Referência

SANTOS, Lara Monalisa Alves dos; ZANONI, Vanda Alice Garcia; ALMEIDA, Jaime Gonçalves de. Inspection method in bamboo roofs: assessment of the conservation conditions by using a drone and sensory analysis. In: INTERNATIONAL CONFERENCE ON NON-CONVENTIONAL MATERIALS AND TECHNOLOGIES (NOCMAT 2022), 18th, 2022. **Anais** [...]. [S. L.]: Zenodo, 2022. DOI: https://doi.org/10.5281/zenodo.6634985. Disponível em: https://zenodo.org/record/6634985#.YuJ7LXbMKUm. Acesso em: 28 jul. 2022.

INSPECTION METHOD IN BAMBOO ROOFS: ASSESSMENT OF THE CONSERVATION CONDITIONS BY USING A DRONE AND SENSORY ANALYSIS

Lara Monalisa Alves dos Santos, University of Brasilia, BR, laramonalisa.arquitetura@gmail.com
Vanda Alice Garcia Zanoni, University of Brasilia, BR, email, vandazanoni@unb.br
Jaime Gonçalves de Almeida, University of Brasilia, BR, jagal@unb.br

ABSTRACT
The site inspection processes are sensorial and require technical knowledge. Accessing the roofs is the biggest challenge due to the risks for safety involved. The objective of this article is to propose a methodological procedure to evaluate the conservation conditions of four buildings located in Brasília, capital of Brazil, and to analyze the main anomalies existing in the bamboo roofing systems, their causes, and their maintenance needs. The site inspection standard recommended by ABNT NBR 16747:2020 were adopted for the sensory analysis. A drone was used for the acquisition of images showing anomalies. Pathologies were classified into five critical damage levels to inform the urgency of intervention needed in the systems.

KEYWORDS
Bamboo roof; drone; roof inspection; building maintenance; anomalies.

INTRODUCTION

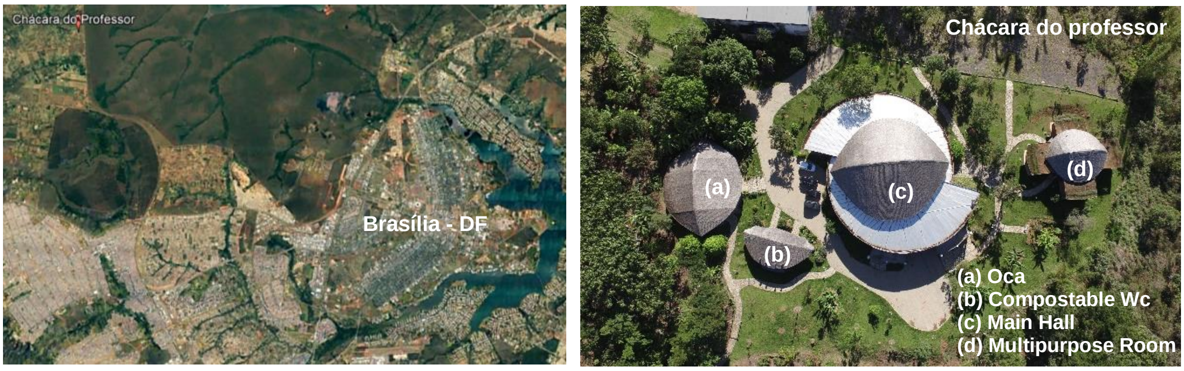
During the service life of the building, the roofing system plays a complex role due to its insulating function as a barrier against external agents – temperature changes, rain, and biological agents, creating a watertight and protected interior environment. Inadequate designs and inefficient execution are factors that can influence the performance of roofing systems (CONCEIÇÃO et al., 2017).

In addition, when roofs are not inspected regularly makes it difficult to identify anomalies that may prejudice the performance and service life of such a system (SILVEIRA; MELO; COSTA, 2020). Roof inspection processes involve hard access, many hours inspecting the elements that make up the system, besides safety risks inherent in the procedures (BROWN; MILLER, 2018). Visual inspection is often limited to the visible areas of the building, due to the difficulty of access (CONCEIÇÃO et al., 2017). In this sense, roof inspection procedures are quite often inefficient.

