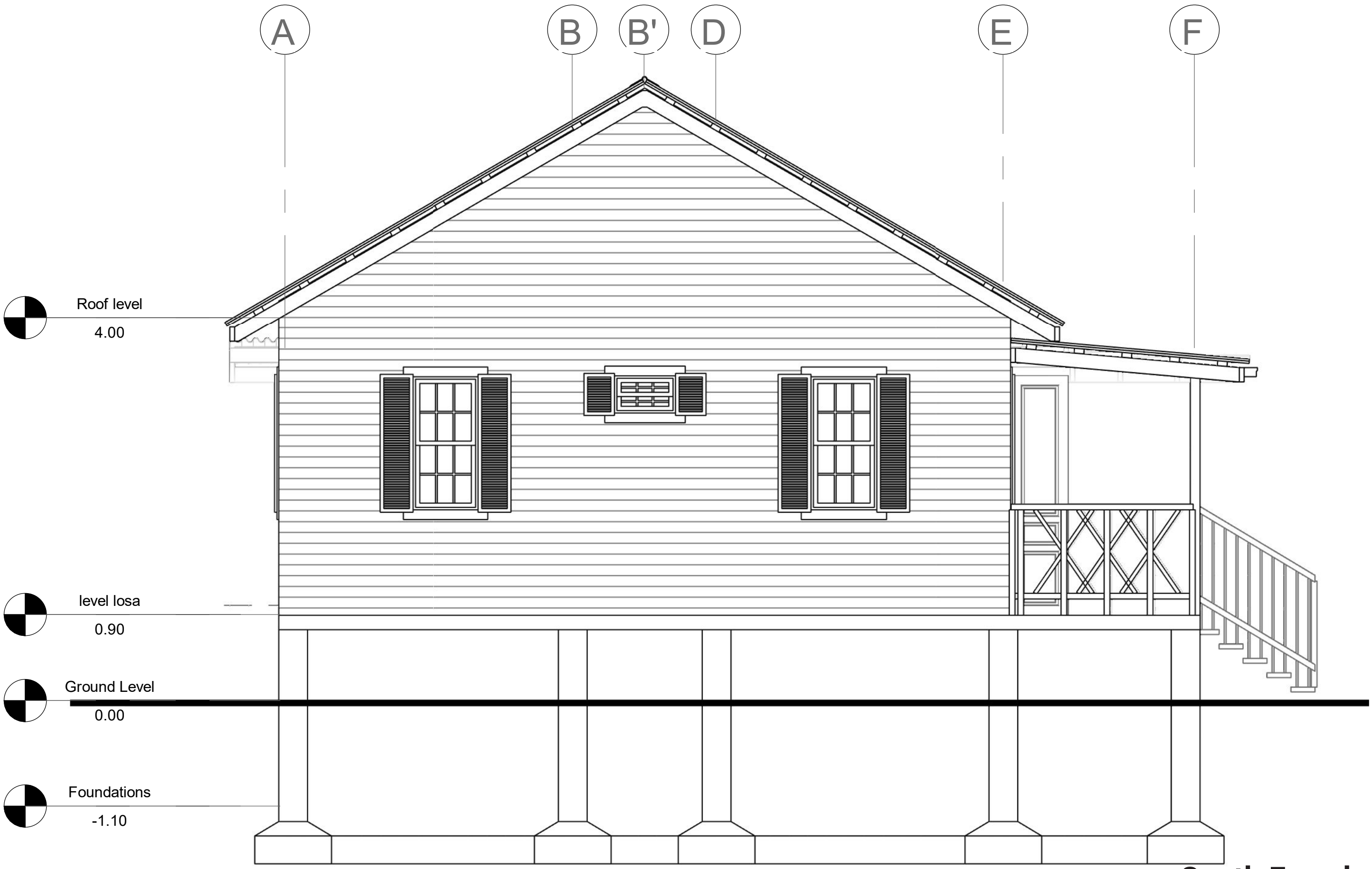


Fig. 218. South Facade. Own elaboration.

