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20th-Century World Built Heritage Facing Water: Conservation of Fallingwater and Boa Nova Tea House

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Abstract: The conservation of 20th-century architectural heritage presents unique challenges due to the modern materials and construction techniques used by pioneering architects. This paper investigates the preservation challenges of iconic architectural works exposed to water environments, focusing on Fallingwater by Frank Lloyd Wright and the Boa Nova Tea House by Álvaro Siza Vieira. These structures, situated in natural settings with significant exposure to water, serve as case studies for examining conservation methods and their broader implications. This study explores archival documents, interviews with conservation experts, and literature reviews to highlight the main degradation phenomena related to the impact of environmental conditions on the material's integrity. Despite limited specific data on monitoring and maintenance, this research underscores the importance of ongoing conservation efforts. Fallingwater's case highlights the necessity of restoration techniques, while the Boa Nova Tea House illustrates minimal intervention strategies to maintain authenticity. This study concludes that the effective conservation of 20th-century built heritage necessitates a balance between preserving original design intents and adapting to environmental challenges. It emphasizes the need for innovative conservation strategies, adherence to international guidelines, and the establishment of comprehensive management and monitoring plans to safeguard the integrity and authenticity of culturally significant architecture.

Keywords: 20th-century built heritage; conservation; monitoring; UNESCO; Frank Lloyd Wright; Álvaro Siza Vieira

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1. Introduction

The 20th century's architectural developments are characterized by significant disruptions that introduce new disciplinary challenges within architecture and heritage conservation. This period, particularly the first way of the century, is defined by the coexistence of divergent discourses, exemplified by the two Athens Charters. The 1933 Athens Charter of the Congrès International d'Architecture Moderne (CIAM) serves as a seminal document in modern architecture, promoting the philosophy of innovation and construction anew, often in contrast to the principles of heritage preservation. Conversely, the 1931 Athens Charter for the Restoration of Historic Monuments is notable as the inaugural international directive advocating for a preservation strategy. This charter also explores the interplay between private and public rights, assigning the responsibility for heritage conservation to national governments through appropriate legislation. Additionally, the 1964 Venice Charter marks a significant evolution by broadening the definition and status of heritage to encompass even "modest works", thereby extending the scope of what is considered worthy of preservation.

The revision of foundational charters, the development of thematic charters, and the increased involvement of regions and continents outside the Western sphere have all contributed to evolving perspectives on heritage value. Key documents shaping these new interpretations include the Krakow Charter of 2000 within the European context, the Burra Charter from Australia with its significant revisions in 1979, 1999, and 2001, the Washington Charter, the Tourism Charter, and the Nara Document. These documents serve as critical references in the analysis of the works of Frank Lloyd Wright (FLW) and Álvaro Siza Vieira (ASV).

The field of modern architectural heritage conservation is an emerging scientific discipline. In 1988, the establishment of DOCOMOMO (International Working Party for Documentation and Conservation of Buildings, Sites and Neighbourhoods of the Modern Movement) marked a significant milestone. In 1992, the formation of the C20 group in the United Kingdom aimed to preserve architectural heritage from 1914 onwards, eventually leading to the establishment of ISC20, an international scientific committee of ICOMOS. The 2003 UNESCO publication "Identification and Documentation of Modern Heritage" was instrumental in framing this topic within the global heritage context. By 2001, international heritage organizations had initiated a dedicated program for modern heritage conservation. At the invitation of ICOMOS, DOCOMOMO conducted a study and proposed a tentative list of Modern Movement properties in the 1990s, which were subsequently considered for the World Heritage List [1]. This report identified four key works by architects and a global selection of about 20 modern buildings, sites, or ensembles that potentially hold "outstanding universal value". The report highlights the application of common criteria, with a broader definition of authenticity encompassing idea, form, construction, detailing, and materials, asserting that the concept holds more significance than the physical form [1].

In the early 21st century, the field of heritage conservation solidified its scope through the active participation of both national and international organizations. Nevertheless, the 2005 ICOMOS report, "The World Heritage List: Filling the Gaps", underscored the underrepresentation of modern heritage within the World Heritage List. Subsequently, international conferences focused on 20th-century heritage were convened in Russia and Australia in 2006, 2007, and 2009. In this matter, the Getty Conservation Institute played a pivotal role in cementing this discourse. The 2011 international colloquium and the 2012 establishment of the Conserving Modern Architecture Initiative (CMAI) led to the 2013 inception of the "Keeping It Modern program" by the Getty Foundation. This program has been instrumental in providing international grants aimed at the conservation of significant 20th-century architectural works (The "Keeping It Modern" program supports the conservation of Álvaro Siza's Piscinas de Maré in Portugal, listed on the UNESCO Tentative List, but not Siza's Boa Nova Tea House or Frank Lloyd Wright's Fallingwater. While other Wright works like the Frederick C. Robie House received support, these notable sites rely on other conservation efforts).

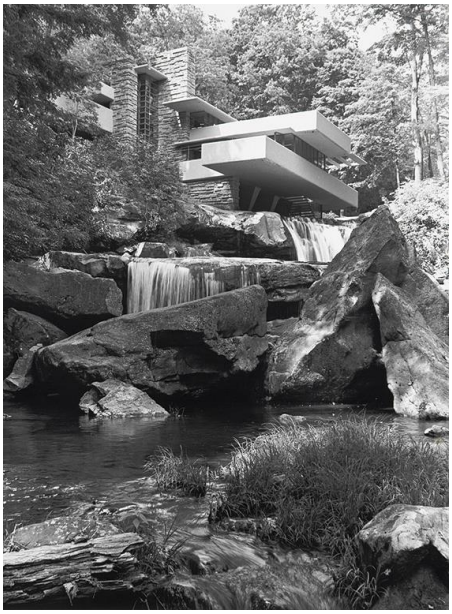
Significant documentary resources include the Madrid–New Delhi Document [2], developed by ICOMOS and the International Scientific Committee on Twentieth Century Heritage (ISC20C), providing guidelines for the conservation of concrete heritage. The Cádiz Document [3], produced by the same committee, is another key reference. Additionally, in 2021, the Getty Conservation Institute and ISC20C released the "Twentieth Century Historic Thematic Framework: A Tool for Assessing Heritage Places", further contributing to the assessment and conservation of 20th-century heritage sites.

The choice of the works of Frank Lloyd Wright and Álvaro Siza Vieira intends to highlight the distinctiveness of their creations (Fallingwater and the Boa Nova Tea House) (Figure 1), their relation and proximity with water, and their underlying outstanding universal value (OUV). Fallingwater is included in the serial nomination "20th Century Architecture of Frank Lloyd Wright", which was inscribed in 2019, and it was the first inscription of a modern building in UNESCO World Heritage for USA. The Tea House is part of the UNESCO nomination "Ensemble of Álvaro Siza's Architecture Works in

Portugal", listed as a tentative candidate since 2017, and it could be the first inscription of a modern building in Portugal.

Considering that the evaluation of "Requirements for Protection and Management" is essential for classification and inclusion on the World Heritage List, this article aims to emphasize the contributions to their preservation, particularly focusing on maintenance issues. The discussion is structured around three main themes:

1. The uniqueness of the work and its author—exploring the idea, form, and concept through architectural analysis;
2. The definition and characterization of construction—including construction techniques, detailing, and materials;
3. The challenges posed by water and exposure to extreme conditions—addressing conservation and maintenance efforts.



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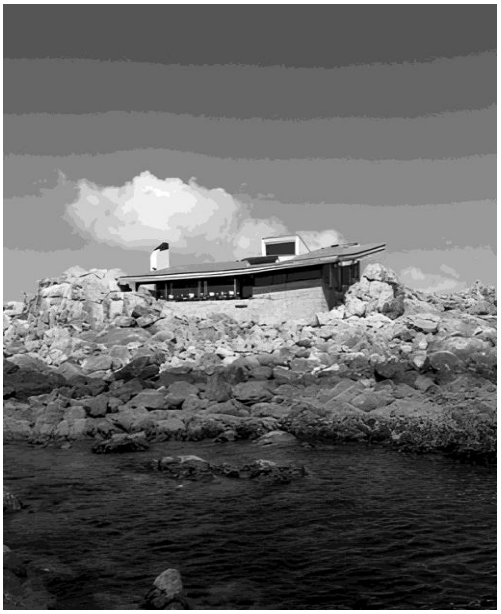

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Figure 1. (**a**) Fallingwater. Reproduced from Ref. [4] ; (**b**) the Boa Nova Tea House. Reproduced from Ref. [5].

2. Conservation of Two Modern Buildings Facing Water

Relating the specific theme of conservation with the 20th-century built heritage, Jukka Jokilehto, a distinguished author in heritage studies, provides an insightful evaluation of Modern Heritage, emphasizing the role of the Modern Movement in shaping 20th-century construction as "recent built heritage" [1]. For Jokilehto, modernity transcends a mere style, representing a global cultural approach with diverse expressions [6].

Drawing on Bruno Zevi's delineation of modern architectural characteristics, Jokilehto highlights a new architectural language marked by asymmetry and dissonance in design. He also notes the multifaceted perception of architectural works (akin to cubism) and the deconstructed and disassembled architectural reality. Additionally, Jokilehto points out the structural relationship as form and space, creating a novel continuum between building, city, and landscape.

It is worth noting that Wright's pioneering idea of the dynamic transformation of architectural space concerning time significantly shapes the architectural experience. Furthermore, examining the works of Frank Lloyd Wright, which are indubitably recognized within the Modern Movement, and those of Álvaro Siza Vieira, one could categorize Siza Vieira's works as "recent built heritage". This categorization allows for a similar

assessment, despite the difference in age between both works, thus demonstrating that they are indeed in line with the characteristics identified by Zevi.

2.1. The Fallingwater

Fallingwater, designed by Frank Lloyd Wright in 1935 and constructed over a creek, between 1936 and 1939, was commissioned privately by the Kaufmann family (Figure 2). Situated in Pennsylvania, USA, it is recognized as a National Historic Landmark and has been on the National Register of Historic Places since the 1970s. In 2019, it was added to the UNESCO World Heritage List. It has been functioning as a museum since the 1960s. It was opened to the public in 1964 after the Kaufmann family donated it to the Western Pennsylvania Conservancy (WPC).

