

Layers of resilience

*Empowering ecological dynamics to
strengthen the built environment*

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Keywords:

weathering, resilience, lifespan, climate change, responsive architecture, environmental flows, materiality

Argumentation of studio choice:

The Architectural Engineering Graduation Studio situates itself at the intersection of architecture and technology, focusing on emerging topics within the built environment, such as climate change and the biodiversity crises, and aims to address these challenges through practical solutions. I have decided to join this studio because its values align with my own interests in architecture, as I mostly enjoy the fine line between architecture and engineered solutions and the way they blend together in carefully considered design proposals. This approach, complemented by the freedom to choose my own site and research topic allows me to delve deeper into an area I have been interested in for a while - the behaviour of materials as they weather and their potential in adaptive construction in a changing climate.

Introduction

In a context increasingly pressed by the climate and biodiversity crises, the theoretical discourse and practices which shape the built environment have shifted in the past 50 years towards sustainable architecture, and more recently, towards adaptability, lifecycle and circularity in construction. However, these strategies primarily focus on addressing and minimizing the environmental impact of the construction industry and thus, on mitigating climate change, but they do not address the inevitable impacts of a changing climate on architecture itself. (figure 1) If buildings are viewed as material repositories (Rau & Oberhuber, 2022), it becomes crucial to consider not only material flows, but material longevity and resilience as well. By perceiving weathering as not solely destructive, but as a process of material exchange that encompasses both destructive and constructive elements, this research paper aims to identify best practices which contribute to material durability, focusing on constructive processes which arise from the weathering of various material pairings. This analysis can lead to a better understanding of material resilience in a changing climate, contributing to a longer lifespan of the built environment.

