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TIMBER BALCONY MONITORING PLAN: REVIEW AND STEP-BY-STEP PROCEDURE

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ABSTRACT: The aim of this paper is to present a step-by-step procedure for defining an accurate and revised monitoring plan for timber balconies. This methodology was defined and tested on 58 balconies with a timber beam structure but can be adapted to a CLT structure. The primary goal is to evaluate and control fungal decay of the various components, enabling preventive and planned interventions before significant damage occurs. Inspection intervals are determined through a prediction model of the progression of decay. The procedure is divided into three phases: a preliminary study and coding stage; an inspection stage, in which conditions are also assessed through non-destructive testing (NTD); and a post-elaboration stage, which is useful for defining interventions and the monitoring plan. These phases have been updated, standardised, and summarised in a procedural flowchart, with new supporting forms developed. The paper concludes with the application of this procedure to a real case study.

KEYWORDS: Timber Durability, Timber Balconies, Life Expectancy, Inspection Procedure, Monitoring Plan

1 – INTRODUCTION

Timber structures have gained significant market growth in recent years, mainly due to their sustainability [1], versatility and speed of construction. For example, according to the 7th Timber Building Report of FederLegnoArredo 2023, global demand in 2022 for sawn conifers exceeded supply for the first time. In Italy alone, the timber construction market increased by 33%, with 3,400 new timber buildings constructed. This rapid expansion has brought attention to several challenges, particularly the durability of wood as a building material. In fact, wood is a biological material and its use in construction and structural applications requires knowledge of both its behaviour in relation to climatic conditions and its vulnerability to external agents. The main factors that reduce the durability of timber elements are biological attacks (fungi, bacteria and insects), chemical decay (e.g. exposure to solar radiation), mechanical stress (prolonged or excessive loads) and physical factors such as moisture, temperature variations and leaching [2]. In addition to these, there are inherent natural defects in the material, such as knots and shrinkage cracks. Due to its ease of developing rapidly and breaking down mechanical properties causing loss of resistant section, fungal attack is the main mechanism of decay and the cause of around 20% of damage in timber structures [3]. Basidiomycetes fungi, germinate on wood with a moisture content of more than 20% and a temperature higher than 4-5 °C, propagating through the hyphae and degrading the cell structure [4]. Correct design choices are based on the 4Ds law [5][6]: “deflection” to prevent water accumulation, “drainage” to promote rapid run-off, “drying” to prevent persistent moisture and “durability” using highly durable timbers (Figure 1). However, in addition to design and installation, maintenance is essential, which includes inspecting the condition of the elements, cleaning to ensure their proper functionality, and carrying out any interventions.

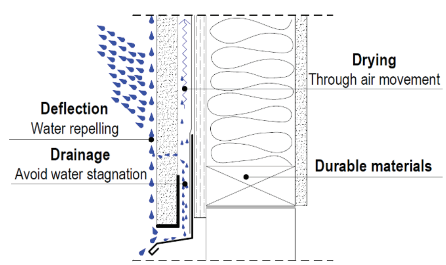

Figure 1. The 4Ds rule applied to the ventilated wall case

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Timber structures are often used for outdoor, weather-exposed applications in service class 3 [7], where risk factors are emphasised. These elements may be in contact with the ground, such as poles and fences, or, more commonly in buildings, above ground, such as canopies, facades, windows and balconies, with different construction details and vulnerabilities, as discussed by Meyer et al. [8]. Among these, balconies are probably the most common elements, also in non-timber structure building, and are often exposed to weather conditions such as rain, sun, humidity and wind. Those conditions can compromise the durability of timber structures, such as in the case of the wooden balcony collapse in Berkeley on 16 June 2015, which claimed six lives, or the collapse of a residential balcony in Brisbane that resulted in one death and 25 injuries in 2008 [9]. In many cases, the replacement of timber balconies with alternative structures is precluded by historical and architectural constraints. Consequently, the implementation of a monitoring program and a scheduled maintenance is imperative. This is not only to ensure durability and long-term safety, but also to mitigate the costs of emergency or extraordinary interventions. Wang and Ross [10] developed an illustrated guide that defines design principles and construction practices to improve the moisture design of timber-framed balconies and decks in medium- and low-rise multifamily buildings. Further guidance can be found in Gaspari et al. [11] and in the German DIN standard [12], which sets out the rules for effective weather protection, that is essential to prevent material decay. The aim of this article is to present a step-by-step inspection procedure useful for defining a monitoring plan for timber balconies, to guarantee high safety levels throughout the element's service life. The entire procedure was developed, tested and validated during an investigation campaign on test buildings owned by ITEA spa, a public company located in the Autonomous Province of Trento in northern Italy, which manages social housing. During the inspection campaign, 13 buildings with a total number of 58 balconies were examined to assess the structural condition and to develop, test and optimise the inspection and monitoring procedure. The analysed balconies, all with beam and deck structures, were 30 years of age on average (Table 1). As shown in Figure 2, most of them face south, west and east, but there are also more critical exposures such as north, northeast and northwest.