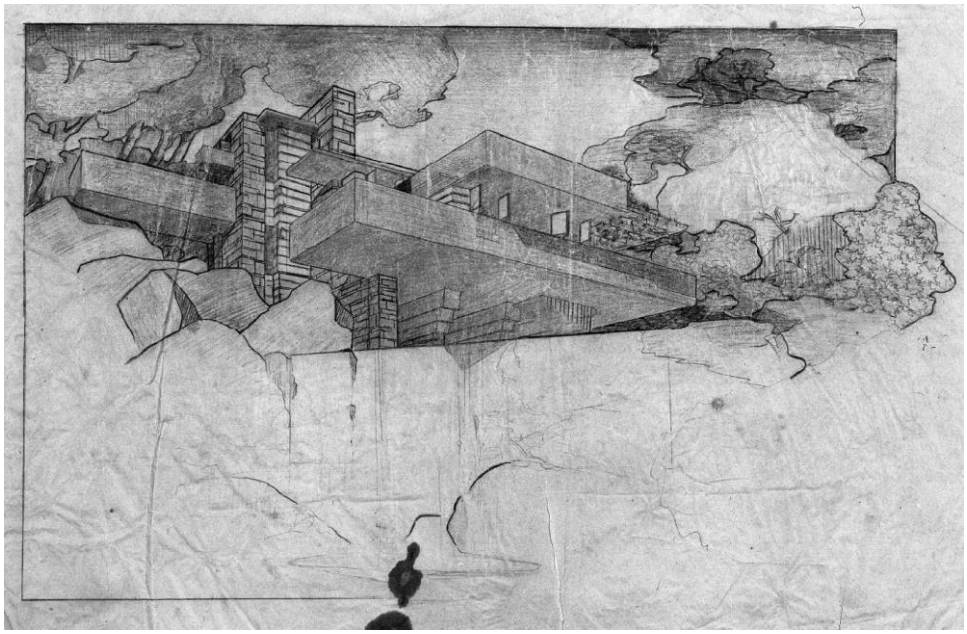

Figure 2. Mr. and Mrs. Edgar J. Kaufmann's house (Mill Run, Pennsylvania). Fallingwater (Drawing number: 3602.051). Reproduced from Ref. [7].

Originally conceived as a family vacation home, Fallingwater comprises a main house and a guest house. The main house, the primary subject of this analysis, is characterized by its extensive exterior terraces, which make up half of the total area, and its distinctive placement over a waterfall. Today, Fallingwater and its surrounding properties are part of the Bear Run Nature Reserve, with its conservation and management led by the environmental organization WPC, under the direction of Justin Gunther.

The Kaufmann House, commonly known as Fallingwater, aligns with the period when Frank Lloyd Wright developed the "Usonian" concept, characterized by small, economical, practical, and comfortable homes that symbolically integrate habitation with nature. Edgar Kaufmann Jr., who closely observed the project's development, noted that Wright designed the structure around a central chimney mass situated directly on a large rock, from which various spaces extended [8]. This integration of site and architecture underscores the contextualist nature of the work.

Concrete served as the foundational element in Fallingwater, with cantilevers extending dramatically [9], given the construction technologies of the era. The design epitomizes horizontality, with the living room and upper terraces projecting at different heights above the densely forested valley. Concrete cantilevers represent a naturalistic formalization, extending Sullivan's "seed germ" metaphor to the entire structure rather than just its ornamentation. Within the house, the cave [9] features a descent from the living room to the waterfall, starkly contrasting to the ascent found in Wright's Guggenheim Museum.

Fallingwater is a groundbreaking example of innovative spatial and structural architecture principles. Wright's ambition was to forge a novel or "exotic" architectural style, as termed by Frampton [9], which diverged from traditional styles and was aligned with modern life [10]. This ambition is vividly expressed in Fallingwater, transcending historical constraints [10]. Wright's design embodies a natural state, capturing an authentic aspect of life typically obscured and tainted by external pressures and constraints. Frank Lloyd Wright adhered to a fundamental principle, creating architecture that was ultimately liberated from all forms of conformism and normative systems. While adopting some European influences—such as the use of reinforced concrete and the clear surfaces evident in Fallingwater—Wright profoundly transformed these elements, integrating them into his uniquely personal vision. This approach was consistent with his perspective from the outset of his career as an independent architect.

Bruno Zevi further contends that Fallingwater exemplifies the ultimate triumph over the constraints that have limited architecture for centuries. In this architectural masterpiece, the conventional "box" is entirely dismantled in a form of "four-dimensional decomposition" [8], where Wright prefigures and stimulates the objectives of Cubist exploration while also promoting the recognition and emergence of De Stijl poetics [8]. In Fallingwater, traditional walls, geometric patterns, symmetries, privileged perspectives, and rigid laws give way to principles of freedom and transformation [8]. Within this framework of freedom, Wright successfully incorporates material density and environmental *continuum* (Figure 3).

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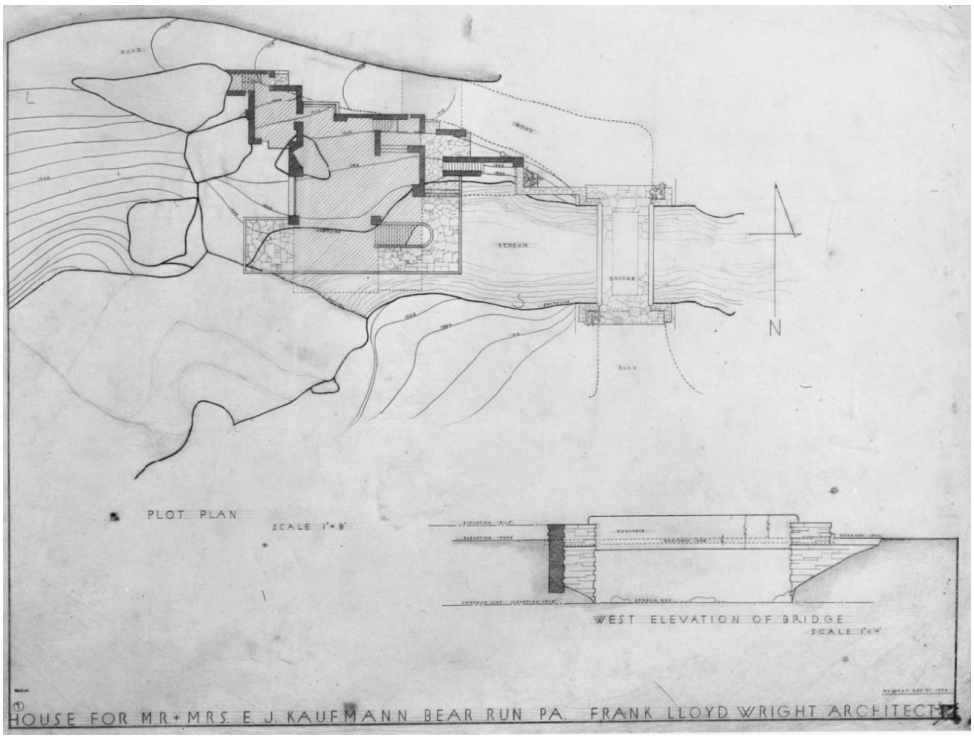

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Figure 3. (**a**) Stairs of Fallingwater—view from southwest of steps and bridge over the stream. Reproduced with permission from from Ref. [11]; (**b**) Kaufmann House, Fallingwater on Bear Run, Pennsylvania, 1935-1937, "plot plan" showing main floor bearing walls. Reproduced with permission from Ref. [12].

2.2. The Boa Nova Tea House

Zevi's concept of *continuum* is also evident in the contextualist work of Álvaro Siza Vieira, particularly in the Boa Nova Tea House. In this project, the architecture is inherently tied to its location. The prominently sacred rocky promontory demands an architectural program that is seemingly mundane: a tea house (Figure 4). However, the archetype of the Japanese tea house—*Chashitsu*—known for its ceremonial rites, imbues this program with a sense of spirituality. Siza's reference to *Chashitsu*, characterized by small wooden houses surrounded by a garden, is reinterpreted here in the context of the rugged rock formations and the coastal indentation facing the Atlantic Ocean. The site, resembling a "shell", was strategically chosen by ASV to protect the interior space, which opens to the exterior not through horizontal sliding panels like the *Chashitsu* but through vertical sliding panes of wood and glass.

Figure 4. Tea House—North View—2023. Reproduced with permission from Susana Milão, Photo_CIAUD-UPT, author archive, 2023.

The Boa Nova Tea House emerged from a competition organized by the Matosinhos City Council, which was won by Fernando Távora. Following the selection of a cliffside site on the Matosinhos coast, Távora entrusted the project to his then-novice collaborator, Álvaro Siza.

The construction of the Tea House spanned from 1958 to 1964. In the 1990s, a violent storm [13] caused substantial damage to the building's exterior and interior. In 2013, Álvaro Siza undertook a renovation project to restore the Tea House, maintaining its original architectural integrity.

Understanding the Tea House necessitates recognizing its integration into the site, where it establishes a respectful yet autonomous relationship with the surrounding environment. The seaward and rocky sides of the building feature exposed concrete, while the landward sides are defined by white walls. Siza Vieira remarked, "this experience proved to be an extremely useful exercise in refining the intensity of expression in such a rich context" [14] (p. 25). Additionally, he noted, "it was necessary to reconcile the autonomy of the building with the preexisting environment" [14] (p. 23) (Figure 5).

The architectural design consists of a rectangular floor plan with an irregular shape, supported by a jagged reinforced concrete base and distinct roofs of varying inclinations, complemented by two simple, plastered, and white-painted chimneys. The walls are minimally protrusive, integrated into the rock, and even camouflaged by it. The seaward-facing walls feature large glass windows with wooden frames, while the landward walls are partially buried, plastered, and painted white, with the main entrance situated on the eastern side. The façades are finished with wooden cornices, and the floors and ceilings are also constructed of wood.

Peter Testa [15] notes that "the volumes and forms of the roofs are the outcome of a meticulous on-site study of the rocky promontory. The floor plan reflects the strategy of accommodating the geological structure and articulates two main rooms connected by an atrium. Various openings enhance the bond with the landscape, such as the horizontal windows that slide below the floor and the restaurant that opens onto a stone terrace. Overhanging eaves extend the jacaranda ceilings, providing protection and modulating the intense Atlantic light".

Approaching the Tea House involves ascending a series of steps along a winding path that offers views of the ocean and surrounding rocks. This journey evokes Japanese tea ceremony traditions, where guests walk along a garden path called *roji* before entering the tea room, setting the appropriate mood for the ceremony [16]. Upon entry, visitors

must descend again, reminiscent of the *Sukiya*-style Japanese residences where entering a tea pavilion required a brief stop and a bow to pass through the small rectangular *nijiri-guchi* entrance. Descending the stairs leads to the dining room, emphasizing the horizontal nature of the space, where the windows fully lower, enhancing the seamless connection between the interior and exterior wooden ceilings.