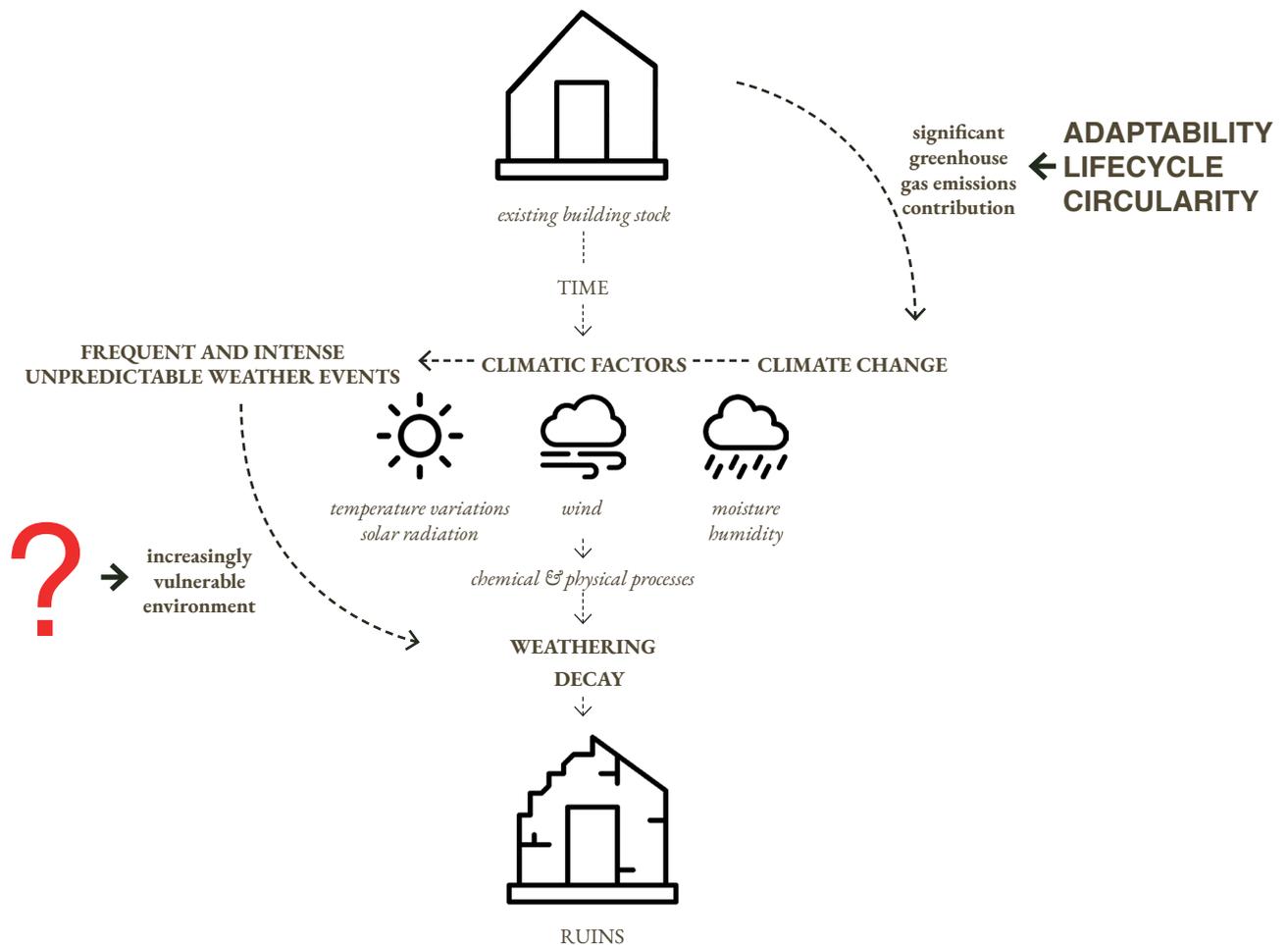


fig. 1-Causal nexus between architecture and climate change

General problem statement

“The whole idea of architecture is permanence. (...) It is an illusion.” (Brand, 1994, p.16-17)

Contrary to the popular opinion that buildings are static once their construction phase has ceased, the built environment has proved over time that it is one of the most dynamic man-made entities, particularly due to human, technological and climatic factors. (Brand, 1994) The latter is the fundamental cause of the weathering and decay of the built environment, well acknowledged phenomena which occur due to temperature variations, wind, solar radiation, moisture and humidity.

The relationship between the built environment and climate, particularly with climate change, is defined by an endless causal nexus in which all design choices that shape architecture can have a significant greenhouse gas emissions contribution, as 37% of the current global emissions are attributed to the construction industry. (United Nations Environment Programme & Yale Center for Ecosystems + Architecture, 2023) Simultaneously, the frequency and intensity of unpredictable weather events associated with climate change make the built environment increasingly vulnerable both externally (due to environmental catastrophes which accelerate the decay of construction systems and diminish materials’ properties) and internally (due to increased indoor temperatures and humidity) (Hacker et al., 2005).

“Finishing ends construction, weathering constructs finishes.” (Mostafavi & Leatherbarrow, 1993, p.5)

However, climate crisis is not the only factor accelerating the external weathering of the built environment. The architectural details which were once conceived for retarding the deterioration processes caused particularly by water (such as sills and cornices) were gradually removed from the construction of modern buildings because they were regarded as “faults” in the design, according to Le Corbusier. (Mostafavi & Leatherbarrow, 1993) These details were then replaced by sealants and various weatherproofing strategies which seem to have reduced the durability of contemporary architecture by allowing water to reach and reside on the façade for a longer time, thus aiding a range of destructive physical and chemical processes to take place.

A close examination of the weathering process which occurs in the built environment suggests that it is not only a destructive process, but rather a material exchange between buildings and their surrounding environment. By shifting the focus from the destructive consequences to the process as a whole, this dynamic relationship sheds light on its constructive capabilities and the possibility of creating protective finishes or facilitating the growth of biological actors, such as moss and lichens, which prevent acid rain and pollution from further decaying them, thus contributing to the protection of the built environment. (Gadd & Dyer, 2017)

In light of the environmental crisis, the contemporary design approach in the construction industry needs to be reassessed and adapted on all scales in order to create a more resilient built environment. It is crucial that this industry acknowledges the impact of climate change on the physical longevity of buildings and adapts accordingly, by implementing design strategies which embrace the dynamism of materials and consider both the destructive and constructive impact of climatic factors on the long term.

Reframing weathering: from an undesirable consequence...

