Conclusion: On the Way to New Species of Lightweight Energy-Conscious Membrane Architecture

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Mankind, an excellent technological animal, capable of conceiving and creating admirable architectures, supported by innovative structural concepts, has every time looked beyond the limits of its time. There is no doubt that today's designer can boast theoretical and practical knowledge based on the millennial experience of his predecessors. Today we are about 186 generations away from that ingenuity that was able to design and build the pyramids, 107 generations from the Etruscan necropolises and from the first experiences of the resistant arch shape, and only 30 generations from the builders capable of that technical refinement that has allowed the Gothic cathedrals to reach us (Zevi 1997). In other words, we can define ourselves as experts in mass construction, which exploits the heaviness of the materials incorporated in the construction to withstand the surrounding conditions. But we are only four generations who wisely and safely use steel in architecture, if, for example, we think of the Eiffel Tower or contemporary iron bridges as a turning point. Even a couple of generations ago we started introducing plastic materials into our artifacts and experimenting with their use in the construction field.

Therefore, we can perhaps still define ourselves as pioneers in the use of tensile-resistant materials and lightweight construction systems with membrane and tensile structural behavior, while even shorter is our experience in the use of fiber-reinforced composite materials based on cement and/or polymeric. This temporally short experience in the structural and architectural conception based on tensile-resistant materials must certainly encourage designers and technicians and scientists, politicians and administrators to finally follow up on that irrepressible desire for knowledge that always pushes us to learn from mistakes—whenever we cross the threshold of the known—and to refine the results, in view of the development of a new architectural, structural and constructive solution.

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There are countless examples in architecture that help us to remember that every technical innovation that has reached a certain level of reliability and relevance in the transformation of the built environment has, at a certain point, been the subject of a "species jump" that always human ingenuity had the courage and perseverance to work for the progress of society (Giedion 1941).

With this book we wanted to underline that the "species jump" of textile architecture and membrane architecture is underway, driven forward by the technical innovations that have taken place in the chemistry of materials on the one hand and by automation and electronic miniaturization on the other.

Furthermore, the research works presented in the book also wants to lead the reader to reflect on the opportunity that these great technological potentials must however be put at the service of environmental sustainability. The development of membrane architecture today can therefore only be in the primary direction of saving resources and energy, considering the scarcity of planet's resources as the first design issue (Manzini 2012). This means to promoting design solutions that use the most advanced production and installation techniques starting from a structural and architectural conception aware of correct and economical use of non-renewable resources throughout the construction life cycle, and to finding the smartest ideas for integrating renewable ones into the building components.

Membrane architecture of the near future must be the emblem of an updated "human construction", in the sense in which Frei Otto defined every architectural work capable of promoting peace and the co-existence of mankind (Otto 1979 in Nerdinger 2005), such as a natural artifact that self-organizes and co-evolves over time together with its users. This new generation of lightweight construction must be the result of a design-production-construction process optimized in every aspect, calibrated to maximize efficiency and minimize material, human and energy resources throughout the entire life cycle of the product.

May this lighter-weight and lighter-energetic membrane architecture contribute to a more sustainable transformation of the built environment? The question is the real challenge behind the research studies presented in the book.

The Chap. 1 aims to introduce the reader and the designer in the field of membrane architecture, presenting its potential and future challenges, the developments for a less-energetic building skin and a more interactive to the user soft, membranous building envelopes.

In the Chap. 2, the life cycle perspective in designing lightweight building systems is presented, with the final aim to demonstrate the advantages of the Life Cycle Design strategy answering to the environmental sustainability of novel lightweight skins.

The Chap. 3 introduces the approach of a programmatic "environmental lightweight" architecture. It analyzes active and passive strategies, focusing on lightweight envelope systems from a historical to a future perspective. It demonstrates the global potential of bioclimatic architecture using sun, wind, and water, both separately and in combination, as the main design drivers. Furthermore, the presented case studies show successful implementations of bioclimatic principles that can inspire future developments. The chapter argues that environmental design should be embedded into the building design process to use visible and invisible natural resources that surround us. Moreover, doing so is possible with lightweight technologies that produce minimal environmental impact and have the possibility to reach net or plus-zero targets. Therefore, only a careful balance of energy harvesting and lightweight solutions could make a successful and accelerated transition towards a sustainable future.

In Chap. 4, the advancement in material science enabling enormous developments of Photovoltaic technologies are presented. From an architectural integration viewpoint, the mechanical flexibility of the Photovoltaic products represents another key consideration, rather than only cost and energy conversion efficiency. The chapter presents descriptions of flexible substrates and thin film Photovoltaic, deepening the two key choices for the flexible Photovoltaic in buildings, the thin film, as well as organic one. The potentials and limits are highlighted: considering building applications the higher transparencies upon visible lights, the multiple color choice are important requirements.

Starting form Chap. 5 on, several industrial developments and applied researches are presented, with the aim to show concrete case-studies and multidisciplinary advancements on the main designing and production domains described in the first part of the book.

In Chap. 5, SOFT-PV research is presented. The work deals with a coupled mechanical and electrical characterization method to monitor the correlation of OPV electrode resistance and cell performance upon tensile strain and to verify the deterioration effect and reason for the tension strain on the OPV performance response.

In Chap. 6, the industrial research project TIFAIN is presented. It addressed a broad range of performances, paving the way toward an integrated design methodology for BIPV facades. The progress was made from the original Tile 1 design towards TIFAIN Diamond that improved both design and performance. Multiple experimental tests were carried out on small and 1:1 scales to validate simulations and demonstrate manufacturing feasibility.

The Chap. 7 aims to analyze fog and dew harvesting's system as a powerful and efficient alternative water resource. A comparison between two areas that are characterized by the fog phenomenon, Chile and Italy are investigated. Moreover, the fog harvesting structural device has been studied to develop an experimental project related to a master thesis dealing with the dew collection in Milan. Furthermore, on-site and in the Lab, the ongoing investigation is also presented.

Finally, in Chap. 8, the pilot project TemporActive is presented as main the result of a research path focused on the environmental comfort of temporary, membrane-based enclosed space. Alternative and unconventional solutions have been studied and organized in relation to the building's expected lifespan, i.e. short-term and long-term temporary, and project context.

Through the presentation of updated knowledge, case-studies of applied research and pilot projects, the book wanted to outline the fundamentals of a light construction of a renewed conception, designed starting from energy saving, and artfully built to be safe and durable, but not eternal. Rather than last indefinitely, the light-energy construction of the future will have to be resilient to changes—even to those currently outside the predictive capacity of designers and standards—and adaptable over time, to meet the changing needs of humankind that will follow and will be able to enhance it.

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