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WATERPROOFING APPLICATIONS IN MASONRY STRUCTURES: A CASE STUDY OF RESIDENTIAL BUILDINGS IN THE NORTHERN ZONE OF MANAUS, BRAZIL

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ABSTRACT

This study analyzed the effectiveness of rigid and flexible waterproofing agents in treating pathologies caused by moisture and infiltration in masonry residences in the northern region of Manaus (AM), Brazil. Technical visits were conducted in 50 residences, with experimental application of products in 6 selected cases. Results showed that the proper use of waterproofing agents, such as modified mortars, asphalt membranes, and liquid rubber, prevented infiltration in 100% of treated cases. Lack of technical knowledge and planning were identified as critical factors for the emergence of pathologies. It is concluded that waterproofing is an essential investment to ensure durability, safety, and habitability in residential buildings, emphasizing the need for specific projects and professional training.

I. INTRODUCTION

The Brazilian civil construction sector has undergone profound transformations over the past few decades, shaped by a complex interplay of socioeconomic development, accelerated urbanization, technological evolution, and the persistent housing deficit that still affects millions of citizens [1]. Driven by government housing programs, private sector investment, and growing demand for urban infrastructure, the industry has expanded rapidly. However, this expansion has not always been accompanied by the necessary structural reforms, regulatory enforcement, or improvements in construction quality. As a result, various systemic issues persist, especially in peripheral urban areas and regions with challenging environmental conditions.

In particular, regions with humid tropical climates, such as the Amazon, present unique challenges to the construction industry. Manaus, the capital of the state of Amazonas, stands as a compelling case study. With an annual rainfall exceeding 2,300 mm and an average relative humidity of 85%, the city experiences intense and prolonged exposure to moisture throughout the year [2], [3]. Under these conditions, the absence of effective waterproofing systems has led to the emergence of recurrent pathologies, especially in masonry buildings. These pathologies, including infiltration, mold, efflorescence, and structural degradation, compromise not only the durability and mechanical stability of constructions but also their habitability, aesthetic integrity, and sanitary conditions.

Waterproofing—defined as the set of techniques, materials, and procedures used to prevent the intrusion of water or moisture into structures—is a critical and strategic stage of the construction process [4]. Its relevance is reinforced by technical standards such as ABNT NBR 15575 [5], which establishes performance criteria for residential buildings, emphasizing the need to ensure water-tightness, resistance to moisture, and long-term structural reliability. Water, in its various states (liquid, vapor, or even ice), is considered one of the most aggressive agents of physical and chemical degradation. It infiltrates buildings through microcracks, capillary rise from the ground, or percolation, leading to pathologies such as efflorescence, corrosion of reinforcement bars, fungal colonization, peeling of coatings, and eventual compromise of load-bearing elements [6], [7].

These manifestations not only reduce the useful life of buildings but also represent serious health risks, particularly when fungi and mold proliferate in indoor environments. Inhabitants are exposed to respiratory illnesses, allergies, and general discomfort due to poor air quality [8]. Thus, addressing waterproofing failures is not merely a matter of structural maintenance but of public health and social well-being.

Despite the development of advanced materials—such as polymer-modified cementitious mortars, asphalt-based membranes, and liquid-applied elastomeric membranes—the implementation of these solutions often falls short. In Manaus and similar urban centers, the rapid and unregulated expansion of the city has resulted in the proliferation of self-built housing, constructed without adequate planning, inspection, or adherence to building codes [9]. These buildings are often erected by informal labor, using low-quality or incompatible materials, and with little or no technical specification regarding waterproofing. As a result, construction errors, neglect of maintenance, and misuse of materials are common, creating a fertile ground for the emergence of chronic pathologies.

Moreover, many homeowners and small-scale builders underestimate the importance of waterproofing in the lifecycle of a building. Due to its relatively low initial cost, it is often considered dispensable, particularly when budget constraints arise. This short-sighted view, focused on short-term savings, inevitably leads to higher future expenses due to corrective maintenance, deterioration of property value, and even legal disputes. Studies have shown that the cost of preventive waterproofing is significantly lower than that of subsequent repair interventions, especially when damage extends to structural components or finishes [10].