...to an embraced process



fig. 2-Old farmhouse in Iceland



fig. 3-Decayed timber door



fig. 4-CaixaForum / Herzog & de Meuron

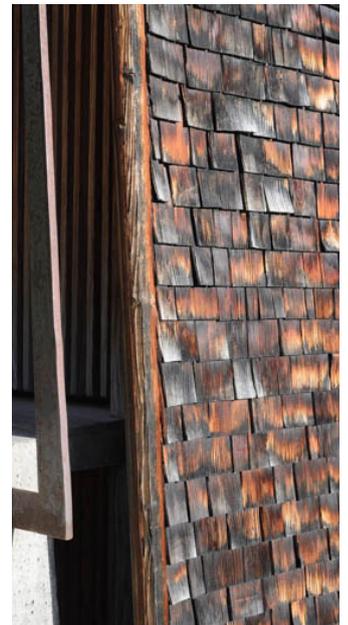


fig. 5-Saint Benedict Chapel / Peter Zumthor

Overall design objective

“When we deal with buildings we deal with decisions taken long ago for remote reasons.” (Brand, 1994, p.16)

When examining the current relationship between architecture and the climatic factors which influence it, the building’s skin seems to be a clearly defined boundary between them, accumulating a lot of tension due to the expectations of what nature should and should not do, often expressed through aggressive maintenance and refurbishment which attempt to bring the construction close to its original condition. While various design strategies acknowledge the environmental factors and focus on modulating them in order to create a comfortable atmosphere inside the building, not many of them seem to engage with the opportunities offered by these factors when coming in contact with the exterior of the building.

Considering this, the overall design objective of this project is to create a building whose skin is not a static boundary which denies the proximity of nature, nor a means to solely control nature for the purpose of creating a comfortable environment within its perimeter. The skin should rather be a dynamic layer conceived to respond to the environment around it by delaying the destructive weathering processes for as long as possible, while accommodating the constructive ones. The choice of materials is crucial, and it will be based on their predictable performance within the climatic and site-specific conditions, while taking into account the possibly occurring physical and chemical transformations, reversing the common belief that these processes are inherently destructive. The facade will be designed to adapt to the inevitable material exchanges between itself and the surrounding environment, ideally accommodating its material enhancement. (figure 6) Ultimately, the goal of the building is to form a materially focused symbiotic relationship with its surroundings and thus extend its lifespan in a changing climate.

Overall design question

How can we **integrate the design strategies aimed at delaying the weathering and decay** of the built environment and the **knowledge of material behaviour and synergies** into a holistic design approach which can **extend the physical longevity of the built environment in a changing climate**, while allowing it to respond to the surrounding ecological dynamics?

