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Lightweight Landscape

Enhancing Design through Minimal Mass Structures

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Preface

In 2012, the School of Architecture and Society of Politecnico di Milano organized the first edition of the lightweight landscape architectural workshop (LLaw). Its aim was to take part in the wider initiative "Campus Sostenibile" and to design new temporary architectures and ephemeral environments for renovations of the area of Leonardo Campus as well as enjoying its open-air living. Special attention was given both to the design of green areas and to the construction of some light canopies. That was the first didactic activity at Politecnico to be focused on our understanding of lightness in the field of architecture and landscaping.

Beginning in 2012 and flourishing today, interest in lightweight structures has been constantly increasing inside and outside academia. We are confident that this distillation of the essays we wrote at that time can go on serving its purpose for students and researchers for years to come.

This book is meant to stimulate readers to apply "lightweight thinking" both in design and construction phases, which means focusing on the minimal quantity of materials to be used in the most efficient way and facing construction – either architecture or landscape – as a temporary instead of immanent presence on the soil.

The book also aims to reproduce the intensive mutual effort made between the different disciplines of the authors and the invited lecturers who inspired that first workshop – architecture designers, structural engineers, urban landscape designers, and LCA experts. We felt able to share this quite innovative designing approach and tried to demonstrate how lightweight thinking in buildings at different scales can be seen as a fruitful effort toward a more energy-saving and sustainable built environment.

The following words by Frei Otto, pioneer designer of membrane structures, sounded as inspiration for our work presented here: "Buildings are an exercise of power, by changing the existing environment and using materials and energies, even if we do not intend it, because we cannot do otherwise. The contrast between architecture and nature is getting bigger and bigger. […] Our times demand lighter, more energy-saving, more mobile and more adaptable, in short more natural, buildings, without disregarding the demand for safety and security. This logically leads to further development of light constructions. The way to minimal mass building, to minimal energy building, that is one with the landscape and at the same time architecture, is yet to be found." (Otto 2004).

Consequently, the most important angle of the book is the understanding of a virtuous overlap between the concept of lightness both in architecture and in landscape design. We cannot actually distinguish on one hand the lightness in architecture and, on the other hand, the lightness in landscape; working on lightness in a built environment means that the two levels of understanding tend to overlap. More often, the lightness in architecture is related to the landscape in which it is placed, and the lightness in landscape is given by its architectures. We believe that the fruitful ground where we should start this hopeful development of a new kind of light construction is actually close to those "non-architecture" creations we have found in between architectural and landscaping design. They look like constructions able to create an architectural identity without architecture, due to a relevant dialog with the urban context or even through an appropriate use of materials and techniques. They are often the results of an experimental design and construction process; they are sometimes ephemeral, sometimes temporary, rarely permanent buildings; they always are the results of a time-based design approach. They refer to a lightweight design concept and a streamlined manufacturing process, not only to a simplistic reduction of weight during the material selection. Eventually, they refer to an ultralight and flexible kind of materials with specific deformation properties such as polymeric composites and technical textiles.

The theme of a lightweight designing approach will deepen from a microscale (minimal mass architecture, lightweight techniques) to a macroscale (urban context and landscape), presenting several case studies, instructive praxis, and design strategies.

The first part of the book – focused on the theme of lightweight technology and advanced textiles materials – previews some concepts and results of European research studies, with the aim to renew the use of membranes in the specific climatic context and particularly to increase the qualified building of temporary spaces and the practiced application of lightweight materials. The second part of the book – focused on the theme of landscape – presents case studies and innovative approaches for seeking a visual lightness that is so critical for improving the quality of landscapes, especially urban spaces.

Within the authors' essays, further essays of the following experts are foreseen: Alessandro Villari, Mediterranea University, Reggio Calabria; Jan Cremers, Hochschule für Technik Stuttgart; Arantza Ozaeta Cortázar, Álvaro Martín Fidalgo, TallerDE2, Spain; Bernd Stimpfle, form TL, Germany; Paolo Beccarelli, University of Nottingham, UK.

Furthermore, a selection of students' works exploited by the 2-week intensive design workshop follows this introduction, with the aim to underline the connection between the two different scales of thinking the students were asked to consider – the landscape level and the building technology level – looking for a new kind of minimal mass architecture, easy to install and to remove if necessary.

Architects, engineers, landscape designers, and LCA experts can find in this book the instructive ideas and examples of how to plan–design–build something "with lightness," where lightness has a triple meaning:

1. that it is possible to be discreet in dealing with the context in which one is working, seeking a visual lightness and a closer pertinence with the cultural and material surroundings;
2. that it is possible to be discreet in relation to future generations, designing constructions that are not eternal, but that last as long as needed and can be taken down or reused or adapted if future generations have different needs from ours; and
3. that it is possible to act in a manner compatible with a global context, focusing on environmental sustainability, minimizing the quantities of materials used in buildings and using these as efficiently and smartly as possible, and considering how they can be reused or recycled at the end of their service life.

These meanings of lightness in buildings turn architectural projects into processes of seeking their identity in urban contexts, adaptivity in architectures, and a wider sustainability of the whole built environment.

This book does not pretend to exhaust the subject but strives to emphasize an attitude of lightness in the field of architecture that is worth paying attention to more and more in the near future, where a renovated set of production tools is transforming the traditional architectural design process, bringing buildings fabrication closer to other industrial artifacts. We know well how much an airplane, a ship, or even a car weighs and that their efficiency and cost are related to matters involved in those artifacts. It is now time to count and weigh also the architecture components, then use – and reuse – them as intelligently as possible.

Alessandra Zanelli

Reference

Otto F (2004) Introduction: on the way to an architecture of the minimal. In: Forster B, Mollaert M (eds) European design guide for tensile surface structures. Tensinet Edition, Brussel, pp 3–6

Logo of "Lightweight Landscape architectural workshop", Politecnico di Milano, 2012 (Design by Andrea Angeli)

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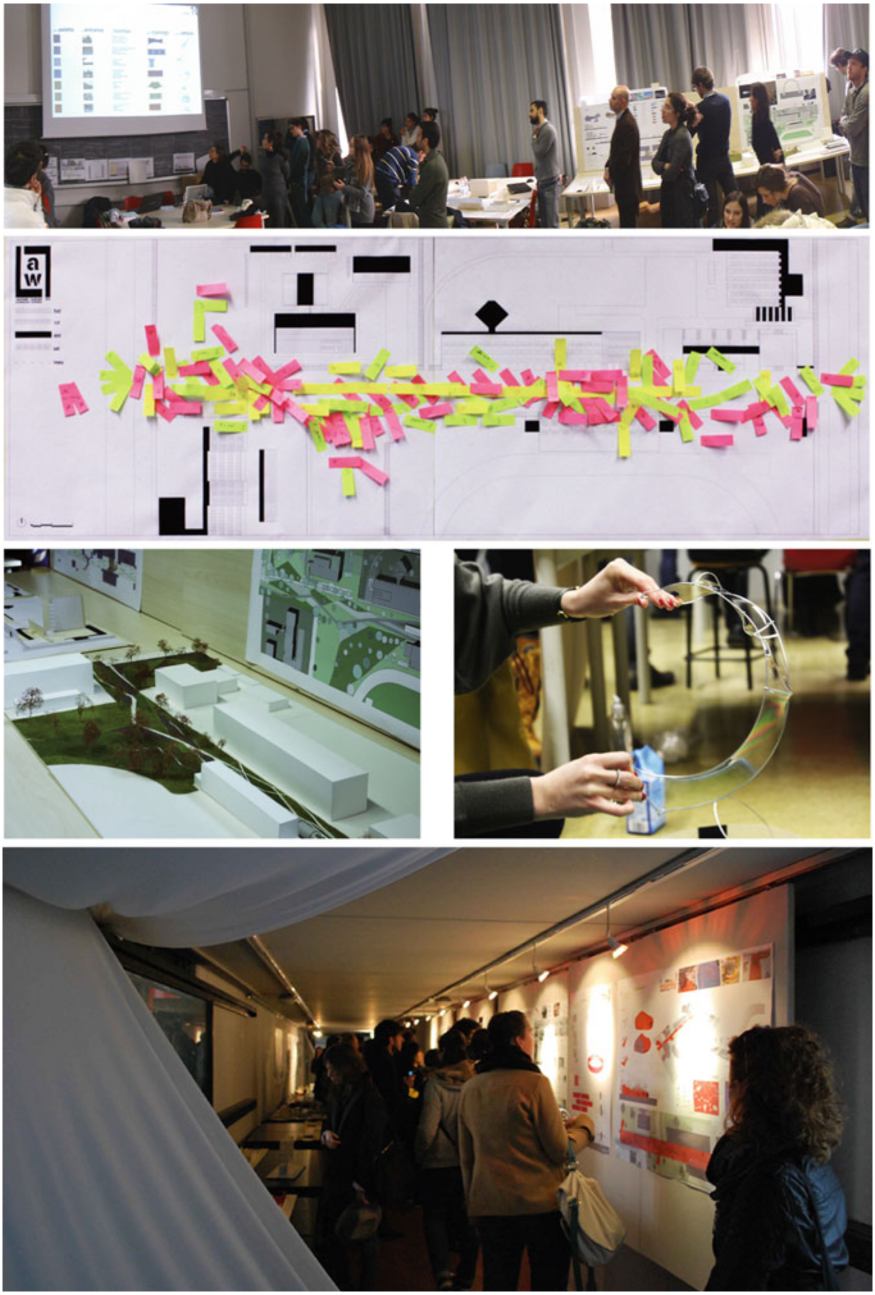


LLaw working session (30 January–4 February) and final exhibition (27 February–9 March)

01

Force Fields

Sara Maani
Enrico Ramunni
Mehdi Shoghi
Samuel Silva Trovato

LLaw
Lightweight Landscape
architectural workshop

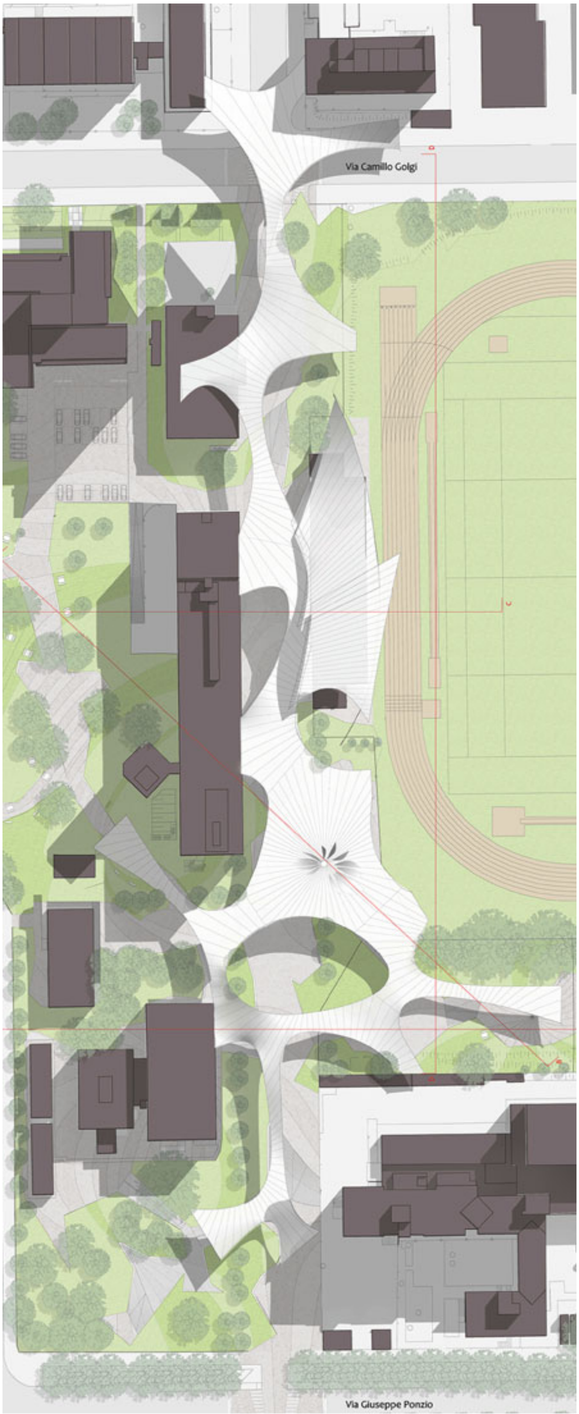
Politecnico di Milano
AY 2011–2012

Parametric Membrane

Enrico Ramunni
Samuel Silva Trovato

M.Sc. thesis in Architecture
Supervisor Luigi Spinelli
Advisor Paolo Beccarelli

Politecnico di Milano
AY 2012–2013



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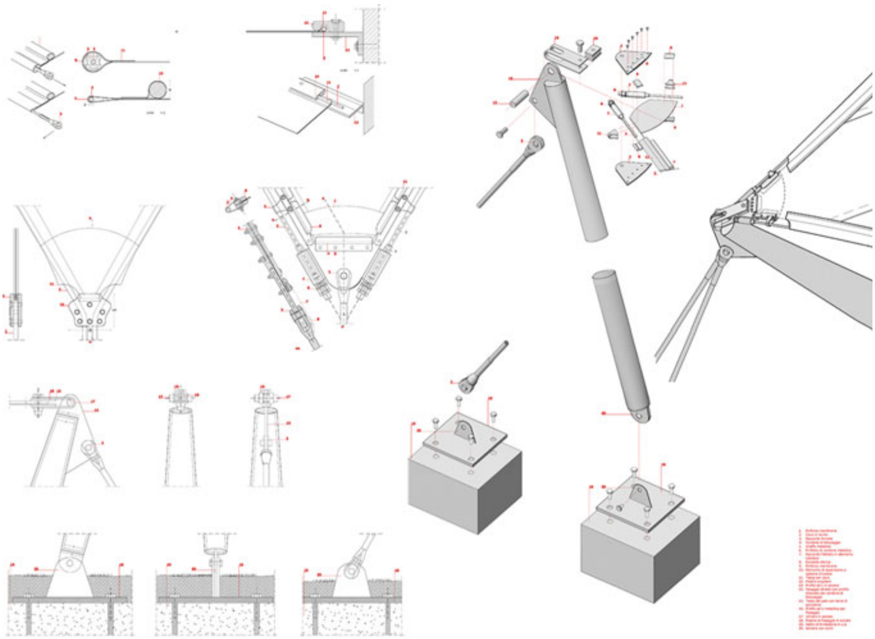
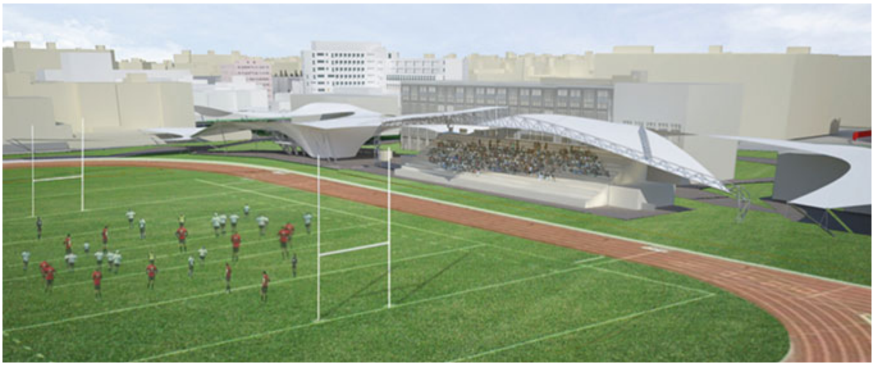
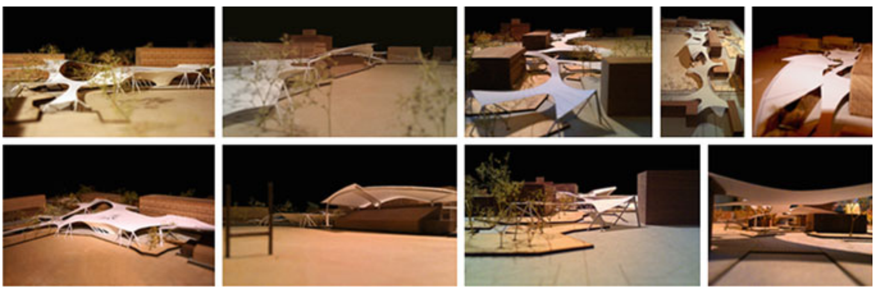


Technical details



Rendering



Model

O2

The Red Carpet

Martino Pacchetti
Stefano Panzeri
Daniele Vezzoli

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Lightweight Landscape
architectural workshop

Politecnico di Milano
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The Red Carpet

Martino Pacchetti
Stefano Panzeri

M.Sc. thesis in Architecture
Supervisor Alessandra Zanelli
Advisor Paolo Beccarelli