No. of inspected buildings	No. of Inspected Balconies	Average balcony age [Years]	Average balcony length [m]	Average balcony width [m]	Average beam spacing [m]
13	58	30	8,90	1,31	0,96

Table 1. Information of inspected balconies

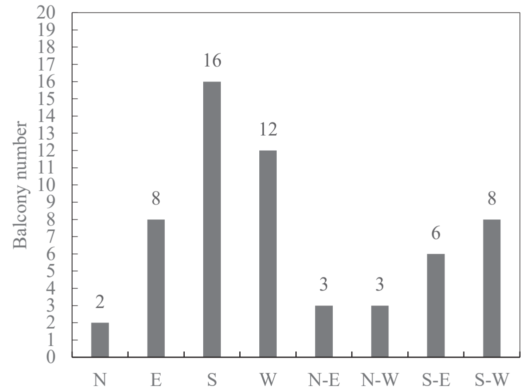

Figure 2. Orientation of inspected balconies

2 – BALCONY TYPOLOGIES AND COMPONENTS

Balconies can have generally exposed structures with beams and decks, which provide better ventilation, but require meticulous design to reduce moisture accumulation at contact points with other structural or finishing elements. Closed structures, such as CLT panels that are not suitable for service class 3, require complete insulation and waterproofing measures [11]. This study focuses primarily on exposed structures, characterized by beams and decks, but also outlines a framework that can be adapted to CLT-structure balcony configurations. To facilitate the inspections, the main structural and finishing components of the balconies were identified. Primary and secondary beams (when present) form the load-bearing structure under vertical loads together with the timber planking or slab made of other materials. Upper finishing layers such as waterproofing membranes or coatings, are often present above them. The structural elements designed to prevent falls from height include the main and secondary posts, horizontal rails, and the handrail (Figure 3).

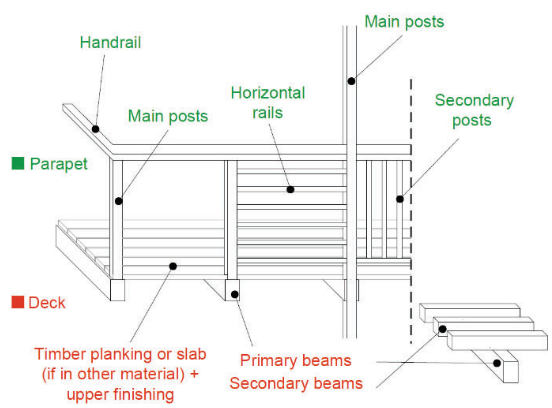

Figure 3. Balcony components and macro-elements

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These components have been grouped into two macro-elements: the deck, which includes the structural and finishing elements, and the parapet, which includes posts and rails. This subdivision facilitates detailed inspection and allows for a uniform data collection across different inspection forms.

3 – STEP BY STEP PROCEDURE

The step-by-step procedure is structured into three primary phases, as shown in Figure 4, to ensure a thorough and systematic evaluation of the structural condition of balconies. The preliminary stage involves the acquisition of essential information and the labelling of the balconies. The investigation stage encompasses surveys, data acquisition, and both visual and instrumental inspections of timber elements. The data gathered during the inspection phase is used to evaluate the current condition of the balconies, to plan and to prioritize maintenance interventions, and to determine the interval for subsequent inspections in the post-elaboration stage. The interval between two inspections is established through the application of a decay prediction model specifically developed for timber elements.