Traditional inspection methods usually comprise a man-made systematic assessment, which involves site inspection and tasks that take time to report the physical condition of the construction elements (PEREZ; TAH; MOSAVI, 2019). To facilitate the execution of roof inspection processes, new technologies are being adopted reducing time, the risk of accidents, and errors in data collection and processing. One of the highlighted technologies is the use of a drone to capture images of anomalies.

In this sense, the main goal of this study is to present a set of tools to support the process of site inspection in bamboo roofing systems using the drone. The procedures for physical assessment and sensory analysis for this type of roofing have specificities that affect decision-making regarding preventive maintenance actions. More specifically, drone inspections seek to capture and collect data in hard-to-reach places in roofing systems, more conveniently and safely.

For this research, four buildings of the Reference Center for Environmental Education were selected, located in the Chácara do Sindicato dos Professores in Brazlândia - Distrito Federal, chosen for the possibility of access. In a total area of 3,600m², since May 2012, the eco-pedagogical space planned to disseminate the culture of sustainability among students and teachers of the public network of the DF. The roofs of the buildings follow a pattern of bamboo structure and wood chip tiles. Since then, two buildings underwent inspection and maintenance in 2019. The bioconstruction complex (Figure 1), designed by architect Sérgio Pamplona and executed by civil engineer Frederico Rosalino, has four buildings: the Oca, the Main Hall, the Multipurpose Room, and the Compostable Bathroom (PAMPLONA; ROSALINO, 2016; PAMPLONA, 2018).



a) City of study b) Implementation

Figure 1: Case Study: Chácara do Professor (Adapted from Google Maps, 2021).

Inspection and maintenance of roofing systems

The site inspection is a process for evaluating the technical conditions, use, operation, maintenance, and functionality of the building and its construction systems and subsystems, in a systematic and predominantly conducted in a sensorial way. The identification of anomalies is led by inadequate functioning, symptoms, apparent signs, or other factors that can be only identified by specific tests (ABNT NBR 16747:2020).

In addition to the standard NBR 16747 (ABNT, 2020) for site inspection, Brazil has made available the NBR 5674 (ABNT, 2012) on Building Maintenance, which establishes the requirements for the maintenance management system with general procedures that must be implemented, aiming at the conservation and/or rehabilitation, to maintain favorable conditions for performance and longer service life.

Ensuring a good performance throughout the service life of the building is intrinsically linked to planned maintenance. Site inspection methods are moving towards faster and more effective means of communicating the condition of buildings so that maintenance repairs can be done proactively and promptly before it affects the performance and service life of the building (PEREZ; TAH; MOSAVI, 2019). Pereira, Brito, and Silvestre (2020) consider that a site inspection system should make use of tools that normalize and aggregate the dispersed information about degradation in various constructive elements. In this regard, Brazil is at a disadvantage position for not having a consolidated inspection standard for bamboo systems.

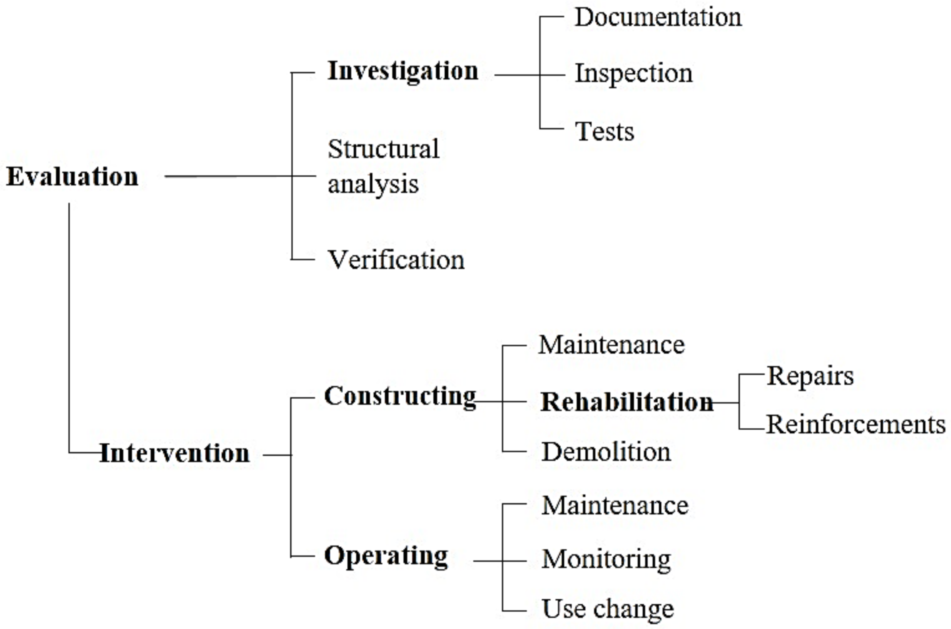
For scheduled site inspections, the standard NBR 16747 (ABNT, 2020) presents methodological procedures based on sensory analysis, which can be organized into stages shown in Table 1. According to the classification of identified irregularities and priorities, further investigations may require thorough inspections and special tests, demanding other specialized actions or interventions.