The Tea House is described as a work "in the style of Aalto but with touches of Mackintosh and Wright" [17] (p. 11), underscoring the undeniable link with Fallingwater, where Japanese influences are also evident. These influences manifest in the use of materials, the integration with the surrounding nature, the waterfall, and the horizontality of the spaces. Bruce Brooks Pfeiffer notes that Frank Lloyd Wright's Fallingwater related its occupants to the ravine and surrounding nature, making it an integral part of daily life. Similarly, the Tea House is "carefully integrated into a rocky outcrop that, in certain places, almost seems to invade the interior space", serving to highlight the site, much like Japanese houses that pay homage to nature [18] (p. 15). Siza's early works, particularly the Tea House, align with a Neoregionalist stance, blending tradition with modernity, and artisanal culture with industrial processes, which are continuous themes in his architectural exploration. Nuno Portas, a prominent voice of the new "organic" generation, also acknowledged this aspect in his writings in the magazine *Arquitectura* [17].

The twisting and variety of the house's planes and volumes, its immersion among the rocks on which the roofs seem to rest, stand in clear contrast with the clarity and volumetric simplicity of the classical chapel nearby, and the way it was placed on the site was oriented considering the prevailing winds. The modern attitude that shaped the project reflects a compromise with the "natural" values of the site, identities perceived as just as important as those of the modern work and always more or less threatened by it. In this context, Wright's influence is evident, particularly regarding the interaction of the white plastered walls of the house with the rocks, granting the latter a certain autonomy as motif and form. The architectural elements—white color, twisted volumes, prominent lanterns and chimneys—serve to formalize the natural elements, transforming rocks and horizon into representation, form, and style [17].

Bernardo Huet observes that these works also address the political–cultural concerns of the Porto group (North Portugal). They explore the expressive potential of natural materials, exhibit refined artisanal detailing, and feature direct references to white walls. Despite these influences, Siza's early works possess a unique quality that evolves, becoming what Gregotti describes as an autonomous archaeology made of all the stratifications of previous trials [19].

The Tea House critiques the coldness of international modernism and, as Kenneth Frampton notes, exemplifies "critical regionalism" with parallels to the architecture of Alvar Aalto and Frank Lloyd Wright, particularly Fallingwater. In the 2024 tribute by the International Committee of Architectural Critics (CICA) in Porto, Siza Vieira emphasized Fallingwater's influence, including it in his list of references. He recalled his visit to the site, highlighting its domestic scale and immense architectural value, which influenced his early work.

Furthermore, the interplay between esthetics and ethics in the international discourse on modernism finds a distinct echo in Portugal, particularly through the work of Siza Vieira, as discussed in both national and international editorial platforms and by authors such as Nuno Portas and Pedro Vieira de Almeida. However, it is through Vittorio Gregotti and the publication of Bruno Zevi's History of Modern Architecture in the 1970s, which included a chapter on the evolution of Portuguese architecture, that a more pronounced international recognition was achieved.

The Boa Nova Tea House, as a singular project in Siza's oeuvre, is seen by Nuno Portas as a deep exploration of interior space, marking a departure from the brutalist principles evident in other works, such as the Parish Center and the Lordelo Cooperative, including the Ocean Swimming Pool, known for its prominent use of exposed concrete. The architectural "promenade" ascending to the spiritual place [20] in the Tea House,

combining erudite and popular cultural references, can be seen during the critique of modernism as a paradoxical and contradictory response to a "third way" (concept by Fernando Távora merges modern and traditional architecture, balancing contemporary and vernacular elements, as discussed in his 1945 work "*O Problema da Casa Portuguesa*") approach to modernism.

In conclusion, it is possible to consider that Jokilehto's categorization of "recent built heritage" [1] allows us to move beyond confining ASV's work to the category of modern architecture and opens up new avenues for interpretation and theoretical framing within architectural theory.

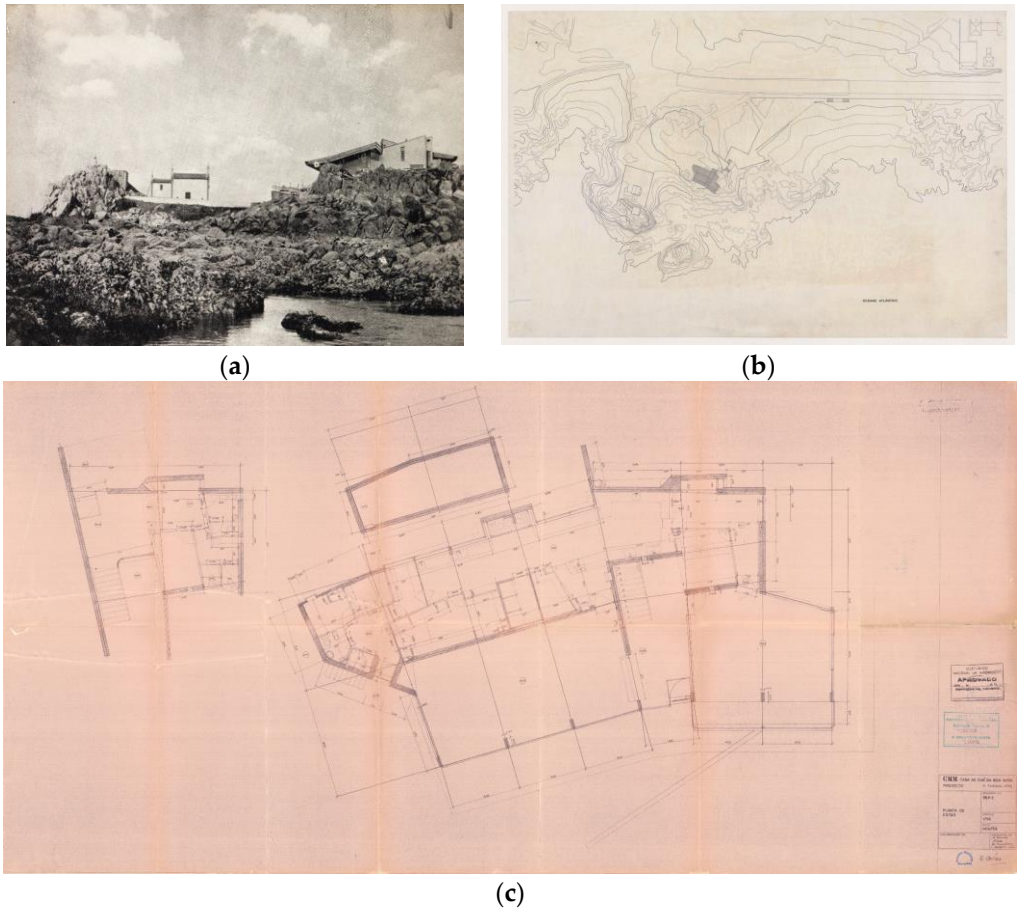

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Figure 5. (**a**) Tea House—view from the sea and proximity with the Boa Nova Chapel. Reproduced from Ref. [21];(**b**) Tea House—general plan. Reproduced from Ref. [21]. ; (**c**) Tea House, plan. Reproduced from Ref. [22].

3. Technological Innovation and Constructive Characterization

3.1. Fallingwater

The structure of Fallingwater consists of reinforced concrete slabs and roofs, cantilevered beams, reinforced concrete pillars, and load-bearing walls made of local sandstone masonry. Through the combination of reinforced concrete and glass with suspended horizontal planes, Wright's architecture creates an illusion of weightlessness. However, this innovation carried risks. It was later found that insufficient steel reinforcement was used to support the concrete structure of the first floor. Kaufmann initially doubted the technical feasibility of Wright's concept and hired consulting engineers to examine Wright's plans. Their recommendation for additional reinforcement of the main floor beams was rejected by Wright, but modifications were made during construction. Over time, the building exhibited structural problems [23].

The terraces and roofs are supported by inverted beams hidden within the slab and have irregular stone flooring. The system consists of concrete joists placed perpendicularly to the beams. Originally, the terrace floors were not waterproofed, nor were the areas where the concrete met the stone. According to Pamela Jerome [24], Wright's interest in the interpenetration of one building material by another (concrete parapets and slabs with stone walls) and the seamless interior–exterior transition posed additional construction challenges. Wright aimed for continuity between the roof and the concrete, using beige-colored gravel as the final layer (Figure 6).

The parapets of the cantilevered balconies are also made of reinforced concrete with rounded ends. All concrete is covered with a 1/4-inch-thick layer of white cement stucco and then painted light ochre. Wright originally proposed covering the concrete with gold leaf, which the owner deemed inappropriate [24]. The exterior color of the concrete is part of a certified color palette based on conservation research. Between the concrete and stone, metal frames were originally painted in Venetian red, later changed in the 1970s to Cherokee red. These frames are characterized by the absence of vertical corner profiles, a solution first used by Wright in the early 1920s in the Hollyhock House and Freeman House projects [24].