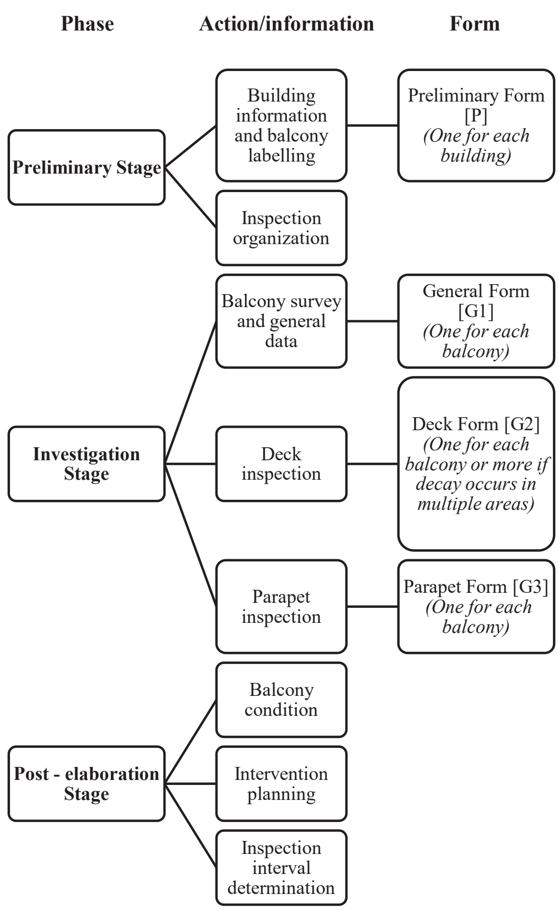

Figure 4. Step-by-step procedure for timber balcony monitoring plan

4 – PRELIMINARY STAGE

The preliminary stage is crucial for gathering and organizing all necessary information before proceeding with field inspections and data collection. By reviewing photographs and technical documentation of the building, balconies can be labelled, facilitating monitoring and data management during inspections. This also helps organize the inspection process. A unique identification label is assigned to each balcony to ensure clarity and precision. With an example provided in Figure 5, the labelling convention follows this structure:

$$FO.FN.SN/IM \tag{1}$$

- *FO*: Facade orientation (North N, North-East N-E, East E, North-West N-W, South S, South-East S-E, South-West S-W)
- *FN*: Floor number (G, 1, 2, 3, …)
- *SN*: Sequential balcony number from left to right when looking at the facade
- *IM*: Inspection mode (A, B, or C)

The inspection modes A, B and C are classified based on the accessibility of the underside of the balcony. In the first case (A), balconies on the ground or first floor are accessible from the ground, allowing for an easier inspection. The second case (B) involves balconies on the second floor or higher, where access to the underside is possible from the balcony below, requiring additional caution. In the third case, where there is no balcony beneath, access to the underside is restricted, and more advanced diagnostic tools or elevated platforms may be necessary if significant deterioration is detected. To facilitate this first phase, a specific form (i.e.: "P form") has been created, which must be filled out during the preliminary stage.

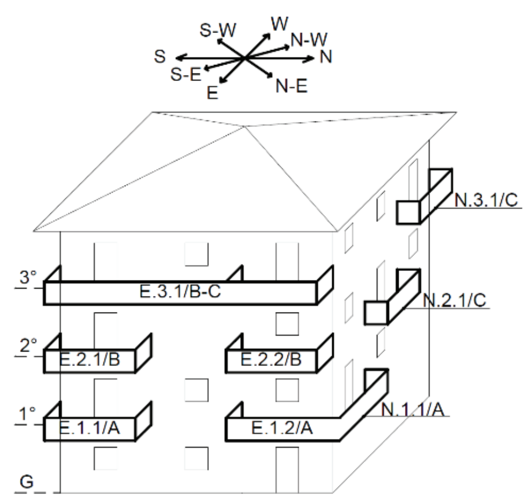

Figure 5. Balcony labels example

5 – INVESTIGATION STAGE

The field investigation aims at collecting essential data for diagnosing the condition of each balcony element and assessing the extent of decay. Key aspects evaluated during the inspection include wood species, moisture content, element geometry, and detailed mapping of decay, defects, and damage. Effective inspection requires proper accessibility, clean surfaces, and adequate lighting. Each component is meticulously examined to identify visible surface alterations or anomalies detectable with suitable tools. For suspected internal issues, specific instrumental tests are carried out. The investigation comprises two interconnected stages: general survey and data collection of the balcony and detailed inspection of the deck and parapet.

5.1 BALCONY SURVEY AND GENERAL DATA

Before initiating the inspection phase, a general survey of the balcony is carried out using Form G1. This step involves collecting essential data on the balcony's geometry, materials, and general stratigraphy, along with identifying the wood species to assess its natural durability and strength, if undetected during the preliminary phase. The survey also includes a visual identification of critical decayed areas and the assignment of a Risk Class: an indicator reflecting the potential risk associated with the combination of exposure conditions, protection methods, and construction techniques. Risk Classes are defined based on European standards (EN 460:1994 [13], EN 335:2013 [14]), German standards (DIN 68800 parts 1 and 2 [12]), and Austrian standards (ÖNORM B 3802 parts 1 and 2 [15], ÖNORM B 2320 [16]). Decision diagrams developed by Gaspari et al. [17] facilitate the classification process, enabling the assignment of risk classes to the upper, lower and lateral faces of balcony beams (Table 2 and Figure 6). This classification provides a framework for evaluating exposure-related risks and prioritizing inspection efforts.