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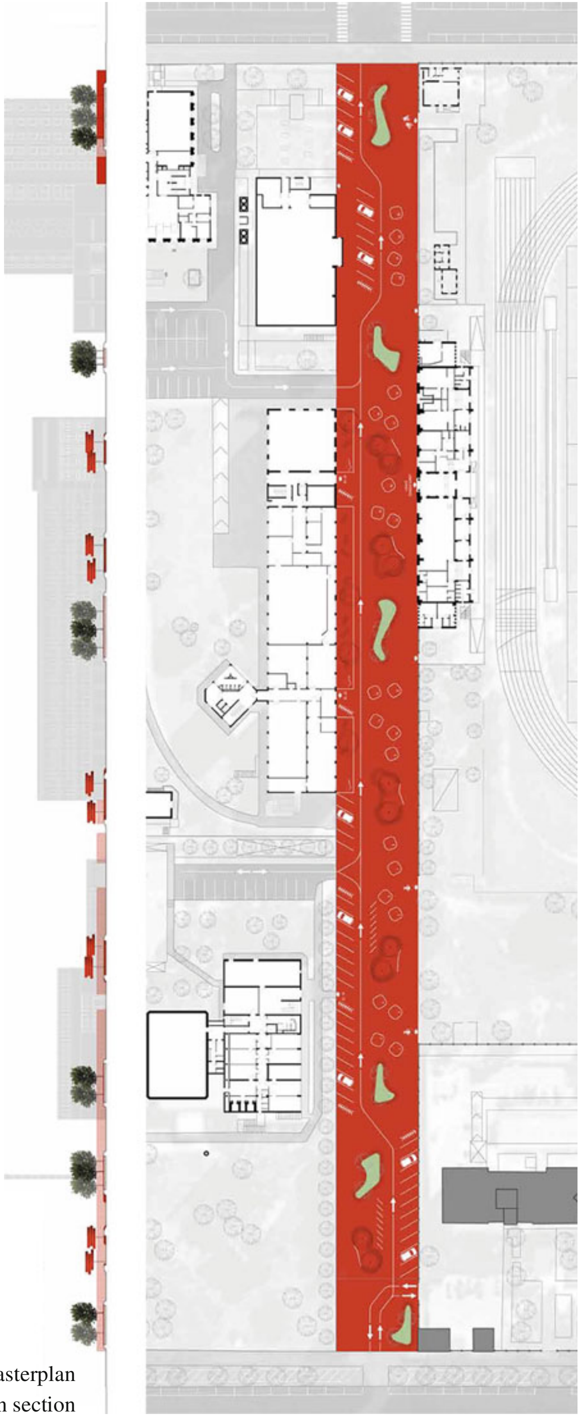
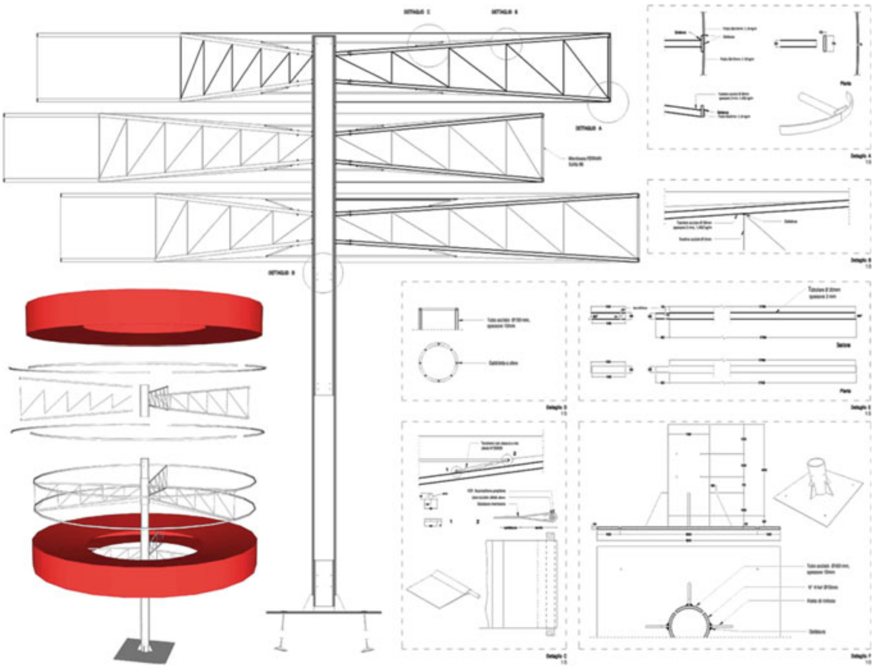
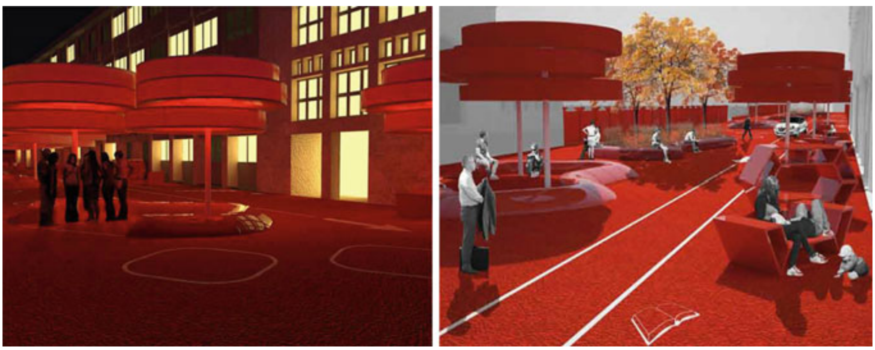


Masterplan
Urban section



Technical detail of shading umbrella

Urban section



Rendering

O3

Threading your way

Erica Mensi
Bianca Miglietta
Laura Pacchioni
Tyler Stahnke

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architectural workshop

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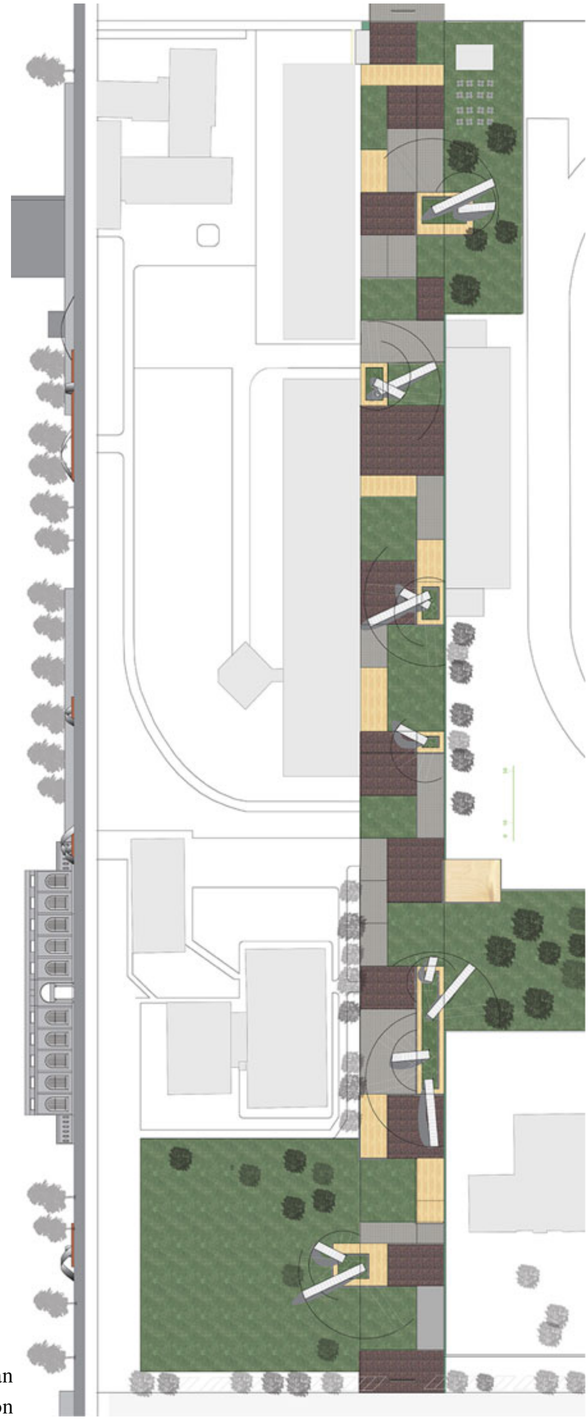

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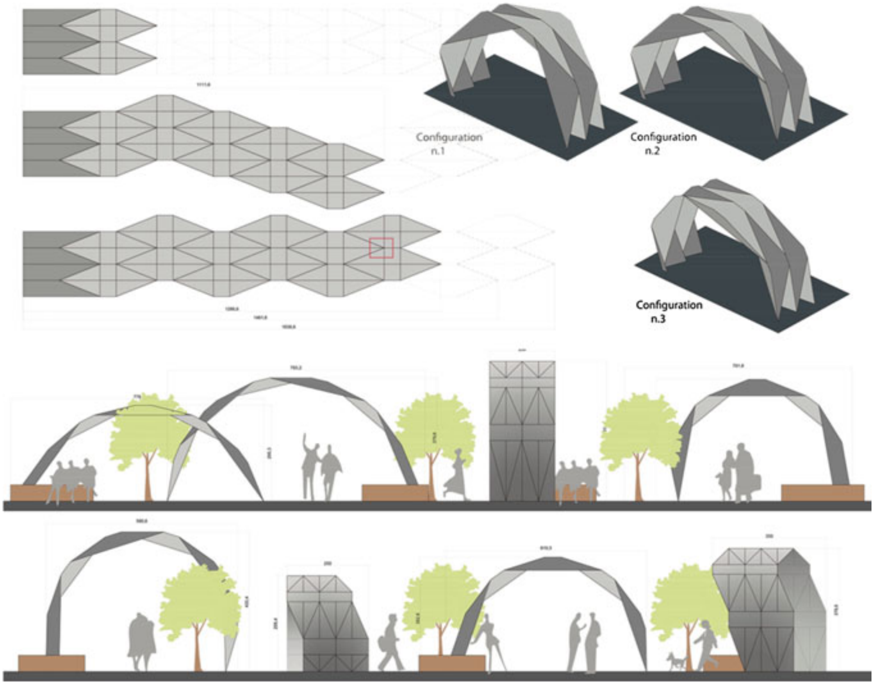
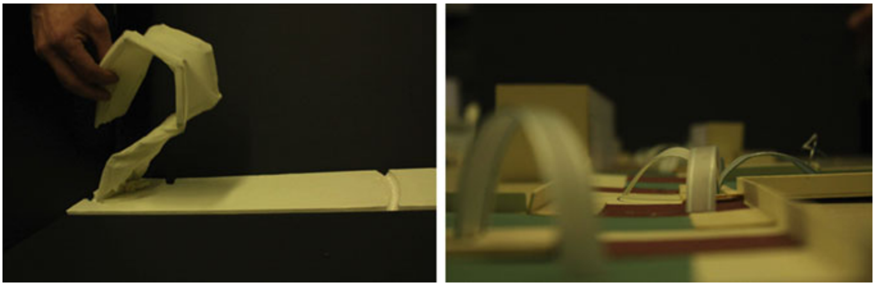


Blueprints of shading system



Models

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PerspectATION

Ayman Wagdy
Sofia Chicherina
Carol Marchini
Marina Paulo

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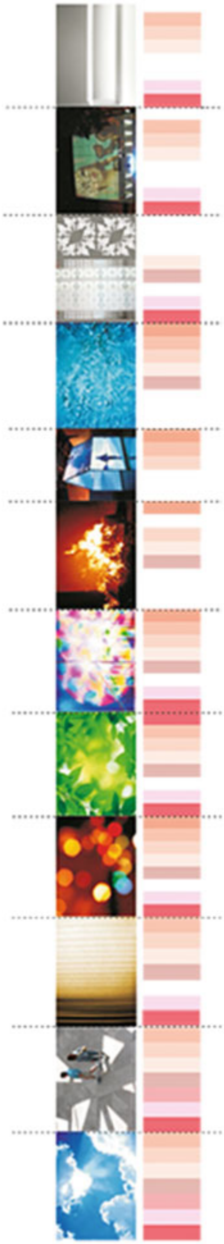

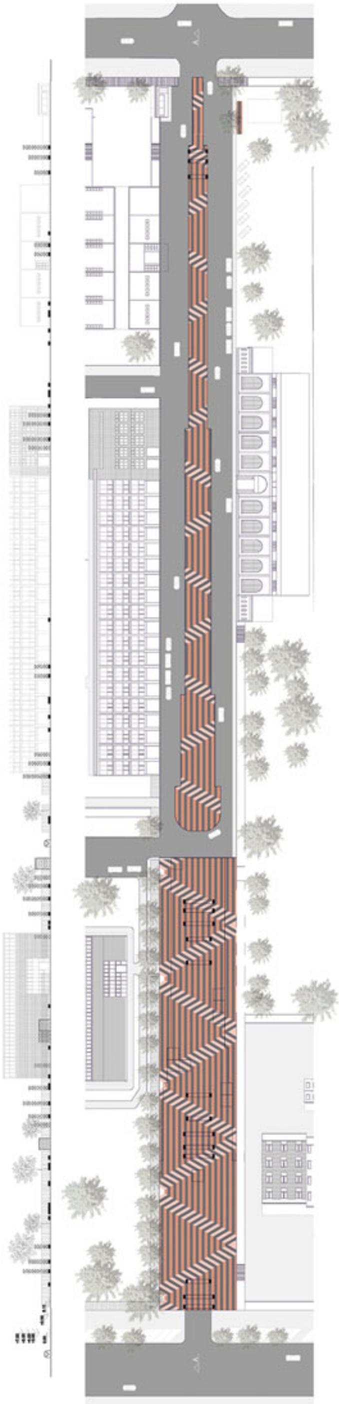

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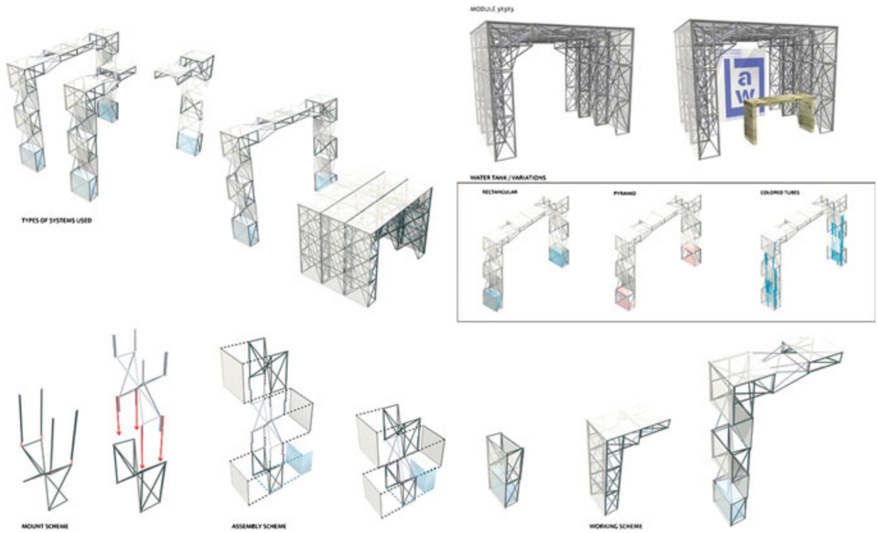
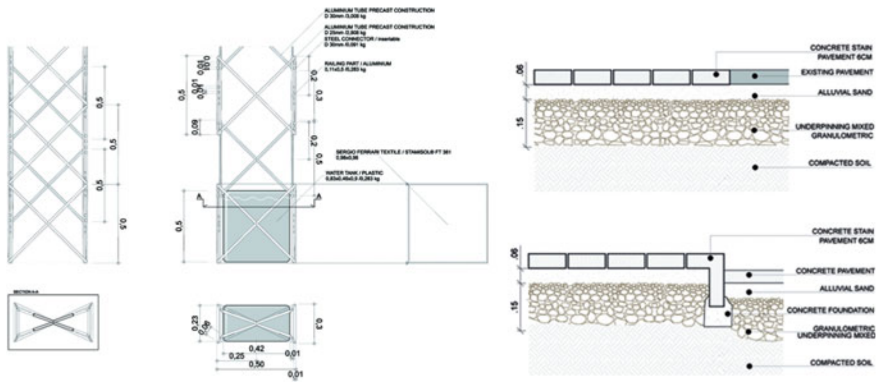
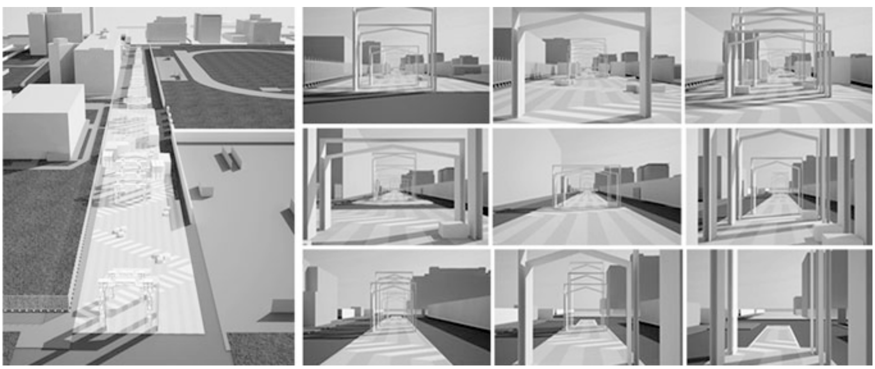
Combination of portals



Component kit and Assembling system



Ground connection and Pavement detail



Rendering

O5

Red Rhythm

Prisca Arosio
Alice Adavastro
Laura Carrera

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architectural workshop

Politecnico di Milano
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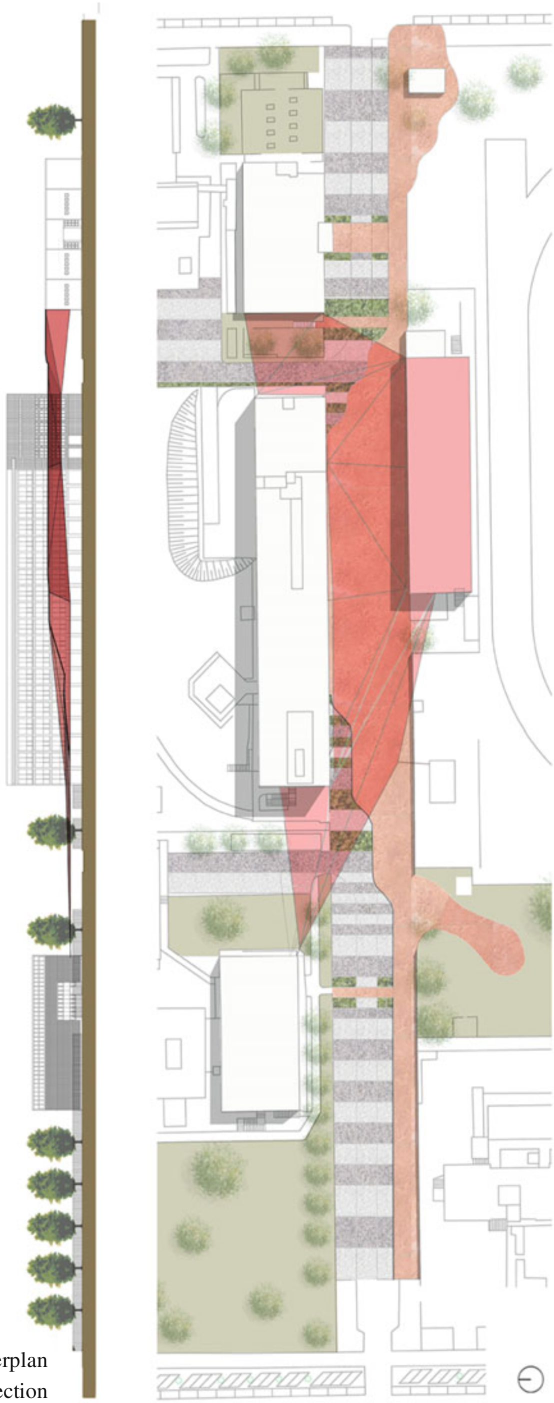

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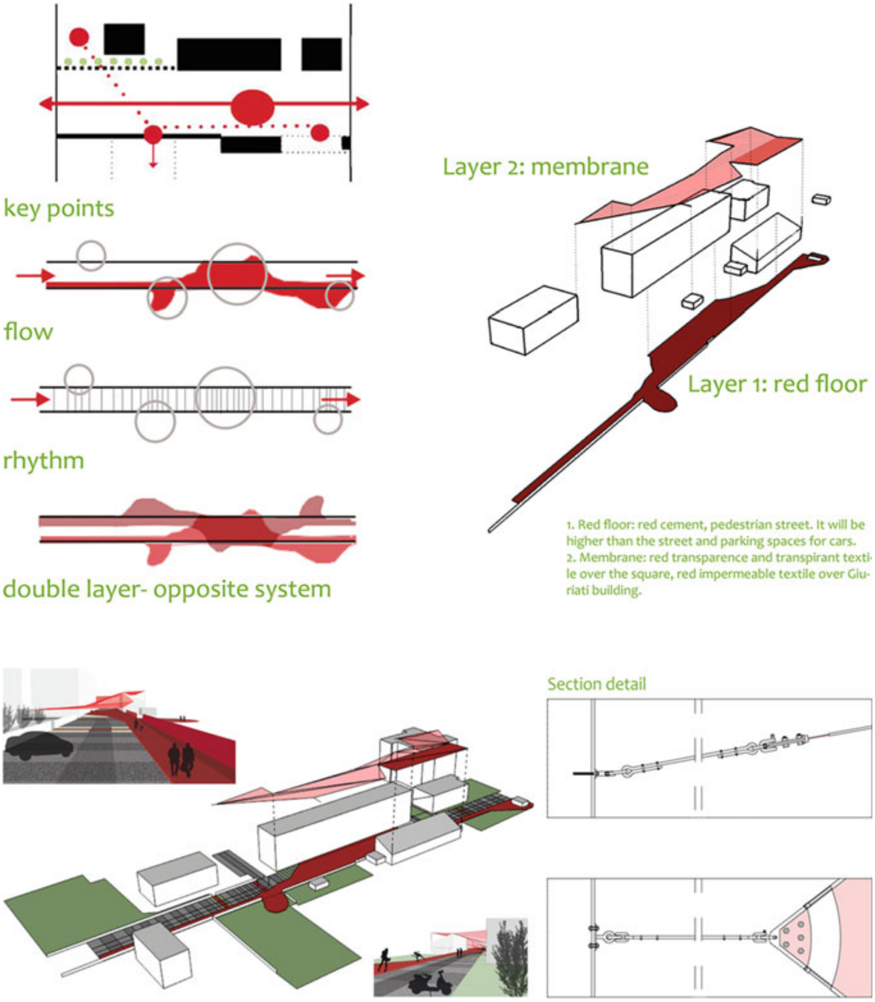