In light of these challenges, the general objective of this research is to investigate the occurrence, causes, and manifestations of moisture-related pathologies in residential buildings located in the northern region of Manaus. The study seeks to identify the most affected building components, evaluate the materials and construction techniques used, and propose practical and technically grounded solutions based on the application of rigid and flexible waterproofing systems adapted to local climatic and soil conditions.

The specific objectives of the study are as follows:

- To identify, classify, and map pathologies such as damp stains, efflorescence, and spalling of concrete layers, particularly in slabs and exterior walls;
- To select and apply appropriate waterproofing systems for various structural elements, including foundations, masonry walls, and roof slabs, considering both static and dynamic performance requirements;
- To analyze the effectiveness of different waterproofing systems—rigid systems such as additive-modified mortars, and flexible systems like asphalt-based membranes or elastomeric coatings—under real-world conditions;
- To formulate technical recommendations for preventive and corrective measures, aligned with the ABNT normative framework, including standards NBR 9575, NBR 15575, and NBR 9952.

This research aims to offer a detailed and contextualized diagnosis of the most common pathologies observed in the region, linking them to construction failures, design oversights, or material inadequacies—particularly in regard to waterproofing. By combining empirical observation, field interviews, and technical analysis, the study demonstrates the feasibility of practical solutions that are cost-effective, sustainable, and locally adaptable.

Furthermore, the contribution of this work lies in bridging the gap between theory and practice, reinforcing the importance of interdisciplinary collaboration between engineers, architects, builders, public agencies, and the communities involved. By raising awareness about the strategic importance of waterproofing, this research encourages stakeholders to view it not as a marginal expense but as an investment in longevity, safety, and environmental performance.

As noted by Jesus [11], preventive maintenance is essential to preserve the intended performance of buildings and avoid premature obsolescence. Buildings are expected to last for decades—often up to 50 years [9] — but without regular inspection and proactive intervention, especially in regard to water control, their lifespan and functionality are drastically compromised.

Finally, this study seeks to address a critical gap in the literature and in applied engineering practice: the lack of systematic research on waterproofing performance in humid equatorial environments, such as the Amazon basin. In these contexts, intense rainfall, high ambient moisture, and clayey, poorly draining soils demand tailored solutions. By focusing on the city of Manaus, this research contributes not only to technical advancement but also to the formulation of more inclusive, sustainable, and resilient construction practices, strengthening the connection between academia, industry, and civil society [12].

II. THEORETICAL REFERENCE

Pathologies in buildings are structural or non-structural anomalies that compromise not only the functionality and performance of constructions but also their safety, comfort, and aesthetic appeal. These manifestations demand a thorough technical diagnosis, careful analysis, and targeted intervention to avoid long-term deterioration and user discomfort [3]. Luduvico [12] compares this process to that of medical treatment: a building, much like a human body, may develop "illnesses" such as cracks, stains, or water infiltration, which require proper identification of causes (diagnosis), prediction of impacts (prognosis), and implementation of corrective measures (therapy).

Thomaz [2] provides a detailed conceptualization of building pathologies, classifying them into categories such as physical deterioration, chemical degradation, and biological attack. He emphasizes the importance of early detection and systematic classification of anomalies to inform the choice of rehabilitation techniques. Among the various strategies for preventing structural degradation, waterproofing stands out as a fundamental line of defense. According to the ABNT NBR 15575 standard [3], waterproofing is a mandatory preventive measure in all types of buildings, especially in regions with high rainfall and humidity indexes, such as Manaus, where annual precipitation exceeds 2,300 mm [13].

One of the most recurrent and impactful pathologies in masonry structures is water infiltration. It occurs when water penetrates through microcracks, poorly sealed joints, or capillary suction from the ground. The consequences are diverse: coating disintegration, paint deterioration, efflorescence (salt crystallization), mold proliferation, and, eventually, structural compromise [14]. These effects are not only aesthetic or material; as Schreiber [11] warns, persistent moisture within homes and buildings can severely worsen the living conditions of residents, particularly those with pre-existing respiratory conditions.

In specific geological contexts, such as areas with clayey soil, water has the capacity to ascend through masonry by capillary action, a phenomenon that allows groundwater to rise up to 1.5 meters within walls [6]. This leads to dark stains near floor levels, flaking of paint, disaggregation of plaster, and a characteristic musty odor. In buildings with exposed slabs and flat roofs, percolation — the slow migration of water through porous surfaces—is another common mechanism of infiltration. These areas often lack adequate slope for water runoff, requiring the application of flexible waterproofing membranes that can accommodate expansion and contraction caused by thermal cycles [9].