	Upper beam face			
	DT1b			
DT2b	**A**	**B**	**C**	**D**
A	1	1	3,1	3,2
B	1	2	4	4
C	2	4	4	5
D	2	2	3,1	3,2
E	2	3,2	4	5
	Bottom and lateral beam faces			
	DT1b			
DT3b	**A**	**B**	**C**	**D**
A	1	1	3,1	3,2
B	1	2	4	4
C	2	4	4	5
D	5	5	5	5
E	2	2	3,1	3,2
F	2	3,2	4	5

Table 2. Tables for risk class assignment [17]

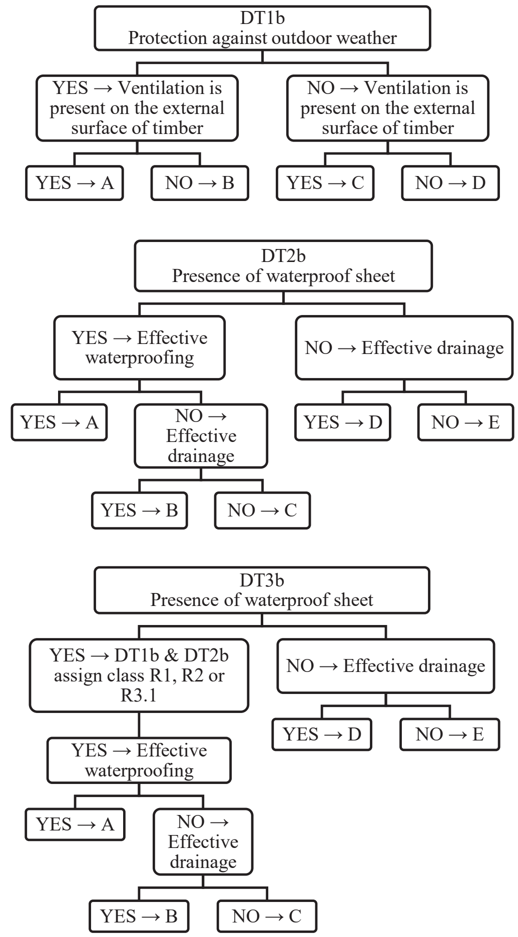

Figure 6. Decision diagrams for the risk class assignment [17]

5.2 DECK AND PARAPET INSPECTION

The balcony inspection phase is essential to ensure the safety and durability of the structures. It is guided by filling out the appropriate forms, G2 for the deck and G3 for the parapet, which allow a structured collection of information and data, useful for defining the state of preservation of the balcony. As shown in Figure 7, the first step is the visual inspection, which can identify critical elements and areas to be analysed more in detail. More than one form can be filled in if several areas of deterioration are detected. A crucial parameter for assessing the risk of decay is the measurement of the wood moisture content (MC). There are several methods for measuring moisture content, studied and analysed by Dietsch et al. [18]. The electrical method proves to be the most effective due to its speed of execution and suitability for relative humidity values between 7% and 30%. An electric hygrometer can be used following the instructions of EN 13183-2 [19].

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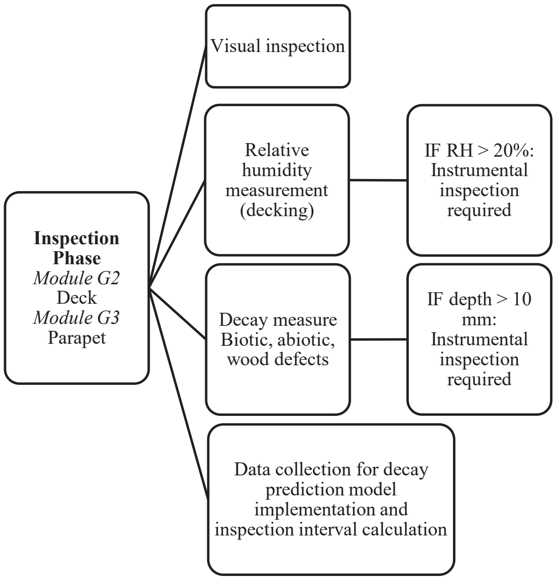