South Facade
1:75

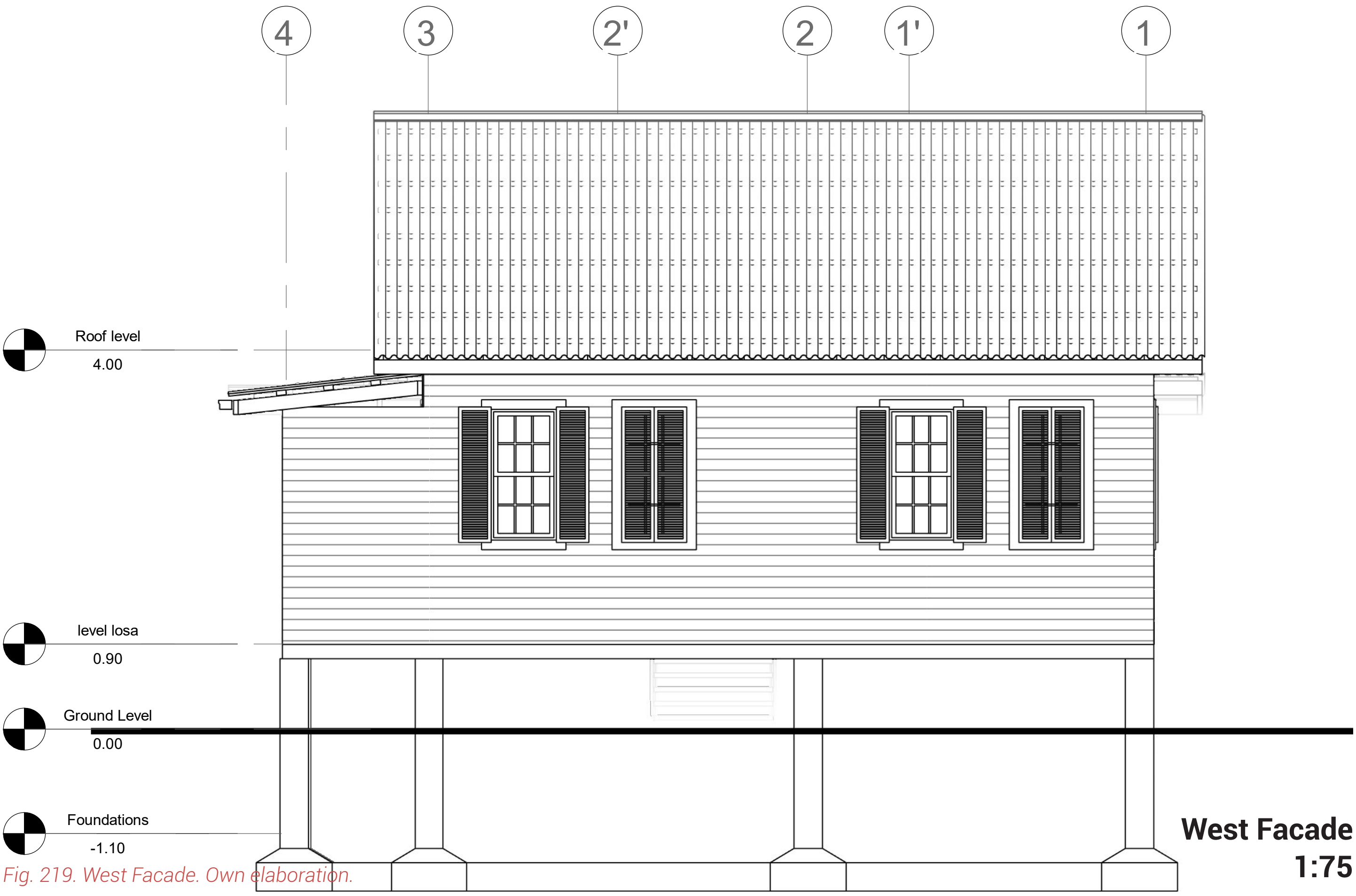


Fig. 219. West Facade. Own elaboration.