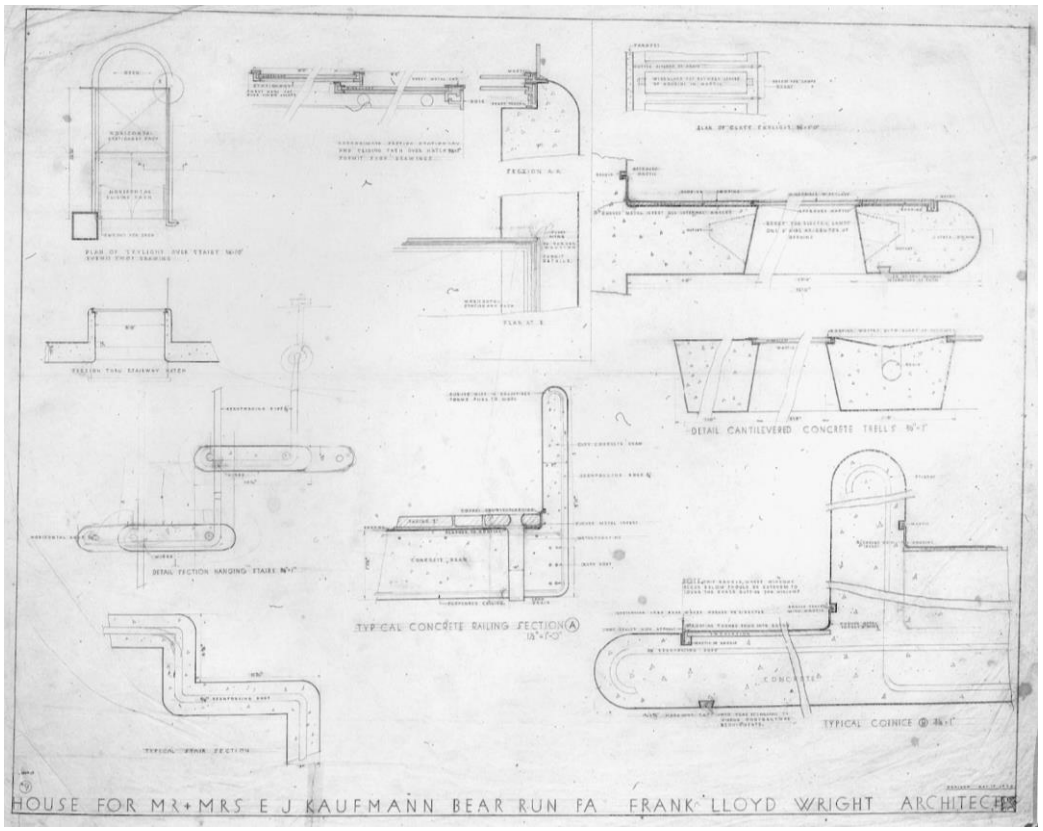

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Figure 6. Detail of the concrete edge. Reproduced with permission from Ref. [12].

The original concrete mix consisted of cement, sand, and river gravel with an average diameter of 1.5 cm. The mortar's poor adhesion to the rounded gravel led to cracks and concrete crumbling. After more than eighty years, structural weaknesses have become apparent, due to the innovative nature of the construction and the possibility that the detailed design was not fully or properly executed.

The main conservation issue facing Fallingwater is the deterioration caused by moisture penetration. The building's permanently humid environment, built on a slope and

over a stream surrounded by vegetation, exacerbates rain and snow infiltration through its structural weaknesses [24].

3.2. The Boa Nova Tea House

The Boa Nova Tea House (Siza, 1958–1963) is based on the use of traditional architectural elements such as wood carpentry and wood ceilings, along with innovative materials like reinforced and cyclopean concrete and copper. Siza employs reinforced concrete for the foundations, entrance slab, and exterior walls (Figure 7). The entire surrounding area, as well as the basement, is supported directly on the rocks or cyclopean concrete walls. The building's pitched roofs are formed by a structure of reinforced concrete and brick slabs. The exterior cladding is Roman ceramic tile, placed over concrete beams anchored to the slabs. These beams have small openings to drain rainwater. Copper is used in the gutters and roof coverings. The interior walls, made of stone or brick, rest on reinforced concrete foundations, plastered and painted white. Afzelia wood is used in ceilings, interior floors, and carpentry [25].

The first architectural restoration campaign led by Siza on the Tea House was in 1991–1992. This was his first intervention in an earlier work and, in his words, an important experience for his subsequent works on pre-existing buildings. Initially intending to modify his original project, Siza ultimately refrained, recognizing the importance of respecting the integrity and coherence of the pre-existence [26].

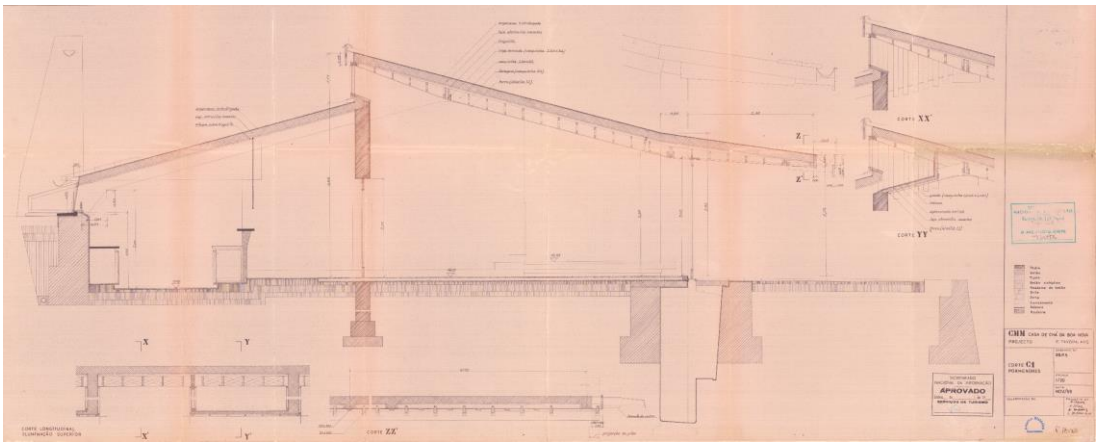

Figure 7. Details. Nov. 1959, signed by Fernando Távora architect. Reproduced from Ref. [22].

During an interview at Architect Álvaro Siza's studio with collaborator Cristina Ferreirinha (information gathered during the authors' visit to the studio of Architect Álvaro Siza. Interview with collaborator Cristina Ferreirinha, who was involved in the 1991 rehabilitation. Visit on 17 June 2024, Porto (Portugal)), who participated in the 1991 architectural restoration, and after examining the archive, a comprehensive list of works needed for the rehabilitation of the Boa Nova Tea House was reviewed. At the time, following multiple site visits and a detailed analysis of the building's state of conservation, Siza determined that, despite the building being in generally good condition, maintenance and conservation efforts were essential, particularly for the infrastructures and materials that were most deteriorated by the seaside location. The intervention was primarily maintenance-focused rather than extensive, with significant attention given to infrastructural improvements, such as integrating air conditioning, a crucial requirement of the new concession for the Tea House (a restaurant). Additionally, it was necessary to create an extension to accommodate a gas installation, leading to the construction of an external facility for gas storage.

This intervention ensured that the Boa Nova Tea House was modernized and preserved, maintaining the functional and esthetic integrity of the original design while updating essential infrastructure and amenities.

The second intervention that Siza undertook was in 2013, due to a new concession of the property. Previously, the Tea House had been abandoned and vandalized, the copper and some furniture had been stolen, and parts of the windows and some ceramic pieces had been broken. However, the state of conservation of the interior was considerably good.

According to Siza, the biggest challenge in conserving the Tea House was its coastal location, as it is constantly exposed to agents that considerably deteriorate its materials. Due to its coastal location, chlorides from saltwater penetrate the concrete, causing local corrosion and detachment [26].

4. Conceptual Linkage

4.1. Attributes and Features in Both Sites and Buildings

The Operational Guidelines for the Implementation of the World Heritage Convention [19] and the criteria for outstanding universal value (OUV) provide a framework for assessing the outstanding universal importance of a property (Table 1). Depending on the type of cultural heritage and its specific context, a property may be considered to meet the conditions of authenticity if its cultural values (as recognized in the nomination criteria proposed) are truthfully and credibly expressed through a variety of attributes, such as the following:

a) Form and design: use and function

Fallingwater is typologically linked to Frank Lloyd Wright's Usonian and Prairie Houses, with the Gale House, built in wood in 1909, being the progenitor of the general type of Prairie Houses [27].

The construction of the bridge over the creek leading to the house showcases a clear influence of Japanese architecture, evident in the drawings and postcards collected by Frank Lloyd Wright. This influence was first implemented by Wright at Taliesin, particularly in the design of the hydroelectric power station over the waterfalls. The Willey House serves as a foundational reference for the Usonian model, highlighting advancements and extensions in roof design and the seamless integration of interior and exterior spaces. Meanwhile, the Freeman House, notable for its use of "textile blocks", exemplifies the concept of balconies that extend and enhance the openness of interior spaces. These elements reflect Wright's innovative approach to blending architectural styles and techniques to create harmonious living environments that bridge natural and built spaces.

Despite addressing a non-residential program, the Tea House assumes a language with strong affinities with other works and projects by Álvaro Siza Vieira. Furthermore, the Tea House establishes conceptual connections with a preceding work, specifically the Carneiro de Melo House in Porto (1959). Other succeeding works and projects include the Luís Rocha Ribeiro House in Maia (1960), the Ferreira da Costa House in Matosinhos (1962), the Rui Feijó House project in Moledo do Minho (1963), the Alves Santos House in Póvoa de Varzim (1964), and the Alves Costa House in Moledo do Minho (1964), culminating this cycle with the Manuel Magalhães House in Porto (1967). The latter fits into ASV's "brutalist" language, like the Ocean Swimming Pool and the Lordelo Cooperative, where there are exposed concrete predominates, and the cantilevered pitched roof is no longer present.

b) Materials and substance: traditions, techniques, and management systems

A significant structural similarity in both FLW and ASV is the use of cantilevered concrete structures. The extended sloping roofs of the Prairie Houses emphasize horizontality and continuity with the prairie landscape. At Fallingwater, the roof is already flat and the veranda fits into a morphotype that combines two horizontal planes [27]. The use of reinforced concrete was also initially considered for the Gale House but was rejected

for economic reasons [28]. The formal precedents present in Wright's Prairie Houses and Taliesin, already in concrete and with sloping roofs, will be transformed with Fallingwater into roofs and horizontal planes. The concrete with Wright is coated and painted, and although concrete was a fundamental structural material in the construction of the Fallingwater, it is not apparent in the final work. However, in the case of ASV, the concrete is structural and apparent in some vertical planes, almost like the foundations (structural elements) emerging from the rocky ground. The concrete and cantilevered roof, however, is covered with ceramic tiles on top and wood on the eaves and underside.

The cantilever at Fallingwater, and the structural solution in reinforced concrete, were indeed innovative, but it was also these elements, associated with waterproofing, that caused the most problems. On the other hand, in this work, the conciliation of stone masonry (walls and floors) with the use of concrete, metal window frames, and the design of the furniture is integrated into the total work. As a result, the restoration and heritage intervention at Fallingwater involved understanding the authenticity and integrity of the project and the work.

In the Tea House, concrete was already a common construction technology which, when combined with more traditional materials and technologies such as ceramic tiles and wood for the eaves and window frames, guaranteed a safer response. From a structural point of view, the cantilevered solution is relatively restrained. In this case, the author, Álvaro Siza Vieira, was directly involved in the restoration and reconstruction processes. Indeed, the adequacy of technical solutions (air conditioning and ventilation) is integrated into the design of the furniture and some architectural elements.

