Journal of Building Technology, 2025, Volume 7, Issue 1
DOI: 10.32629/jbt.v7i1.3772
ISSN Online: 2717-5103
ISSN Print: 2705-1390

Conservation of Housing Heritage in Coastal Areas: The Siboney Case

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Abstract: The objective of this study was to conduct a pathological study of four existing housing typologies in the coastal settlement of Siboney in Santiago de Cuba, as this area is one of the highest-priority community councils for the projections contemplated in the country's strategy to address climate change. The measurement equipment and methods used for the diagnosis and characterization of the coastal settlement of Siboney are described. A survey of damage, their causes, assessments based on measurement results, and an update of technical specifications were conducted. It was stated that minimizing risks in the life cycle of buildings in coastal areas allows for planning work and resources to achieve the quality and flexibility of the areas and facilities, so that the combination of these results leads to the proposal of appropriate actions for the conservation of these buildings.

Key words: coastal zone; conservation; buildings; technical state; pathologies

1. Introduction

A comprehensive life-cycle risk assessment of buildings allows for elements such as structures, materials, and installations to be considered at each phase of the project for future conservation and maintenance actions. Cycles to extend a building's useful life must be established as part of construction planning, considering ecological and economic aspects.

Conservation or maintenance in harmony with the environment achieves functionality and flexibility in buildings by reducing life-cycle costs. Changes in operational procedures will be necessary, such as monitoring the condition of the building and its impacts for quality assurance (Riemenschneider and Weischer, 2015).

The Cuban government pays special attention to environmental issues, for which it has created and approved, among other measures, the Tarea Vida (Life Task). This plan aims to address climate change through a program that demonstrates the political will to act on this complex phenomenon. This Plan to Address Climate Change in the Republic of Cuba (Ministry of Science, Technology, and Environment (Citma), 2017) is comprised of actions and tasks related to research on coastal areas and their vulnerability.

Currently, the country's governing bodies are showing interest in conserving coastal heritage, stemming from the recognition of the global need to maintain a sustainable environment by combining anticipated global changes and taking into account the island's insular status, the narrow and elongated shape of the island, and the existence of low-lying areas along much of its coastal perimeter.

Vulnerabilities in Cuba's coastal zone can be classified in different ways: structural, economic, social, and ecological. The research conducted a study of the vulnerability of buildings in terms of structural and non-structural elements, caused by pathologies that affect their proper performance. Among the most notable structural vulnerabilities are: inability to withstand sea penetrations, and poor or inadequate technical construction conditions in buildings of different types. (Batista et al., 2019).

Despite the existence of a political and regulatory framework favoring the protection and preservation of coastal heritage in Cuba, there are risks affecting coastal areas and, consequently, nearby buildings. Therefore, it is important to identify these risks and mitigate them with effective interventions (Cuba, Council of State, 2000).

The coastal zone constitutes the interface between the atmosphere, the hydrosphere, and the lithosphere. This dynamic interaction is also sensitive to the effects of climate change. The coexistence of diverse environments and resources makes the area attractive for human settlements. These settlements function as residential areas and sites for a variety of productive activities (Domínguez and González, 2015).

These conditions affect the infrastructure of communities, generating a series of damages and injuries to buildings that reduce their useful life and the quality of life of their inhabitants. This is consistent with studies that allow for the establishment of strategies for the conservation of this built heritage, supported by Decree 327 (Cuba. Council of Ministers, 2014) for the control of the investment process in Cuba, whether state or private.

An example of this is the province of Santiago de Cuba, located in the southeastern part of Cuba. Its bay is one of the areas prioritized by this plan. The municipality of Santiago shows changes in the risk values of its popular councils compared to 2011 studies, primarily the popular councils of Siboney, Ciudamar, Agüero, Mar Verde, and Sigua (Citma, 2017).

The town of Siboney was severely affected by Hurricane Sandy. It is a coastal town located 14 km from the city of Santiago de Cuba. It borders the Gran Piedra mountain range and the Ramón de las Yaguas area to the north, the Caribbean Sea to the south, the Sigua area to the east, and the Abel Santamaría Urban District to the west. It covers an area of 113.80 km² (Figure 1).