Table 1: Procedures for a site inspection (Based on the standard ABNT NBR 16747:2020)

STAGES OF SITE INSPECTION BASED ON ABNT NBR			
Stage 1	**Stage 2**	**Stage 3**	**Stage 4**
Documentation and data gathering	Data analysis	Classification of irregularities	Issuance of the report
Data analysis	Evaluation of pathological manifestations	Organization of priorities	
Anamnesis - data collected through interviews	Use evaluation	Recommendation	
Survey	Maintenance assessment		

The standard "ISO 13822:2010 Bases for design of structures – Assessment of existing structures" establishes methodological procedures for the evaluation of performance, according to the flowchart in Figure 2 that shows the different phases and includes actions, analysis steps, and proposals for existing structures, aiming at evaluation and/or intervention, being used as support for the sensory inspection.

Figure 2: Flowchart for evaluating existing structures (Based on ISO 13822:2010 and BRITO, 2014).



Narrowing the object of this research, NBR 16828-1(ABNT, 2020) and NBR 16828-2 (ABNT, 2020) standard establish basic requirements for projects and structures made with bamboo-stem, addressing the physical and mechanical properties, serviceability, and durability. The requirements defined by the regulations show that bamboo structures must meet the minimum quality requirements during their construction and service, and the additional requirements are established together with the person responsible for the project and the contractor.

METHOD

The proposed method for evaluating bamboo roofs is based on NBR 16747 (ABNT, 2020), NBR 16828-1 (ABNT, 2020), and NBR 16828-2 (ABNT, 2020). For the trial of the method, four roofs made of bamboo were selected in buildings of the Centro de Referência em Educação Ambiental, located in Brazlândia - Distrito Federal. Data collection was carried out through a survey and site inspection procedures, according to the guidelines defined by NBR 16747 (ABNT, 2020). A survey was carried out for sensory analysis and the photographic record of anomalies using the drone in areas of difficult access. Table 2 presents the methodological procedures for site inspection, based on the guidelines of NBR 16747 (ABNT, 2020), in this case, designed for the roofing system under study.

Table 2: Methodological design for site inspection applied to the roofing system.

ROOFING SYSTEM	ELEMENT	ANOMALIES	DAMAGE LEVEL	ACTION
Projects	Roofing	Typology	Level 1	Repair
Structural behavior	Crate (Rafters and Slats)	Extension	Level 2	Reinforcement
Conditions of use and maintenance	Structure (purlin)	Possible causes	Level 3	Maintenance
Exposure conditions	Waterproofing blanket	Degradation mechanism	Level 4	New tests
	Ceiling		Level 5	

To understand the actual state of conservation of the roof system and the relationship between cause and effect, it was necessary to propose criteria at five levels of damage, assigned in Table 3, considering the priority of the damage and the urgency of maintenance.

Table 3: Damage classification in bamboo-stem roofing elements.

LEVEL OF CRITICITY	CRITERIA
1	No Maintenance required
2	Routine Maintenance and monitoring
3	Need for Preventive maintenance
4	Need for Corrective Maintenance, inspections with specialized teams
5	Urgent Corrective Maintenance needed, inspections with specialized teams for immediate action

Table 4 shows the classification of anomalies in bamboo roofing systems, characterizing the type of element, the causative agents, the anomalies, and their probable causes. Once identified the anomalies, the level of damage should be adopted urgency levels for maintenance, restoration of performance to increase the service life of the inspected element.