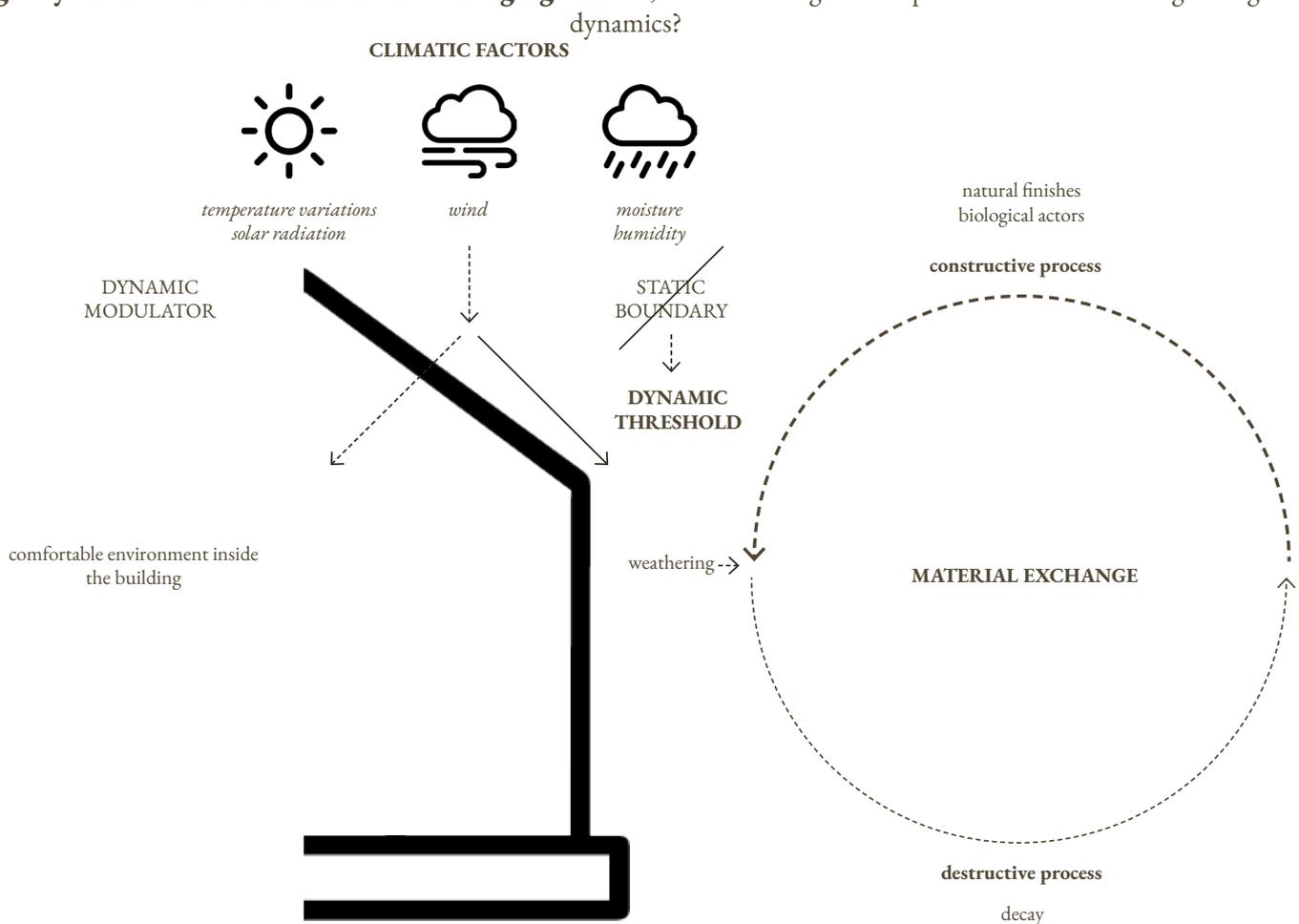


fig. 6-Building skin as a dynamic threshold

Reflection on the relevance

From a societal and use point of view, the value of the design objective relies on its contribution to extending the lifespan of the built environment in the context of climate change, as well as to the creation of a comprehensive set of architecture details underpinned by material synergies and behaviour. This topic is increasingly relevant as it does not rely on unsustainable materials or practices, but rather on strategies which embrace ecological flows.

Thematic research objective

Bearing in mind the dual consequences of the weathering process in the built environment and seeing it as a material exchange rather than a subtractive process, it becomes crucial to research and identify the optimal large- and small-scale design strategies which find a balance between the two. This extensive research could fill in the knowledge gap on strategies which can extend a building's lifespan, with a focus on material behaviour when exposed to climatic factors. While the aim of these strategies is to minimise the destructive consequences of weathering and decay for as long as possible, they will also embrace the inevitable physical and chemical reactions which occur, as well as the resulting finishes. Considering this, the aim of the research is to find the optimal way to seamlessly pair macro design strategies, such as the ones considering the influence of climatic and site-specific factors on material behaviour, with micro design strategies, such as materials adjacency, layering or strategic pairing, and translate the fusion of the two into a dynamic and future-proof building facade.

The purpose of this research is to understand how architecture can transition from being regarded and designed as a static element within the built environment to being a dynamic one which reacts to the changing climate and evolves simultaneously with its surroundings, key aspects which can contribute to its longevity. The objective of the research is to develop a catalog of strategies which can ensure a building's material longevity and capacity to adapt to extreme climatic factors.

Thematic research question

What are the **optimal large- and small-scale design strategies** which can contribute to **extending a building's lifespan** in a context defined by increased climatic fluctuations?

- Subquestion 1:** What environmental factors and conditions contribute the most to material decay?
- Subquestion 2:** How do materials behave when being exposed to those environmental factors?
- Subquestion 3:** What material combinations can create synergies when weathering together and enhance each other in time?
- Subquestion 4:** What kind of architecture details aimed at delaying the weathering and decay are currently implemented in architecture and how can they be improved?
- Subquestion 5:** How can various material pairings which create synergies be implemented in technical details which delay the weathering and decay?

Reframing weathering: from simple material exchanges...

...to material synergies



fig. 7-Casa Sabugo / Tagarro-De Miguel
Arquitectos



fig. 8-moss grown on a brick facade



fig. 9-corner detail, various materials



fig. 10-foundation detail, various materials

Reflection on the relevance

From a societal and scientific point of view, the thematic research objective addresses a knowledge gap in the construction industry which is crucial in the current global context of a changing climate and resource scarcity.