The beach's socioeconomic purpose is tourism (facilities for national and international tourism), and the population is urban. The coastal settlement of Siboney has 1,206 inhabitants (586 men and 620 women) and 486 housing units. (Provincial Directorate of Physical Planning (DPPF) of Santiago de Cuba, 2018)

Figure 1. Satellite view of the Siboney People's Council. Google Map (2018)

According to information provided by the Provincial Directorate of Physical Planning of Santiago de Cuba (2018), this settlement has four building types, with a total of 420 properties (Chart 1). It can be seen that the highest percentages are located in types I (56.1%) and III (30%). Of this total, 183 are in good condition, 216 are in fair condition, and 21 are in poor condition (Chart 2). However, when analyzing the technical and construction condition, it is clear that 56% is between fair and poor. It is important to highlight that 44% is in good condition, reflecting an area with palpable economic development, driven by tourist rentals.

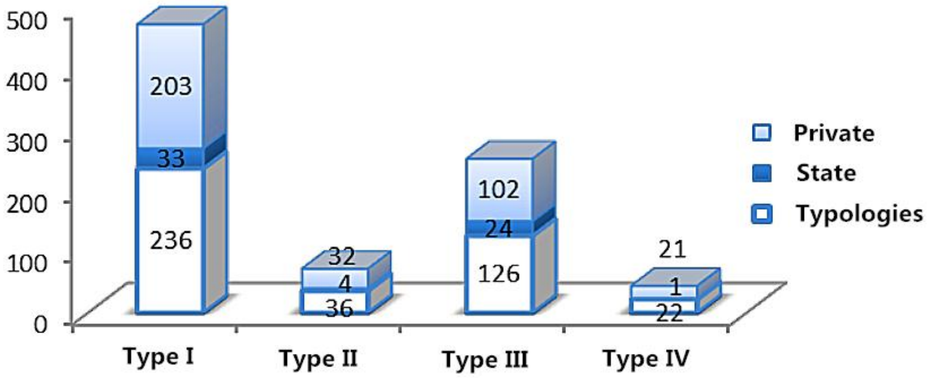


Chart 1. Number of buildings by state and private construction type in the coastal settlement of Siboney. DPPF (2018)

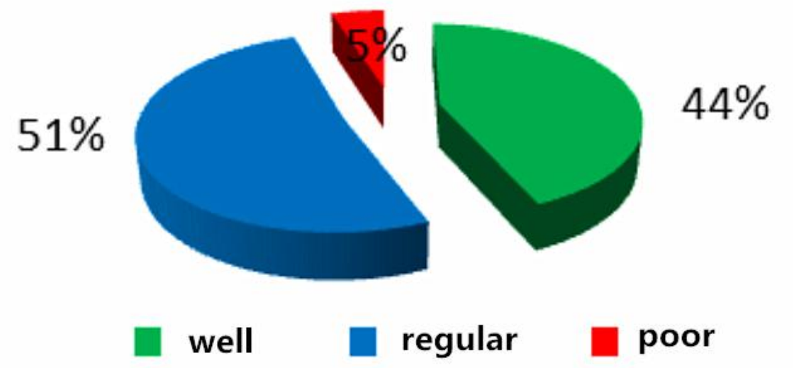


Chart 2. Technical and construction status of the homes in the Siboney Beach settlement. DPPF (2018)

The research covers the four typologies, which, once characterized, exhibit different behaviors. Once the initial surveys and analyses are carried out, a common factor is the outdated technical conditions and the presence of pathologies such as humidity, erosion, cracks, rotting of wooden elements, and corrosion of both concrete and exposed steel. (Figure 2)

Through the organoleptic evaluation and the application of surveys, vulnerabilities generated by inadequate construction practices, the use of materials lacking quality control, and the absence of adequate technical standards for buildings in coastal areas, resulting from a lack of knowledge at the community level, are defined.

Figure 2. Evidence of the main pathologies found in buildings with construction types I (Concrete), II (Masonry), III (Masonry and Light Roof), and VI (Wood) 2018-2019. (Authors)

According to the survey, the four existing typologies show significant deterioration, exacerbated by Hurricane Sandy in 2012, which hit the province of Santiago de Cuba, and also by a lack of maintenance.

Based on the elements discussed, the objective of this research is to evaluate the pathological behavior, which will then allow for proposing actions to improve the technical condition of the four housing typologies present in the coastal settlement of Siboney in Santiago de Cuba.