The use of the drone is necessary to support site inspection, this tool was used at specific points to visualize anomalies in inaccessible places where the sensory analysis could not reach for data collection about the roofing system.

Table 4: Classification of anomalies in bamboo cover systems.

ELEMENT	**ROOFING**			
AGENT	**ANOMALIES**		**PROBABLE CAUSES**	**SOURCES**
• Actions of bioclimatic agents; • Maintenance actions; • Execution error.	**T-1**	Excessive deformation of the roof	• Existence of large spans in the structure; • Equipment on the roof; • Circulation of people and loads on the roof; • Ineffective maintenance of the structure; • Weathering	Morgado (2012); Conceição (2015)
• Actions of bioclimatic agents; • Maintenance actions.	**T-2**	Tonality differences	• Replacement of elements by others with a different tone; • The action of atmospheric agents. • Fungal colony due to water infiltration.	
ELEMENT	**FRAME (**rafters and slats**)** / **STRUCTURE (**purlin)			
AGENT	**ANOMALIES**		**PROBABLE CAUSES**	**SOURCES**
• Physical agents (pathology of structural origin)	**E-1**	Long crack	• Temperature variations; • Connections transmitting bending moments to the culms; • Traction stresses transverse to the fibers.	Brito (2014); Ballesté (2017)
	E-2	Short crack		
• Biotic agents	**E-3**	Xylophagous insects	• Inadequate harvesting and treatment of bamboo; • Humidity, oxygen, and temperature are suitable for hosting biotic agents.	
• Bioclimatic agents	**E-4**	Photodegradation	• Ultraviolet rays chemically degrade the lignin present in bamboo.	
ELEMENT	**WATERPROOFING MEMBRANES**			
AGENT	**ANOMALIES**		**PROBABLE CAUSES**	**SOURCES**
• Execution error; • Maintenance actions; • Bioclimatic agents.	**M-1**	Detachment of the waterproofing membranes	• Irregularity of the parameters (base, substrate, and protection layer); • Application of the blanket under environmental conditions. • Absence of overlapping fixing joints. • Inadequate protection of the upper edge of the blanket. • Wind actions.	Morgado (2012); Conceição (2015)
• Large trees	**M-2**	Surface dirt and debris build-up	• Blockage of gutter mouths	Conceição (2015)
• Execution error; • Maintenance actions.	**M-3**	Inadequate design of downpipes	• Absence of downpipes; • No protection grids.	
ELEMENT	**CEILING**			
AGENT	**ANOMALIES**		**PROBABLE CAUSES**	**SOURCES**
• Actions of bioclimatic agents; • Maintenance actions;	**F-1**	Moisture patches (condensation on the ceiling)	• Inappropriate application site; • Lack of proper maintenance.	Zuehl (2019)
	F-2	Detachment		

RESULTS AND DISCUSSIONS

Through sensorial site inspection, the main anomalies present in the roofing system were found and identified in each element of the system. To assist in the inspection process in areas of hard access, the drone was fundamental for the identification of anomalies.

Roofing

The accentuated deformation (T-1) is associated with the loss of functionality of the support structure, in this case, the rafter (Figure 3 in Table 5). Monitoring is necessary to carry out corrective actions, such as the removal of compromised elements, correctly replacing their fixations for greater stability.

Regarding the difference in the shade (T-2) in Figure 4, the affected elements must be maintained with wax, varnish, or paint, following the necessary recommendations for bamboo pieces exposed to the weather, at least every 6 months.

Table 5: Anomalies present in the roof of the Main Hall building.

ELEMENT	ANOMALIES	DAMAGE LEVEL
 Figure 03 - Excessive deformation of the roof  Figure 04 - Excessive deformation of the roof	**T1-** Excessive deformation of the roof **T-2** Tonality differences	**2 –** Medium-term actions with the need for monitoring

The damage for the two manifestations found in the inspection is level 2, due to the anomalies, maintenance and monitoring should occur every 6 months with eventual repairing.