Figure 7. Inspection procedure

In the case of surface treatments, knots or the presence of bark, it is recommended to use a system that allows measuring in depth, such as a hygrometer with a hammer electrode. The moisture content of 20% is identified in Chapter 14 of [20] as a "reasonable safety margin against fungal damage". If this value is exceeded, instrumental investigations are required, as fungal spores can germinate, giving rise to hyphae, the filaments that make up the mycelium, potentially indicating a risk of material degradation [21]. If it rained 48 hours before the measurement and moisture content of >20% is detected, it is suggested that the measurement is repeated 2 days later, in order not to incur in distorted results. In addition to checking the moisture content, it is essential to detect decay, distinguishing between biotic decay (due to fungi or insects), abiotic decay (caused by environmental factors) and intrinsic wood defects. If the fungi decay is more than 10 mm deep, it is necessary to continue with the instrumental inspection. In this step, the degradation is quantified, both in terms of extent and depth. Instruments such as the rubber hammer are useful for testing the integrity of materials and detecting any areas of voids or detachments. The percussion test allows for quick estimates of the depth of the damage: dull sounds indicate advanced decay and require further investigation [22]. Other useful instruments are the awl and the calliper, to check the depth of alterations, measure dimensional variations, and check fastenings, as well as metal plates to assess the depth and width of cracks. The instrumental inspection, necessary in the case of M.C. > 20% or depth decay > 10 mm, provides not only a qualitative but also a quantitative estimate of deterioration. It can be performed through non-destructive investigations such as dynamic penetration with the Pilodyn, a quick and simple method that uses the insertion of a cylindrical tip to determine relative density. This can provide information on the superficial state of wood, with a limited insight on the whole section. However, despite its limitations, the use of the Pilodyn for quantitative measurements on decaying wood has been tested, comparing the results with gravimetric density measurements [23]. A drilling resistance test (i.e. Resistograph) can provide further insight, by measuring the resistance to the penetration of a metal drill into wood, thus identifying the depth of decay and the residual section of the material. The Resistograph is particularly useful for identifying decay damage but is not effective for non-extensive xylophagous insect attacks. Despite the absence of a specific standard, this tool is widely used for its speed, low invasiveness and the accuracy of the data collected, which can be as high as 80% [24].

6 – DATA ELABORATION STAGE

After completing the inspections, the following stage involves processing the collected data, a critical step to optimize subsequent intervention and inspection costs and time. Each balcony is assessed to determine its overall condition and based on this evaluation, appropriate maintenance or restoration measures are planned, tailored to the identified issues. Simultaneously, the monitoring plan is established, providing a solid guideline for professionals.

6.1 DAMAGE, BALCONY CONDITION AND INTERVENTIONS

The balcony condition was classified into four levels: *excellent*, *good*, *mediocre*, and *bad* (Table 3). "Excellent" condition refers to balconies with no visible signs of decay, while "good" condition includes superficial damage like abrasions or paint peeling, which do not compromise structural integrity and require only sanding and repainting. "mediocre" condition is characterized by more noticeable damage, such as localized decay of structural elements, requiring more complex interventions, including the replacement of certain parts.

Decay	**Risks**	**Interventions** *and timing*	**Condition**
None	None	None *Future**	Excellent
Flaking paint	Decay trigger	Smoothing and painting *Future**	Good
Surface decay (not affecting the handrail)	Decay diffusion	Smoothing and painting *Future**	Good
Punctual decay	Decay diffusion	Structural repair or replacement *Future* or immediate depending on condition*	Mediocre
Handrail decay	Wounds	Structural repair or replacement *Immediate*	Mediocre
Diffuse decay	Collapse	Structural repair or replacement *Immediate*	Bad

Table 3. Damage - intervention - condition correlation

Finally, "bad" conditions refer to balconies with widespread decay, severely affecting structural safety, requiring immediate and substantial repairs, such as replacing structural components and safety work. This classification helps professionals determine the necessary interventions, guiding them in setting priorities and timelines to ensure the safety and durability of the balcony. Interventions vary depending on the severity of the damage, with preventive or corrective actions to be scheduled based on the condition observed during the inspection. To support this classification, the damage-intervention-condition correlation table (Table 3) was developed, providing a structured framework for decision-making. Figure 8 presents examples of the most common types of degradation.

Figure 8. Photos of different types of decay on inspected balconies

6.2 MONITORING PLAN DEFINITION

The monitoring plan is established by implementing a decay prediction model (Figure 9) specifically designed for timber structures and components. Initially developed by Wang et al. [25][26] over a decade of research in Australia, the model has been subsequently adapted to the Italian climatic and structural context by Gaspari et al. [11].

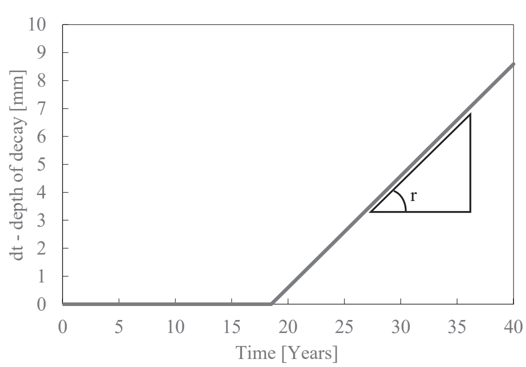

Figure 9. Decay prediction function of timber element above ground

This model predicts the worst-case scenario and estimates the loss of timber material due to decay (i.e., "depth of decay", d_t) over time, expressed in millimetres, and establishes a correlation between design choices and the specific environmental conditions of the analysed construction detail. The predictive function is calculated as follows and is governed by two key parameters:

$$d_t = 0 \text{ if } t \leq t_{lag}$$
$$d_t = (t - t_{lag}) \cdot r \text{ if } t > t_{lag} \quad (2)$$