The covering of the concrete cantilever with wood in the Tea House and the mortar covering with rounded tops in the Fallingwater protect, on the one hand, the support but require more maintenance due to the water and humid environment.

c) Location and setting: spirit, feeling, and other internal and external factors

The placement of the construction in a rocky and rugged place is common in both works. The location of the Tea House on the coastal zone facing the Atlantic Ocean in the European continent, and the Kaufmann house over a waterfall in a natural park in the interior of the American continent, places the two unique buildings in the presence and influence of fresh and salt water. Weisberg highlights Frank Lloyd Wright's fascination with water, evidenced by his collection of Japanese photographs and woodcuts of houses near waterfalls, dating back to at least 1905, the period during which the Imperial Hotel project in Tokyo was carried out. In fact, at Taliesin, Wright had built a small dam to create an artificial waterfall and a hydroelectric power plant [27].

The exceptional locations of the Tea House and Fallingwater, one on the coast and the other inland near a waterfall, demonstrate the architects' shared interest in integrating their designs with the distinctive natural features of the respective sites. Both Siza and Wright use the built environment with the presence and influence of water, whether fresh or saltwater, as a defining element of the genius loci, or "spirit of place" [29].

Fallingwater is deeply integrated with the natural landscape of the Bear Run Nature Reserve. The architect intentionally situated the home directly over the waterfall, allowing the flowing water to pass underneath the cantilevered concrete terraces. Similarly, the Boa Nova Tea House designed by Álvaro Siza Vieira demonstrates a sensitivity to integrating the built environment with the natural landscape. Siza's design approach, like Wright's, embraces the relationship between the constructed and the natural.

External factors such as legislation, soil classification, and property ownership guides determine the degree of protection and the measures that can be implemented.

The coastal zone in Portugal is considered part of the public maritime domain with a defined status since the late 19th century and legal framework and competencies assigned to the central government. The Coastal Zone Management Plans (POOC) have been in effect since the late 20th century. These plans set protection regimes for natural resources and values, defining permitted, conditioned, or prohibited activities in the terrestrial protection zone (up to 500 m from the coastline) and the maritime protection zone.

The deliberation on building projects in the coastal zone in Portugal involves the action of various public stakeholders, namely the municipality and the Regional Coordination and Development Commission.

The construction of the Boa Nova Tea House by Siza Vieira occurred in 1963, long before the implementation of the POOC in Portugal. Currently, not even the exceptional approach of the program and architecture could guarantee its existence.

On the other hand, in the USA, the Western Pennsylvania Conservancy (WPC) has a significant responsibility in preserving and managing the Bear Run Nature Reserve, which is deeply integrated with the iconic Fallingwater house. The WPC has developed a conservation plan that guides the protection and restoration of land and water, promoting the diversity of the region's native ecosystems. They also manage the reserve's trail system and issue permits for certain activities to regulate public use. This organization has been actively acquiring additional land to expand and protect the Bear Run Nature Reserve. In 2019, they purchased forested property near the Fallingwater entrance to safeguard the scenic views and landscape. Protecting these lands is crucial to maintaining the integrity of the natural environment that is so intrinsic to the Fallingwater experience [30].

In summary, the Western Pennsylvania Conservancy has a comprehensive responsibility for the long-term stewardship and management of the Bear Run Nature Reserve, while in Portugal the responsibility lies with the government through various entities—state and municipal—and territorial plans. While Fallingwater's management complexity is well documented, the Boa Nova Tea House presents a more nuanced scenario. The lack of readily available information and limited public access to details about the conservation efforts highlight the need for greater transparency and openness regarding the management and preservation of this significant structure. Both buildings, taking into account the protection of territories and natural ecosystems, could not be built, and paradoxically, due to their uniqueness and respect for the environment, they are a reflection of an era.

Table 1. Comparative analysis—component features and attributes.

FALLINGWATER /KAUFMAN HOUSE	BOA NOVA TEAHOUSE
Form and design; use and function: Main house (holiday) and Guest House, including bridge across the stream. Cantilevered house over a stream/waterfall; Extended upper balcony. Cultural Tourism - WPC	**Form and design; use and function;** Construction on the geological structure of the rocks. Incline roofs; Rectangular plan, irregularly shaped, resting on a reinforced concrete platform. Tea house, restaurant, Cultural Tourism.
Materials and substance; traditions, techniques and management systems: Support pillars on geological rock structure. Beams supported by the rocky escarpment. Walls and floors in local stone masonry. Steel-reinforced concrete balconies with internal grid structure. Flat roof and cantilevered balconies. Structural stone masonry walls. Combining traditional techniques (Stone walls) with innovative construction technologies (concrete).	**Materials and substance; traditions, techniques and management systems:** Sloping roof with pillar and beam structure and reinforced concrete slab. Tiled roofs with prominent cantilevered eaves. Long, horizontal windows with a recess in the floor (west elevation). Sloping ceilings clad in wood and copper sheeting. White chimneys (formal elements) finished with simple eaves. Combining traditional techniques (wood and concrete).
Location and setting; spirit and feeling; and other internal and external factors: Location on the north bank above the waterfalls. Access path through the park and forest, crossing a bridge as part of the Japanese tradition of approach. A response to the Kaufmanns' desire to live in the park near the waterfall Small area of flat open land on the north bank. Close contact with the water, intimate experience, accessed by stairs from the inside. Natural Park and reserve.	**Location and setting; spirit and feeling; and other internal and external factors:** Location on the Atlantic coastline. Access path (promenade architecturel) between a view of the sea and the rocks that surround the building; Approach ritual, Japanese tradition. Construction integrated into the rocks with reduced visual impact; Slope exploited to accentuate interior views of the sea. Religious and symbolic place, small church nearby. Protect coastline.

4.2. Conservation Works and Plans Developed in Both Sites and Buildings

In the Tea House (1958-1963), there were two periods of heritage interventions, the first in 1991-1992 and the most recent in 2012-2014. The property belongs to the municipality, and despite being in the public domain and covered by territorial agencies, it has been granted a concession for private and commercial use.

The Kaufmann house (main house)—Fallingwater—built between 1936 and 1937 and completed with the guest house in 1939, according to the WPC chronology, opened to the public as a museum in 1964 and has been on the National Register of Historic Places since the 1970s, and in 2019 it was classified by UNESCO (serial nomination).

Both buildings, iconic works of architecture, have restoration as a common degree of heritage intervention. The conservation approach initially responds to risk, functional, and esthetic issues, considering the constructive weaknesses in the face of the work's innovation (Figure 8).

At Fallingwater, the restoration was due to structural problems associated with the concrete consoles (and the water access staircase) and, just as the construction solution was innovative for the time, the repair methods used were also experimental and precursory (for instance, the combination of steel, stainless steel, and carbon fiber reinforcement with the use of high-strength steel post-tensioning). The building was permanently monitored and documented until 1955, and the process is deposited in the Avery Library Archives at Columbia University. The concrete finish made it possible to compensate for the extensive repair work [31].

After 50 years of construction and a continuous process of repairs, the largest flood since 1956 occurred in 1989. In other words, the condition of the site raised questions about maintenance and how to respond to the extreme conditions caused by the presence of water.

The first moment of intervention consisted of developing studies and research to support conservation actions. The second moment relates to a comprehensive exterior restoration program, work divided into several phases to maintain public visits. Due to chronic leaks, the restoration involved the reconditioning of all roofs and the waterproofing of all terraces. In addition, there were widespread failures of the stuccoed concrete surfaces. The steel door and window frames were corroded. The stuccoed concrete and steel features were restored as part of the construction project. Certain features were to be reconstructed, such as the stairs to the creek, which were already a failed reconstruction; this was decided only after several attempts by WASA to use trowel-applied patching, and cast-in-place patching also failed [32]. Disassembly and reassembly of the stone walls adjacent to the path to the guesthouse under the stepped canopy, which had shifted due to frost, were also included as part of the project, along with the restoration of the leaking skylights.

The third moment corresponds to the present and the obtained information arises from the contact made with the architect in charge of preservation at WASA/Studio—Pamela Jerome. After the UNESCO World Heritage inscription in 2019, a campaign to raise funds started. This was only in 2022 through the "World Heritage Preserved: Forging a Future for Fallingwater" campaign that made it possible to start a major preservation work in the building. And once again, WASA was called back to work on the building.

According to Pamela Jerome (contact established by email with Pamela Jerome between March and May 2024), there had not been a preservation master plan since the first major intervention in 1988. The first one, co-authored by her and Norman Weiss, was produced in 1999 and updated in 2019. Moreover, there was no restoration project in the 1980s (the house was constantly being repainted, and in 1988, an unsuccessful re-roofing/waterproofing of the terraces was carried out). The first holistic restoration of the building took place in 1999–2002. The type of waterproofing system was tested through the application of several in situ trials that were monitored over a year.

The final solution was an opaque water-repellent stain that was applied on the concrete surfaces as a finishing coat. In this way, it was possible to see what worked and what failed and adjust the design approach accordingly.