West Facade
1:75

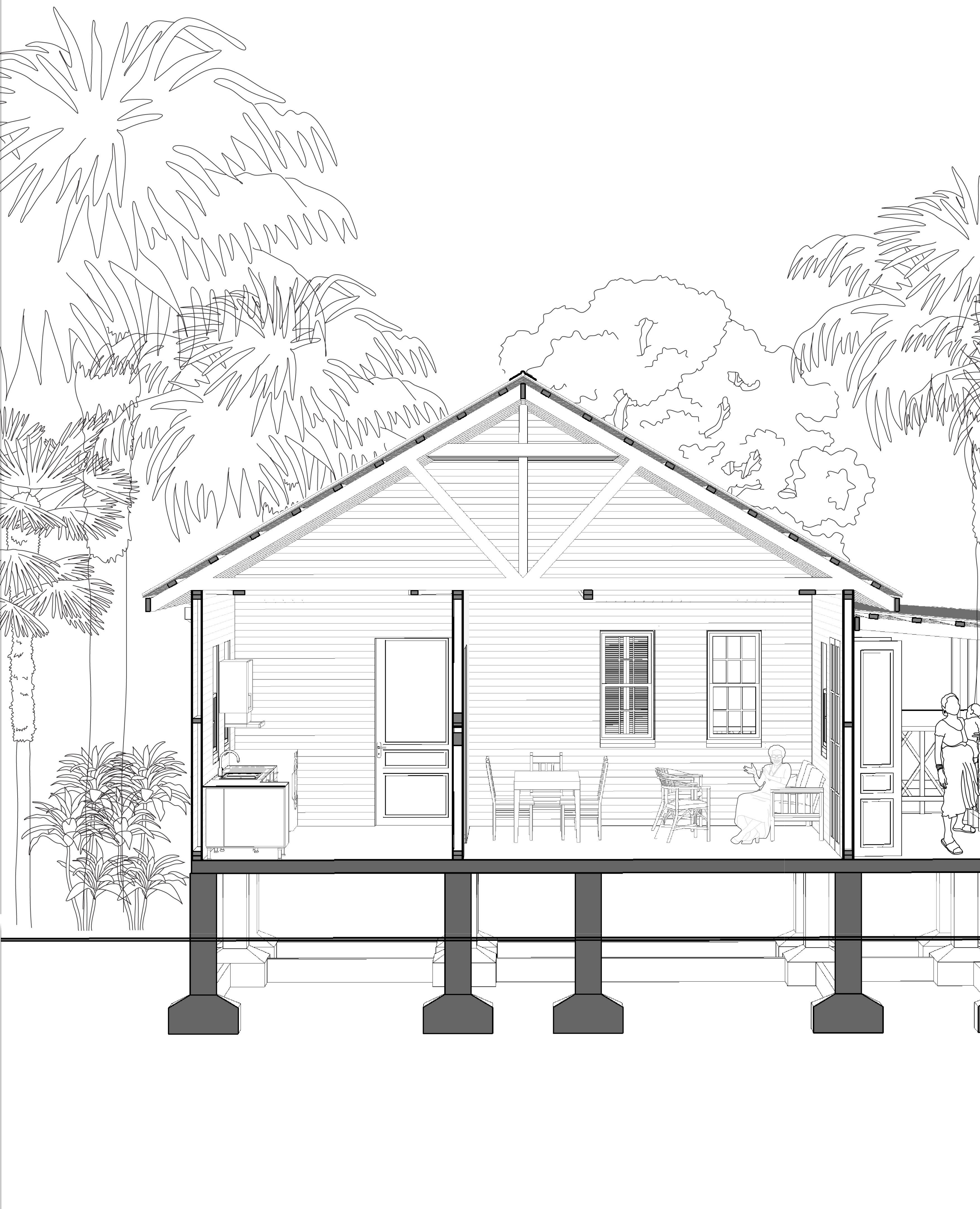
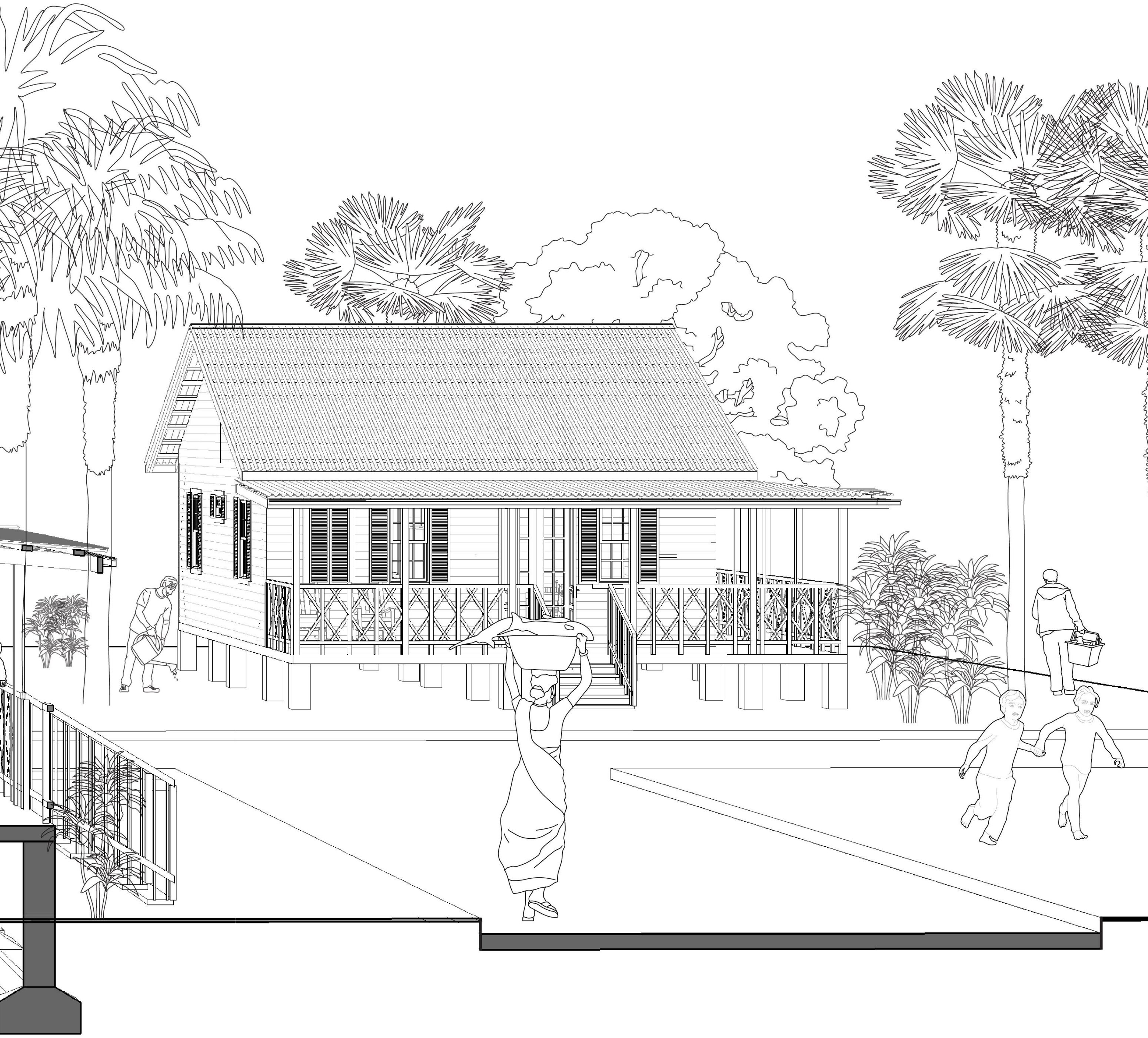