Thematic research methodology

The assessment needs to stem from a thorough analysis of the decaying processes which occur in the built environment, with a focus on façade systems. Understanding what are the design strategies and technical details which fail first and what are the underpinning reasons is key in rethinking them for contributing to a longer, yet sustainable building lifespan. Integrating knowledge of ecological flows and natural processes which occur on weathered materials within these strategies would allow architecture to blend better within the ecological network of the city and become more responsive to an ever-changing climate.

The research methods which are going to be employed are literature study, case-study analysis, research by design and interviews with specialists/researchers in the behaviour of various materials. While the first two methods are going to be qualitative, the case-study analysis will be quantitative, as a set of design principles can only stem from an extensive analysis of weathered and decayed buildings.

Research question	What data do you need?	How can this data be collected?	How will this data be analysed?	What will be the expected result?
1. What environmental factors and site conditions contribute the most to material decay?	- qualitative data of the weathering patterns on buildings and the site conditions in which they occur	- literature review of scientific papers & case study analysis	- analysis of the causal relationship between the most common weathering patterns and the underpinning climatic factors	- summary of the most common failures/decaying patterns in architecture - conclusions about possible alternative design strategies
2. How do materials behave when being exposed to those factors?	- qualitative data on material weathering behaviour	- literature review of scientific papers & interviews with researchers in material behaviour	- analysis of the most common physical and chemical reactions which occur on facades	- summary of the advantages and disadvantages of using particular materials in specific climatic conditions
3. What material combinations can create synergies when weathering together and enhance each other in time?	- qualitative data on material weathering behaviour	- literature review of scientific papers & interviews with researchers in material behaviour	- analysis of particular chemical and physical reactions which can contribute to material enhancement and longevity and the context in which they occur	- conclusions of optimal material pairings and synergies in architectural detailing
4. What kind of architecture details aimed at delaying the weathering and decay are currently implemented in architecture and how can they be improved?	- contemporary design strategies which allow buildings to embrace weathering	- literature review & case study analysis	- summary of the design strategies and qualitative assessment of their efficiency (compared to older buildings which have implemented similar strategies and have weathered in the meantime)	- in/effective design strategies which embrace weathering and ecological flows
5. How can various material pairings which create synergies be implemented in technical details which delay the weathering and decay?	- qualitative data on design strategies which delay weathering and decay and the materials used	- case studies & literature review of scientific papers	- evaluation of various design strategies and the way they decay due to material failure	- opportunities for improving these technical details with material pairings which enhance each other as they age

Expected results of thematic research and design implementation

The results of the thematic research and design implementation will address a gap in the discourse on how architecture responds and adapts to climate change by offering a new perspective on weathering. They will also serve as a stepping stone for rethinking resilience in the built environment. The analysis will result in a set of large- and small-scale strategies which aim to **delay the destructive consequences of weathering while embracing its inevitability**. Moreover, they will **facilitate the constructive processes** it entails in order to **allow for mutual enhancement through material synergies**. The novelty of this approach lies in pairing materials based on current and predicted climatic conditions at the site, with **the goal of enhancing their longevity as they weather together, thus allowing architecture to become adaptable and dynamic in**