- r, the rate of decay (mm/year)
  $r = k_{wood} \cdot k_{climate} \cdot k_p \cdot k_t \cdot k_n \cdot k_w \cdot k_{geom}$ (3)
- t_{lag}, the onset time of decay, represents the time required for the decay process to begin.
  $$t_{lag} = 8.5 \cdot r^{-0.85} \quad (4)$$

The rate of decay, r, is computed as the product of multiple coefficients that account for various factors influencing the durability of timber elements. Risk classes, assigned to the elements via decision trees, directly influence the $k_{climate}$ parameter, which reflects the climatic conditions. It is calculated as:

$$k_{climate} = 0.03 \cdot (t_{wet,\ rain})^{0.4} \quad (5)$$

with $t_{wet,\ rain}$ expressed in hours/year representing the time the wood component remains wet due to direct or indirect rainfall. Its rating varies according to the risk classes (Table 4).

Risk classes	$t_{wet,rain}$
1	365 hr/year
2	365 hr/year
3.1	rainfall estimation
3.2	rainfall estimation
4	8766 hr/year
5	8766 hr/year

Table 4. $t_{wet,\ rain}$ and risk classes correlation

For the first two classes, the detail is always considered dry while for class three the average rainfall data for a return time of 10 years is used. The rainfall height h in mm/year is transformed into rainfall time t_p in hr/year by means of an IDF curve (Intensity-Duration-Frequency curves), determined using the following function:

$$t_p = \sqrt[n]{(h / a)} \quad (6)$$

where a and n are parameters that depend on the area of interest [27]. In risk classes 4 and 5 the details are always considered wet. The function works on each face of the timber element and, depending on the geometry and orientation, varies through the k_{geom} parameter. For the analysed balconies, the model is simplified by applying the predictive function exclusively to the upper face of the most decayed beam, identified as the critical point. This simplification assumes that, in cases of widespread decay affecting other elements, immediate repair or replacement would be necessary. In above-ground structures with

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plane contact between two timber elements, the function parameters are presented in the Table 5.

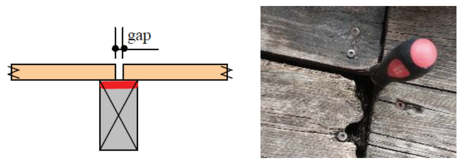

Figure 10. Surface where the decay prediction model is applied

Parameters	Cases	Value
$k_{climate}$ Exposure to rain	Depends on risk class and location	$0.03 \cdot (t_{wet,\ rain})^{0.4}$
k_{wood} Natural durability [28]	Durability class 1 / 2 / 3 / 4	*0.50 / 0.62 / 1.14 / 2.00*
k_n Connectors on the surface	Present / Not present	*2.00 / 1.00*
k_p Surface treatment	Varnished / Not varnished	*1.00 / 1.10*
k_t Element Thickness	t ≥ 20mm / t < 20mm / Other cases / With contact elements	*1.00 / 0.50 / 0.50 · t / 1.00*
k_w Element Width (w)	w ≤ 50mm / w ≥ 200mm / Other cases / With contact elements	*1.00 / 1.50 / 0.84 · w / 1.00*
$k_{geom,1}$ Contact with other elements	Flat / Embedded / No contact	*0.60 / 1.00 / 0.30*
$k_{geom,2.1}$ Contact material type	Wood / Steel / Concrete	*1.00 / 0.70 / 0.60*
$k_{geom,2.2}$ Contact surface	Upper surface / Other surfaces	*0.30 / 0.60*
$k_{geom,2.3}$ Gap between upper planks	Gap / No gap	*1.20 / 1.00*

Table 5. Parameters of decay prediction function

The data required for the implementation of the decay prediction model and the assignment of risk classes are easily available through the completion of the G1 and G2 forms during the inspection phase in sections 5.1 and 5.2. The inspection interval, Δt in years, is determined by inverting the decay formula and setting a decay increment, Δd_t, equal to 2 mm. This value represents the minimum detectable value to warrant a new inspection. Subsequent inspection intervals are then calculated based on an expected decay of 2 mm.

$$\Delta t = 2/\, r_{average} \tag{7}$$

Where $r_{average}$ is calculated as the average between the decay rate from the model r_{mod} and the decay rate from the inspection r_{insp} computed by solving the following equation, where d_{insp} represents the decay measured during the inspection.

$$d_{insp} = (t - (8.5 \cdot r_{insp}^{-0.85})) \cdot r_{insp} \tag{8}$$

Using the average of the model decay rate and the inspection decay rate considers both the measured depth of decay and the exposure and risk conditions of the balcony. This approach provides a more balanced and representative decay rate by considering both theoretical modelling and actual inspection data. For newly built or renovated balconies, it is recommended to use only the decay prediction model to determine the first inspection interval.