Fig. 220. Perspective Section. Own elaboration.



Perspective Section

6.5. Conclusions

The Archipelago of San Andres, Providencia, and Santa Catalina is located in a vulnerable region due to the presence of hurricanes. In recent years, it has been particularly affected by some events such as Hurricane Iota in 2020 and Hurricane Julia in 2022. These hurricanes have threatened various aspects of the Archipelago, including its natural landscape, people, and traditional architecture. The latter, protected by Colombian law and considered national heritage, reflects a marked influence of Caribbean Creole architecture. However, it currently does not receive adequate recognition in the Country, representing a disconnect from the evolutionary history of the region's construction traditions. These phenomena have had a significant impact due to inadequate preparation, given the absence of national regulations in the Country addressing the construction of hurricane-resistant housing.

On the other hand, it is crucial to **recognize the importance of preserving Creole architecture in the islands.** New constructions have adopted techniques and methods that are disconnected from the rich local architectural tradition, endangering both the material and immaterial heritage of the region. This lack of attachment to Creole architecture not only disregards the inherent advantages it offers in terms of resilience against natural phenomena such as hurricanes but also undermines the deep connection this architecture has with the traditional cultural dynamics of local communities. Preserving Creole architecture is not only about conserving historic buildings but also safeguarding a fundamental part of the cultural identity and resilience of the islands in the face of contemporary challenges.