Frame

The cracks found are in the long (E-1) and short (E-2) categories, present in the four buildings analyzed, Figures 5 in Table 6. It was noted that repairs were carried out with metal clamps only in the Oca, Compostable Wc, and Main Hall, in the latter the caulking also took place. Cracks are gateways for insects to colonize the culms. Varnishing is needed and verifying the need for clamps or caulking, as well as inspection, cleaning, and periodic maintenance of the structures.

Cracks are caused by temperature variations, as bamboo tends to balance its internal moisture accordingly to the environment in which it is located. Another factor that causes cracks in the direction of the fibers because they are aligned in a single direction and not uniformly distributed in the parenchyma matrix, and this causes the variation of mechanical properties along with the culm thickness.

Table 6: Anomalies present in the roofing crate.

ELEMENT	ANOMALIES	DAMAGE LEVEL
 Figure 05 – Long crack present in the frame of the Multipurpose Room building	**E-1** Long crack	**4 –** Actions requiring corrective maintenance

The damage level attributed to anomalies is level 4 and is based on actions that need corrective maintenance. This type of manifestation compromises the structural stability of the system and the safety levels of users.

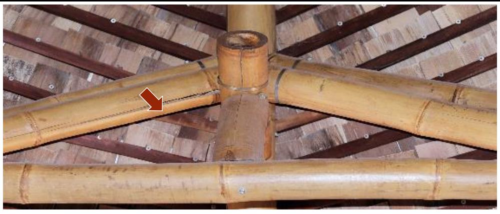
Structure

In Figure 6, it was possible to identify the presence of the short fissure (E-2) caused by temperature variations and its exposure to the weather, located on the external and internal sides of the buildings. For structural parts present inside, preventive maintenance must be carried out every 2 years.

Biological degradation was identified through the presence of xylophagous insects (E-3) in the structures of all buildings because of the lack of preventive maintenance, see Figure 7. The insects feed on different parts of the stem (woody tissue), while the advanced fungi stage affects mechanical strength. It is important to point out that action must be taken on the causes of occurrence of anomalies, as the number of affected parts may increase.

Photodegradation (E-4) is an anomaly and was identified only on the outside of the structure, Figure 8 in Table 7. This anomaly is caused by the building's implantation and its solar orientation. The pieces that show photodegradation are located on the north, south, and east facades. As a result of the direct exposure of the structural elements to climatic conditions (rain and sun), there is a change in the color of the bamboo, creating an environment conducive to attack by biotic agents and humidity, accelerating its deterioration. The recommendations are cleaning, sanding, and varnishing to restore the uniformity of the color and the protection of the material.

Table 7: Anomalies present in the structure.

ELEMENT	ANOMALIES	DAMAGE LEVEL
 Figure 06 – Short crack in the structure of the Multipurpose Room building	**E-2** Short crack	**4 –** Actions requiring corrective maintenance
 Figure 07 - Short fissure and the presence of xylophagous insects detected in the compostable Wc building	**E-2** Short crack **E-3** Xylophagous insects	**3 –** Actions requiring corrective maintenance
 Figure 08 – Structure with the presence of photodegradation on the north facade of the Main Hall building	**E-4** Photodegradation	**3 –** Actions requiring corrective maintenance

In the crate system, level 3 of damage was assigned, being actions requiring preventive maintenance. The system needs monitoring and intervention for the corrections and treatments of the damaged elements since it compromises the structural stability of the system and may trigger other types of manifestations with damage level 4.

Waterproofing membranes

The detachment of the waterproofing membranes (M-1) from the gutters is found along the section (Figure 09), and the main cause was the poor execution of the finishing caused by its completion. Another aggravating factor is the support of the stairs in the region of the wooden colon, used for access by the maintenance team, which impairs the stability of the eaves. The lack of this colon causes the rotting of the system caused by the action of atmospheric agents.

Surface dirt and debris accumulation (M-2) in Figure 10 are evident in the waterproofing membranes of the Main Hall building - they are interconnected and associated with poor maintenance (Table 8). However, the low slope of the roof and the drainage system, the incorrect execution of the element, and the environmental actions (strong winds, biological action, and atmospheric pollution) can cause the appearance of this type of anomalies. The entire blanket must be cleaned with a low-pressure water jet or manual brushing.