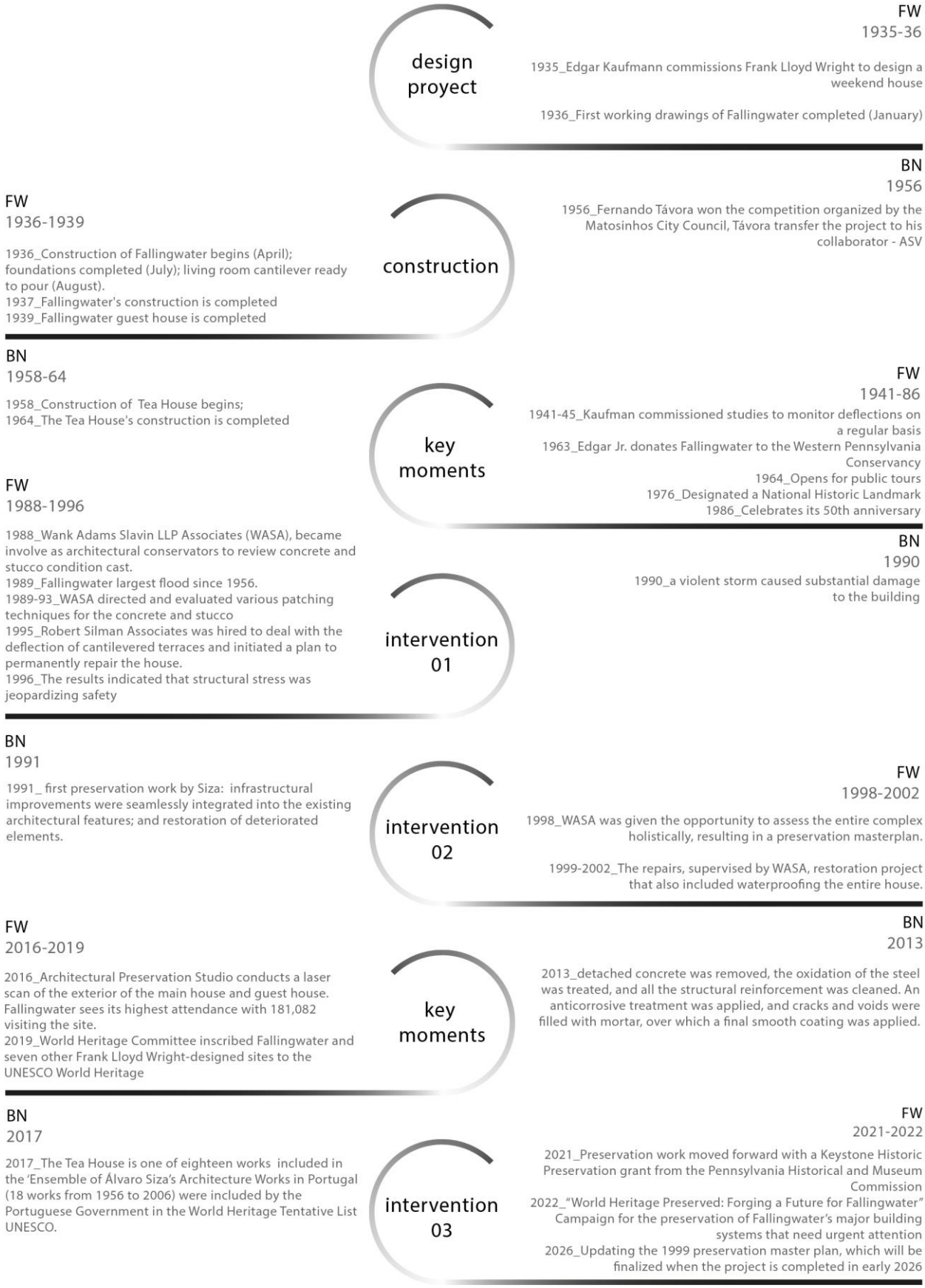

Figure 8. Comparative analysis of both sites and buildings—Fallingwater (FW) and Boa Nova Tea House (BN). Diagram produced by the authors.

In architectural heritage, the degree of intervention can reflect different approaches, from maintenance to reconstruction and adaptation, and depends on the author and the subject responsible for the action and the project. These different levels of intervention can be combined in the same work, depending on the objectives and impacts sought. Actions can range from less invasive interventions, such as maintenance, to more in-depth interventions, and it is possible to apply a combination of degrees of intervention in a single heritage project to respond to specific needs and adequately preserve the cultural asset [33,34].

At the time of designing the Kaufmann House, Wright was a veteran American architect with over 45 years of experience, while Siza, at the time of designing the Boa Nova Tea House, was among the young architects emerging in Europe and Portugal as an alternative in the re-evaluation of modern architecture. However, heritage preservation in these two cases was different.

The role of the owner's son, Edgar Jr., in the Kaufman house was fundamental, not only because of his specific knowledge of the disciplinary area of architecture but also because of his connection to the world of art and culture, namely the MOMA. With the donation of the house in the 1960s and FLW's death in 1959, the research carried out by the conservation and restoration teams in the 1980s involved resorting to primary sources by consulting the builders and architects who collaborated on the project (Figure 9)—on display at Columbia University—and the process of documenting and monitoring the building over the decades, including from the initial occupation and immediately after the work.

Figure 9. Edgar Kaufmann Jr.'s 1963 comments at the Fallingwater transfer ceremony deeming the house a public architectural masterpiece and a natural resource to be conserved by the Western Pennsylvania Conservancy. Reproduced from Ref. [35].

At the Boa Nova Tea House, Siza's involvement in the restoration and conservation process was permanent. In the 1990s, the building in question underwent its first restoration intervention, in which the architect played a crucial role. His work was not only

limited to architecture but also extended to creating furniture for adaptation and responding to the introduction of air conditioning systems. In March 2011, this building was classified as a National Monument, along with the Piscina das Marés, also designed by ASV. This classification reinforces the historical and cultural importance of the building, recognizing it as a heritage site to be preserved. The restoration work carried out in the 1990s, under the guidance of the architect, allowed the architectural and esthetic integrity of the building to be maintained.

The architects of the modern era used exuberant new materials that were not fully understood in terms of their long-term performance. The mistaken idea that modern buildings required low maintenance exacerbated many of the issues with materials and construction, such as early material failures, inefficient details, and poor energy performance [36].

The original architects of modern buildings are not always successfully consulted or involved in major conservation works, despite requests from statutory heritage bodies. The creator tends to take an evolutionary approach that is primarily esthetics-based, both to the building itself and in terms of their design development. This suggests that while the input of the original architect can be valuable, the most effective conservation solutions may come from a careful analysis and interpretation of the original design rather than relying solely on the architect's vision [36].

However, ASV in both architectural restorations demonstrated that its position of minimal intervention and the principle of neutrality were guaranteed. In FW's intervention, the principle of authenticity and integrity prevailed over the work and stemmed from the technical quality of the teams and the associated architectural restoration.

5. The Challenges of 20th-Century Built Heritage Facing Water

5.1. Materials Degradation

Water consistently emerges as a prominent degradation agent in material conservation studies across various substrates [37]. Within the domain of concrete structures subjected to marine and freshwater environments, water assumes a pivotal role as a catalyst for multifaceted degradation processes. Understanding the intricate interplay between these degradation mechanisms is paramount for elucidating the comprehensive degradation profile of concrete when exposed to water surroundings. The degradation of reinforced and unreinforced concrete within marine and freshwater environments can be divided into physical phenomena such as freeze–thaw cycles, mechanical processes including erosion and abrasion, chemical degradation mechanisms typified by sulfate attack, carbonation, calcium leaching, and chloride-induced corrosion, biological influences characterized by biogenic attacks, alongside structural overloading [38,39]. Moreover, reinforced concrete represents a higher challenge due to the corrosion of the steel structure, which represents one of the main concerns in conserving 20th-century built heritage [40].

Chemical actions stemming from the composition of water contribute to the hydration products of cement, engendering intricate reactions that undermine the structural integrity of the concrete. Concurrently, the crystallization pressure of salts within the concrete matrix, exacerbated by alternating moisture and dry conditions, poses a challenge, particularly along exposed surfaces. Corrosion of embedded steel within reinforced or prestressed structures emerges as a pervasive concern, precipitated by the corrosive environment inherent to humid environments. Physical erosion, catalyzed by the relentless force of direct water contact, further exacerbates the degradation trajectory of concrete structures [41].

The permeability of concrete is a critical parameter in assessing its durability, intimately tied to its inherent porosity [39]. This porosity is largely governed by the composition ratio of cement, water, and aggregate constituents, as well as the temperature and duration of the curing process [39,42]. Within the matrix of concrete, the presence of capillary pores serves as the primary conduit for permeation. Particularly, under elevated

porosity conditions, an interconnected network of capillary pores facilitates direct communication between the concrete's surface and its interior, thereby accentuating its permeability profile [42].

There is a direct relationship between porosity and water absorption; concrete structures with higher porosity present a higher coefficient of water absorption [43]. Moreover, freeze–thaw cycles drastically accentuate the degradation phenomena in such highly porous structures. The expansion of frozen water produces pressure on the cement matrix, resulting in microcracking and material deterioration [44].

When addressing concrete built heritage conservation, understanding the material is of paramount importance. As previously mentioned, 20th-century architecture was fairly experimental, not only in a plastic and esthetic perspective but also in terms of the material and construction techniques. In the first buildings, concrete was poorly cast and there were few standards and regulations for the construction systems. Additionally, there was a general notion that concrete was almost "eternal", and this wrong idea of the material's durability was associated with low (or inexistence) maintenance [45]. All these factors contribute to the challenges related to the conservation of concrete.

In the case of Fallingwater, two main factors deeply influenced the building's degradation: the design and the water. Regarding the latter, part is also inherent to the structure's design due to the lack of impermeabilization and the exposure of the concrete surfaces, which resulted in infiltrations and moisture penetration. Furthermore, the building is located in an extremely humid environment, surrounded by nature and with a stream that crosses under the cantilever [24,31] (Figure 10a).

In the case of the Tea House, water and the structure's design are again the two main agents of degradation. The proximity to the ocean leads to several degradation phenomena in the building not only by the direct action of water in the materials but also by the constant sea salt impregnation. As a consequence, there were two restoration campaigns, one in 1991/1992 (after a storm) and in 2012-2014. While in the first intervention the main focus was on repairing external degradation phenomena that occurred after the storm and the seamless integration of new infrastructural equipment in the interior, the second intervention was performed after a longer exposure to the sea environment and a consequence of an abandoned state. In the latter, the main degradation phenomena identified was in the reinforced concrete. Detachments, cracks, and erosion due to the corrosion of the reinforcing steel, exposure to chlorides, and undergoing carbonation were found (Figure 10b) [26].

(**a**) (**b**)

Figure 10. The relationship with water. (**a**) Fallingwater. Reproduced from Ref. [11] and (**b**) Tea House. Reproduced from Ref. [5].

Water is a permanent element in these two iconic buildings, existing in all forms: liquid from rain, stream, and ocean; moisture due to the humid environment; and ice during winter. Consequently, a conservation and maintenance plan is fundamental to ensure the preservation of each building.

Even though the conservation of 20th-century heritage still represents a challenge, in the last few years, more attention from academia and professionals has been given to this issue. Research, publications, and conferences, alongside international regulations and charters, are fundamental to creating awareness and establishing good practices in the preservation of twentieth-century architecture.

5.2. Monitoring and Maintenance

Regular monitoring and maintenance of the conditions and risk factors affecting concrete are crucial for extending the efficacy of conservation efforts and ensuring the longevity of built heritage. These activities, integral to the building's comprehensive maintenance plan, should be considered essential conservation measures as they significantly reduce the need for extensive interventions that could lead to the loss of original material. To safeguard the original concrete, as well as any applied repairs or treatments, a dedicated budget, adequate access to the concrete, and the engagement of skilled maintenance personnel with clearly defined roles and responsibilities are necessary. By incorporating these measures into the maintenance plan, the building's durability and historical integrity can be effectively preserved.