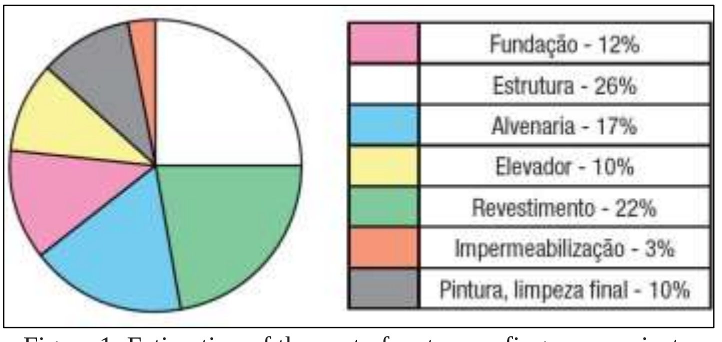

Figure 1: Estimation of the cost of waterproofing on a project.
Source: Authors, (2025).

Despite its critical function, waterproofing is often undervalued, both in financial and technical terms. As shown in Figure 1, waterproofing typically represents only around 3% of a project's overall cost, a proportion that belies its crucial role in ensuring durability and habitability over time. This low investment often results in higher costs later due to repairs, maintenance, or legal disputes with property owners.

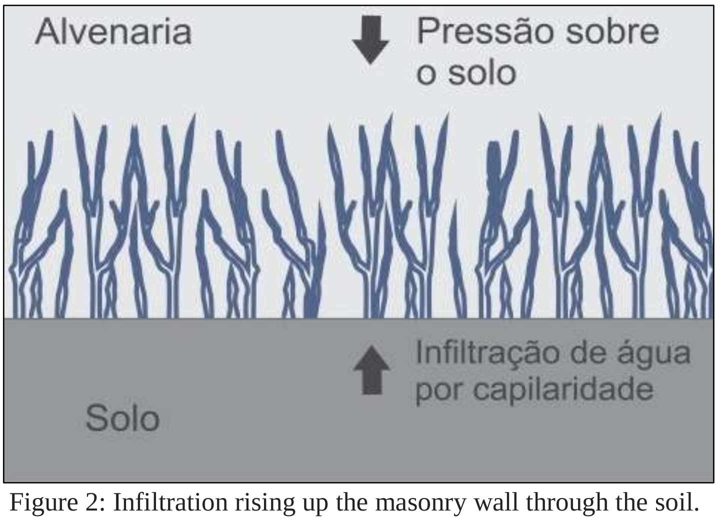

Figure 2: Infiltration rising up the masonry wall through the soil.
Source: Authors, (2025).

Among the visible consequences of infiltration is efflorescence, which presents as white crystalline deposits of salts (mainly calcium carbonate) on the surface of walls or floors. These deposits indicate chronic moisture penetration and are often accompanied by internal pressure caused by salt crystallization, leading to microcracking and weakening of the concrete [5]. More critically, moisture facilitates corrosion of steel reinforcement bars, particularly in beams and columns, which can reduce their service life by up to 20 years in tropical climates with high humidity and aggressive environmental exposure [15].

Additionally, biological agents such as fungi—including Stachybotrys—can proliferate on damp surfaces. These organisms not only affect indoor air quality but also release allergenic spores, increasing the risk of respiratory illnesses and allergic reactions [7]. Cracks themselves can vary in severity: microcracks (less than 0.1 mm wide) are often due to drying shrinkage or thermal fluctuations, whereas fissures (greater than 0.5 mm wide) are typically related to deeper structural problems such as foundation settlement or mechanical overload [16].


Figure 3: Appearance of efflorescence on the masonry wall.
Source: Authors, (2025).

To prevent and mitigate these pathologies, the selection and proper application of waterproofing systems are essential. The ABNT NBR 9575 standard [17] defines waterproofing as the use of materials and techniques to block fluid ingress into building components. These systems are generally classified into three main types:

- Cementitious systems, typically composed of waterproofing mortars mixed with chemical additives, are rigid and recommended for use in foundations and water tanks.
- Asphalt-based systems, such as polymer-modified bitumen membranes (e.g., torch-on membranes), are more flexible and suitable for roofs and terraces.
- Polymeric systems, including PVC membranes and liquid-applied membranes like elastomeric rubber, provide high elasticity and are ideal for areas subjected to constant movement or temperature fluctuations [18].