Concept and Technical details

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From MONO to MULTI

Maksim Gorbulin
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Arian Heidari Afshari
Mehrnaz Rajabi

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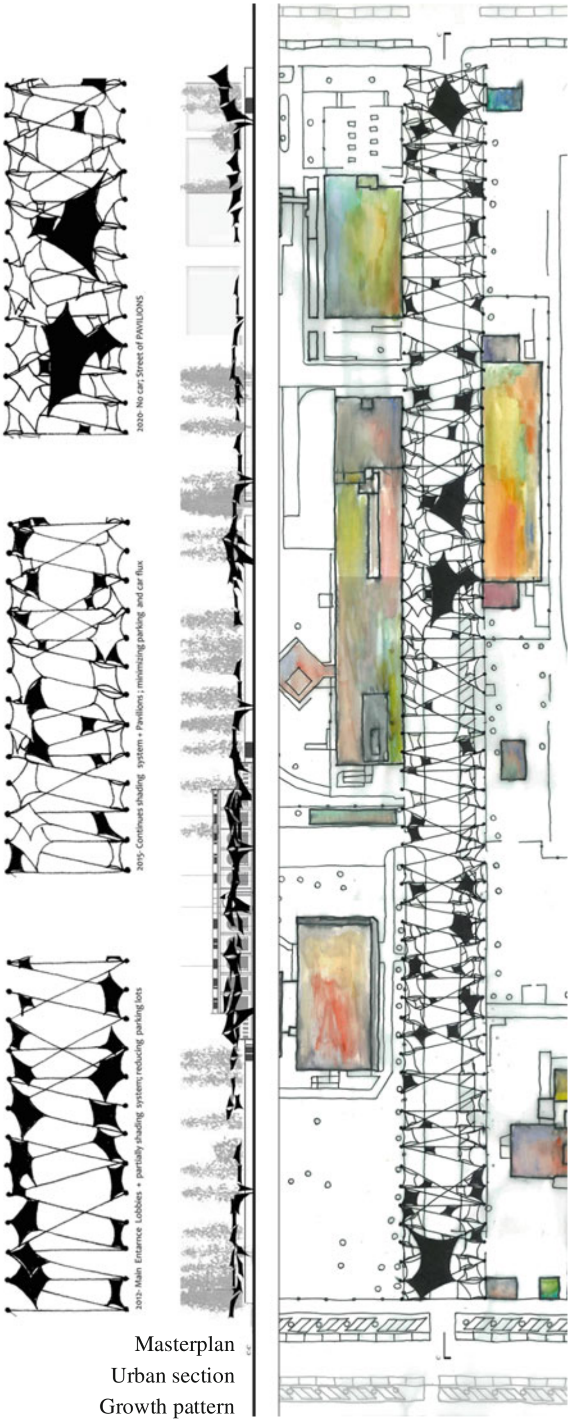

Masterplan
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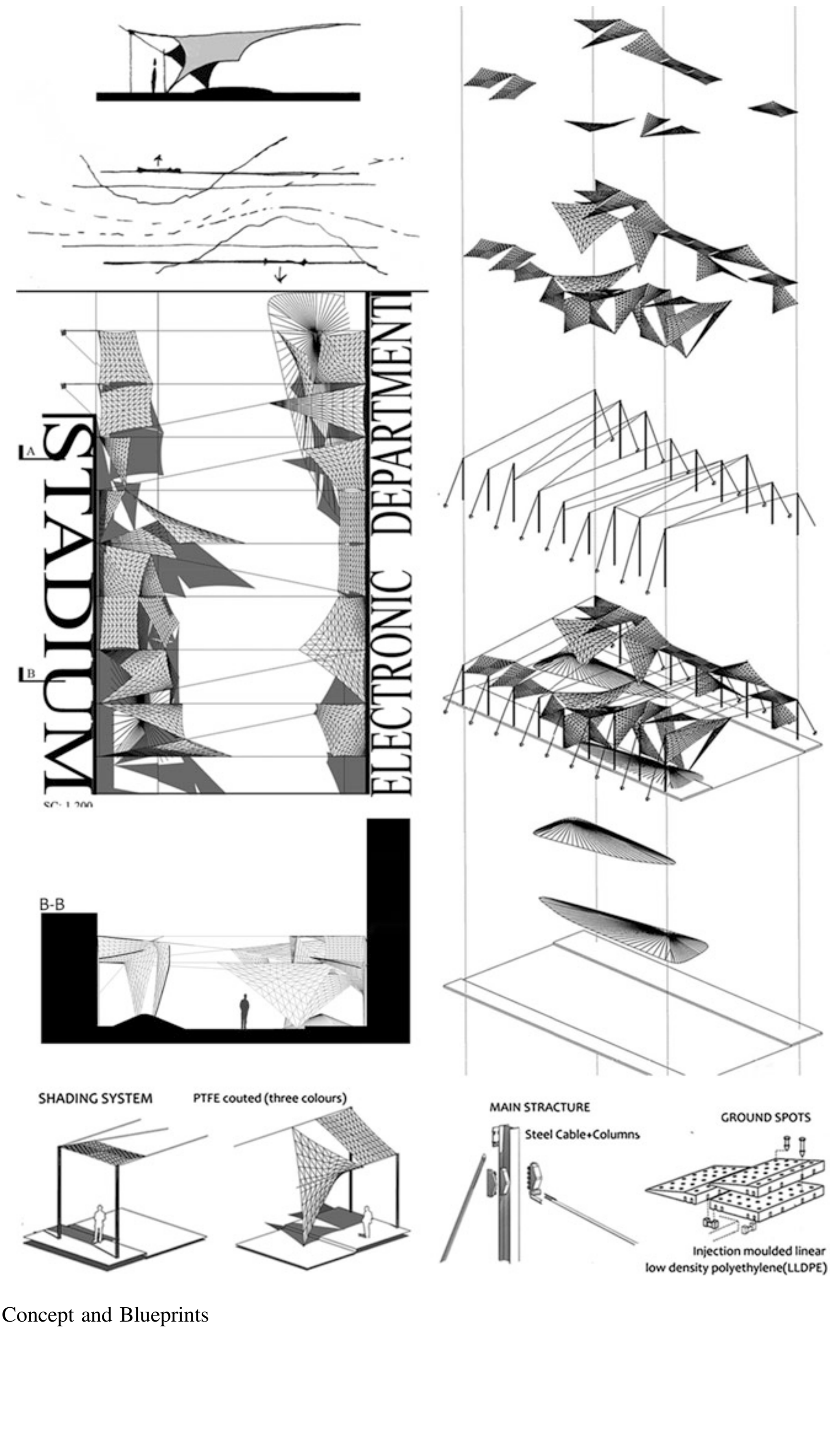
Growth pattern



Concept and Blueprints

Part I
Lightweight Architecture

Chapter 1
Designing with Lightness

Alessandra Zanelli

Abstract For ages lightweight architecture has used textiles taking advantage of their main characteristics: the structural behaviour, the performance of forms, the adaptability at different times and contexts. The chapter shows how it also profits by an efficient link between product design and industrial production.

1.1 Introduction

This first chapter will introduce a kind of architecture – lightweight, temporary, minimal protective shelters – that have been largely neglected by architectural history books, but for which we believe the moment has come to re-evaluate, since they possess characteristics which prove extremely interesting for our non-migratory but ever increasing transient lifestyle. Lightweight environments have the form of construction of necessity, like the shelters used by man in ancient times and also today by nomadic peoples; they are usually made of materials easy to find and to handle, such as textiles and other thin raw materials, to create adaptable spaces, which can be easily disassembled and transported. In other words, lightweight constructions respond to the Vitruvian principles of firmness, commodity and delight, distancing themselves from the classical interpretation embodied by everlasting monumental architecture.

We ought to state that the association of the adjective "lightweight" with architecture is relatively recent, starting from the "structural revolution of architecture" (René Sarger), when new materials able to be tensioned, such as steel ropes, cable nets and fabrics, appeared in the construction field.

If we try to create a picture of man's tectonic ability evolution – in terms of both technical ability and structural understanding – throughout the esthetical stages of

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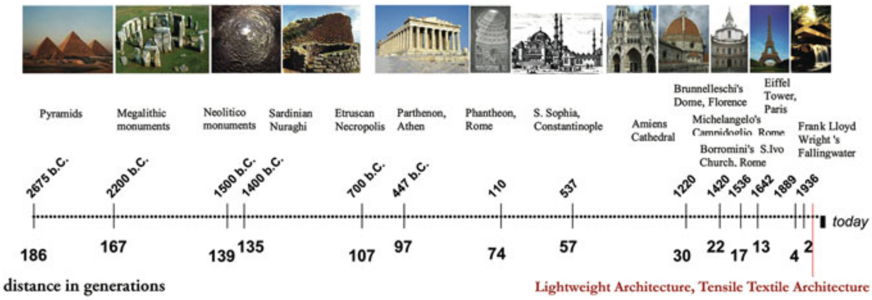

Fig. 1.1 Timeline of the esthetical and technical abilities of man (sketch of the author from the sources: Zevi 1997 and Sarger 1967)

monumental architecture, we won't be able to find lightweight architecture at all. Bruno Zevi reminds us that the designers of Modern Architecture are distancing themselves more than 180 generations since man built the Pyramids. If we overlap the timeline of Sarger with Zevi's generation stages we can place the lightweight architecture starting from at least two generations from today (Fig. 1.1). The meaning of this tentative is double:

1. to underline that the technical ability of man in using lightweight materials has been underestimated or even deemed irrelevant to the evolution of architecture;
2. to remember that, from a structural point of view, knowledge of light-weight architecture is rather new, so we can still consider the current lightweight artefacts as a result of experimental building processes.

Therefore, a reduction of the subject is needed, considering "textile architecture" as the contemporary, more charismatic and performance promising expression of the whole lightweight architecture.

In a rather provocative manner, we call this field "textile architecture" to highlight that current technical textiles – such as coated fabrics, fluor-polymer films, woven and non-woven membranes – can and should be seen as proper building materials, like stone, bricks and wood, to create some outstanding architectural structures.

In *Der Stil* (1863) Gottfried Semper indicates that, of the four technical arts (textiles, ceramics, carpentry and masonry), textile is primary among leading aspects of the other three, thus implying that the knot and weave, as the major operation of textile, are the essential architectural mode of production, and that cladding, the pinning of the fabric onto a frame, is the primary significant act of enclosure.

Textile is really the primary technical art in making architecture, and all those primitive, ephemeral buildings made of textiles are based on constructional principles that have been understood and transmitted for many thousands of years. This knowledge has been exploited throughout history, whenever lightweight and portable, adaptable solutions are required, such as nomadic tents, sails, sun-shading structures such as *velaria* or *toldos*.

Since textile architecture has seen a period of great innovation both in technology and materials in the last fifty years, thus becoming more and more distant from those primary and genuine forms of ephemeral enclosures, it seems time to take stock of the present situation and think over alternative solutions, which are more consistent with a new need of flexibility, with a new esthetic concept and, last but not least, new obligatory environmental safeguards.

This chapter aims to open a discussion on how to renovate textile architecture – its forms, structural concepts and production ways – restarting from the best examples of our past and reintroducing in the contemporary construction those weight and materials reduction criteria which belong to the best examples of temporary buildings.

1.2 Textile Architecture: Learning from the Past

We notice a widespread cultural resistance from Italian designers when choosing lightweight materials for architecture. In general, we also notice that designers do not have the opportunity of studying the origins and development of lightweight structures and ephemeral architecture and, in particular of membranes. On the other hand, we well know of the great importance Italian designers reserve for the study and knowledge of history, which often becomes the basic reference of design, maintaining a connection between the use of materials and typologies used in historical architecture and those usable still today. Some examples of the forgotten history of lightweight structures – properly textile structures – created in Italy from the 15th century to the early 20th century could help to start a turn in the tide of this self-defeating current local tendency (Campioli et al. 2008).

It is well known that important studies have been conducted through the observation of coins, frescoes and bas-reliefs, that have already shown the presence of textile sunshade roofs in theatres, amphitheaters, circuses and stadiums in the 1st century B.C., both in Rome and in the flourishing area of Campania (Otto 1984). Their progressive diffusion in other areas of the Roman Empire, in Magna Graecia and in Asia Minor, has also been noted. Such roofs were realized re-using old naval sails and it was really thanks to their sailing experience that the Romans were able to consider the advantages of a transformable and ephemeral shading shelter, instead of a permanent roof. In fact, a retractable textile cover is foldable when the wind increases, since protection from the sun is superfluous, and it also allows for complete enjoyment of open air space during summer evenings.

Towards the end of the 15th century a new passion for ancient theatre and comedy was added to the consolidated tradition of open-air public parties. The velarium of the ancient Roman amphitheaters became an essential formal element of classical theatre (Chastel 1964), as documented by Caesariano, who first translated the books of Vitruvio into the vernacular in an illustrated edition (Fig. 1.2). Caesariano worked on his illustrated version of Vitruvio during his stay in Ferrara from 1499, at the same time as celebrations took place in the court of Isabella

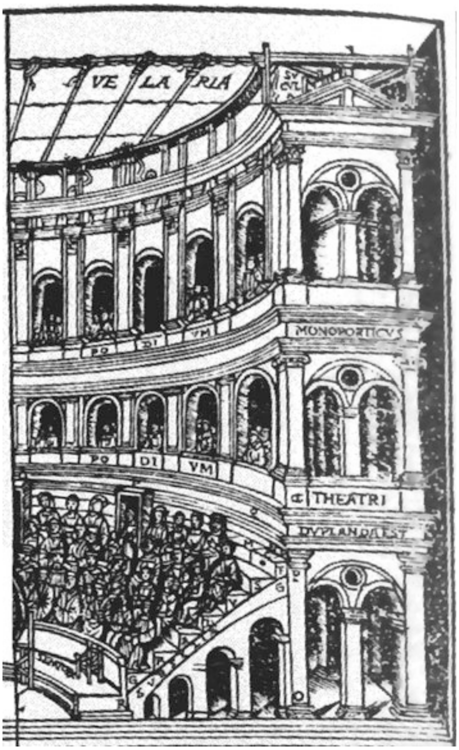

Fig. 1.2 Caesar Cesariano, 1521: detail of an incision about the form of the classical theatre according to Vitruvio (*Source* Ricci 1971)

d'Este, and this means, according to Ruffini (1983), that Ercole I d'Este commissioned the work.

This is also evidence of the great attention that the nobility of the Italian courts reserved for theatrical shows in those years. For example, the representation of Plauto's comedy Anfitrione is documented in the courtyard of the d'Este family building on February 5th 1487. The reporter of the period describes a thin, dark textile cover suspended above the courtyard, above which some lamps were positioned, whose light shone through the textile roof, creating a starry sky effect for the audience (Ruffini 1983).

In the last years of the 16th century, the architect Buontalenti turned into a luxurious tournament field the courtyard of Pitti Palace, to celebrate the wedding of Francis I to Bianca Cappello. In this case, the cover of the courtyard protects spectators from the cool autumn air. The official description of the events organized for October 15th 1579 is documented by Rafaello Gualterotti and illustrated by the incisions of Accorsio Baldi and Sebastiano Marsili (Fig. 1.3). Also in this case, the use of the textile ceiling is documented, "so the calm of the night didn't offend the spectators", as did that of seventy putti with lanterns that reflected the light projected on the ceiling to illuminate the underlying space from the galleries (Zangheri 2001, p. 204).

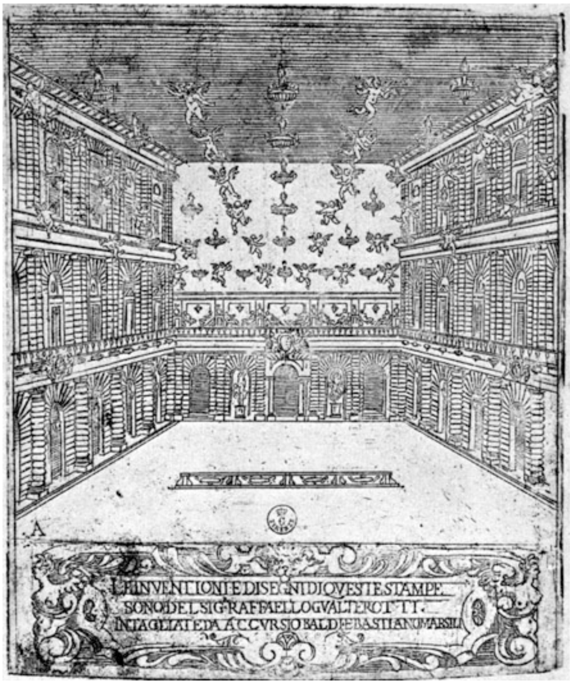

Fig. 1.3 View of the courtyard of the Pitti Palace with the apparatus for the "bar games" built in 1579, Florence, drawn by Accursio Baldi, Sebastiano Marsili (*Source* Zangheri 2001)

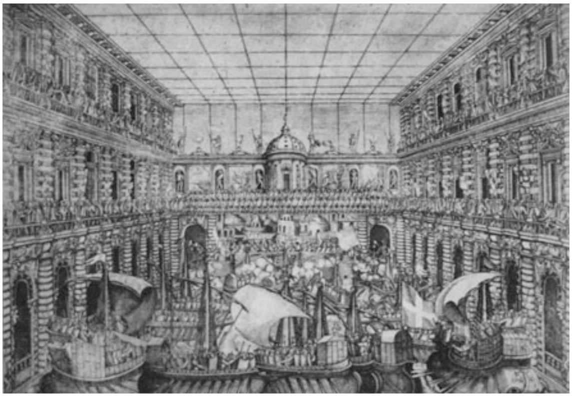

Fig. 1.4 Orazio Scarabelli: the apparatus of Naumachia games designed by Bernardo Buontalenti in the courtyard of Pitti Palace, Florence, 1589 (*Source* Zangheri 2001)

The transformation of the same courtyard of Pitti Palace continues after about ten years, when a new apparatus was constructed for another "bar game", the Naumachia, which is a pretend naval battle, on 11th May, 1589 on the occasion of Ferdinando I's wedding to Cristina of Lorena. On that occasion, the architect Buontalenti designed a textile roof solution that today we should define as an example of bioclimatic architecture (Fig. 1.4). As the spectators were not only situated on the terraced galleries and under the porticos, but also near the windows on the galleries surrounding the courtyard, the courtyard was entirely covered by strips of red cloth and illuminated by suspended lanterns. The reporters of those celebrations, Simone Cavallino and Joseph Pavoni, further describe the presence of a reconstructed Turkish fortress on the Boboli garden, side of the theatre. During the nuptial supper inside the Palace, the courtyard was completely flooded, using underground water ducts, to stage the naval battle that simulated a clash between a Christian fleet and the Turkish fortress. While the dramatic scene was underway, the elevated position of the audience meant that they could also look over into the Boboli garden, while the textile panels on that side were raised: this not only served to make the scene more spectacular, but also allowed fresh air to enter the covered space through the open side (Zangheri 2001, p. 208).