2. Materials and Methods

The study of pathologies in a building allows for the establishment of criteria regarding their evolution, in order to correct existing deficiencies and promote a conservation concept tailored to the possibilities of each case (Tejera and Álvarez, 2010, p. 34). This research characterizes the existing population and outlines the selection criteria, as well as an analysis of the lesions found and their causes. Some aspects related to the predominant materials, which exhibit different behavior due to the aggressive environment, are evaluated. Measurements are taken to characterize the lesions and define the technical condition to validate appropriate actions that contribute to the stakeholders and community knowledge in general, all of which is supported by a systems approach to the life cycle of buildings.

In conjunction with the surveys, surveys were conducted among residents of the samples of the four typologies, which allowed for the verification of opinions, dissatisfaction, lack of knowledge on construction issues, and other important aspects such as the number of interventions or maintenance performed.

With Hurricane Sandy's impact on Santiago de Cuba, the Siboney settlement marked a turning point in the housing sector, with buildings damaged and a large number completely destroyed. Each typology was affected differently, so for the study, selection criteria had to be defined in each case, always taking into account a percentage based on the current population (≥ 30%). (Table 1)

Table 1. Sample selection by type (DPPF 2018)

Type	Population (P) (DPPF 2018)	Current population (CP)	Sample ≥ 30 % (PA)	Key features and assessments
I Concrete	203	163	Building E-14 10 apartments	Prefabricated buildings were chosen because they are the most deteriorated. These types of homes are in good condition and are used for tourist rentals (high purchasing power). Two buildings were completely destroyed by Sandy.
II Masonry	32	30	11	Two were destroyed by Sandy and 17 were in good condition.
III Lightweight roof and masonry	102	67	20	35 were destroyed by Sandy and 17 were in good condition.
IV Wood	21	14	7	7 were destroyed by Sandy and 3 were in good condition.

The homes selected for this research have a rectangular floor plan, a structural system of load-bearing walls or skeletons, predominantly concrete roofs, precast concrete slabs, and lightweight roofs with clay, fiber cement, and/or metal tile closures. Masonry walls are generally made of stone, and wood in the case of Type IV.

The following criteria were used for the sample selection: Type I, II, III, and IV buildings; buildings considered residential; accessibility to the homes; and evidence of associated pathologies and injuries in the buildings.

(1) Type I

Walls: precast concrete panels, reinforced or unreinforced, concrete blocks, terracotta bricks, ashlar, masonry

Ceilings: cast-in-situ reinforced concrete slab, precast reinforced concrete slab, prestressed reinforced concrete joists with concrete or terracotta vaults, or cast-in-situ reinforced concrete forms and layers.

Floors: granite, marble, integral terrazzo, polished terrazzo tiles, premium hydraulic tiles, glazed ceramic tiles.

(2) Type II

Walls: concrete blocks, terracotta bricks, ashlar, masonry, pressed blocks or bricks made of stabilized soil, rammed earth, and edging.

Ceilings: vaults, domes, or arches made of concrete blocks, terracotta bricks, or pressed bricks made of stabilized soil, or other elements that guarantee their durability; reinforced concrete or prestressed joists with flat or vaulted slabs made of concrete, terracotta, stabilized soil, edging, ferrocement, etc.

Floors: terrazzo tiles, hydraulic tiles, glazed terracotta tiles

(3) Type III

Walls: concrete blocks, terracotta bricks, ashlar, masonry, pressed blocks or bricks made of stabilized soil, edging, rammed earth, rammed earth, adobe, ferrocement sheets, hardwood, or precious woods.

Roofs: supported by prestressed concrete beams or prestressed beams, metal or sawn wood, covered with clay tiles, asbestos cement, or vibrated mortar (TEVI).

Floors: hydraulic tiles, fired clay slabs, polished cement mortar floors.

(4) Type IV

Walls: wood planks, blocks, or pressed bricks made of stabilized soil, masonry, edging, rammed earth, adobe, and mud.

Roofs: supported by metal beams or sawn or round wood, covered with metal or cement sheets, ceramic tiles, and plant fibers.

Floors: hydraulic tiles, polished cement mortar

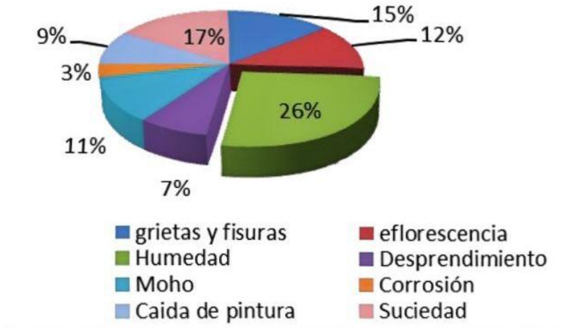
3. Results

Once the properties were selected (Table 1), the lesions were identified using a template or spreadsheet that would facilitate the work and provide the greatest amount of information. Of the homes studied, most showed considerable deterioration due to a lack of maintenance since their construction. Several of the properties were built in the 1930s, 1940s, and 1960s; in others, inadequate interventions were carried out.