Rigid systems, while effective in static zones like underground tanks or base walls, often fail when applied to areas that experience structural movement above 0.3 mm. In such cases, flexible waterproofing solutions—such as EPDM membranes—are more appropriate. These materials accommodate expansion and contraction and offer increased durability, though at a slightly higher cost. On average, waterproofing can represent 2% to 5% of a building's total construction value, depending on the system and complexity of application [19].

Standards such as NBR 9952 (focused on asphalt membranes) and NBR 15575 (building performance requirements) provide guidance on the minimum physical, chemical, and mechanical resistance that waterproofing materials must meet to ensure their effectiveness over time [20]. Modern waterproofing strategies also benefit from integration into Building Information Modeling (BIM), where detailed information about materials, compatibility with other systems (e.g., plumbing), and structural joints can be digitally simulated and documented in the design phase [21].

Finally, the success of any waterproofing system depends not only on proper design and material selection but also on professional execution. According to data from VEDACIT [9], the use of trained and certified professionals (e.g., engineers with CREA accreditation) reduces the likelihood of waterproofing failures by up to 80%, underscoring the importance of expertise in both the planning and execution stages.

III. MATERIALS AND METHODS

The research was conducted in the Northern Zone of Manaus (Amazonas State, Brazil), a region marked by rapid urban expansion and a predominance of self-built single-family homes. According to IBGE data (2022), the municipality had an estimated population of 2,063,547 inhabitants, distributed across an area of 11,401.09 km², with a GDP per capita of BRL 45,782.75 [22].

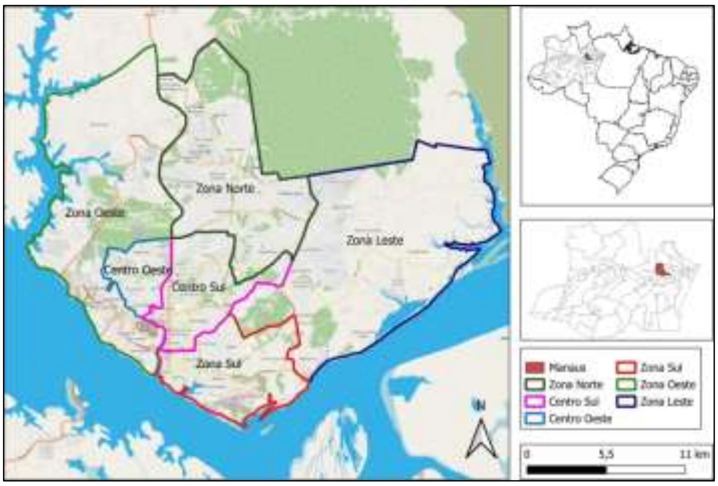

Figure 4: Map of the city of Manaus divided by zones.
Source: [13].

The Northern Zone of Manaus comprises a diverse set of neighborhoods, including Colônia Terra Nova, Novo Israel, Monte das Oliveiras, Cidade Nova, Santa Etelvina, Lago Azul, Piorini, Colônia Santo Antônio, and Fazendinha. These districts are marked by accelerated urban growth, heterogeneous urban morphology, and high rates of self-constructed housing. As such, they provide a relevant and complex field for investigating recurring construction pathologies—particularly those linked to moisture and lack of waterproofing.

The sample for this study consisted of 50 residential buildings, strategically selected along the main thoroughfares of the aforementioned neighborhoods. Selection criteria were defined based on accessibility, typicality, and evidence of deterioration, particularly in structures showing visible signs of moisture-related pathologies, such as damp spots, water infiltration, mold proliferation, efflorescence, and partial degradation of plaster and paint. Homes exhibiting these anomalies were considered as units of analysis, allowing for targeted observation and empirical intervention.

The methodological framework adopted for this research is qualitative in nature, focusing on a comprehensive, exploratory, and interpretive approach. Fieldwork was conducted through on-site technical inspections, developed in collaboration with local civil engineers, construction companies, and building maintenance professionals. These visits allowed the team to identify critical failure points in masonry structures, especially in elements directly exposed to environmental conditions, such as roof slabs, retaining walls, beams, baldrames, and external vertical surfaces.