With the beginning of the construction of permanent theatres in Italy, temporary theatres with accompanying *velaria* become more and more sporadic. They were still used for Comedies often represented in the streets at the end of the 18th century. In the meantime new occasions arose for the creation of temporary spaces in Italian cities after the French revolution and at the beginning of the industrial revolution: they had an essentially civil character, providing shelter for city parties, restaurants and cafes in pavilions immersed in the gardens of cities to animate the afternoon stroll of the citizens. In some cases the short period foreseen for the installation justifies the use of textile parts.

The previously wooden structures were increasingly replaced by slender iron and glass structures of industrial origin, and the membranes became integrated into the glass facade, functioning as sunshades or acoustic insulation. The point of reference is certainly the great English greenhouses and the French markets, where this use of membranes is clearly demonstrated. The acoustic membranes employed inside the Crystal Palace of London during the crowded "Haendel Festival" concerts (Fig. 1.5) organized in 1859, after the dismantlement of the whole building from Hyde Park to Sudenham, are an important example of this new role of textile membranes.

With the coming of bourgeois society, temporary shelters used for religious festivals or for private celebrations of the nobility are dying out more and more, while the architecture gives the impression of a new civil magnificence only through permanent

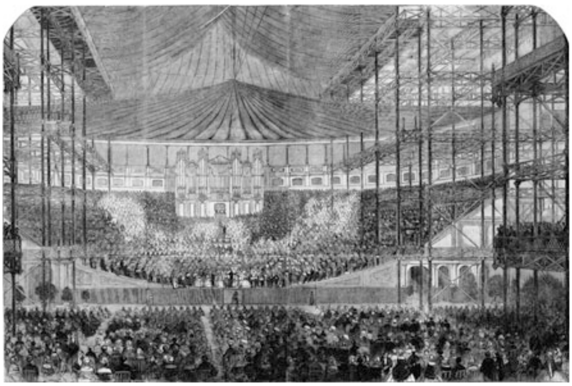

Fig. 1.5 Acoustic membranes for performances inside the Crystal Palace during the Haendel Festivals, London, 1859 (*Source* Forsyth 1985)

constructions. Temporary structures are relegated to travelling uses: on one hand circuses are quickly transformed from wooden structures to an adaptable membrane structures from the end of the 19th century and at the beginning of the 20th century. On the other hand, a new form of travelling theatre theorized by futurists was never built. However their theories inspired the “Tespi trucks” of the following period, which are theatres in membranes and steel itinerant structures by Fiat trucks. According to that theorized by the futurists, since 1928 “Tespi trucks” crossed the whole Italian peninsula during the summer months, a stage for prose and later lyric performances, both in small centers and great cities. “Tespi trucks” were created by the institute of the working men’s club (OND) and promoted by the fascist national government, to improve education of the popular masses (Pacini 2004).

Antonio Valente was the architect who designed them and oversaw the construction of typology of the Tespi prose theatre and later also of the bigger Tespi lyric (Niccolai 2004). All executive aspects of Tespi travelling theatres involved accuracy, choosing lightweight materials and designing flexible parts to facilitate the assembling and dismantling processes. The manufacture of the textile membranes was submitted to a producer in Milan, called the Italian Workshop of Waterproof Fabrics, who recognized them from Valente’s drawings, using innovative fabrics for the period, guaranteed for a long resistance in time (Pacini 2004). This workshop also documented the assembling process of a Tespi lyric textile dome (Fig. 1.6). The experience of “Tespi trucks” represents a meaningful example of Italian temporary architecture, in which clever design and attention to the most innovative materials of the epoch are joined together.

These historical examples show the skill of the ancient architects in using membranes for their unique characteristics. They were able to design innovative architectural spaces using the flexibility of membranes to create surprise effects and to modify the position of textile shelters in relationship to climatic changes during the whole of the year, thus improving the internal climate of an enclosed space. Another considerable aspect is that temporary structures of the past were commissioned to great architects, while today it is too often thought that a temporary structure can also be built without a good project, with the idea that it will be demolished soon.

Furthermore, a fundamental lesson comes to us from the two main pioneers of lightweight construction of the 20th century: Frei Otto, the father of tensile textile architecture, and Buckminster Fuller, the father of geodesic structures.

Fig. 1.6 Assembling phases of the dome of a Tespi lyric theatre, by the Italian Workshop of Waterproof Fabrics, 1928 (*Source* Cardone and Coccu 2005)

In the following lines their design strategies will be briefly refreshed with the aim of demonstrating their experience as extremely consistent, up-to-date and even innovative at the present age. In different times and ways both Frei Otto and Bucky Fuller warned contemporary designers that a design revolution is coming, and if it means using resources efficiently and competently, then humanity will be able to sustain the generation to come.

1.3 Performance of Form

Truly, in these recent years textile architectures seem to have developed a knack for distancing themselves from the best examples of the beginnings, becoming more and more heavy, fixed and permanent, in other words textile-based monumental buildings instead of lightweight and temporary presences in the landscape. That could be positively considered as a necessary step of the textile technology evolution and a result of its successful development on the global construction market. On the other hand, we will see that a further stage of development had to be foreseen: the current scientific and technical progress really made feasible some pioneers' ideas that were considered dreams during the fifty years of the past century.

The first notable statement from Frei Otto was that too little attention is paid to integrate engineering skills into conceptual design processes which are considered the domain of architects: this is one of the reasons why the situation of lightweight and natural architecture is not yet really satisfactory. The "synergetic" design strategy theorized by Buckminster Fuller seems to be coherent with the Frei Otto thinking and his *form-finding* design process.

Fuller pinpointed the importance of designing and thinking vectorially, where lines are energy, and where the architecture is structure, material, geometry before becoming form. During a famous interview he said: "One of the most important things you should do in a school of architecture is that every student when designing or drawing should make a list of all functional requirements and also materials and resources that are employed, in order to figure all the weights, amount of energy, amount of time; all of these must be on the drawing, every time, every drawing. As we do with the aeroplane, we know everything of its performances. The designers must be responsible for technology itself, where the resources are coming from, and how we get them… the designers must be responsible from beginning to end" (Pettena 1975, 1978).

Textile architecture could be termed "straightforward" and "transparent". A designer must not see textile elements as mere ornaments or ways of covering things that, aesthetically, one might not wish to be seen. In this, there is perfect correlation between form and structure. You need to break out of the old paradigm used to conceive a building, thinking first of a form and then entrusting the engineers with the task of resolving how it can be erected and stay up safely. Then, at the end, you might return to thinking about the materials that can be used for the planned structure. This is not how things work in the field of lightweight and, more precisely, in textile-based architecture. Here, the material is everything. The ability to deform it means you have to play with the architectural and structural form at the same time, successively refining the one and then the other in a repeated process that is never disengaged from the materials being used. Moreover, the visual lightness and static efficiency will be greatly improved in the end result if you are skilled to create a form able to guarantee the best performances, removing more and more matter and weight from the supporting elements.

A lightweight form necessarily assumes the specific characteristic of the matter, which the designer decides to use: textiles, woven, non-woven materials, transparent films, laminated composites, plastic sheeting, nets, or even simply light (Fig. 1.7) and air (Fig. 1.8). It seems the best chance for the designer to play with these material elements, getting the most efficient, saving-material, functional and comfortable building solution.

Fig. 1.7 *The form of light*. Frei Otto, temporary shelter for the Stromeyer catalogue, 1954. The covered space is qualified by the designed form of the seams stitching different textile panels, quite evocative of the translucency of natural leaves (*Source* Morganti 1965)

Fig. 1.8 *The form of air*. Buckminster Fuller, 1949. Transparent pneumatic cushions framed by electrical plastic tubes become a prototype of an ultra-lightweight geodetic dome (*Source* Baldwin 1996)

1.4 Soft Materials, Adaptive Skins

There is a real need to learn about these special materials that are so lightweight and deformable. However, if these special materials are used badly and in a makeshift manner, then one can cause more damage than using traditional materials. In the best scenario, one doesn't achieve the desired lightness for the design; while in the worst scenario, the structure simply doesn't stay up or collapses straight away. Some key points that help to fully understand the specific nature of textile architecture – using textile materials properly and as efficiently as possible – are: first, the best use of the chosen material; second, the volume and layout is suited to the chosen function; third, the structural conception is effective and fully consistent with the proposed architectural form.

The main interesting attitudes of current technical textiles are: first of all, the possibility to create continuous surfaces, such as a real skin; second, they can have different permeability to sunlight, so the designer can use seam lines to emphasize some elements, connections, parts of the textile surface; finally they can be waterproof, air-tight, coated with low-energy or even self-cleaning finishing layers, suitable for specific functions.

Most of those properties are typical of the other wide spread common building materials, while the deformability to the loads and the mechanical resistance to the tension stresses are the main peculiar properties of fabrics. They are indeed "soft" materials. The ability of the designer is to use them to get on the whole both stable structures and beautiful architectures, which always achieve the feeling of a "transitoriness" through the continuous deformability and imperceptive movement of the fabric itself. Quite appropriate is the statement of Kengo Kuma concerning his temporary Tea House: "the architecture ought not to be something that separates human beings from nature and from the environment that surrounds them. I always try to unite the body with the environment through the use of natural and soft materials. I believe deeply in this effort" (Kuma 2004) (Fig. 1.9).

Fig. 1.9 *The soft form*. Kengo Kuma Architects: Temporary Tea House, made of two textile membranes stabilized by inner air pressure. A perimeter steel U profile connects the two layers of membranes and also works as a temporary foundation (*Source* Courtesy Form TL Archives)

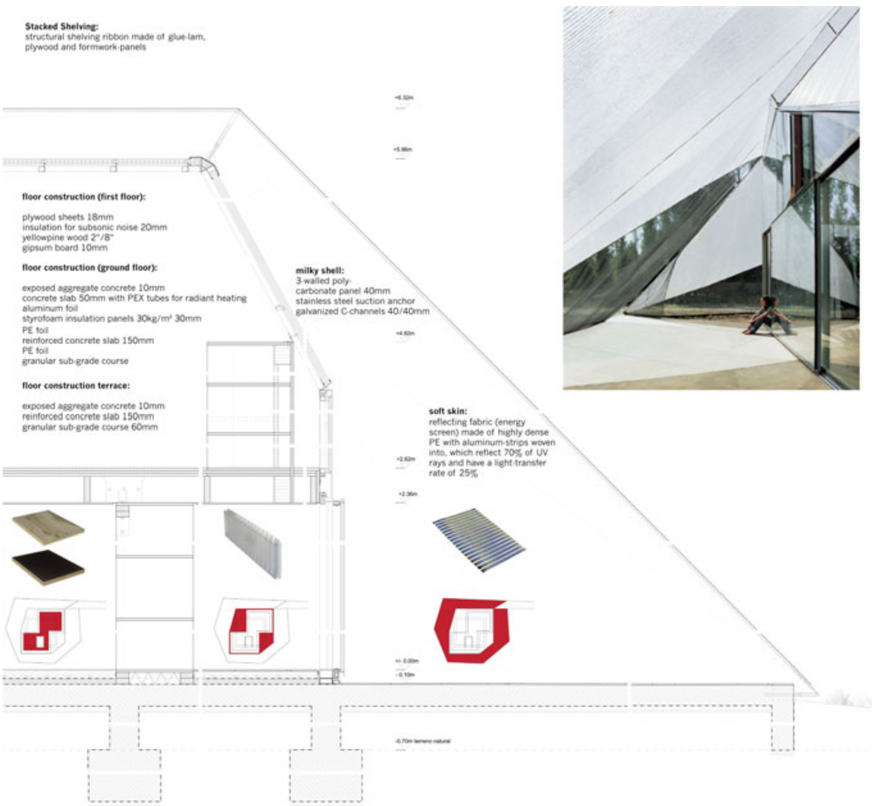

Fig. 1.10 *The adaptive skin*. FAR architects, vertical section of the Wall House and a view of the open air perimeter protected by the soft textile skin (*Source* Courtesy FAR Archives)

If we focus on the macro-scale, from the material to the building system, we should see that textiles and other kinds of flexible films and foils are more easily suitable to create adaptive enclosures, again only if the designer is actually able to follow the deep nature of these soft materials.

The Wall House designed by FAR architects in 2008 (Fig. 1.10) seems a clever example of adaptive building skin, which performs an extremely high energy efficiency for Latin American standards. It looks like no so much sophisticated than that Lord Rogers has been dreaming as architecture of the future: animated by a holistic ecological view of the globe, non-mechanical, fluid, seamless and self-regulating, programmed by electronic means and so on, but it seems to well interact with the user and the climate.

The primary structure of the house is made of prefabricated plywood tri-dimensional components; an inner skin, so called *Milky Shell* is made of poly-carbonate sheets and steel frames, while the outer skin, so called *Soft Skin*, consists of two different woven textiles, the energy screen and an insect membrane. Both materials are commonly used in green house construction. The energy screen consists of a combination of highly reflective aluminum strips, which are woven together with polymer fibers. The diamond-shaped skin uses – depending on directional orientation – an energy screen that reflects between 50 and 75 % of the sunlight away from the building. By moving away from the polycarbonate shell up to 4 m and more on the ground floor, a usable exterior space develops under the skin. Mosquitoes and other insects cannot penetrate the membrane. It contains three zippers, allowing inhabitants to easily move in and out of the tent. Along the ridge the distance between the two layers Soft Skin and Milky Shell is reduced to roughly 45 cm. Air can flow through this remaining gap, allowing the warm air to be sucked through the pivot-hung opening out of the interior. Through the spatial and material configuration of the individual wall layers the project develops an appropriate architectural approach of dealing with the local climate (summer between 30 and 35 °C, winter up to 10 °C).

1.5 Time-Based Design Strategy

Since lightness is the focus of the design, it is important to ask how long the structure being designed will last. Time is a project variable, determining the method used to define connections between the component parts and dictating the installation rules. However, it also sets the rules for how easy the structure must be to disassemble entirely, at the end of its use, or partially, during maintenance.

Protection can also be seasonal. For example, one might plan a series of structures to provide shade in the spring and summer, increasing the amount of space used in an otherwise overly sunny zone. Alternatively, one might have in mind a protected, transparent “cocoon” that uses the winter sun to make the internal climate milder and create areas that students can use, in the winter, when the number of spaces for students is notably lacking. In all cases, it must be possible to “reverse” the details and dismantle the structure such that no traces are left once it is no longer in use.

The main question dealing with a time-based design process is: am I planning a construction for a day, a week, ten years or more? This is really quite a challenge for us since were are more akin to creating designs that last for indeterminate periods, without considering how overbearing such structures might be for future generations. I should be fine think that even the form of architecture is changing in order to respond a different life-span: that is quite right for each textile architecture where the life-span can play a huge role in determining the materials choice and consequently the cost of the building.

A good time-based design strategy takes into account the manner of use the structure in the time, in order to design the best, most durable, easy to handle, joints connection between elements. Each temporary structure has to be planned as a kit of components, fully produced off-site and ready to install on-site. The importance of the role played by the detailing design stage is clear and this needs to be a multidisciplinary process.

1.6 Fabrication and Delivery

The designer of a lightweight architecture cannot ignore two crucial stages of the building process that typically seem not so much related with architectural skills: the fabrication of the textile membrane and the delivery of all the pieces of the kit which is going to be installed on site.

The construction process of a lightweight architecture is closer to the automotive production process than a typical building process. All the components are pre-fabricated; a final manufacture is responsive to the pre-assembling stage off-site and then of the installation on-site. It is a short process as the building site becomes merely the assembly point for pieces made elsewhere. The project contains all the details needed for putting everything up in the shortest time possible.

Design, fabrication and material properties are integrally linked. The fabrication process is defined not only by the end goal that a client requires but more critically by a profound understanding of how material works, what is good and what the material is like. The designer has to fully understand the properties of the materials, if he is really looking to transform them into useful everyday objects.

Only by understanding the materials of his project can he adapt his idea to suit the best fabrication process (Fig. 1.11). Yet, overall, he can also celebrate the fabrication process as part of the language of the design itself.

However, fruitful interaction between designers and specialist fabricators is beneficial. For each project, the designer must be able to clearly communicate his ideas to his process specialist. At the same time, fabricators will adapt their process to suit the product. Likewise, the designer may have to adapt his ideas to suit the limitations of the fabrication processes. The more symbiotic this relationship is, the more cost-effective the process is and the more satisfactory the product becomes.

Fig. 1.11 *The form of tessellation*. Sanina and Marcelo Architects, Madrid, 2009. Following the tessellation concept, an ephemeral house was created by a sequence of textile layers, each one produced in a different manner (*Source* Courtesy SM Archive)

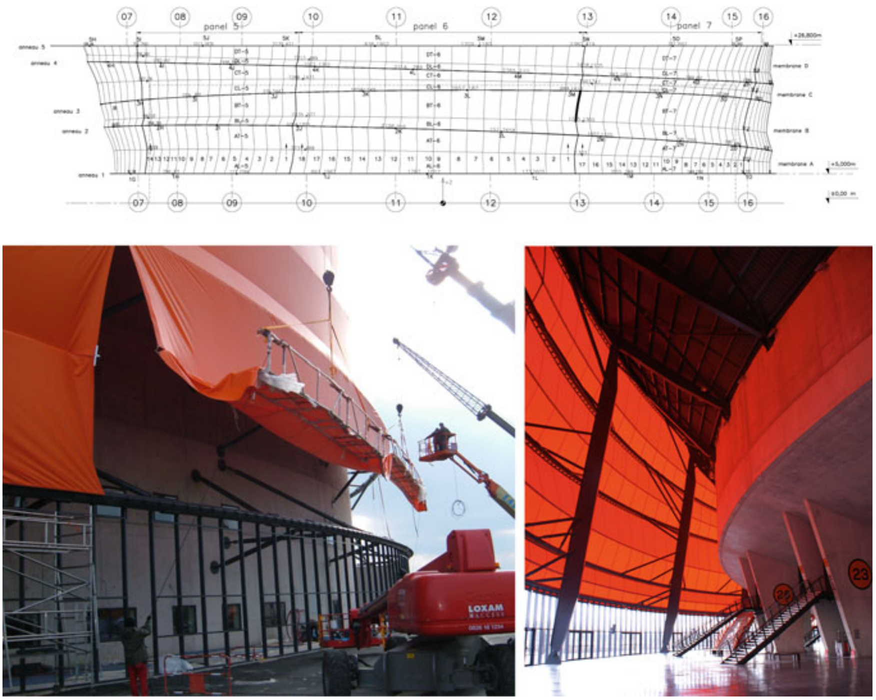

Fig. 1.12 *Textile as a building product*. Massimiliano and Doriana Fuksas, Zenith Auditorium, Strasbourg 2008. The impressive textile skin of this permanent architecture was installed in only ten weeks. The detailed front drawing shows the partition of different big textile panels which were produced and then installed (*Source* Courtesy Canobbio Archive, *left*; Courtesy Fuksas Archive, *right*)

Accumulated knowledge of manufacturing techniques and material properties suitable for permanent buildings (Fig. 1.12) allows designers to adapt successfully to new demands and challenges, exploring the limits of new materials and developing new techniques for traditional materials. It also makes it possible to transfer advanced techniques from one productive sector to another one, typically from more sophisticated fields of application (automotive, aero spatial, dressing, fashion) to the building sector.