For a better understanding of the variety of pathologies found, the table shows the behavior of the lesions identified by typology. (Table 2)

As observed, there is a predominance of dampness, erosion, cracks, exposed steel, rot, and most of the secondary damage caused by the presence of water in the structural and non-structural elements of the buildings (beams, columns, slabs, balconies, cornices, and others). This corroborates the hypothesis that even in cases where maintenance actions have been carried out, the true causes of the damage have not been adequately addressed, the materials used are inadequate, and the aggressive coastal environment has not been considered. All of the above supports the hypothesis of incorrect diagnoses and a lack of community knowledge regarding construction actions in the area. Dampness is a common and damaging damage to buildings, especially when salts and chlorides from the sea are present.

Table 2. Representation of injuries across housing types: Siboney case, Santiago de Cuba. Authors

<table>
<tr><th>Typology/Number of homes</th><th>Injuries and % presence</th></tr>
<tr><td>I (10 apartments)
</td><td>
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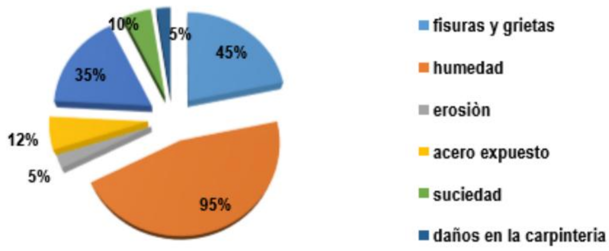
</td><td>
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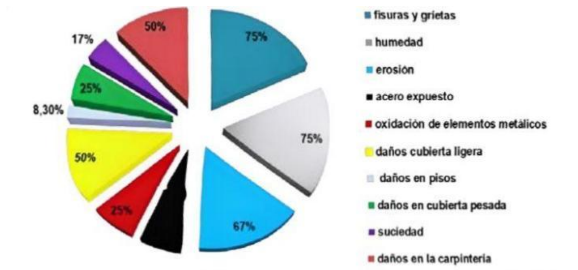
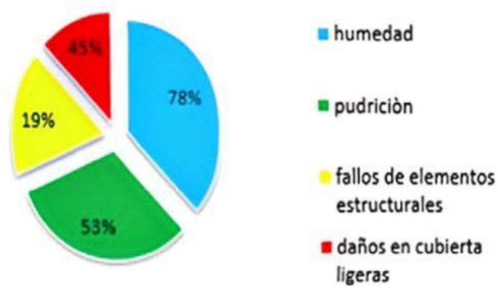
</td><td>
</td></tr>
<tr><td>IV (7)
</td><td>
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Serious and rapid structural deterioration is currently occurring due to the attack of chlorides dissolved in the air on concrete. These deteriorations are present in marine environments with high relative humidity and constant wind action, such as coastal areas, as is the case under study. Humidity is also the underlying cause of the rest of the associated pathologies and injuries detected.

Considering that measurement is a relevant aspect of scientific research, which seeks to make sense of the process of observing objects, processes, and other aspects of reality, non-destructive testing (NDT) is currently the quality control test chosen by construction entities worldwide because it is easy to perform and does not cause damage to the buildings where it is applied.

The Universidad de Oriente in Santiago de Cuba has the Integrated Laboratory of Advanced Technologies for the Conservation of the Heritage of Eastern Cuba, which is designed to conduct non-destructive testing for studies and research.

Considering the results of surveys and instruments for pathological evaluation (spreadsheets and surveys), the equipment to be used is defined, which in all cases was the equipment to measure humidity in masonry and/or concrete walls and the one to measure humidity in wood, (Hydrometer T600 and Digital Humidimeter Delmhorst Model: BD2100). In the case of fissures and cracks, it is essential to determine their behavior, that is, if they are active or inactive and thus be able to define the most appropriate solution (Fuentes, 2014, p. 33). There are many techniques and equipment used for their measurement, among which we can find: manual and digital fissurometers (see figure 3). The characterization of the cracks to be able to define their treatment is supported by the Cuban regulations of general requirements for the design and construction of concrete structures.