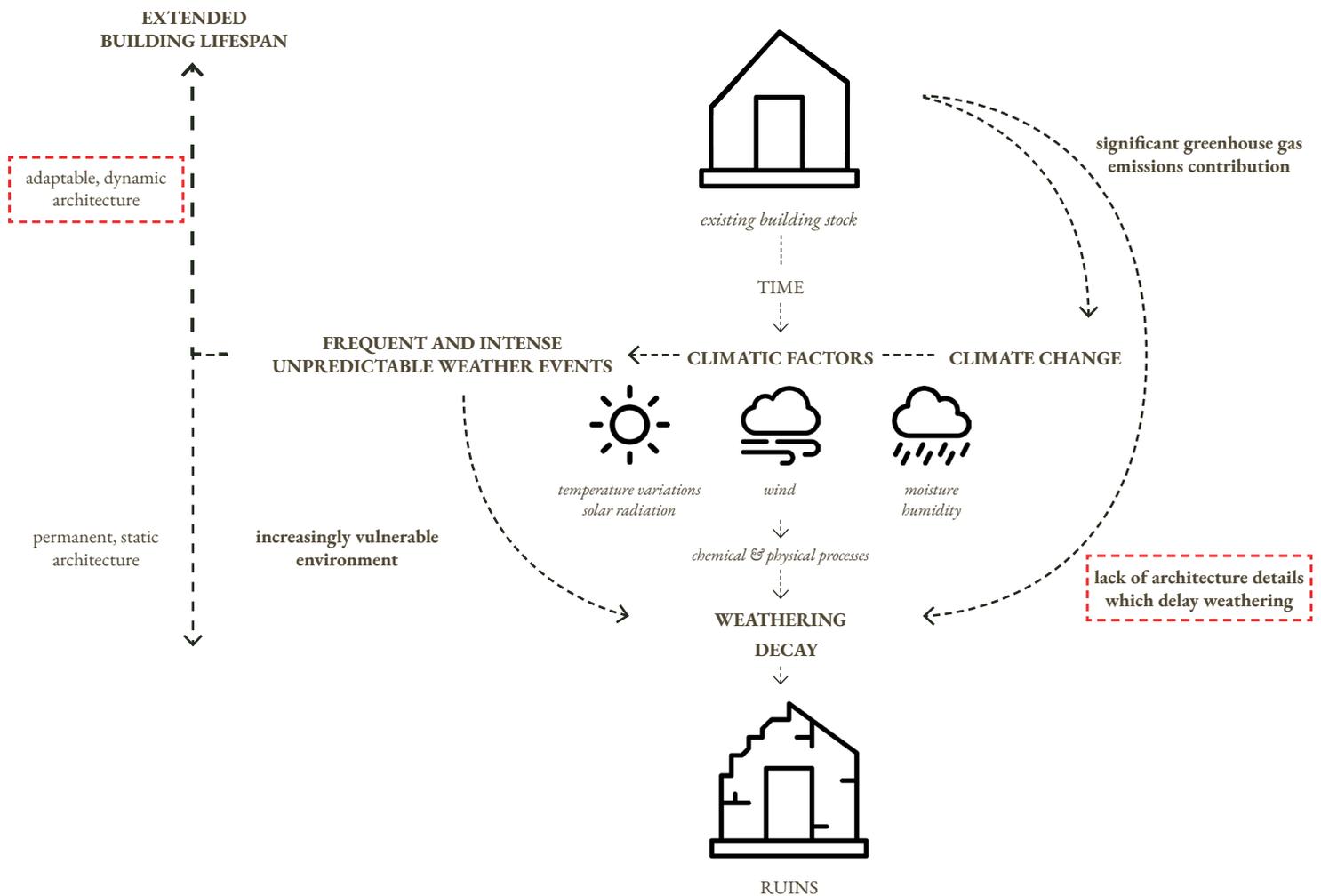
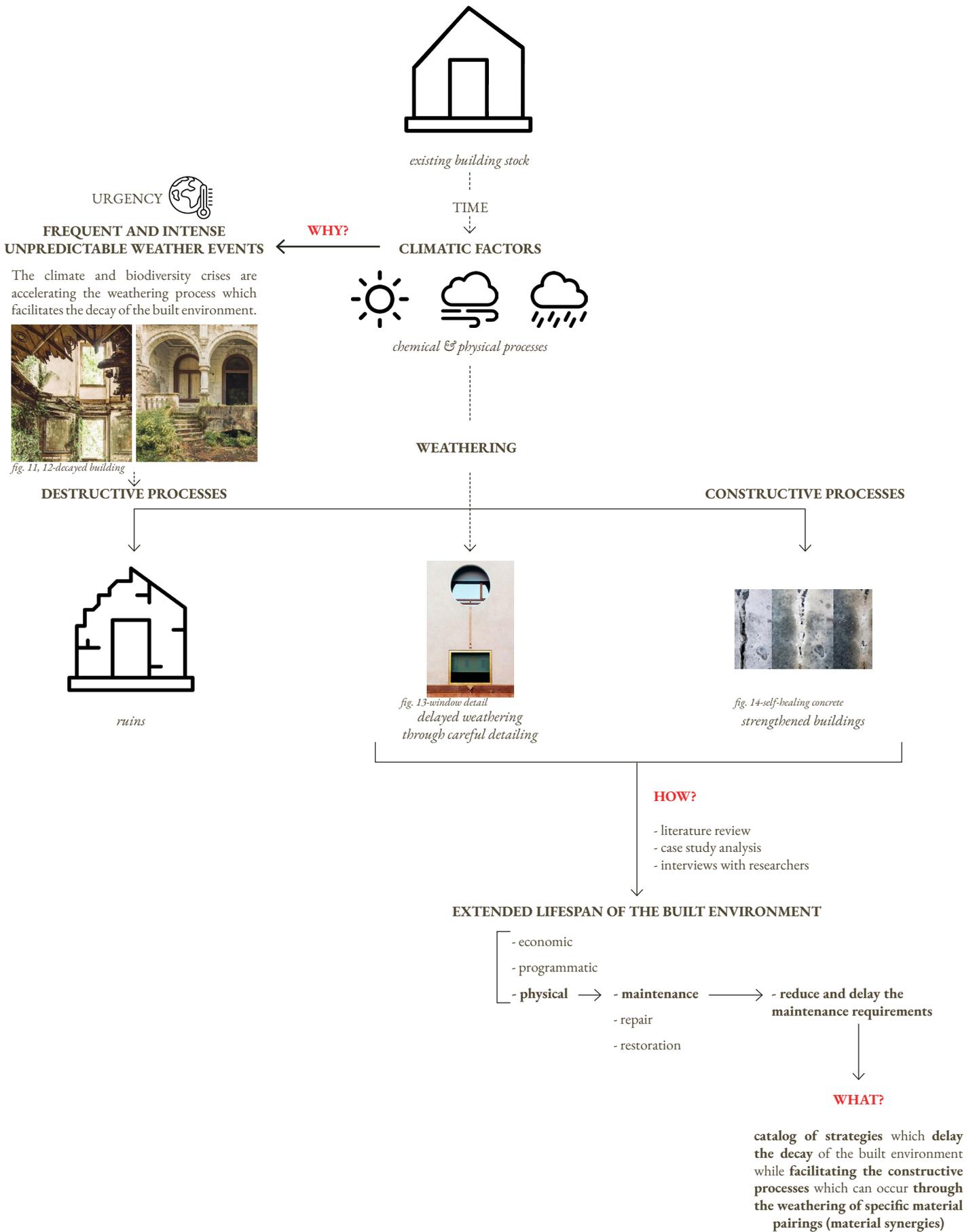