Starting from the research question: **"Considering the evolution of Creole architecture in the Caribbean, along with the historical impact of hurricanes, can this traditional architecture be integrated with hurricane-resistant construction regulations in the Archipelago of San Andres, Providencia & Santa Catalina?"**, an investigation is undertaken that encompasses multiple topics. The development of these topics not only answers the research question but also establishes conclusions in the field of Creole heritage and recognition, as well as in the domain of hurricane-resistant construction regulations.

Based on the analysis of the information found about Creole architecture in the Caribbean region and in the Archipelago as heritage, the impact and vulnerability of these areas to hurricanes, and regulations for designing constructions resistant to these phenomena, **a comparative matrix is proposed that integrates the characteristics of two variables: Creole architecture and hurricane-resistant architecture supported by national and international literature**. This matrix is **considered the first practical outcome** of the thesis and serves as a guide for the development of a **conceptual architectural proposal as a second practical outcome,** concluding that **the integration of these two variables is possible,** in line with laws protecting Creole architecture as national heritage, thus addressing the research question posed. The comparison between these two variables demonstrates that vernacular architecture emerges as a product of transformations shaped by the hostile environment prone to hurricanes; therefore, similarities are found with some criteria found in the regulations. These regulations for hurricane-resistant constructions primarily focus on topics such as joints and reinforcements, thus not compromising changes in the traditional design of Creole architecture, achieving a correct integration.

Regarding **Creole heritage and recognition,** a historical gap in the origins of Raizal architecture in the Archipelago has become evident, hindering its understanding as the evolution of a pre-existing architecture, linked to a timeline that encompasses more areas. From the research conducted, and based on international literature on the origins and evolution of the **Caribbean architecture known as "Creole",** it is concluded that **the native architecture of the Archipelago exhibits a remarkable convergence in construction techniques and design decisions,** all of them influenced by shared cultural and climatic dynamics. This intersection makes it possible to affirm that **this native architecture is also a manifestation of the Creole style.** Therefore, it is imperative to recognize it as an essential part of the tangible and intangible heritage, both in Colombia and in the Caribbean region.

It is important to highlight that while the answer to the research question is positive, with the development of constructions that integrate Creole architecture and regulations for hurricane-resistant architecture being feasible, some **critical aspects must be considered** during construction.

Firstly, the review of international literature and its application in national construction documents reveals a series of suggestions regarding quantities and materials for hurricane-resilient buildings. However, as these recommendations are not adapted to specific contexts, they may prove unsustainable for communities with particular economic and social conditions. A notable example is the quantity of hurricane straps required for the connections between walls and roofs, the high costs of which are impractical for housing construction on the islands. It's important to note that **designing in a low-resource manner doesn't imply compromised resilience to natural phenomena.** Rather, it involves adapting strategies to fit within a constrained budget without sacrificing effectiveness. Many communities facing scarce resources have successfully navigated these challenges by leveraging locally available materials and expertise, resulting in an **architecture with context-compatible strategies.** However, these strategies must also be supplemented with external modern interventions, such as regulations, to ensure comprehensive resilience without compromising the essence of Creole architecture. Therefore, it becomes imperative to make adjustments that achieve an **appropriate balance between resilience and costs,** taking into account the economic realities of the communities being served. This necessitates a nuanced approach that considers not only the immediate costs but also the long-term benefits and sustainability of the proposed interventions. By doing so, we can ensure that infrastructure investments align with the needs and capacities of the local population while fortifying communities against the risks posed by natural disasters.

Similarly, it is important to have the support of different institutions or organizations to successfully carry out these projects. It is essential to recognize that, although **homes may suffer damage** depending on the intensity of these phenomena, **their primary function is to preserve the lives** of people both inside and outside the structure.

As a second critical point, it is important to note that the design proposal emerges from the matrix, a data collection system that serves as a basis for Creole hurricane-resistant constructions. However, it should be emphasized that it is not a construction manual, and therefore, **the respective technical verifications must be carried out when constructing a project.**

In conclusion, the challenges faced by the Archipelago of San Andrés, Providencia, and Santa Catalina underscore the **critical need for comprehensive measures addressing its vulnerability to hurricanes.** By recognizing and valorizing Creole architecture as both tangible and intangible heritage, implementing tailored regulations for hurricane-resistant constructions, and balancing resilience with affordability in housing initiatives, **the Archipelago can enhance its capacity to withstand future natural disasters while safeguarding its rich cultural legacy.** Through collaborative efforts and informed decision-making, the Archipelago can forge a sustainable path forward, ensuring the preservation of its heritage for generations to come.

07

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