In the literature, monitoring and maintenance plans for heritage concrete buildings commonly refer to the importance of establishing a team of specialists and technicians with proper know-how and skills, which should follow a well-defined program of conservation actions. This maintenance plan can include periodic inspections (roof, drainage, flashing, structures, finishings, air filters, joinery), which can result in single cleaning actions, minor repairs, and replacement of expired protection products or finishings. Additionally, measurement systems such as humidity and temperature meters, fissurometers, and structural sensors (vibrations or other movements) can provide vital information that helps to identify risk factors and mitigate degradation phenomena. Registration and documentation are extremely important to ensure the correct follow-up maintenance works [2,3,40].

When addressing World Heritage, maintenance is a crucial issue. UNESCO refers to the importance of monitoring and maintaining architectural heritage as a way to ensure the preservation of its outstanding universal values [46]. Moreover, maintenance performed by specialized teams that respect the authenticity and integrity of the buildings can also avoid the loss of the age patina [36]. The assessment of the place's significance and the knowledge of the existing materials and construction techniques are equally important when designing a conservation or maintenance plan.

The maintenance plan for the FLW serial nomination recognized by UNESCO presented in 2019 encompasses several key elements (Based on the information available on the UNESCO website https://whc.unesco.org/en/list/1496/documents/ accessed on 14 August 2024): it ensures legal protection through listings on the National Register of Historic Places and National Historic Landmarks, involves the Frank Lloyd Wright World Heritage Council for coordinated management, and establishes visitor management principles to enhance the visitor experience while respecting the buildings' integrity. Additionally, the plan emphasizes community involvement and utilizes various conservation and management instruments to address the unique needs of each site, all aimed at preserving and maintaining the architectural significance of Wright's works. In the case of ASV, there is no specific maintenance plan mentioned for the Ensemble of Álvaro Siza's Architecture Works in Portugal as part of its UNESCO tentative list submission. However, Álvaro Siza's approach to conservation and maintenance is well documented [26]. Siza advocates for ongoing maintenance to prevent decay, especially in modern buildings that use industrialized materials, which may be more vulnerable to deterioration. This approach

suggests a focus on continuous care and preservation rather than sporadic rehabilitation, ensuring the longevity and authenticity of his architectural works.

On the other hand, the periodic reporting process for UNESCO World Heritage sites is a structured system designed to ensure the ongoing evaluation and preservation of inscribed properties. UNESCO recommends that States Parties engage in periodic reporting, which generally occurs approximately every eight years (Based on the information available on the UNESCO website https://whc.unesco.org/en/periodicreporting/ accessed on 14 August 2024). This reporting schedule allows for regular assessment and helps maintain the integrity and authenticity of such culturally significant sites.

This process is particularly relevant for modern architectural works like those of Frank Lloyd Wright and Álvaro Siza, which are recognized for their significant contributions to modern architecture. Frank Lloyd Wright's serial nomination was inscribed on the UNESCO World Heritage List (UNESCO Website—The 20th-Century Architecture of Frank Lloyd Wright https://whc.unesco.org/en/list/1496/ accessed on 14 August 2024) in 2019. In contrast, the Ensemble of Álvaro Siza's Architecture Works in Portugal was submitted to the UNESCO in 2017 but has not yet been inscribed (UNESCO Website—Ensemble of Álvaro Siza's Architecture Works in Portugal https://whc.unesco.org/en/tentativelists/6224/). The tentative list serves as a precursor to full nomination, allowing States Parties to prepare and refine their proposals for eventual inscription.

Both Wright's and Siza's works highlight the importance of modern architecture and its relationship with the environment, often facing water, as seen in the examples of the Sydney Opera House (UNESCO Website—Sydney Opera House—https://whc.unesco.org/en/list/166/ and https://whc.unesco.org/en/list/166/documents/ accessed on 14 August 2024) and Pampulha Modern Ensemble (UNESCO Website—Pampulha Modern Ensemble—https://whc.unesco.org/en/list/1493/ and https://whc.unesco.org/en/list/1493/documents/ accessed on 14 August 2024). However, in these cases, shorter reporting cycles of five and two years, respectively, have occurred depending on specific circumstances and recommendations. This flexibility in reporting cycles ensures that unique challenges and conservation needs are addressed in a timely manner.

An accurate and specific maintenance plan for heritage buildings constantly exposed to the water environment is fundamental. The materials' deterioration is faster, and a lack of maintenance actions can lead to severe structural degradation. In the case of 20th-century buildings, that are mainly in reinforced concrete, the long exposure to water can cause the corrosion of the steel structure, cracks, detachment, and loss of material. When these degradation phenomena are not stopped, this can lead to a critical and sometimes irreversible disappearance of the original material. Monitoring and maintenance of 20th-century architectural heritage buildings that are situated in a water environment emerge as mandatory actions to prevent the loss of an important legacy.

The monitoring and maintenance of heritage buildings, particularly those in challenging environments like Fallingwater and the Boa Nova Tea House, require a multifaceted approach that combines traditional conservation techniques with modern technology. By implementing comprehensive maintenance plans that include detailed scientific diagnoses and continuous monitoring, this allows us to significantly extend the lifespan of these heritage buildings while preserving their authenticity and historical significance.

For Fallingwater, a comprehensive monitoring system that includes environmental and structural sensors has been implemented. This system tracks humidity, temperature, and the movement of structural elements. The integration of this technology has enabled the early detection of potential issues, allowing for timely interventions. Detailed scientific diagnoses have revealed areas of concern such as potential voids and areas where water infiltration has caused damage. These findings have informed targeted conservation strategies, including localized repairs and the application of advanced waterproofing materials [23].

Similarly, the Boa Nova Tea House should employ rigorous monitoring and maintenance practices to address its unique environmental challenges. Regular inspections focus on the impact of marine conditions, such as noticing that salt spray and humidity on the building's materials should be implemented. Specific measures, including the application of protective coatings to metal components and the periodic re-application of water-repellent treatments to stone and concrete surfaces, could be performed. These efforts ensure that maintenance interventions are both effective and minimally invasive, preserving the building's historical integrity while addressing contemporary conservation challenges.

6. Final Remarks

Analyzing a unique work integrated into a UNESCO serial nomination, like Frank Lloyd Wright's Fallingwater, also known as the Kaufmann House, subjected to severe conditions and constant water exposure, provides specific insights within the framework of recent built heritage. Furthermore, wear and intensive use due to tourism, seasonal changes, and shifts in use and ownership must be considered.

As a seminal work, Fallingwater is both innovative for its time and revealing of constructional weaknesses. It features materials such as concrete, stone, metal, wood, and glass, utilizing a mixed construction system of structural granite masonry walls and cantilevered concrete pillars and slabs. Issues with waterproofing, cladding, window frames, flat roofs, and terraces, integral to the architectural expression, pose model problems for other recently built heritage works, including 21st-century legacies. Initially, conservation and restoration efforts with varying intervention levels were continuously undertaken at Fallingwater, making it a "laboratory" for diagnosing and treating 20th-century heritage pathologies. The restoration project and maintenance plan emerged more recently, sustained by the continuity of the technical team and the responsible architect.

Although the Boa Nova Tea House is less complex than Fallingwater, the meticulous attention shown by the original author in the restoration project underscores that a conservative approach is most suitable for subsequent actions. Therefore, future restoration actions and projects for 20th-century architecture and recently built heritage should adhere to principles of minimal intervention, authenticity, and neutrality [47]. Nonetheless, an integrated management maintenance plan for ASV's works could more effectively address severe conditions and foreseeable wear from tourism.

Moreover, maintenance is crucial for built heritage conservation, as defined in various international charters. The Venice Charter of 1964, the European Charter of Architectural Heritage of 1975, and the Krakow Charter of 2000 all emphasize maintenance and repair as core components of the conservation process. Implementing a preventive maintenance program can minimize the need for later interventions, thus extending the lifespan of historic buildings.

The singularity of both works (OUV) and the wear due to severe conditions (water environment) and increased cultural tourism necessitate heightened attention to maintenance and preventive measures. In this context, the Krakow Charter's caution regarding cultural tourism, despite its economic benefits, should be acknowledged as a potential risk.

The World Heritage Committee mandates that conservation status reports details of any threats to the outstanding universal value (OUV), integrity, and authenticity of heritage properties. For cultural assets, varying degrees of risk are recognized. Specifically, imminent and proven dangers include severe material deterioration, structural and/or ornamental element decay, loss of architectural and urban coherence, degradation of urban or rural space or the natural environment, and significant losses in historical authenticity and cultural significance. Potential dangers encompass threats such as changes in legal ownership status, reduced protection measures, absence of conservation policies, the threatening effects of land-use planning projects, urbanization, the outbreak or threat of armed conflicts, and impacts from climatic, geological, or other environmental factors.

Both Fallingwater and the Boa Nova Tea House are exemplary architectural works situated within distinctive natural landscapes. Fallingwater, located within a natural park, is subject to regulations that guide public use but depend on cultural tourism revenue for its preservation. In contrast, the Boa Nova Tea House, a public asset governed by municipal and state authorities yet operated by private entities, requires balanced regulation and restoration measures akin to any World Heritage property. The severe extreme conditions—exposure to ocean, rain, and snow—necessitate meticulous maintenance. This approach could serve as a model and reference for similar heritage sites facing challenges from ongoing climate change.

These findings emphasize the critical importance of balancing use and preservation in architectural heritage within natural settings while highlighting the innovative insights gained from linking the conservation challenges of Fallingwater and the Boa Nova Tea House. By drawing parallels between these two iconic structures, this study not only identified shared vulnerabilities but also underscored the significance of preserving their authenticity and integrity. The interdisciplinary approach that combined architectural history, conservation science, and practical insights from those directly involved in the restoration processes provided unique information about the practical challenges of these interventions. This work can contribute to addressing contemporary environmental challenges in heritage conservation, reinforcing the need for ongoing monitoring and maintenance to ensure the longevity of these and other significant cultural assets.