The accumulation of water in the gutters is due to the inexistence of drains with an inlet and, because of the dirt present, the drains are obstructed by the foliage of the trees existing in the place and by the bad dimensioning of the devices. The waterproofing layer must be cleaned, the element (gutter and downpipes) replaced by another with greater capacity for rainwater drainage and the installation of an inlet drain.

The downpipes (Figure 11) have a poor connection (M-3) and were not sized according to the roof area and flow. The drainage system must be resized, increasing the slope of the gutter, checking mainly the occasional cases that are disconnected. The number of inlet drains and downpipes should also be increased.

Table 8: Anomalies present in the waterproofing membranes of the Main Hall building.

ELEMENT	ANOMALIES	DAMAGE LEVEL
 Figure 09 - Detachment of edge colon	**M-1** Detachment of the waterproofing membranes	**4 –** Actions requiring corrective maintenance
 Figure 10 – Waterproofing membranes	**M-2** Surface dirt and debris build-up	**4 –** Actions requiring corrective maintenance
 Figure 11 - Downpipes with poor connection and flow	**M-3** Inadequate design of downpipes	**4 –** Actions requiring corrective maintenance

The waterproofing membranes system presented level 4 of damage and the actions in need of corrective maintenance. Superficial dirt and debris accumulation impair the correct functioning and durability of the entire roofing system, as it has presented the accumulation of rainwater, and this leads to the percolation of water into the ceiling system-oriented wooden boards (OSB) causing humidity stains and their detachment. In addition, the accumulation of water causes splashes on the bases of the walls in contact with the external floor.

Ceiling

For humidity stains (F-1) presented on the ceiling, it is recommended to replace the gutters. The waterproofing system must be repaired and the damaged OSB elements replaced (Figure 12 in Table 9). In many cases, water stains are eliminated by removing the existing debris itself, but in this case, only taking this action is not enough.

In the green roof system of the multipurpose hall (Figures 13 and 14) the points with the highest amounts of mold are caused by the drained water in the region of the gutters. In this system, anomalies related to lack of maintenance and errors in project execution were found.

The appearance of signs of detachment (F-2) of the OSB linings of the roof with the green roof and the waterproofed roof indicate points of water accumulation. These anomalies are caused by the clogging of the gutters and drainage systems, indicating the need to repair the system (blanket and downpipes) and the replacement of parts that show signs of deterioration.

Table 9: Anomalies present in the lining.

ELEMENT	ANOMALIES	DAMAGE LEVEL
 Figure 12 – Infiltration caused by the accumulation of water present in the Main Hall building	**F-1** Moisture patches	**4 –** Actions requiring corrective maintenance
 Figure 13 - Infiltration caused by the accumulation of water present in the Multipurpose Hall building	**F-1** Moisture patches	**4 –** Actions requiring corrective maintenance
 Figure 14 - Infiltration caused by the accumulation of water present in the Multipurpose Hall building	**F-2** Detachment	**4 –** Actions requiring corrective maintenance

The ceiling system whose material is OSB needs corrective maintenance, being characterized by level 4 of damage. Therefore, the action to be taken depends primarily on the repair of the upper system that has caused this type of anomalies, due to the presence of humidity and the detachment of the OSB lining. The identification of these manifestations is just an initial warning that deserves to be quickly dealt with, otherwise, it represents a danger for users.

CONCLUSIONS

The site inspection, predominantly sensorial and with the use of a drone, made it possible to identify the anomalies present in the roof systems of the four buildings and diagnose the causative agents. The photographic record was a fundamental tool for the visual assessment of the state of conservation of the systems. The main manifestations were concentrated in the frame with the action of biotic and abiotic agents, in the waterproofing membranes system, in the OSB lining with the action of atmospheric agents, inadequate sizing of the downpipes, and poor installation of the colon.