From the full sample, a subset of six residences was selected to receive experimental application of waterproofing products, enabling practical, in situ evaluation of different systems. The goal was to examine the performance of rigid systems (such as waterproof mortars with chemical additives) and flexible systems (including asphalt membranes, polymeric coatings, and elastomeric products) in the specific environmental conditions of Manaus.

During field assessments, a recurring challenge identified was the residents' limited technical knowledge regarding waterproofing materials and procedures. Many homeowners lacked basic understanding of the causes and consequences of infiltration, leading them to adopt ineffective or inappropriate solutions. Frequently, incompatible or substandard paints, non-certified sealants, or improvised mixtures were found to be applied to problem areas, exacerbating rather than mitigating moisture-related issues. In some cases, additives were improperly dosed, or applied without following manufacturer specifications, resulting in failures of adhesion, coverage, and impermeability.

To facilitate meaningful engagement with the communities involved, the research team adopted an open and participatory communication approach, conducting semi-structured interviews and collaborative discussions with key stakeholders: homeowners, construction workers, site foremen, and local engineers. These conversations provided valuable insights into the decision-making processes related to construction and maintenance, highlighting knowledge gaps, financial limitations, and behavioral patterns. They also allowed for the co-identification of priorities for intervention, fostering a sense of ownership and trust among participants.

To ensure the health and safety of all involved, particularly during the phases of product application and testing, strict Personal Protective Equipment (PPE) protocols were implemented. The use of boots, PVC or rubber gloves, helmets, protective eyewear, solvent-resistant masks, and appropriate clothing (long sleeves and trousers) was mandatory, in line with standard construction site safety regulations [23].

The application of waterproofing products required specific tools and equipment, adapted to each material's nature and intended surface. These included trowels, smooth and notched screeds, wide brushes, paint rollers, torches for torch-on membranes, plastic or metal buckets, and wheelbarrows for material transportation. Tool selection and handling were conducted strictly following technical datasheets and manufacturer guidelines, ensuring optimal performance and accurate assessment of product behavior under field conditions [24].

The sampling strategy was intentionally non-probabilistic, based on purposive sampling techniques. This choice was guided by the need to access buildings that exhibited clear and relevant symptoms of water-related damage, while also ensuring logistical feasibility for technical interventions. According to established qualitative research practices, purposive sampling allows for the in-depth exploration of complex phenomena within specific contexts, providing rich and meaningful data [25].

The selected buildings were, in most cases, single-story homes built more than ten years prior to the study. A large portion had been constructed by local masons, construction workers, or even by the residents themselves, without the support of qualified professionals or engineering supervision. As such, many of the structures lacked architectural and technical planning, presenting construction deficiencies that directly contributed to the emergence of moisture-related pathologies. These include the absence of foundational sealing systems, inadequate external paving, and misapplication of finishing materials.

Additionally, the lack of investment in skilled labor—often due to financial constraints—was identified as a key factor in the poor implementation of waterproofing solutions. Many households reported that they opted for the cheapest available materials, or skipped the waterproofing step entirely, believing it to be unnecessary or unaffordable.

Post-inspection interviews with residents were essential in complementing the visual diagnoses made during site visits. These interviews were divided into two parts: initially, a structured script with open-ended questions was used to understand residents' general perceptions regarding moisture control, thermal comfort, structural quality, and maintenance practices. In the second phase, targeted follow-up questions were posed, addressing specific topics such as knowledge of waterproofing systems, experience with rigid or flexible products, and familiarity with Brazilian technical standards, notably ABNT NBR 9575 and NBR 15575 [3], [17].

The combination of visual inspections and resident interviews enabled the triangulation of data, reinforcing the validity of the findings. Based on these observations, the team created comparative charts and frequency tables to analyze the recurrence and distribution of pathologies across the sample. The most common anomalies included:

- Accumulation of sludge on external walls due to poor rainwater drainage;
- Moisture infiltration into retaining walls;
- Absence of perimeter pavement, allowing water ingress near the foundations;
- Cracks at beam-column junctions, often caused by differential settlement or thermal stress.

Each pathology was quantified in terms of occurrence rate, allowing the team to identify patterns and critical areas. These insights directly informed the selection of techniques and materials for the experimental applications, as well as the development of a set of technical recommendations for broader application.