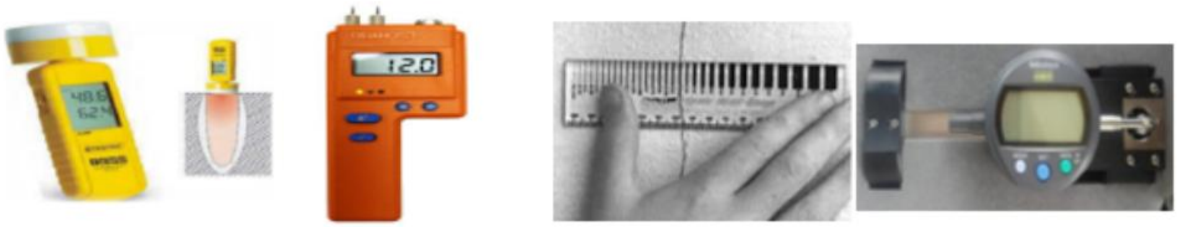

Figure 3. Hydrometers for stone and wood walls, manual and digital crack meters.
Integrated Laboratory of Advanced Technologies for the Conservation of the Heritage of Eastern Cuba.
Universidad de Oriente.

In order to determine the method to be followed for moisture measurements in the four typologies, the following must be known or identified: location of the lesion, type of moisture, affected area (AA) and surrounding spaces, causes, and their integration with the characteristics of the area in question.

As the first step, the measurement points were defined. First, it is important to clarify that this work refers to two types of measurements: one was taken on walls from the ground to the slab with three measurement points, and the other, from the slab to the ground with three measurement points in the case of typologies I and II. For typologies III and VI, measurements were taken at three points only on the walls. (Figure 4).

The measurements showed that the highest moisture values were found at the points closest to the ground, demonstrating the existence of a damp source generating this lesion and allowing it to be classified as rising damp.

Figure 4. Representation of the points in the measurement zones applied to the 4 typologies. (Authors)

If a dispersion of values is observed between measurement points, the infiltration of moisture is considered to be caused by water seeping out from the outside of the building, just like in the case of Type IV (wooden buildings). Experimental verification of the humidity levels in the homes allowed for a direct relationship with the visual observations, as the presence of this damage was evident in all cases and that values, even considered low, affect the proper functioning of the buildings and can generate other secondary damage.

Fissures were another of the most prevalent damages in Type I, II, and III homes, so they were monitored. This was carried out for five weeks, considering three is the minimum time. The availability of the equipment's user manual facilitated the procedure.

The use of the crack meter demonstrated that the fissures and cracks are potentially active, and although they are not growing rapidly in length, they require urgent intervention, as the passage of time can have negative consequences due to the aggressive environment present.

The data from the surveys confirm that there is a widespread lack of knowledge among the population regarding construction work and a lack of awareness of the importance of maintenance for the conservation of buildings, especially in coastal areas with such aggressive environments.

The technical condition of the buildings in the study sample was subsequently updated using the procedure defined by the National Housing Institute. The results confirm the need to update this procedure throughout the settlement due to the discrepancy with the data obtained at the beginning of the investigations.

Finally, a proposal was made for each of the typologies, including not only construction operations but also material selection and maintenance techniques. This led to the decision to develop a catalog of actions to be submitted to the Siboney People's Council, so that residents could have a reference document for successful interventions in their properties.

3. Conclusions

The surveys demonstrated that the coastal environment always negatively influences buildings. There is a greater tendency to conserve heritage and cultural buildings than domestic dwellings.

The incorrect selection of concrete types and exposure to adverse weather conditions are breeding grounds for the fundamental damage suffered by buildings, which is exacerbated by the perennial presence of moisture and the appearance of active cracks, as the primary and predominant pathologies in all samples of types I, II, and III. In the case of type IV, buildings where wood predominates, the presence of moisture absorption in the studied homes is demonstrated. This moisture is found in a high level in almost all cases. Those most affected are those that have not received at least one maintenance intervention and those with deteriorated roofs. Evaluating the causes of the damage allows for the design of the appropriate solution, selection of materials, and maintenance proposals, all of which guarantee the effectiveness of the intervention.

The limited public awareness of the importance of building conservation contributes to their accelerated deterioration, since conservation is not considered a system in the life cycle of buildings, developed in the aggressive environment of these sites.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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