Buildings in direct contact with atmospheric agents showed a state of degradation with large amounts of anomalies. Attention is paid to the need for regular inspections to keep the roofing system in good shape, identifying the causative agents. Damage levels were concentrated on 2, 3, and 4, ranging for maintenance actions with the need for monitoring or corrective maintenance. It is worth mentioning the importance of prioritizing the points that presented these levels of damage since the bamboo roofing system showed a sensitive behavior to temperature variations combined with humidity.

Therefore, the set of tools proposed in this study to support decision-making regarding maintenance should guide actions accordingly to the level of damage found. A preventive maintenance plan must be drawn upon checklist sheets to carry out periodic inspections to prospect for the appearance of anomalies in the roofing systems. The performance of maintenance actions on the elements of the systems aims to prolong their performance and service life, meeting the requirements of bamboo structures, among which structural stability and durability stand out.

ACKNOWLEDGMENTS
The authors would like to thank the Center for Research and Application of Bamboo and Natural Fibers CPAB/UnB for the research project grant and the Graduate Program in Architecture and Urbanism for the financial support for production and research activities.

REFERENCES
ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. NBR 16747: Inspeção Predial – Diretrizes, conceitos, terminologia e procedimento. Rio de Janeiro: ABNT, 2020, 20 p.
ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. NBR 5674: Manutenção de edificações – Requisitos para o Sistema de gestão de manutenção. Rio de Janeiro: ABNT, 2012.
ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. NBR 16828-1: Estruturas de Bambu - Parte 1: Projeto. 1 ed. Rio de Janeiro: ABNT, 2020. 33 p.
ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. NBR 16828-2: Estruturas de Bambu - Parte 2: Determinação das propriedades físicas e mecânicas do bambu. 1 ed. Rio de Janeiro: ABNT, 2020. 20 p.
BALLESTÉ, J. F. Desempenho construtivo de estruturas de cobertura com colmos de bambu Joan Font Ballesté. [s.l.] Universidade de São Paulo-USP, 2017.
BRITO, L. D. Patologia Em Estruturas De Madeira: Metodologia De Inspeção E Técnicas De Reabilitação. [s.l.] Universidade de São Paulo-USP, 2014.
CONCEIÇÃO, J.; POÇA, B.; FLORES-COLEN, I. Inspection, Diagnosis, and Rehabilitation System for Flat Roofs. Journal Of Performance Of Constructed Facilities, v. 31, n. 6, p. 04017100, 2017.
FERRAZ, G. T.; BRITO, J.; FREITAS, V. P.; SILVESTRE, J.D. State-of-the-Art Review of Building Inspection Systems. Journal Of Performance Of Constructed Facilities, [s.l.], v. 30, n. 5, p.04016018-04010188, out. 2016. American Society of Civil Engineers (ASCE). http://dx.doi.org/10.1061/(asce)cf.1943-5509.0000839.
FRANÇA, N. P.; KANAI, J.; FONTANINI, P. S. P. Veículo aéreo não tripulado e aplicações na construção civil de transportes – um estudo de caso na cidade de Salvador. In: ENCONTRO NACIONAL DE TECNOLOGIA DO AMBIENTE CONSTRUÍDO, 18., 2020, Porto Alegre. Anais... Porto Alegre: ANTAC, 2020.
GOOGLE. Google Earth. Disponível em: <http://earth.google.com/>. Acesso em 21 maio. 2021.
HEZAVEH, M. M.; KANAN, C.; SALVAGGIO, C. Roof Damage Assessment using Deep Learning. 2017 Ieee Applied Imagery Pattern Recognition Workshop (Aipr), [S.L.], v. 1, n. 1, p. 1-6, out. 2017. IEEE. http://dx.doi.org/10.1109/aipr.2017.8457946.
HIDALGO-LOPÉZ, O. Bamboo. The gift of the gods. Bogotá: D'vinni Ltda., 2003.