The systematized knowledge derived from this study holds the potential to guide construction companies, independent professionals, and public agencies in the implementation of preventive and corrective strategies. By identifying the main technical gaps and behavioral trends affecting waterproofing efficacy, this research promotes the improvement of construction quality standards and the adoption of long-term, sustainable solutions.

Moreover, the findings underscore the urgent need for investment in technical training, capacity-building programs, and public awareness campaigns. Promoting better understanding of waterproofing techniques and their importance is not only essential for improving construction practices but also for encouraging the development of safer, more efficient, and more accessible materials in line with national standards for durability and performance [3], [17], [20].

IV. RESULTS AND DISCUSSIONS

The findings of this research are grounded in empirical evidence and technical concepts previously outlined in specialized literature on waterproofing (Section 2). While this study adhered to technical criteria in the handling and application of waterproofing materials, it is recommended that such services be executed by qualified professionals, strictly following surface preparation, system selection, and application steps in compliance with current technical standards.

The applied systems demonstrated satisfactory performance until the conclusion of the research. However, if end-users lack familiarity with product behavior under specific conditions, preliminary testing is advised prior to definitive application.

As per ABNT NBR 15575 [3], an effective waterproofing system must meet the following performance requirements:

- Resistance to static and dynamic loads;
- Accommodation of substrate expansion and contraction due to thermal variations;
- Resistance to climatic, chemical, and biological agents;
- Watertightness under hydrostatic pressure and soil moisture;
- Adhesion, flexibility, and physico-mechanical stability aligned with design specifications;
- Adequate service life under projected conditions.

Data collection involved technical visits to 50 residences in the Northern Zone of Manaus. Purposive sampling targeted areas with high incidence of moisture-related pathologies, such as leaking slabs, damp walls, and deteriorated retaining walls. Interviews with residents, foremen, masons, and civil engineers enabled a comprehensive analysis of factors contributing to pathological manifestations.

Figure 5: Number of residences per pathology-affected area.
Source: Authors, (2025).

Figure 5 illustrates the profile of those responsible for constructing the surveyed residences, revealing that homeowners predominantly executed or supervised the work. This reality directly impacts the adoption (or absence) of proper waterproofing practices.

Figure 6: Parties responsible for residence construction.
Source: Authors, (2025).

Practical application of waterproofing systems was conducted in six residences, with data organized in Table 1. The table details waterproofing types, building age, and percentage of estimated 50-year residential lifespan achieved [26].

Table 1: Service life of waterproofed residences relative to estimated lifespan.

Residence	Waterproofing Type	Service Life (Years)	Lifespan Achieved (%)
Street A	Rigid	18	36%
Street B	Rigid	15	30%
Street C	Rigid	17	34%
Street D	Rigid	4	8%
Street E	Flexible	12	24%
Street F	Flexible	20	40%

Source: Authors, (2025).

As Ferreira [18] notes, building longevity is directly tied to proper waterproofing system execution, which acts as a protective barrier against infiltration and structural degradation. Absence of such systems leads to pathologies like stains, mold, coating detachment, compromised habitability, and structural instability.

During interviews, residents reported critical infiltration and thermal discomfort issues. Per NBR 15575 [3], such conditions violate minimum habitability and safety requirements, particularly when structural integrity or occupant mobility is compromised.

Resident dissatisfaction with cracks, mold, and infiltration directly impacts physical and psychological well-being, underscoring the need for buildings ensuring long-term performance. Most pathologies stemmed from design flaws, poor execution, lack of technical product knowledge, or absent preventive maintenance.

Figure 7: Root causes of pathologies in surveyed residences.
Source: Authors, (2025).

V. CONCLUSIONS

The findings presented in this case study reaffirm that no building—whether residential, commercial, or industrial—is inherently immune to water infiltration. Regardless of architectural design, construction quality, or intended use, the presence of moisture in masonry structures represents a consistent and latent risk, especially in regions characterized by humid equatorial climates, such as Manaus. When waterproofing systems are improperly designed, inadequately applied, or entirely neglected, pathological manifestations inevitably emerge, compromising both the physical integrity of the structure and the quality of life of its users.

One of the most concerning consequences of moisture infiltration is its direct impact on human health, particularly in households with occupants suffering from respiratory conditions or allergies. The proliferation of mold, mildew, and fungi on interior surfaces, often accompanied by foul odors and visual deterioration, creates environments that are not only uncomfortable but also clinically unsafe. Additionally, water ingress through slabs has been observed to cause concrete deterioration, corrosion of reinforcement bars, and fragment detachment, leading to safety hazards for the building's inhabitants and visitors.