7 – CASE STUDY APPLICATION

The following case exemplifies the method applied to one of the four balconies of a building owned by ITEA S.p.A., located in the province of Trento. The main characteristics of the balcony are shown in the Table 6.

FO	FN	PN	IM	Coding	Year
W	1	1	A	W.1.1/A	1993
Length [m]	**Width [m]**	**Type**	**Material**	**Beam Section [mm]**	**Deck height [mm]**
5,50	1,30	Beam + deck	Timber Red fir	145x170	40

Table 6. Characteristics of the balcony

The balcony is not protected from weathering and has no waterproofing. Ventilation and drainage are ensured by the spacing between the deck boards and a correct slope system. Utilising the decision diagrams outlined in section 5.1, the balcony is assigned to the risk class 3.1. During the inspection, total peeling of the paint and diffuse surface degradation were observed. Additionally, there was punctual decay near the connections of the penultimate plank on the deck above the T4 beam. Analysis with Resistograph revealed deep degradation of approximately 85 mm, of which 40 mm related to the decking and 45 mm to the beam (Figure 11). The parapet, by contrast, is in good condition. According to Table 3, the balcony is in mediocre condition, and an immediate intervention to replace the degraded boards must be planned. As show in Table 7, the decay prediction function is subsequently applied to the upper face of the analysed beam, using the data collected by filling in the G2 form. The predicted degradation is 66 mm, compared to the 45 mm measured on the beam; this value is deemed acceptable, as the function predicts the worst possible outcome. Following the inspection carried out in July 2024, the next inspection is scheduled for July 2025.

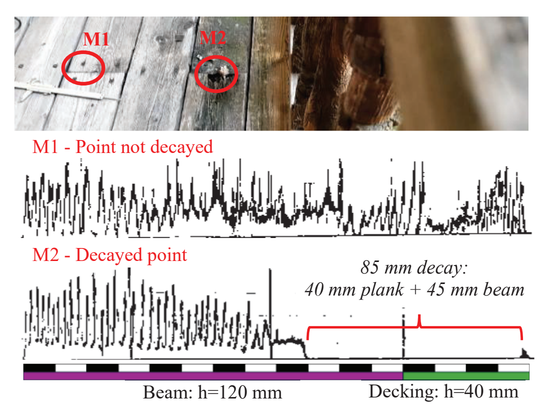

Figure 11. Resistograph measures in decayed and non-decayed points

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k_c	k_{wood}	k_p	k_n	k_t	k_w	k_{g1}	k_{g21}	k_{g22}	k_{g23}
0,46	2	1	2	1	1	1	1	2	1
r_{mod} [mm/Years]		r_{isp} [mm/Years]		r_{ave} [mm/Years]			Δt [Years]		
2,43		**1,54**		**1,99**			**1,00**		

Table 7. Decay prediction model applied to case study

8 – INSPECTION CAMPAIGN RESULTS

As previously outlined in the introduction, the step-by-step procedure for defining an inspection and monitoring plan for timber balconies was optimised and validated through an extensive inspection campaign on 58 balconies of 13 buildings in the province of Trento in northern Italy, featuring timber beam and plank structures and variable orientations (Figure 2). A relevant issue pertains to the timing of the entire process. The implementation of an optimised protocol and predefined inspection forms enabled a substantial reduction in execution time, resulting in significant economic savings, in addition to the inherent benefits of scheduled maintenance for timber elements. For each macro-phase, average times were recorded, highlighting the variability in total duration depending on the balcony's condition. During the inspection campaign, various types of damage were identified, ranging from minor paint peeling to widespread degradation, leading to more severe structural issues. A balcony in bad condition is more time consuming in terms of elements to be analysed, instrumental investigations and post-processing. The recorded times for completing each phase are given in Figure 12 where:

- *L_t* is the labelling time, i.e. the average time for the coding and preliminary phase: approximately 6 minutes for each balcony
- *I_t* is the inspection time, i.e. the average time for the survey phase: approximately 22 minutes for each balcony, ranging from 16 minutes for a balcony in good condition to 37 minutes for a balcony in poor condition
- *E_t* is the processing time, i.e. the average time for the data processing phase: approximately 12 minutes for each balcony