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION. 13822: Bases for design of structures - Assessment of existing structures. 1 ed. Ethiopian: Ethiopian Standards Agency, 2010. 50 p.
INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO): Bamboo - Structural design, ISO 22156: 2004.
LIESE, W. Research on bamboo. Wood and Science Technology. v.3, n.21, p.189-209, 1987.
LIESE, W. The anatomy of bamboo culms. In: INTERNATIONAL NETWORK FOR BAMBOO AND RATTAN (INBAR). China. Technical Report 18. China, 1998.
MARÇAL, V. H. S. Análise Comparativa de Normas Técnicas Internacionais para o Emprego do Bambu – Colmo em Estruturas Prediais. 193 f. Dissertação (Mestrado) - Curso de Arquitetura e Urbanismo, Universidade de Brasília, Brasília, 2018.
MESQUITA JÚNIOR, A. L. Identificação e quantificação de patologias em uma estrutura de bambu: estudo de caso da "oca", sinpro, brazlândia/df. 2019. 59 f. TCC (Graduação) - Curso de Engenharia Florestal, Universidade de Brasília, Brasília, 2019.
MORGADO, J. N. P. L. V. “Plano de inspecção e manutenção de coberturas de edifícios correntes” (2012). 267f. Dissertação de Mestrado – Universidade Técnica de Lisboa, Lisboa.
PAMPLONA, S. B. P. Chácara do Professor – Sinpro: obras avançam. 2018. Disponível em: https://arquinatura.wordpress.com/2013/08/27/chacara-do-professor-sinpro-obras-avancam/. Acesso em: 22 dez. 2020.
PAMPLONA, S.; ROSALINO, F. Centro de referência em educação ambiental do SINPRO-DF. 2016. Disponível em: https://2e3bf711-4399-4c9a-b7fd-61f4cad82c43.filesusr.com/ugd/998d18_c61410af870e4bbd95701f728313cd55.pdf. Acesso em: 21 dez. 2020.
PEREIRA, M. A. R.; BERALDO, A. L. Bambu de corpo e alma. Bauru: Canal 6, 2008. 240p.
PEREIRA, C.; BRITO, J.; SILVESTRE, J. Global Inspection, Diagnosis and Repair System for Buildings: homogenising the classification of repair techniques. XV International Conference On Durability Of Building Materials And Components. Ebook Of Proceedings, [S.L.], p. 827-834, 2020. CIMNE. http://dx.doi.org/10.23967/dbmc.2020.072.
PEREZ, H.; TAH, J. H. M.; MOSAVI, A. Deep Learning for Detecting Building Defects Using Convolutional Neural Networks. Sensors, [S.L.], v. 19, n. 16, p. 1-22, 15 ago. 2019. MDPI AG. http://dx.doi.org/10.3390/s19163556.
REGLAMENTO COLOMBIANO DE CONSTRUCCIÓN SISMO RESISTENTE NSR10. Título G - Estructuras de madera y estructuras de guadua, Capítulo G.12- Estructuras de guadua. Colômbia, 2010.
ROSALINO, F. Pré Fabricação de Treliças de Bambu para Coberturas. Anais do Workshop de Tecnologia de Processos e Sistemas Construtivos, [S.L.], p.1-12, 5ago.2017.Galoa. http://dx.doi.org/10.17648/tecsic-2017-72097.
SANTOS, B.; LORDSLEEM JR. A. Revisão sistemática da literatura sobre o uso de veículo aéreo não tripulado (VANT) como equipamento de transporte. In: ENCONTRO NACIONAL DE TECNOLOGIA DO AMBIENTE CONSTRUÍDO, 18., 2020, Porto Alegre. Anais... Porto Alegre: ANTAC, 2020.
SILVEIRA, B.; MELO, R.; COSTA, D. B. Using UAS for Roofs Structure Inspections at Post-occupational Residential Buildings. Lecture Notes In Civil Engineering, [S.L.], p. 1055-1068, 14 jul. 2020. Springer International Publishing. http://dx.doi.org/10.1007/978-3-030-51295-8_73.
STAFFA, L. B. J.; SÁ, L. S. V.; LIMA, M. I. S. C.; COSTA, D. Uso de técnicas de processamento de imagem para inspeção de estruturas de telhados de edificações para fins de assistência técnica. In: ENCONTRO NACIONAL DE TECNOLOGIA DO AMBIENTE CONSTRUÍDO, 18., 2020, Porto Alegre. Anais... Porto Alegre: ANTAC, 2020.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest associated with the work presented in this paper.

DATA AVAILABILITY

Data on which this paper is based is available from the authors upon reasonable request.