1.7 Towards a Minimal Mass Architecture: Open Questions

In conclusion, some open questions for future designs have to be pinpointed. First of all, it is clear that the adaptivity achieved by changing the stiffness of materials, saving materials and getting structures light as possible, or by modifying electronic means in order to respond to a specific climatic condition, seems to be more and more a feasible task.

The real challenge now seems to overcome cultural resistance (Kronenburg 1995), introducing these lightweight design concepts, materials and building processes in one building area where science and the most advanced production techniques are not being applied: the house. Soft textile materials are very widely used in industrial design and furniture; a different task is to plan a whole textile-based building or even a housing stock. The development of textile architectures, able to perform a more comfortable and responsive relationship between people and the built environment they use, is the real challenge of today. Starting from minimal mass environments could help in focusing this task from a simpler perspective, taking into account that we are overseeing an experimental field of knowledge.

A second very challenging task is to deepen the theme of the lightweight foundation. The Australian architect Glenn Murcutt, who in turn got the idea from the Aborigines "touch the earth lightly", remind us of the importance of being discreet when considering the foundations and development of the building. Designing with lightness belongs also to that part of the construction that too often, especially when seeking a temporary solution of a specific problem, is built in a cheap and makeshift manner.

Last but not least, we believe the admonition from the ingenious Buckminster Fuller "doing more with less" has to guide each new design concept, not only that dealing with temporary requirements but also all permanent functions. It clearly advises the use of as little material as possible, in the best possible manner, as part of a project focusing on global ecology/economy, and not simply on direct financial return (Fig. 1.13).

Fig. 1.13 *Textile homes*. Sail in the Desert's houses, Longitude 131°, Ulurur-Kata Tjuta National Park, Nothern Territory, Australia, 2002, Cox Richardson Architects (*Source* Courtesy Cox Richardson Architects Archives)

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Chapter 2
Designing with Membranes

Paolo Beccarelli

Abstract This contribution offers an introduction to membrane structures and the experimental approach which has characterised this building system since its origins. In particular, the chapter offers an overview of the design approach currently adopted for tensioned membrane roofs.

2.1 Tensioned Structural Systems

The term tension structures describes the category of buildings in which the load bearing capacity is achieved through tension stress in the majority of the components, such as cables, technical fabrics or foils. The only exception is represented by rigid boundaries and structural members which are generally subjected to compression and bending.

According to Lewis (2003), tension structures can be subdivided in boundary tensioned membranes, pneumatic structures and pre-stressed cable nets and beams.

Boundary tensioned membranes are realised by means of lightweight, highly flexible membranes with a level of pre-tension which generates stiffness in the surface. The tension state is introduced by means of one dimensional flexible elements such as cables or ties which can be applied as flexible edge boundaries, or in order to increase the surface curvature through ridges and valleys. The overall equilibrium of the structure is provided by rigid edges and supporting members generally subjected to compression and/or bending. The surface load bearing capacity is provided by its double curvature and the pre-tension introduced. Under imposed load due to snow or wind, the fabric surface undergoes large displacements and a consequent increase in material stress, which can increase up to ten fold.

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The term pneumatic structures includes all the lightweight structures in which the load bearing capacity is achieved by means of air under pressure. They are mainly subdivided into two categories: the buildings characterised by a single layer, stabilised by a slight difference in pressure between the inside and the outside of the structures, and the structures made by two or more membrane layers stabilised by air under pressure.

Cable structures are load bearing structures composed of flexible linear elements under tension, with the only exception being rigid members or supports such as rigid ring beams or masts. They can be subdivided in cable nets, which describe three-dimensional surfaces, and a two-dimensional version represented by cable trusses and girders.

2.2 Tension Structures and Conventional Roofing Forms

Design of tensioned membrane structures is a relatively new branch of engineering. The basic assumptions on which the design is based, and the realisation of conventional, rigid structures, are not applicable to flexible, tensioned structures which require a totally different approach.

Firstly, the shape of a tensioned structure cannot be dictated but has to be found through a "form-finding" process which represents the starting point of the design action. Given a chosen boundary and level of pre-stress, the tensile surface adopts its own, unique shape.

Compared with conventional roofing forms, this type of structures are characterized by a nonlinear behaviour due to the behaviour under working load and the materials commonly used. The load bearing capacity is reached through changes in surface tensions and very large displacements which have to be considered during the structural analysis. The level of pre-stress in a fabric membrane plays an essential role for the structural response and it has to be balanced to provide the required stability under load (flattering) and prevent tearing under imposed loads due to high levels of stress. The traditional compression and/or bending stresses are limited to the supporting structure while the membrane and the cables are generally characterised by a reduced bending and shear stiffnesses.

Finally, the computational analysis, unlike that of a conventional structure, is a crucial part (and cost) of the whole design project (Lewis 2003, p. 17).

Despite the considerable increase in the difficulties which have to be faced, both in the design phase and in realisation phase, the interest in tension structure is continuously increasing. Firstly, they offer architectonic solutions with dramatic expressivity which have no rivals from the aesthetic point of view, with the only exception being concrete shells. Nevertheless, concrete shells require a larger quantity of material and hardly reach the effects of lightness and luminosity due to the use of translucent membranes. Secondly, from the structural point of view, they provide, with the compromise of higher deflections and a major risk of dynamic instability, a lighter alternative to traditional load-carrying elements in which the material is subjected to tension instead of compression and bending (in which the occurrence of instability does not allow full use of the material resistance). Thirdly, the small quantities necessary of the material employed, which can be further reduced in hyper-lightweight structures, represent a fundamental advantage in the field of temporary structures, both in seasonal application and in emergency contexts where the building elements should be easily stored, transported, mounted and dismounted. In addition, the reduced amount of material results in a lower environmental impact which can be assessed through specific LCA analyses.

These features highlight the fundamentally different approach between conventional roofing forms and tension membranes which require a tight collaboration between the subjects involved in the design and realisation of this type of building. Considering the design phase, it can be seen that ordinary structures are generally the outcome of two different figures: the architect, in charge of the initial proposal and its development from the aesthetical point of view up to the singular detail, and the engineer responsible for the static equilibrium of the structure, which has to meet the aesthetic requirements within a reasonable cost and feasibility of the structure. This approach is practicable because the rigid-type constructions are characterised by small deformation, thus there are no considerable consequences on the geometrical shape, which is generally chosen at priori with limited attention to the structural problems investigated by the engineering office once the project is approved. The same organisation characterises the building erection with reduced collaboration between the companies involved, who are generally responsible for the execution of a single activity, with no considerable consequences for the other phases.

This methodology is totally inadequate for tension membranes. The aesthetic issues go hand in hand with the structural aspects because the overall shape of the structure depends on its equilibrium. Thus, the membrane shape cannot be imposed, but it has to be found by working on the boundary conditions and the internal stress distribution due to pre-stress. This imposes a tight cooperation between architects and engineers in the design phase, which should consider the technical limitations due to material production, erection and maintenance. For this reason the manufacturer and material producer are generally involved at the early stage of the project development, which should consider aspects related to the chosen material and the technology available at the workshop in charge of manufacture of the structure. This generally includes specific welding and sewing machines, cutting tables, software and other mounting devices.

Another considerable difference between conventional structures and tension membranes is the mathematical approach used in the structural design. The terms *linear* and *non-linear* behaviour describe both the material properties and the overall structural behaviour. A linear behaviour describes a directly proportional stress-strain relationship which leads to n-fold changes in deflection as a consequence of n-fold changes in the applied loads. Lewis (2003) highlights that "structures which obey a linear load-displacement relationship will automatically be characterised by a linear stress-strain relationship (Hook's law) for the material". However, the opposite may not be true. The latter is the typical situation of cable structures which, despite the linear behaviour of the cable under tension, are characterised by an overall non-linear behaviour due to the influence of geometric changes on equilibrium requirements. The phenomenon is still further magnified in the membrane structure due to non-linearity of the material depending on the complex interaction between warp and fill (crimp interchange) and the coating layer.

The comparison between conventional roofing forms and tensioned membranes is generally based on the mere confrontation of a few parameters which generally comes from evolution of the building technology. The expectancies about parameters concerning mechanical properties, the thermal and acoustical insulation, the durability and so on, depends on a long building tradition based on concrete, steel, timber or masonry and does not describe efficaciously the potentialities of lightweight structures. Thus, for example, it is useless to compare directly the durability of a covering made with tiles and an envelope realised by means of transparent ETFE pillows, and this is generally true for a wide range of parameters. A superficial comparison can result in the perception of membrane structures as a cheap, temporary version of permanent rigid structures, with a consequent race to increase their performance at any cost, resulting in the loss of the original lightness and translucency. Whereas the strong points of tension structures are their lightweight and the efficiency with which the material is used. This approach is particularly suited to temporary structures, deployable structures, emergency shelter and wide span structures and offers interesting opportunities concerning the reusability of building components and their recycle at the end of the life span.

2.3 The Design Process: From Physical Models to Computer Based Software

As stated above, the standard design approach is not applicable to tensioned structures. This, basically, depends on the fact that while conventional "linear" structures do not show noticeable changes in their overall shape once subjected to loading, "non-linear" structures undergo large displacements which influence their geometry and the way in which equilibrium is attained; thus an iterative approach is required for their analysis. Therefore, the design of traditional rigid structures follows a linear sequence in which the initial architectural shape is transmitted to the engineering office in charge of the structural design; subsequently once the architectural shape has been upgraded in accordance with the structural requirements, the definitive project is transmitted to the builder for the realisation of the construction. The correlation between the several subjects is generally reduced to the correct information transfer between two consecutive phases. Only masterpieces of modern architecture and engineering are an exception to this procedure.

Fig. 2.1 The model of the New Juventus Stadium in Turin tested in the wind tunnel of the Politecnico di Milano (*Source* Courtesy Canobbio S.p.A.)

Whereas, the initial shape of membrane structures is the result of a preliminary structural analysis called "form-finding", which assures that each point of the surface is in equilibrium, given the tension ratio in warp and fill direction and the boundary conditions. The architectural and the structural idea should converge to a solution which is both aesthetically pleasing and structurally efficient and feasible. The design process cannot leave out of consideration the issues related to the material chosen, the manufacturing and the erection. It is therefore desirable that manufacturers and material producers are involved in the project development at the earlier phases of the projects, when the type of membrane material is selected, with consequent repercussion on the joints realisation and assembling procedure.

The design process of tension membranes can be summarised in three main steps: the form-finding, the static analysis and the patterning, with the possible addition of dynamic analysis if required. Nowadays, these steps are the key features of several software used in the design of membrane and cable net structures, according to the target considered by the developers, the design software includes one, two or all the modules. However, before the spreading of the computerised design methods, these steps were carried out by means of physical models with accuracy and scales of representation depending on the technical aspects investigated (Fig. 2.1).

2.3.1 Form-Finding

Through the form-finding process the initial, equilibrated shape of the structure is determined. As described above, the initial shape of a membrane structure is a function of the stress ratio in a warp and fill direction and the boundary conditions; external loads are not considered at this stage. The membrane configuration in the three-dimensional space cannot be imposed at priori and is the result of an accurate calibration of the various parameters and the combination of the basic shapes, such as cones, barrel vaults and hypars.

In absence of the current computerised software, this phase was initially carried out by means of physical models. This approach has been widely used by the team of researchers and designers coordinated by Frey Otto at the Insitut für Leichte Flächentragwerke (IL: Institute for Lightweight Structures), and several important realisations, such as the Olimpic Stadium in Munich, have been designed through this approach, combined with a very simple computerised method (Songel 2010). Although physical models represent a valid method for visualization purposes, it has to be said that they lead to inevitable problems due to the correct determination of the local stress state, the deflection under load and the error magnification when the measures carried out on the model have to be scaled up to full-size.

2.3.2 Static Analysis

The static analysis is performed assuming as initial configuration the one determined in the form-finding stage. Through static analysis it is possible to predict the stress and the displacements which arise in the tensioned surface due to the presence of external loads such as snow or wind. According to the current European design code or the national set of rules, it is necessary to consider the most

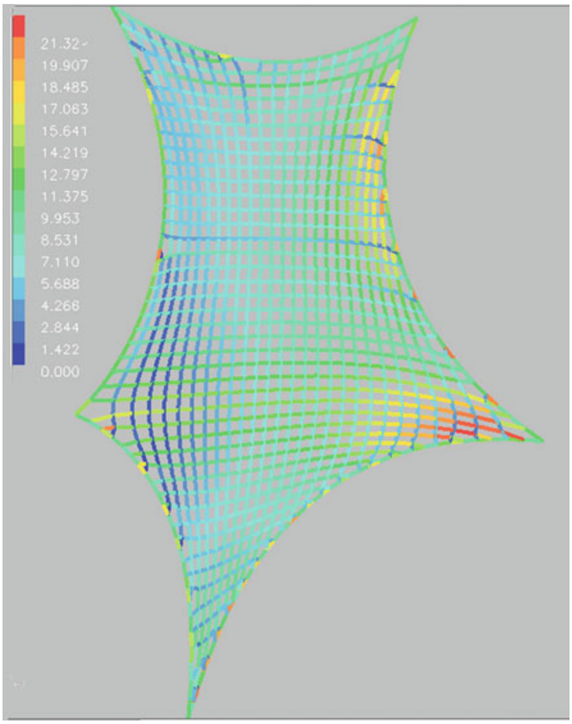

Fig. 2.2 Example of a stress distribution map, expressed in kN/m, obtained through a commercial software for form finding and structural analysis (*Source* Paolo Beccarelli)

significant loading conditions obtained by combination of the expected loads with safety factors, due to the uncertainty concerning their assumed magnitude and position. The analysis results are generally represented by means of coloured patterns distributed on the structure, which indicate, for each loading condition, the value of the parameter considered (stress, strain, deflection, etc.). Moreover, for further detailed consideration, the values are generally available in the form of a database divided for each element.

Despite the similarities with static analysis currently carried out for traditional structures, the assumptions of small deflections and the linear behaviour of both material and structure are not suitable for tensioned structures. For this reason the mathematical models employed are completely different compared with those commonly used, and should follow an iterative computation able to determine the final equilibrium form.

The determination of stress distribution is a crucial step in the design process, since the membrane choice or the detail resistance depends on the maximum value noticed (Fig. 2.2).

When required, the results of the static analyses can be integrated with dynamic analyses which investigate the effects due to a fluctuating external load, such as the wind pressure. The potential risk of collapse due to aeroelastic flutter can be investigated through simulating software or sophisticated tests performed in a wind tunnel.

2.3.3 Patterning

Through the patterning design stage, the three dimensional surface, found by means of the form-finding, is flattened, obtaining a two dimensional cutting pattern for manufacturing of the fabric canopy, beginning from rolls of materials. This operation is generally based on mathematical studies carried out for several applications, such as determination of the surface area of solids or topographic issues related to the realisation of accurate bidimensional maps of the globe. It has been demonstrated that this operation cannot avoid a certain amount of error during the transformation of a three-dimensional shape into a two-dimensional surface. Physical models were widely used for this operation but the increasing accuracy of computerised software has progressively reduced their massive use to a simple interactive comparison of the results obtained through software (Fig. 2.3).

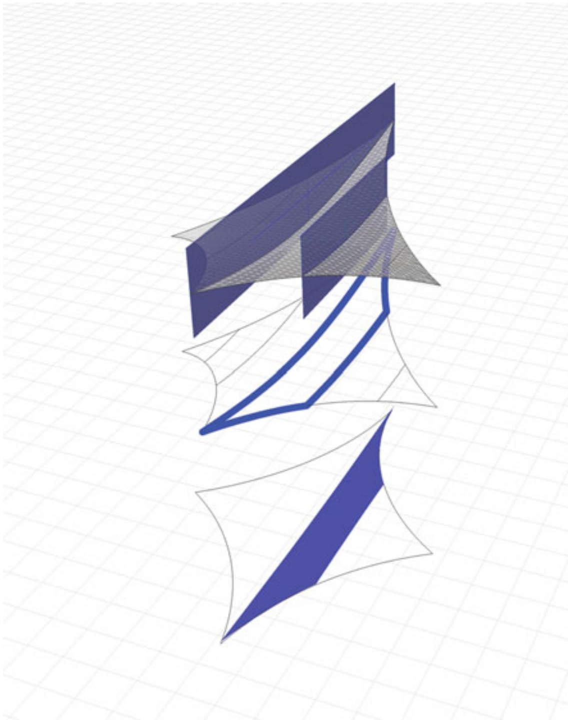

Fig. 2.3 The patterning process. The surface is divided into strips according to a layout based on structural and/or aesthetical reasons. Finally, the three dimensional form is developed into a two-dimensional cutting pattern form (*Source* Paolo Beccarelli)

2.4 Fabrication, Transportation and Erection

Once the design phase is completed, the working drawings are transmitted to the companies in charge of the realization of the structure. They generally concern the realization of three main parts of the final building: the foundation, the supporting frame and the membrane.

Once the fabricator receives the necessary material from the material producer, the strip of material, which cannot exceed the width of the material, generally between 1.80 and 3.00 m, is cut out of the roll, avoiding local damages.

The strips of material are then joined together in order to obtain the biggest panel of fabric transportable and mountable, reducing the use of welding machines or other high precision processes on the building site.

Transportation is facilitated by the foldable material and its reduced weight. However, this operation is critical for the membrane, which could easily be damaged by an incorrect folding process or the presence of rigid elements which can lacerate the fabric or compromise the protective layers.

After the individual structural components are fabricated at the works and transported to the construction site, the erection process consists of their assembly. On one hand, the erection process is facilitated and accelerated by the high level of prefabrication which characterizes this type of structure. On the other hand, the realization and assemblage of the components require a level of accuracy unusual for civil structures, with consequent demand for specialized workers and equipment.

2.5 Final Considerations on the Design Approach for Membrane Structures

A superficial approach to this matter can lead to the belief that the modern software of simulation can easily overcome the difficulties in representing the behavior of natural structures. This is generally not true because the initial assumptions can invalidate the model reliability especially if the virtual approach reduces the direct correlation with the principles studied. Whereas, the new technologies, such as the three-dimensional scanner, provide powerful tools for an integrated study of the natural principles, based on both the physical and the virtual approaches.