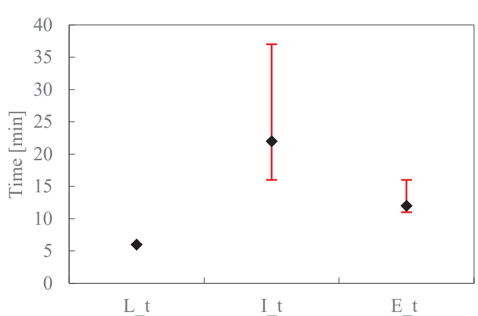

Figure 12. Process time per balcony

The total time process for each balcony (*B_t*), from coding to the definition of the monitoring interval, can therefore be calculated using the following formula:

$$B\_t = C\_t\,[min] + I\_t\,[min] + E\_t\,[min] \qquad (9)$$

Taking the analysed balconies as a reference, the total average time per balcony is approximately 40 minutes. During the inspection campaign of the 53 balconies, 43% were classified as being in bad or mediocre state, which took more time to assess, while 57% were in good or excellent condition, as shown in the Figure 13.

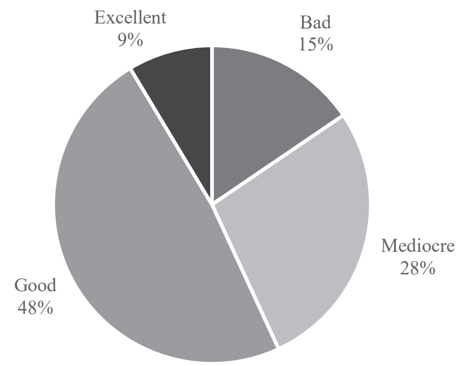

Figure 13. Inspected balcony condition

To provide a clearer understanding of balcony monitoring intervals, a representative balcony was selected from the 58 inspected cases. This reference balcony is approximately 30 years old, made of spruce, located in the town of Trento, with a decking featuring gaps and exposed connectors. The model decay rate r_{mod} was calculated using the decay prediction model (Eq. 3), considering different risk classes, which reflect the varying vulnerability of the balcony. Subsequently, by simulating different actual conditions, the measured decay depth was varied, allowing for the calculation of the inspection decay rate r_{insp} (Eq. 8). Finally, the inspection interval was determined for all *risk class - decay depth* combinations, effectively linking vulnerability to actual condition, as shown in Figure 14. The results exhibit a logarithmic trend, indicating that for risk classes 1, 2, and 3, inspection intervals remain relatively similar. However, in risk classes 4 and 5, where exposure conditions are more severe, inspections must be conducted at shorter intervals. Furthermore, as the balcony condition deteriorates, inspection intervals drastically decrease, eventually requiring such frequent inspections that intervention becomes necessary to optimize monitoring efforts and costs.

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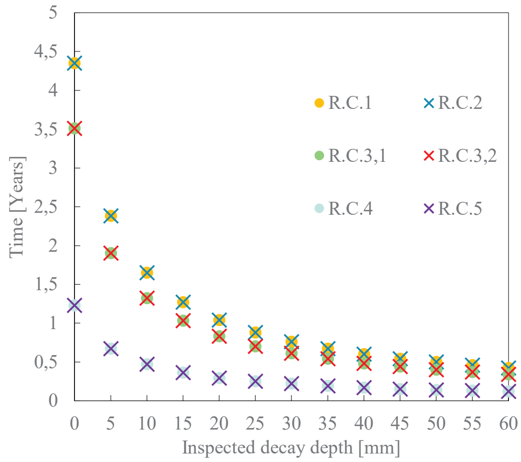

Figure 14. Inspection interval according to balcony condition and risk class

The observation of the analysed balconies revealed that certain details are particularly critical and require specific attention during inspection. Being the element most exposed to rainfall, planking is particularly vulnerable to decay, especially in the presence of reduced spacing between boards, tongue-and-groove joints and unprotected connections, which favour the stagnation of water. The heads of boards and beams, characterised by a high capacity for moisture absorption, are subject to accelerated decay if not adequately protected. Other critical details detected are the upper face of the beam, the connection to the masonry, the post-to-beam connection and the handrail.

9 – CONCLUSION

This study demonstrates the effectiveness of a standardised and optimised procedure for the monitoring of timber balconies. The proposed methodology not only preserves the integrity of the structural elements, preventing significant damage and minimising the need for invasive and expensive restoration, but also improves the overall efficiency of the inspection and maintenance process, resulting in reduced costs. Future research could extend this methodology to other timber structural elements, with a focus on critical details such as the wall-foundation interface. Such research developments would further improve the maintenance strategies of timber structures, contributing to the overall safety and sustainability of the construction industry.

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