fig. 15-Problem identification hinting towards possible solutions



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- figure 15 - [Problem identification hinting towards possible solutions] by author

Planning

week no.	teaching week	months	dates	important dates	RESEARCH	DESIGN
36	1.1	September	2-6			
37	1.2		9-13		define overall research question	
38	1.3		16-20			
39	1.4		23-27			
40	1.5		30-4			
41	1.6	October	7-11		data collection literature analysis	
42	1.7	14-18				
43	1.8	21-25			assess the feasibility, constraints and opportunities of the topic	
44	1.9	28-1			define overall design and technical questions	reference projects
45	1.10	November	4-8	P1		review research plan prepare presentation
46	2.1		11-15			
47	2.2	18-22			data collection literature & case study analysis	
48	2.3	25-29			organise interviews	
49	2.4	2-6			choose a site	
50	2.5	9-13				
51	2.6	16-20				
52	Christmas break	December	23-27			
1	2.7	30-3				
2	2.8	January	6-10		finalise graduation plan & research paper	catalog of best design practices and strategies
3	2.9		13-17			preliminary concept design
4	2.10	20-24	P2		graduation plan research paper	masterplan strategies
5	2.11	February	27-31			develop concept design
6	Spring break		3-7			massing strategies
7	3.1	10-14				sketch design
8	3.2	17-21				1:500 plans/ sections
9	3.3	24-28				1:200 plans/ sections
10	3.4	3-7				refine design
11	3.5	10-14				1:200 plans/ sections
12	3.6	17-21				1:100 plans/ sections
13	3.7	24-28				set up details
14	3.8	31-4				finalise design
15	3.9	March	7-11	P3		
16	3.10		14-18			adjust design based on feedback
17	4.1	21-25				technical details
18	4.2	28-2				model
19	4.3	5-9				finalise presentation
20	4.4	April	12-16			
21	4.5		19-23	P4		
22	4.6	26-30				finalise reflection paper
23	4.7	May	2-6			
24	4.8		9-13			
25	4.9	16-20	P5			finalise drawings
26	4.10	23-27				finalise catalog/booklet