Despite the progressive diffusions of the computerized approach to the design of tensioned structures the role of the physical models and tests has not been completely replaced, on the contrary, they represent an unavoidable resource in specific phases. For the architectural design the initial models of study are a better way for architects to familiarize themselves with the three-dimensional surface. For this reason a mixed approach involving computational and physical models is finally suggested.

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Chapter 3
Lightweight Materials and Environmental Quality Requirements

Carol Monticelli

Abstract This chapter introduces the theme of life cycle thinking design, underlining how the use of materials in buildings has to be cross-linked to their life span and desired performances. The challenge of using soft materials is mainly related to energy efficiency, thermal behaviour and recyclability.

3.1 Introduction

Wide-ranging theoretical consideration of landscape design, configuration of the urban context, seeking the right form, and indeed of building in general, necessarily requires thinking about questions concerning implementation techniques through a rigorous study of materials, techniques and building processes: architectural technology must be part of design from the earliest stages, and design must be associated with time. In Italy, contemporary design has the enormous responsibility of balancing the permanent temporal nature of an urbanized context, in the majority of cases historical, with the temporariness represented by new designed spaces. Here, the word "temporariness" is used to refer to the option of redefining and re-constructing; to a capacity for adaptation, rather than a brief period of use in time. The variable of "time", along with the variables "energy" and "weight" currently constitute a cultural and methodological basis for a contemporary approach to environmental design.

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3.2 Time – Environment – Life Cycle Thinking

An eco-compatible construction is the outcome of a design and construction process if the meta-design is guided by the concept of life cycle thinking. This entails considering the impact of the stages prior to building the property, including deciding what materials and technologies are suited to the project's context and end purpose, the property management stage, disassembly at the end of its life, and how waste is handled (Perricciolі 2004). It is no longer sufficient merely to consider a property's energy load in order to deem it sustainable. We must look further: we must assess the consumption of non-renewable raw materials, quantify emissions of polluting substances and waste production during the production period, and forecast emissions during usage. The confines of the system that we must consider have become broader, entailing a change in paradigms and in our approach to design. Energy, the environment and time are becoming the new design variables for buildings that we simply cannot do without (Commoner 1972). Among the complexities of this new design path, environmental requirements for building sustainability entail further investigation of the "building/environment" relationship in terms of its life cycle and, on a scalable basis, between the building and its underlying elements (Monticelli 2006).

3.3 Form, Matter and Energy Efficiency – Search for Lightness

In design, attentiveness to optimizing a building's form and its elements with a view to deploying architecture that uses materials rationally and functionally, that is to say, more lightweight, means redressing the balance between nature and the "built". In turn, this means embarking on a search for lightness as a design paradigm, with its implicit double meaning of high formal and high material efficiency.

The affirmation of a new design ethic and new design paradigms is also leading to the emergence of new types and forms of built designs that are often determined by a necessary integration with new mechanisms and materials for eco-efficient buildings.

The search for lightness is research into materials. Research into lightweight materials is all about reducing the thickness, the section and the quantity of materials in a construction. Research into materials has overturned the relationship between designers and materials: if in the past materials suggested their own most appropriate use, today designers mould and define materials to cater to the project's requirements, no longer with any limits. From a life cycle design and eco-efficiency standpoint, designed materials such as polymers have a characteristic that traditional materials do not: reduced weight for the same volume (density) (Otto and Rasch 1996). This is paramount if the objective is to pursue savings in materials and energy, although it must also be assessed in terms of the other stages of the life cycle (Figs. 3.1 and 3.2).

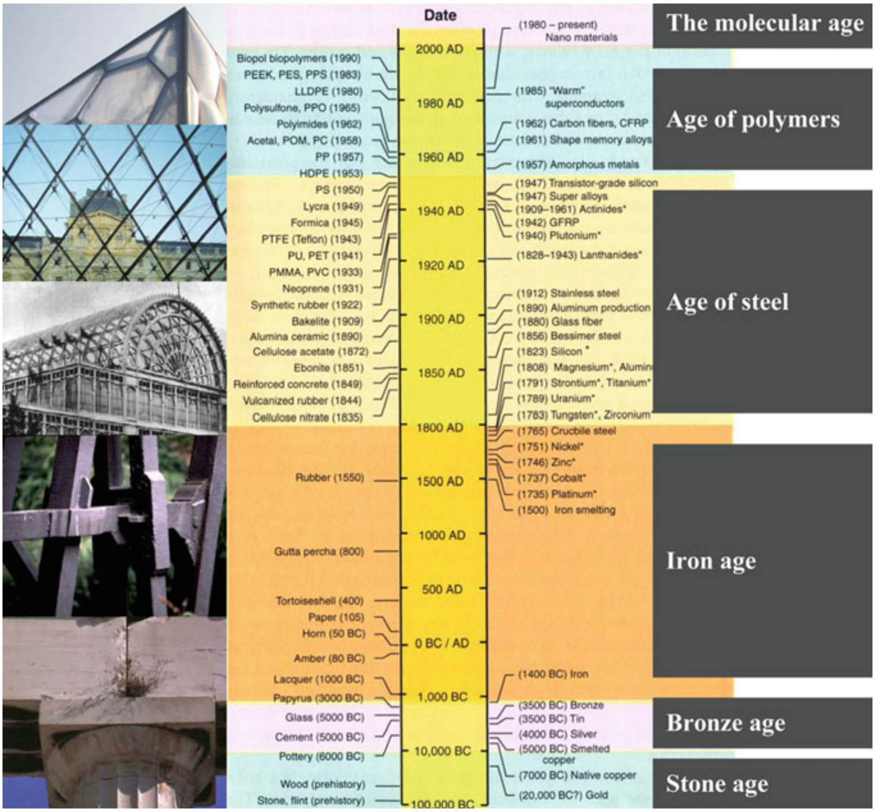

Fig. 3.1 The discovery and evolution of materials, seen in an historical time sheet, shows the search of lightness, from the age of stone to the actual molecular age: if in the past materials suggested their own most appropriate use, today designers mould and define materials to cater to the project's requirements (*Source* Ashby 2009 with elaboration of the author)

3.4 Verifying Indoor Comfort Using Lightweight Materials

In Italy, material culture has always approached building by using massive materials whose thermal inertia, combined with the thickness of strong walls, effectively caters to internal building comfort in both summer and winter conditions. If, in the same context, a building is designed using lightweight materials, whatever their thickness within the envelope, their mass, which ensures thermal inertia, is intrinsically lower. It is therefore necessary to consider the potential and limitations of these materials in relation to the function of the building where used. If the lightweight materials considered for a project include membranes, which are no longer just used for structural purposes but are far more often employed in

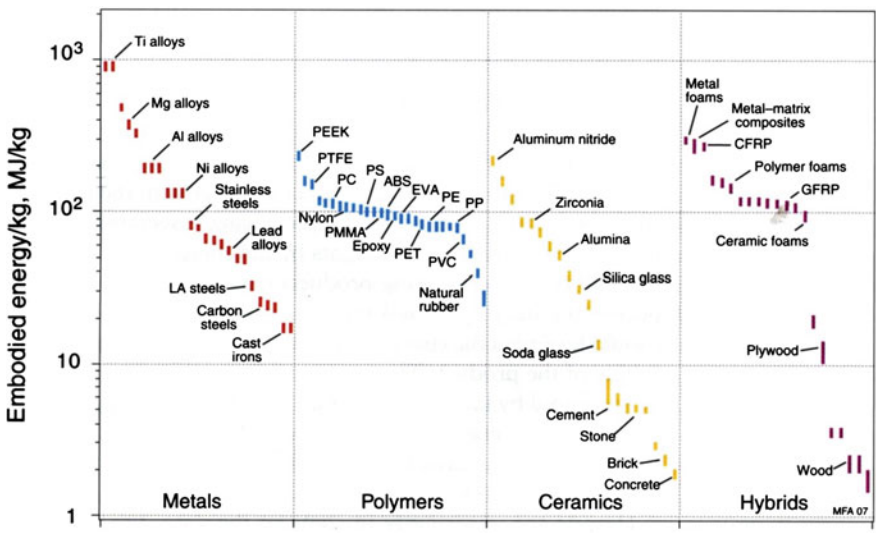

Fig. 3.2 Bar chart of embodied energy of basic materials by weight: by this measure polymers are more energy intensive than other "older" materials, but in the building systems they allow lightweight solutions and less involved quantities, with respect to the same functions of the other families of materials (*Source* Ashby 2009)

permanent building shells, ultra-light weight corresponds to polymer film-like ultra-thinness. Membranes offer undeniable advantages such as the translucent nature of textile membrane roofing and the option of retaining natural light; they also make it possible to achieve a good level of internal environmental quality if they are lower treated. On the other hand, owing to their thin section, membranes bring with them difficulties in maintaining optimal environmental conditions in differing external situations (Fig. 3.3).

Nonetheless, when used in projects, in terms of function and the degree of temporariness/permanence, membranes must ensure comfort through their mechanical, thermal-hygro, acoustic and visual performance (in the latter case, exploiting 10–15 % luminous transmittance and a reduction in artificial lighting), while respecting fire resistance, vulnerability to condensation, and environmental impact performance associated with material manufacturing processes and their lifetime.

As far as thermal-hygro comfort is concerned, in the case of massive walls, radiation and convection play a lesser role and are often neglected, with the focus instead being placed on conduction and associated parameters for thermal resistance, phase shift and attenuation of waves of heat. For membranes, where mass is irrelevant and thermal resistance is close to zero, convection and thermal radiation play a vital role and must be controlled. Heat exchange through thermal radiation depends on a membrane's thermal and optical properties and the surrounding space. Another aspect that should be considered with regard to membrane thermal-hygro

Fig. 3.3 The i.F.O.B.A. architects solved the problem of the lighting in this project (Aura House, Tokyo, 1998), choosing an entire curved envelope made of translucent textile membrane and using the textile as material for a permanent building (*Source* Nishizawa et al. 2000)

comfort is their thermal-light radiation properties, which are more representative of their thermal behavior with respect to the value of transmittance. Consequently, architects should take this information into account when comparing the energy and environmental performance of different textile products and when simulating micro-climatic conditions within tensile structures. This latter property depends on a number of factors such as solar absorption, and solar reflectance and emissivity, in addition to the type of textile and the coating from which they are made.

Two potential avenues may be pursued to obviate the ineffective thermal-hygro response of membrane lightness and thinness: (a) multi-layer membranes in which the number of layers is increased (with differing functions) using a variety of insulating, reflecting, water resistant materials etc., fibrous insulating materials, air chambers and foams; (b) insulated membranes featuring air blades, in which a layer of low density insulating material is inserted between the external structural skin and the internal lining (Fig. 3.4).

From a design point of view, the former solution ensures lowering the passage of heat and a reduced risk of condensation, as well as better control of thermal gain, light transmission and acoustic characteristics. The latter solution offers greater mechanical stability, greater thermal stability and humidity/condensation control, along with lower translucency or semi-transparency, in some cases reducing to zero transparency and diffused light (Fig. 3.5).

As well as other context-related issues, it is important to be aware of a project's climatic characteristics. If the project is part of a sustainability plan for a specific area in Milan, for example, as well as constructing an experimental setup of a

Fig. 3.4 Example of a multi-layer membrane installed into the Portuguese Pavilion, Expo 2000, Hannover, Germany: the number of layers is increased with differing functions (*Source* Zanelli 2007)

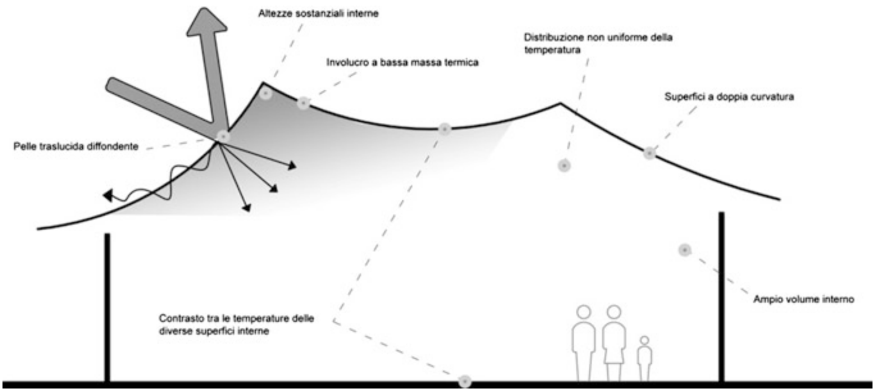

Fig. 3.5 Characteristics of a textile envelope in a building, which influence the environmental indoor behaviour (*Source* author drawing)

lightweight covering system, the climatic conditions in the city during the year must be known. For example, with regard to Milan's average winter temperature (January average temp. 1.4 °C, absolute minimum temp. −15.6 °C), building and health regulations require that a temperature of 20 °C must be catered to within enclosed spaces in order to guarantee adequate internal comfort; in summer

(July average temp. 23.1 °C, absolute maximum temp. 39.3 °C), the design must guarantee 23 °C indoors. In Milan, the annual average temperature is 12.5 °C (data sourced from the Weather Forecasting Station at Milan Linate).

3.5 The Right Membrane Technology for the Specific Context and Life Span

In designing lightweight architecture, the executive and definition phase of material construction techniques should commence with a heuristic phase. If the project is for open/openable spaces through the configuration of lightweight covering systems, it is important to choose one of the following possible scenarios depending on the project context:

– In the case of a permanent hyper-insulated enclosed building of a compact shape (i.e. cocoon-like) which ensures an efficient response to environmental requirements in winter, during the design stage it is vital to envisage how the high-temperature and radiative effects of sunlight in summer will be managed: it is necessary to thoroughly examine critical issues and implement a number of design strategies. With enclosed membranes, it is vital to ensure appropriate ventilation by adopting a number of strategies such as internal air layer mixing; in summer, natural ventilation must be ensured through features that are included during the design phase – for example, planning to position a number of openings into the covering; a continuous supply of air must be guaranteed from the outside in order to avoid areas of internal heat, whereas during the winter heat dispersion must be reduced to a minimum, along with the entrance of air from the outside, by mixing internal layers of air (through de-stratification fans or adjustable-sized waterproof openings).
– In the case of a permanent building open in the summer, it is necessary to envisage an option for enclosing the volume during the winter season, which means focusing on the paradigms of adaptability and transportability as well as form (this may also include an option of adding layers of covering in order to ensure greater comfort in a cold climate), all of which must be considered from the design concept stage onwards (Fig. 3.6).
– In the case of a seasonal building designed for the summer, which, for example, offers shade and shelter from heat radiation, there is no need to consider thermal insulation. However, if the building's function is to serve as a place for study or reading, what is more likely is the need to investigate acoustic insulation of the system to be designed; the prevailing choice would be to opt for extreme lightness and ease of assembly/disassembly by adopting a reversible structure in order to facilitate disassembly at the end of the summer season. In the case of open membranes whose function is to provide shade, it is possible to avert the radiative effect by employing sun-reflective materials (65–80 %) that avoid the generation of shade and overheating in the membrane; to create greater shade it

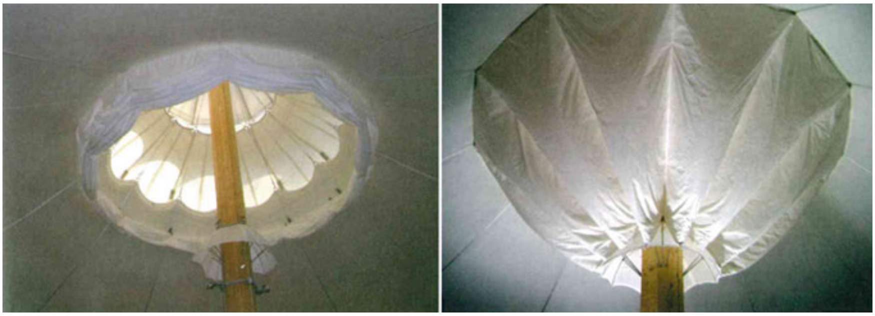

Fig. 3.6 Example of folding/re-folding membrane designed and installed with the strategy of reduction of the indoor volume during the winter time, Leonnberg, Germany (*Source* Zanelli 2007)

would be opportune to opt for colored coatings; adopting a grid-based tensile structure provides a cooling effect in addition to natural ventilation (Fig. 3.7).

– In the case of seasonal buildings designed for the winter, the prevailing environmental requirement is heat insulation and rendering the covering functional; owing to the thinness of lightweight materials, the envelope must be layered with multiple elements, each of which is functional to the various roles that envelopes must provide (impermeability to water, permeability to vapor, thermal and acoustic insulation, the internal/external visual relationship, etc.). To pursue the lightweight paradigm in any event despite this necessary layering it is vital not to increase the overall weight of the building, as at a later date it must be disassembled and reassembled.

Fig. 3.7 A case of a seasonal structure designed for the summer, which offers shade and shelter from heat radiation, El Cairo, Egypt (*Source* Zanelli 2007)

A number of important design strategies may be identified by considering a building's permanent or temporary nature from a lifestyle thinking approach:

– For "permanent" buildings, more attention must be paid to the operational phase (energy requirements for heating and cooling, maintenance), including the need for more envelope insulation, greater mass, more materials, and consequently a greater environmental impact during production processes; consideration of what material and technological solutions to choose and their environmental impacts takes place subsequently.
– For "temporary" buildings, the role of the impact of building components remains prominent, considering that in some situations energy heating and cooling plants and consumption during the usage phase are not required; at the design stage, the expected life span, which is almost always known and definable, is extremely important. One option is to use construction elements characterized by a high environmental impact, high embodied energy and good durability: their impact may be absorbed over forty, fifty or sixty years. A second option is for the materials chosen to provide low energy content if the lifetime is short, or else good durability despite their high environmental impact so that they may be reused/recycled: in this way the total impact is sub-divided into multiple life cycle loops (Monticelli 2009).

In the field of lightweight materials and membranes, materials used for temporary functions can become used for permanent functions. The building materials used in permanent functions are also used for temporary functions: at the design stage it is important to precisely define the building's function, be aware of its context and establish the expected life cycle of the building under design.

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Chapter 4
High Performance Lightweight Building Envelopes Made of Foils and Textiles

Jan M. Cremers

Abstract This chapter shows how architectural membranes for roofing and façades seem to be an effective alternative to traditional systems. Universities and R&D sectors of companies are collaborating to obtain the best performances as possible by the use of innovative technologies and coatings.

4.1 Introduction

Besides glass, a variety of other translucent and transparent materials are just as highly attractive to architects: plastics, perforated metal plate and meshing, but maybe most of all membrane materials which can also withstand structural loads, cp. Koch (2005), Knippers et al. (2010) and Knippers et al. (2011). Earlier applications of textile materials have served the purpose of keeping off sun, wind, rain and snow while offering the advantage of enormous span widths and a great variety of shapes. The development of high performance membrane and foil materials on the basis of fluoropolymers, e.g. translucent membrane material such as PTFE (poly tetraflouroethylene) coated glass fibres or transparent foils made of a copolymer of ethylene and tetrafluoroethylene (ETFE) were milestones in the search for appropriate materials for the building envelope.

The variety of projects that offer vastly different type and scale shows the enormous potential of these high-tech, high performance building materials which in its primordial form are among the oldest of mankind. Their predecessors, animal skins, were used to construct the very first type of building envelopes, namely tents. Since those days, building has become a global challenge. Usually building structures are highly inflexible but long-lasting and they account for the largest share of global

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primary energy consumption. It is obvious that the building sector has to develop international strategies and adequate local solutions to deal with this situation.