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References

1. UNESCO World Heritage Centre. *Identification and Documentation of Modern Heritage*; World Heritage Papers No. 5; UNESCO: Paris, France, 2003.
2. ICOMOS. *Approaches for the Conservation of Twentieth-Century Architectural Heritage: Madrid-New Delhi Document*; ICOMOS: Paris, France, 2017.
3. ICOMOS. *The Cádiz Document: InnovaConcrete Guidelines for the Conservation of Concrete Heritage*; ICOMOS International: Paris, France, 2021.
4. Wright, Frank Lloyd. Architect, Balthazar Korab Studios, Ltd, photographer. *Fallingwater, Mill Run, Pennsylvania. Exterior. Pennsylvania, None*. [Between 1955 and 2007] Photograph. Available online: https://www.loc.gov/item/2020714524/ (accessed on 8 May 2024).
5. Morgado, J. *Boa Nova Tea House Renovation*; Available online: https://www.joaomorgado.com/eng/projects/boa-nova-tea-house-renovation (accessed on 8 May 2024).
6. Jokilehto, J. *A History of Architectural Conservation*, 2nd ed.; Routledge: London, UK, 2018. https://doi.org/10.4324/9781315636931.
7. Wright, Frank Lloyd. *Project 3602: Edgar J. and Liliane Kaufmann house (Mill Run, Pennsylvania), Fallingwater, View from below*. Repository: Avery Architectural & Fine Arts Library, Columbia University Avery Drawings & Archives Frank Lloyd Wright Foundation Archives: architectural drawings, 1885-1959 Series VI: 1930s, New York. Available online: https://www.jstor.org/stable/community.36562339 (accessed on 8 May 2024).
8. Zevi, B. *Frank Lloyd Wright a cura di Bruno Zevi*; Serie di Architettura/4; Zanichelli: Bologna, Italy, 1979.

9. Frampton, K.; Portas, N.; Castán, S. *Profissão Poética*; Gustavo Gili: Barcelona, Spain, 1981.
10. Benevolo, L. *Historia de la Arquitectura Moderna*, 1st ed.; Taurus Ediciones: Madrid, Spain, 1963.
11. Historic American Buildings Survey. Creator: Frank Lloyd Wright, Edgar J Kaufmann, Liliane S Kaufmann, Jacques Lipchitz, College Of Architecture And Environmental Design Kent State University, Elizabeth Corbin Murphy, et al., Boucher, Jack E, photographer. *Fallingwater, State Route 381 Stewart Township, Ohiopyle, Fayette County, PA. Ohiopyle Fayette County Pennsylvania, 1933*. Documentation Compiled After. Photograph. Available online: https://www.loc.gov/item/pa1690/ (accessed on 8 May 2024).
12. Wright, Frank Lloyd. *Project 3602: Edgar J. and Liliane Kaufmann house (Mill Run, Pennsylvania), Fallingwater, Working drawings.* Repository: Avery Architectural & Fine Arts Library, Columbia University Avery Drawings & Archives Frank Lloyd Wright Foundation Archives: architectural drawings, 1885-1959 Series VI: 1930s, New York. Available online: https://www.jstor.org/stable/community.36562399 (accessed on 8 May 2024).
13. El Croquis. N. *68/69 Álvaro Siza 1958 1994*; El Croquis Editorial: Madrid, Spain, 1994.
14. Siza, Á. *Imaginar a evidência*; Edições 70: Lisbon, Portugal, 1998.
15. Testa, P. *Álvaro Siza*; Martins Fontes: São Paulo, Brazil, 1998.
16. Okakura, K. *O livro do chá*; Edições Cotovia: Lisbon, Portugal, 2009.
17. Gomes, P.V. Casa de Chá da Boa Nova, 1991. In *Casa de Chá da Boa Nova*; Álvaro Siza Vieira 1958–1963; Blau: Lisbon, Portugal, 1992.
18. Jodidio, P. *Álvaro Siza*; Taschen: Köln, Germany, 2003.
19. Gregotti, V. Architecture recenti di Álvaro Siza. Controspazio 1972, 9. In *Profissão Poética*; Frampton, K., Portas N., Castán, S., Eds.; Gustavo Gili: Barcelona, Sapin, 1988; p. 187.
20. Figueira, J. O restauro da Casa de Chá. Revista Patrimonio 2017–18. 2018. Available online: https://hdl.handle.net/10316/101510 (accessed on 8 May 2024).
21. Siza, A. Studies, details, elevations, and plans, Casa de chá, Restaurante da Boa Nova, Leça da Palmeira, Álvaro Siza fonds, Collection Centre Canadien d'Architecture/Canadian Centre for Architecture, Montréal,. Available online: https://www.cca.qc.ca/en/archives/447183/alvaro-siza-fonds/469692/architectural-projects/473701/casa-de-cha-restaurante-da-boa-nova-tea-house-boa-nova-restaurant-leca-da-palmeira-portugal-1958-1959-1963. (accessed on 8 May 2024)
22. Municipal Archives Matosinhos, Portugal
23. Silman, R. The Plan to Save Fallingwater. In *Scientific American*; Nature Publishing Group: New York, NY, USA, 2000; Volume 283, pp. 88–95.
24. Norman, W.; Jerome, P.; Gottlieb, S. Fallingwater: Materials-Conservation Efforts at Frank Lloyd Wright's Masterpiece (Part 1). *Assoc. Preserv. Technol. Bull.* **2001**, *32*, 44–55.
25. Ferreira, T.; Barbosa, F.; Fernandes, E. Construction culture between tradition and modernity: Three works by Álvaro Siza. In *History of Construction Cultures*, 1st ed.; Mascarenhas-Mateus, J., Paula Pires, A., Eds.; CRC Press: Boca Raton, FL, USA, 2021; pp. 594–601. https://doi.org/10.1201/9781003173434.
26. Ferreira, T.C.; Fernandes, E. Alvaro Siza's Tectonic Shift in Leça da Palmeira: From Design to Conservation. In Proceedings of the 16th International Docomomo Conference Tokyo Japan 2020+1. Inheritable Resilience: Sharing Values of Global Modernities. Docomomo 2021, Tokyo, Japan, 10–14 September 2021.
27. Weisberg, R. Frank Lloyd Wright's Fallingwater: A Case Study in Inside-the-Box Creativity. *Creat. Res. J.* **2011**, *23*, 296–312. https://doi.org/10.1080/10400419.2011.621814.
28. Toker, F. Fallingwater rising: Frank Lloyd Wright, E.J. *Kaufmann, and America's Most Extraordinary House*; Knopf: New York, NY, USA, 2003.
29. Norberg-Schulz, C. *Genius Loci: Towards a Phenomenology of Architecture*; Rizzoli: New York, NY, USA, 1980.
30. Weconservepa. WPC Adds Land to Bear Run Reserve. 2024. Available online: https://weconservepa.org/blog/wpc-adds-land-to-bear-run-reserve/ (accessed on 2 May 2024).
31. Matteo, J. Fallingwater—Structural intervention, in time. In *Structural Analysis of Historical Constructions*; Modena, C., Lourenço, P.B., Roca, P., Eds.; Taylor & Francis Group: Abingdon, UK, 2005.
32. Jerome, P.; Emilio, D. Digital Documentation of Frank Lloyd Wright's Masterpiece, Fallingwater. *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci.* **2017**, *XLII-2/W5*, 389–393. https://doi.org/10.5194/isprs-archives-XLII-2-W5-389-2017.
33. Stubbs, J. *Time Honored: A Global View of Architectural Conservation*; John Wiley & Sons: Hoboken, NJ, USA, 2009.
34. Orbasli, A. *Architectural Conservation: Principles and Practice*; Blackwell Science: Oxford, UK, 2008.
35. Fallingwater. Fallingwater Archive, 1994.22, Courtesy of the Western Pennsylvania Conservancy Available Online: https://waterlandlife.org/entrusted-wpc-1963/ (accessed on 8 May 2024)
36. Macdonald, S. 20th-Century Heritage: Recognition, Protection and Practical Challenges. In *Heritage at Risk 2002/2003*; Jaeger, R., Ed.; ICOMOS: Paris, France, 2003; pp. 223–229.
37. Ziegler, V.; Reicher, C.; Greiving, S.; Neugebauer, C.; Klanten, C. Resilience and Cultural Heritage in Urban Development: From Holistic Guidelines to Practical Approaches. *Blue Pap.* **2024**, *3*, 1. https://doi.org/10.58981/bluepapers.2024.1.02.
38. Fulin Qu; Li, W.; Dong, W.; Tam, V.W.Y.; Yu, T. Durability deterioration of concrete under marine environment from material to structure: A critical review. *J. Build. Eng.* **2021**, *35*, 102074. https://doi.org/10.1016/j.jobe.2020.102074.
39. Pratiwi, W.D.; Putra, lF.D.D.; Triwulan; Tajunnisa, Y.; Husin, N.A.; Wulandari, K.D. A review of concrete durability in marine environment. *IOP Conf. Ser. Mater. Sci. Eng.* **2021**, *1175*, 012018. https://doi.org/10.1088/1757-899X/1175/1/012018.

40. Macdonald, S.; Gonçalves, A.P. *Conservation Principles for Concrete of Cultural Significance*; Getty Conservation Institute: Los Angeles, CA, USA, 2020.
41. Papadakis, V.; Vayenas, C.; Fardis, M. Physical and Chemical Characteristics Affecting the Durability of Concrete. *Mater. J.* **1991**, *88*, 186–196.
42. Zhang, S.P.; Zong, L. Evaluation of Relationship between Water Absorption and Durability of Concrete Materials. *Adv. Mater. Sci. Eng.* **2014**, 650373, Volume 2014. https://doi.org/10.1155/2014/650373.
43. Wang, Y.; Li, L.; An, M.; Sun, Y.; Yu, Z.; Huang, H. Factors Influencing the Capillary Water Absorption Characteristics of Concrete and Their Relationship to Pore Structure. *Appl. Sci.* **2022**, *12*, 2211. https://doi.org/10.3390/app12042211.
44. Harrison, T.A. Concrete Degradation: Addressing the real causes. In *Controlling Concrete Degradation. Proceedings of the International Seminar, University of Dundee, UK*; Dhir, R.K.; Newlands, M.D., Eds.; Thomas Telford Publishing: London, UK, 1999.
45. Macdonald, S. Conserving concrete. In *Conservation Perspectives, The CGI Newsletter 34*; Getty Conservation Institute: Los Angeles, CA, USA, 2019.
46. UNESCO. Operational Guidelines. 2023. Available online: https://whc.unesco.org/archive/opguide12-en.pdf (accessed on 2 May 2024).
47. Australia ICOMOS. *The Burra Charter (The Australia ICOMOS Charter for Places of Cultural Significance)*; Australia ICOMOS Inc.: Canberra, Australia, 1999.