From a structural and performance standpoint, waterproofing must be treated as a fundamental and non-negotiable element of the construction process. It is not merely a protective finish or optional step, but rather a technical necessity that should be planned and integrated into all phases—from architectural design and material specification, to execution, inspection, and maintenance. Building users and property owners must be educated and empowered to demand compliance with waterproofing standards and to recognize watertightness as a key performance indicator of any construction project.

The study revealed that the application of well-specified waterproofing systems—whether rigid or flexible—can significantly reduce the occurrence of critical anomalies. These systems not only prevent fissures in exposed slabs and enhance the performance of retaining walls and foundation beams, but also block moisture penetration toward steel reinforcements, thus extending the structural life cycle. As a result, indoor comfort improves, the value of the property is preserved, and the maintenance costs associated with deterioration are drastically reduced.

As Gatto [27] insightfully points out, housing plays a foundational role in the development of individuals and communities, especially in developing countries like Brazil, where housing conditions are intrinsically linked to social mobility and urban equity. In this regard, ensuring the quality, safety, and durability of residential construction—through practices such as proper waterproofing—is not just a technical objective, but also a social imperative.

This research also calls attention to the fragmentation within the construction chain, where manufacturers, designers, applicators, and consumers often operate in silos. Overcoming this disconnect requires establishing more integrated workflows, multidisciplinary collaboration, and greater awareness of waterproofing as a specialized subfield within Civil Engineering. This would support not only technical consistency but also innovation in materials, methods, and regulatory frameworks.

The systematic evaluation of 50 residences in the Northern Zone of Manaus revealed a pattern of pathologies that mirror those found throughout the city and across similar climatic regions, largely stemming from economic constraints, lack of technical oversight, and limited understanding of waterproofing systems among both professionals and end users. These conditions are further aggravated by the absence of legal and regulatory mechanisms that mandate the inclusion of waterproofing strategies in standard project documentation. The lack of enforcement and oversight leaves ample room for omission, improvisation, and error, ultimately affecting the safety and longevity of buildings.

Consequently, one of the key conclusions of this study is that waterproofing should be regarded not as a dispensable cost, but as a long-term investment—an integral part of sustainable building design that ensures structural integrity, property valuation, and the well-being of its occupants. Even in cases where waterproofing is successfully applied during construction, its long-term effectiveness is contingent upon regular maintenance and periodic inspections, particularly in high-risk environments subject to intense rainfall and humidity fluctuations.

The current demand for high-performance materials, combined with increasing awareness of building failures, is already fostering positive shifts in the waterproofing sector. New products with enhanced physical, chemical, and environmental resistance are being introduced, alongside growing investments in technical training, certification programs, and digital modeling technologies, such as BIM, that allow for precise waterproofing planning and simulation. These developments signal a broader paradigm shift in construction culture, where quality and performance standards are becoming central rather than peripheral concerns.

Moreover, empirical studies like this one, which document the frequency and distribution of pathological manifestations, have the potential to inform material development, guide public policy, and optimize construction practices. They provide actionable insights for researchers, industry professionals, regulatory bodies, and municipal authorities, contributing to a more robust and resilient building sector.

Through this research, not only were key areas of water-induced deterioration identified, but they were also treated using appropriate products and protocols, reinforcing the importance of evidence-based interventions. The outcomes validate the application of waterproofing systems grounded in technical rigor, local feasibility, and long-term durability.

In conclusion, the pursuit of quality, longevity, and health in civil construction—especially in humid and climatically vulnerable regions such as Manaus—demands a comprehensive, systemic, and interdisciplinary approach. Waterproofing, far from being a minor detail, must be elevated to the status of critical infrastructure within every construction project. Only then will it be possible to safeguard built heritage, promote healthier living environments, and build a more equitable and resilient urban future.

VI. AUTHOR'S CONTRIBUTION

Conceptualization: Wmilison Sousa da Silva
Methodology: Wmilison Sousa da Silva
Investigation: Wmilison Sousa da Silva
Discussion of results: Wmilison Sousa da Silva
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Supervision: Edinaldo José de Sousa Cunha
Approval of the final text: Edinaldo José de Sousa Cunha

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