Principally, building envelopes as façades or roofs are the separating and filtering layers between outside and inside, between nature and adapted spaces occupied by people. In historic terms, the primary reason for creating this effective barrier between interior and exterior was the desire for protection against a hostile outside world and adverse weather conditions. Various other requirements and aspects have been added to these protective functions: light transmission, an adequate air exchange rate, a visual relationship with the surroundings, aesthetic and meaningful appearance etc.

Accurate knowledge of all these targets is crucial to the success of the design as they have a direct influence on the construction. They determine the amount of energy and materials required for construction and operation in the long term. In this context, transparent and translucent materials play an important role for the building envelope as they not only allow light to pass through but also energy.

4.2 Innovations

In the last few decades, rapid developments in material production types (e.g. laminates) and surface refinement of membrane materials (e.g. coatings) have been constant stimuli for innovation, cp. Cremers and Lausch (2008) and Cremers (2011). As a result, modern membrane technology is a key factor for intelligent, flexible building shells, complementing and enriching today's range of traditional building materials (Fig. 4.1).

4.2.1 Second Skin Façades

The Centre for Gerontology, a spiral building in the South of Germany, houses a shopping area on the ground floor and provides office space on the upper floors (Fig. 4.2). A special characteristic is the horizontal walkway arranged outside of the standard post and rail façade which forms the thermal barrier. The walkway is protected from the weather by a secondary skin. The complex geometry, the creative ideas of the architect and the economic conditions have been a special challenge and led to the implementation of a highly transparent membrane façade with high visibility between the inside and the outside due to its much reduced substructure. Moreover, because of this 'climate envelope', an energy saving intermediate temperature range is created as a buffer, which can be ventilated naturally by controllable, glazed flaps in the base and ceiling area. This secondary skin has a surface area of approximately 1550 m^2 and was constructed by the Hightex Group as a façade with a pre-stressed single layer ETFE membrane with a specially developed fixing system using lightweight clamping extrusions. This was the first

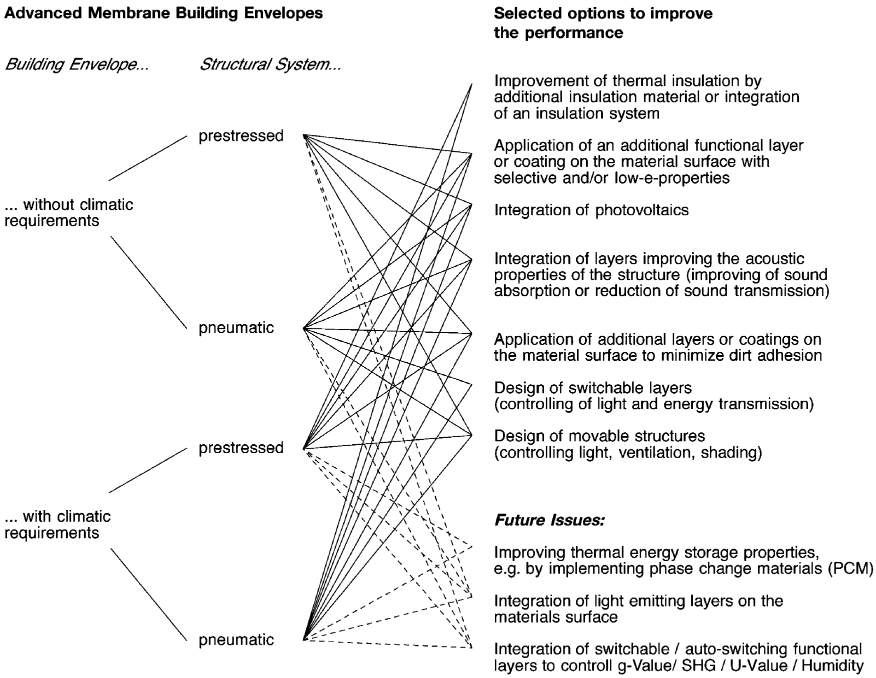


Fig. 4.1 Selected issues for future membrane research activities (*Source* Jan Cremers)

Fig. 4.2 Second skin façade of the Centre for Gerontology, Bad Tölz (*Source* Jan Cremers)

implementation of this type of façade featuring a second skin made of single layer stressed ETFE membrane anywhere in the world (Fig. 4.3).

Printing the transparent membrane with a silver dot fritting pattern serves as light scatter and sun protection. The flouropolymer-plastic ETFE used, which until then was mainly used for pneumatically pre-stressed cushion structures (Figs. 4.3 and 4.4), has a range of outstanding properties which predestinates it for building envelopes:

Fig. 4.3 Slovenská Sporiteľňa Bank Headquarters, Bratislava, Slovakia (*Source* Courtesy Hightex)

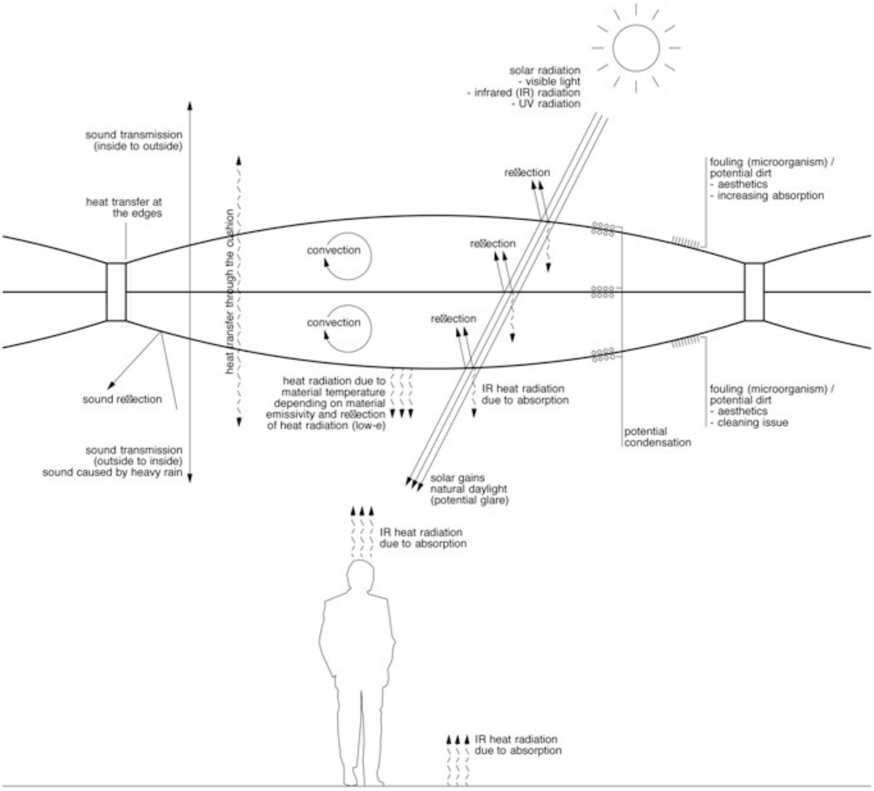


Fig. 4.4 Building physics of a pneumatic cushion structure (*Source* Jan Cremers)

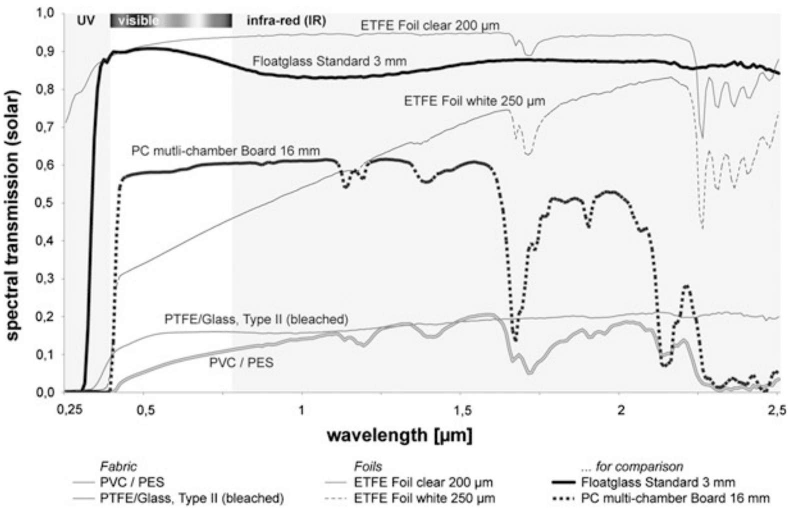


Fig. 4.5 Solar transmission of different envelope materials (*Source* Jan Cremers/Courtesy ZAE-Bayern)

– The life expectancy is far beyond 20 years if the material is used according to specifications.
– The ETFE-membrane is flame retardant (B1) according to DIN 4102 and other international standards. Tests have shown that, due to the low mass of the membrane (which is only between 0.08 and 0.25 mm thick, with a density of approx. 1750 kg/m^3); there is minimal danger of any material failing down in the event of fire.
– The ETFE membrane is self-cleaning due to its chemical composition, and will therefore retain its high translucency throughout the entirety of its life. Any accumulated dirt is washed off by normal rain if the shape and the connection details are designed correctly.
– The material is maintenance-free. However, inspections are recommended in order to find any defects (for example damage caused by mechanical impact of sharp objects) and to identify and repair such damage as early as possible. It is also recommended that the perimeter clamping system and the primary structure are regularly inspected.
– The translucency of the ETFE membrane is approximately 95 % depending on the foil thickness, with scattered light at a proportion of 12 % and direct light at a proportion of 88 %. Compared to open air environment, the dangerous UV-B and UV-C radiation (which causes burning and is carcinogenic) is considerably reduced by filtration (Fig. 4.5).

– ETFE membranes can be 100 % recycled. Additionally, this membrane system is extremely light (about 1/40 of glass). The ETFE system is unmixed and therefore separable.

In order to reduce solar gain or to achieve specific designs while maintaining the transparency, two dimensional patterns can be printed on the membrane.

Because of the zero risk of breakage, unlike glass, no constructive limits have to be considered when used as overhead glazing.

The outstanding properties of this membrane material ensure a constant high-quality appearance lasting over decades.

4.2.2 A Modular Approach to Membrane and Foil Façades

Most projects incorporating textile constructions are prototypes and have an extremely high share of innovative aspects, which have to be solved and also impose a certain risk to the designer and the executing companies. Therefore it looks promising to closely look into the options of following a modular approach. Most of the activities are still in an R&D phase. However, a first important building has been realised: for the Training Centre for the Bavarian Mountain Rescue in Bad Tölz a modular façade has been developed together with the architect Herzog + Partner which comprises approx. 400 similar steel frames with a single layer of pre-stressed ETFE foil (Fig. 4.6).

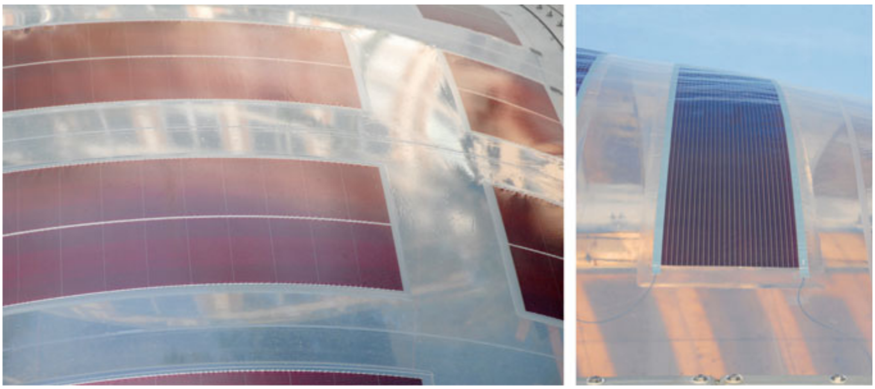
Fig. 4.6 Training Centre for the Bavarian Mountain Rescue in Bad Tölz, Arch. Herzog + Partner (*Source* Jan Cremers)

4.2.3 Flexible Photovoltaics Integrated in Translucent PTFE- and Transparent EFTE-Membrane Structures: 'PV Flexibles'

Hightex is working together with its sister company SolarNext on significant innovations to improve building with advanced membrane material. Among them are new 'PV Flexibles' that are applied on translucent membrane material or fully integrated in transparent foil structures (Figs. 4.7 and 4.8). The technology being developed is flexible amorphous silicon thin film PV embedded into flouropolymer foils to be used on PTFE membranes and ETFE foils, cp. Cremers (2007) and Cremers (2009). These complex laminates can be joined to larger sheets or applied in membrane material and be used on single layer roofs or façades. They can also be used to replace for example the top-layer in pneumatic cushions.

PV Flexibles do not only provide electricity – in an appropriate application in transparent or translucent areas it might also provide necessary shading which reduces the solar heat gains in the building and thereby helps to minimise cooling loads and energy demand in summer. This synergy effect is very important because it principally helps to reduce the balance of system cost for the photovoltaic application. In a report, the International Energy Agency gives an estimation of the building-integrated photovoltaic potential of 23 billion square meters. This would be equivalent to approx. 1000 GWp at a low average efficiency of 5 %.

Up to now solutions for the integration of photovoltaic in free spanning foil and membrane structures have not been available, although these structures are predestined for the use of large scale photovoltaic applications (shopping malls, stadium roofs, airports etc.). PV Flexibles allow addressing market segments of the building industry which are not accessible to rigid and heavy solar modules in principle. The basic PV cell material is very thin (only approx. 51 μm) and



Figs. 4.7–4.8 Flexibles, flexible a-Si-PV integrated in ETFE foils: functional mock-up built in 2010 (*left side*) and PV ETFE cushion built in Rimsting in 2007 (*right*) (*Source* Jan Cremers)

lightweight. Therefore, it is predestined for use in mobile applications. But as it is fully flexible at the same time, it is also an appropriate option for application on membrane constructions.

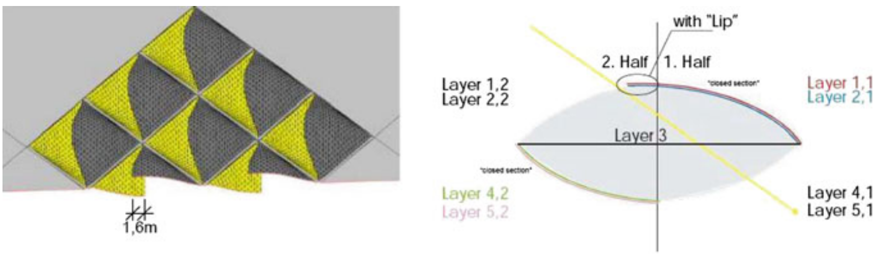
PV Flexibles can be directly integrated in ETFE and PTFE membranes for the generation of solar energy. First applications have been executed successfully in the South of Germany already in 2007 and since then are currently monitored with regard to their output performance (Figs. 4.7 and 4.8).

4.2.4 Functional Coatings for Membranes

The development of functional coatings on membrane material has a special impact also. In the past this has led to the development of low-E-coated and translucent coated glass fabric (emissivity less than 40 %) which has been applied for the first time by for the new Suvarnabhumi Airport in Bangkok, Thailand which was opened at the end of 2006.

The development of transparent selective and low-emissivity functional layers on ETFE film consequently has been the next step to allow accurate control of the energy relevant features of the material. The first project to make use of this newly developed type of material was the large shopping mall “Dolce Vita Tejo” near Lisbon in Portugal with a roof area of approx. 40,000 m^2 (Figs. 4.9 and 4.10).

The cushions are very large with dimensions of 10 × 10 m very large and are made of three layers. Here, the transparent, selective low-E-coatings together with the specific north-shed-like geometry of the foil cushions help to realize the client’s wish to have as much light as possible but also to reduce solar-gains at the same time: customers shall feel like being outside but in an environment of highest climate comfort (Figs. 4.11 and 4.12).



Figs. 4.9–4.10 Principle of roof cushion solution for Dolce Vita Tejo, Portugal (*Source* Courtesy Transsolar, Stuttgart)

Figs. 4.11–4.12 Dolce Vita Tejo, designed by Promotorio Architects (*Source* Courtesy FG + SG)

4.3 Design Process

The variety of new technologies developed in the field of foil and membrane construction and materials are definitely expanding and enriching architectural design options to realize advanced technical solutions and new shapes. However, a solid background of know-how and experience is needed to derive full advantage of the innovative and intriguing offers. As an architect or designer you can only feel comfortable with technologies of which you have at least a basic understanding. This actually poses a great challenge to the educational system for architecture but also to the membrane industry, which is a comparable small sector. At the end, every new product and technology has to be introduced to the market and made known to architects and designers, who need resources for marketing activities and promotion. Also, it requires a great deal of pre-acquisitional activities of direct consulting to planners in early design stages to enable the development of functional and technical sound and also economical solutions. Therefore, it will be a long (but still very promising) road to follow until the technologies described here will be commonly used in the building sector and become something that could be called a 'standard'.

4.4 About Hightex

Hightex Group is a specialist provider of large area architectural membranes for roofing and façade structures. The membranes are typically used in roofs and façades for sporting stadia and arenas; airport terminals; train stations; shopping malls and other buildings. This type of structure is a competitive alternative to glass as it is lighter and safer as well as being flexible to create complex shapes and it can span larger areas. Hightex uses environmentally friendly materials and is focussed on innovative technology and coatings, which help to reduce a building's energy costs. Hightex, one of only a very few international companies to design and install these structures worldwide, has been involved in the construction of a number of very high profile buildings including The Cape Town Stadium and Soccer City Stadium in Johannesburg, both for use in the FIFA 2010 competition, the Wimbledon Centre Court retractable roof, the roof of the Suvarnabhumi International Airport in Bangkok and the grandstand roof at Ascot Race Course.

Recent projects include Ansih Kapoor's "Leviathan" for Monumenta (Grand Palais, Paris 5-2011), Stadium «Olimpijskyj» in Kiev/Ukraine, National Stadium Warsaw/Poland, the retractable roof of the famous BC Place Stadium in Vancouver/Canada and the Maracana Stadium in Rio de Janeiro/Brazil.

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Chapter 5
Small Plus-Energy Buildings, Innovative Technologies

The Prototype-Building home$^+$ of HFT Stuttgart

Jan M. Cremers

Abstract A case study of innovative materials and sustainable design. Home$^+$ is the result of an interdisciplinary university team enrolled at the Solar Decathlon Europe 2010 competition (Cremers (2011), Cremers (2010), Cremers and Eicker (2010), Cremers and Palla (2011) and Fiedler (2009)). The concept combines modularity of inner spaces with an efficient energy system in which one key element is a ventilation tower, a traditional building element renewed by using new technologies.

5.1 Introduction

In the following we present the architectural and engineering design of our contribution to the Solar Decathlon Europe 2010. The University of Applied Sciences Stuttgart participated at this international competition for universities, which was held in June in Madrid. An interdisciplinary team of architects, interior designers, structural engineers and building physicists developed and built a small residential self-sufficient building prototype of 74 m^2 for 1 or 2 people which can provide more energy than it needs. The basic idea of the home$^+$ design is to use traditional means of hot and arid zones and to combine them with new technologies, using solar energy as the only energy source and equipped with technologies that permit maximum energy efficiency. The first aim was to optimize home$^+$ in the points of the architectural/bioclimatic concept (ratio of volume to surface, orientation, natural lighting and ventilation, passive conditioning and solar protection) and the building structure (high thermal insulation, use ecological materials and thermal mass) through energetically and energy saving aspects. Solar systems such as photovoltaic and solar thermal, integrated in the design concept, adopt added functions like shading, cooling via night sky radiation and the aesthetic effect. By this means it is

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Figs. 5.1–5.2 Photographs of home^{+} during the competition in Madrid (*Source* Jan Cremers)

possible to minimize the heating and cooling demand. In the summer, during the day the phase change materials (PCM) integrated into the PCM ceiling are able to passively cover a part of the cooling demand and a 1200 litres tank is used to dissipate internal loads via a radiant floor in free cooling mode (Low energy cooling). Additionally, several active components are added to maintain comfort conditions during temperature peaks, such as a reversible heat pump which also uses the tank as a heat sink. At night, the PCM ceiling is passively regenerated through photovoltaic-thermal (PV/T) collectors on the roof that act as heat sink tanks. Electricity consumption for the HVAC systems is therefore reduced to a minimum and the electricity balance of the house is largely positive (surplus of 7500 kWh/year) for the climate of Madrid. The basic innovations of home^{+} are the ventilation tower, the photovoltaic-thermal collectors and also the multi-coloured PV modules (Figs. 5.1 and 5.2).

5.2 Design Concept

The design is based on architectural and energetic considerations. The starting point is a compact and highly insulated volume, with a small surface-to-volume ratio. The volume is segmented into four modules, which are positioned with interspaces between them. These climate gaps are used for lighting, ventilation, pre-heating in winter and passive cooling in summer. One of these gaps is higher than the others, containing the “ventilation tower”. Based on traditional principles of climate control, the ventilation tower is a key element for the energy concept as well as for the outer appearance of the building and the interior space. The modules and the gaps are bound together by the building envelope, which is covered in large areas with photovoltaic elements.

The modular design of the building facilitates not only transport to Madrid and assembly there, but also allows thinking about a modular building system with different requirements. Using the same basic modules it is possible to create living and working space for singles, couples, families or apartment-sharing communities in detached and semi-detached as well as in multi-family houses. Furthermore, it allows this modularity to adjust home+ into other climate conditions through adjustments of the climate gaps, especially the ventilation tower. We are aware that the ventilation tower, which is a key design feature of home+, is a very specific measure for a climate like Madrid. In this case, the tower cools the air down by evaporation. For example, in coast areas, instead of the tower there can be wind turbines and in colder areas it can be a hot water tank or a chimney.

The interior shows a clear zoning. Each of the modules has its own function beginning in north-south direction with; the terrace, the living area and the dining area. The different functions are marked by the gaps, but can be used as one big space also. This is especially important for the two dinners we invited our neighbours to in the solar village in June 2010. The more private working and sleeping area is separated by the volume of the ventilation tower. In east direction each area is accompanied by a serving zone (kitchen, entrance and facilities, bath); while the west side offers built-in storage zones. Therefore the building receives a clear structure in the north-south direction. East and west facades are as closed as

Fig. 5.3 Floor Plan [North to the left] (*Source* HFT Stuttgart)

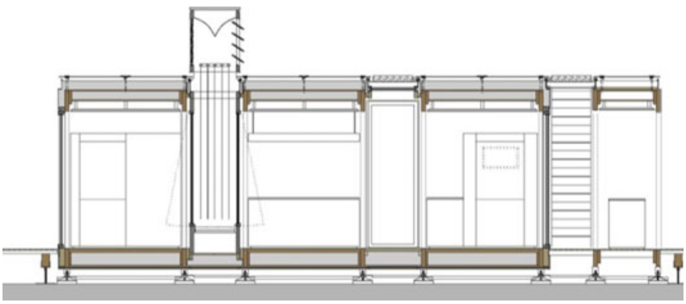


Fig. 5.4 Longitudinal Section (*Source* HFT Stuttgart)

possible (excepted the gaps) in opposition to the north and south facades where the solar irradiation is controllable. While the steep summer sun is kept out by a porch, the flat winter sun can enter deep into the house (Figs. 5.3 and 5.4).

5.3 Energy Concept

The basic idea of our design is to use traditional means of dealing with the climate in hot and arid zones and to combine them with new technologies. Thermal mass, sun shading and evaporative cooling will help to achieve a comfortable indoor climate with passive means. The key element of our passive cooling concept is a new building component that we call "ventilation tower" (VT), which is also an important feature of the interior design. In addition night cooling via sky radiation and evaporation is used to discharge Phase Change Material (PCM) and support a radiative cooling floor. Active cooling is supplied by a reversible heat pump powered by a photovoltaic system. Since the building was designed for the hot summer in Madrid, most of the challenges arise in the cooling methods of the system. This study makes an emphasis in this specific area (Fig. 5.5).

5.3.1 Innovative PV Modules

For electricity generation, a large PV system of 12.5 kWp is installed on the roof on both west and east façades. Each façade is completely covered with 7 polycrystalline PV-Modules (3 kWp each) except for the gaps. On the roof, two different

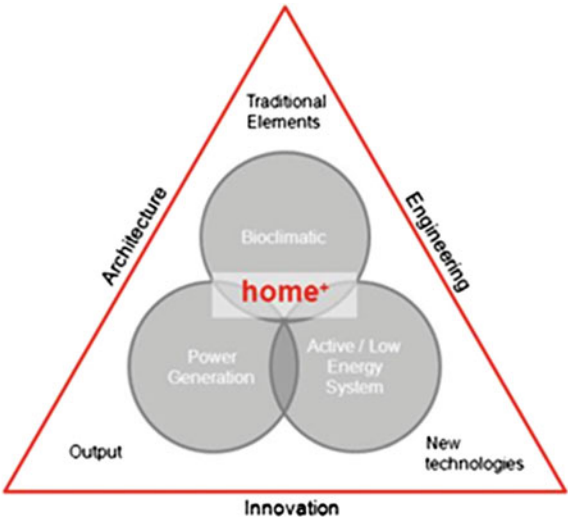


Fig. 5.5 Interaction between Architecture and Engineering (*Source* HFT Stuttgart)

Fig. 5.6 Pictures of home+ during the competition in Madrid (*Source* Jan Cremers)

types of modules are installed; 12 small polycrystalline PV-Modules (1.5 kWp) are located on the east and west sides and 12 monocrystalline PV/T modules (photovoltaic/thermal collectors) (5 kWp) in the middle of the roof.

The innovation in this system is that, within the polycrystalline PV glass/glass modules, two different solar cells are combined and integrated. The reason for applying two different types of solar cells for roof and façades is a matter of design. Whereas the multicolour cells on the façade are an important design feature of our house, the monocrystalline cells on the roof have been selected to provide a maximum of power output per roof area. To link the two areas, we have introduced a new way to combine differently coloured cells in a dot-like pattern to achieve a transitional effect from one to the other area: the façade modules will turn with their colours gold and bronze around the edge, then becoming black with the monocrystalline modules in the middle of the roof (Fig. 5.6).

5.3.2 Passive Cooling System and Heating via Ventilation

In such a highly insulated building, control of the air supply by ventilation plays a decisive role. The segmentation of the house into climate gaps and modules makes it possible to use the glass-covered gaps for natural lighting and ventilation. In order to get the best results in energy consumption, air quality, air temperature and handling through the different seasons, the building will have 3 phases of passive ventilation, which are as follows:

- **Air Preheating** will be used when the ambient temperature is between 15 and 21 °C. Especially on sunny winter days it will help to heat the air in a passive way. The plants in these gaps humidify the air by evapo-transpiration which improves the air quality.
- **Cross Ventilation** operates in moderate climate conditions when the ambient temperature is between 18 and 24 °C; during the day and/or at night the air flows

through the totally opened gaps, thereby allowing a high air exchange through cross-ventilation. On hot summer days this is also used at night to cool down the mass of the building in a passive way.

– The **Ventilation Tower**, a new building component, which depicts the traditional tower ventilation in desert areas. The height and the orientation of the VT results from the prevalent wind flow. Statistics have shown that the wind direction comes typically from the south or the north. So we have the opportunity to catch the wind from both sides. The middle part of this gap has the function to ventilate and cool down the interior air without mechanical effort when ambient conditions are favourable. When the wind speed is high enough, the ambient air is caught by the tower, cooled through downdraught evaporative process and supplied to the building through the casement window at their basement. The areas left and right of it are used as Solar Chimneys (SC), to expel the exhausted air. On the inside of these glazed gaps are installed absorber plates to absorb solar radiation. They warm up and radiate heat to the air inside the SC. This warm air will then extract the interior exhausted air and transport it to the outside. This effect is caused by thermal lift and the wind pressure above the VT. Through the orientation, the air inside the SC is heated up all day long (Fig. 5.7).

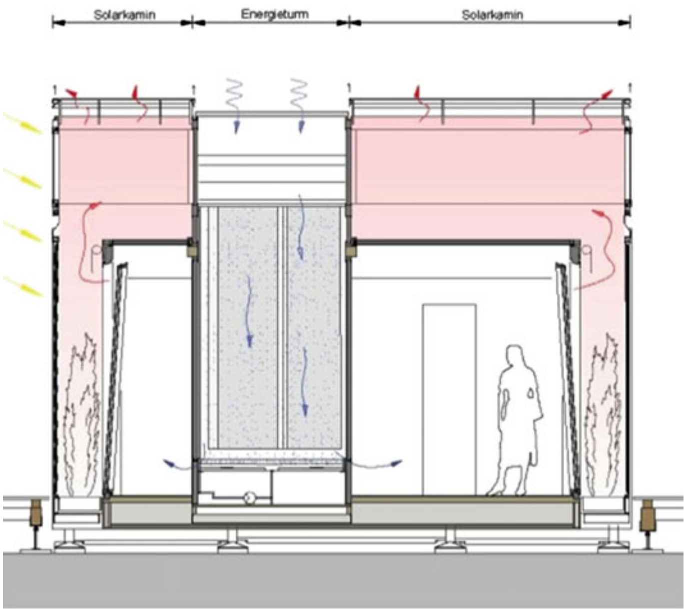
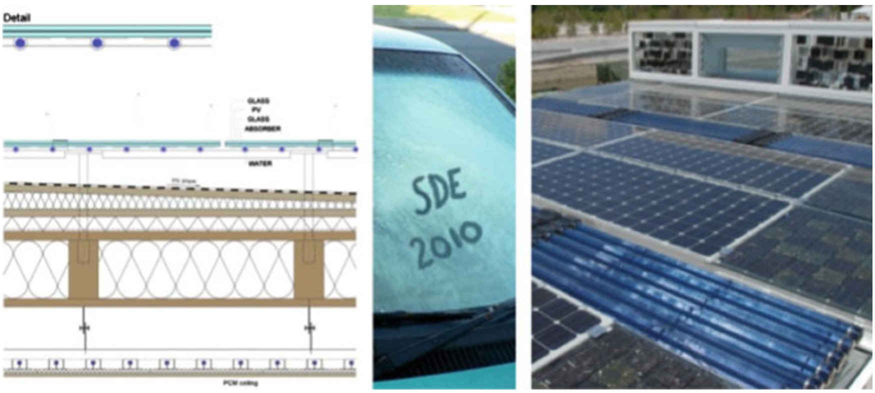


Fig. 5.7 Transversal section through the ventilation tower (*Source* HFT Stuttgart)

5.3.3 Low Energy Cooling Systems

The best way to avoid temperature peeks during the day is to use thermal mass. During the day, the PCM ceiling uses the latent heat of the PCM to store the heat and maintain room temperature around the melting temperature (21–23 °C). During the night, the PCM ceiling is actively regenerated using cold water from the night radiative cooling system on the roof towards the clear night sky; the PV/T collectors. Radiative cooling is based on heat loss over long-wave radiation emission from one body towards another body of lower temperature, which acts as a heat sink. In our case, the cooled body is the PV/T module surface and the heat sink is the sky since the sky temperature is lower, especially during night, than the temperatures of most of the objects upon earth. The cold water is stored in a cold storage and used during the day to activate the radiant floor. Hence, the hybrid photovoltaic and thermal modules have two main functions: generate electricity (all year long during the day) and to regenerate both heat sink tank and PCM ceiling during the night (summer). In this way it is possible to use the valuable areas on the roof in a double way for a maximum output. The third possible mode, the cooling of the PV-cells during the day and generation of hot water is not under consideration in our concept.

The conventional ventilation system (active) is equipped with a heat recovery system between the return air and the supply air for winter and summer. Additionally an indirect evaporative cooling device enhances the cooling capacity through ventilation in summer (Figs. 5.8, 5.9, 5.10, 5.11, 5.12 and 5.13).



Figs. 5.8–5.10 Principle of PV/T collectors on the roof and PCM ceiling (*Source* HFT Stuttgart)

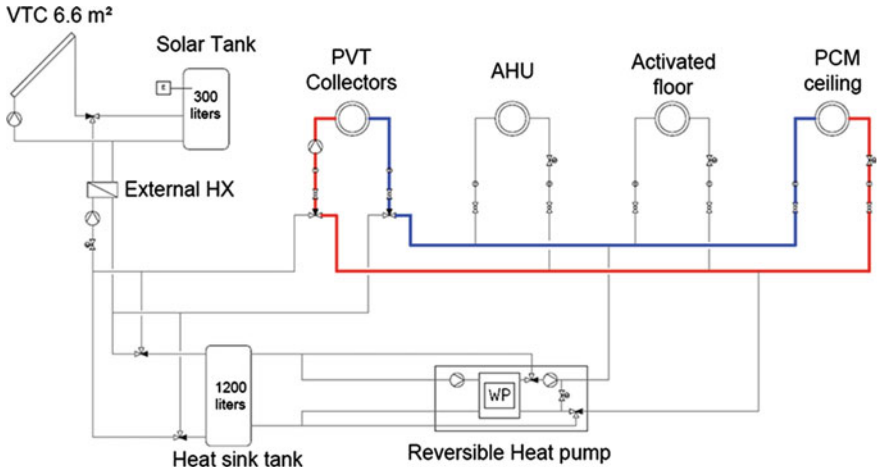


Fig. 5.11 Hydraulic scheme of summer night PV/T collectors and PCM ceiling [1st Period] (*Source* HFT Stuttgart)

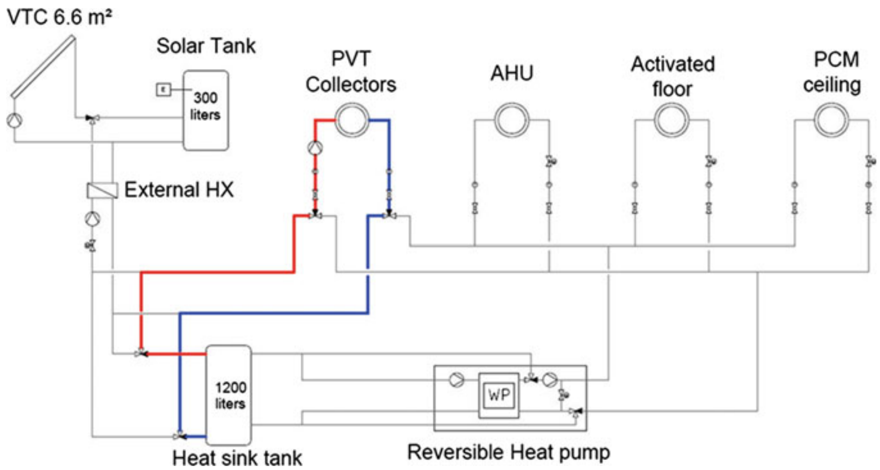


Fig. 5.12 Hydraulic scheme of summer night PVT collectors and heat sink tank [2nd Period] (*Source* HFT Stuttgart)

5.3.4 Back-up Cooling System

In order to satisfy domestic hot water, heating, and cooling demands, several active components have to be added to the basic concept of maximizing passive solar means and effects. When the passive or the low energy cooling systems cannot cover the demand, the reversible heat pump removes heat from the radiant activated floor to cool down the house. The choice of an electrical solution for the back-up is

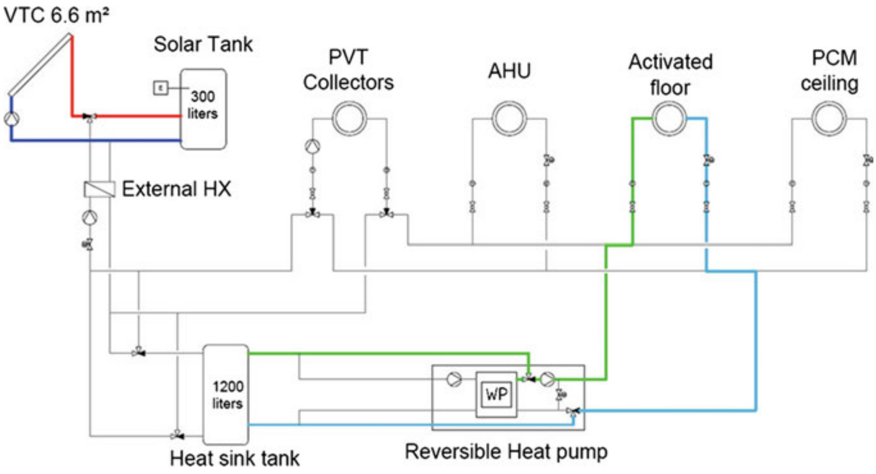


Fig. 5.13 Hydraulic scheme of summer free cooling at day (*Source* HFT Stuttgart)

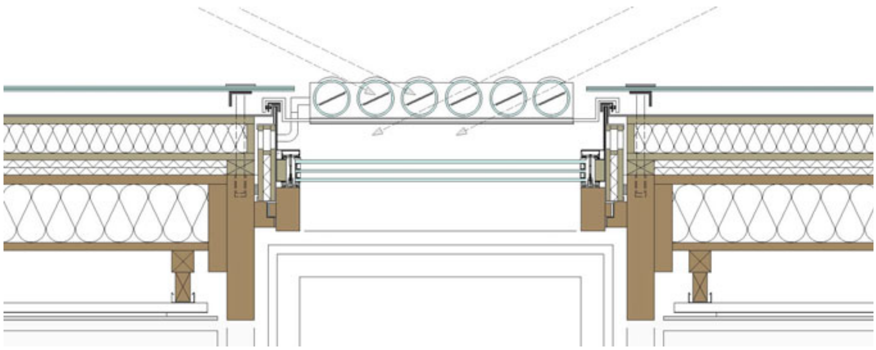


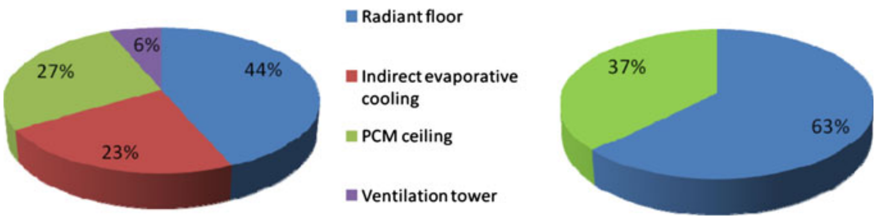
Fig. 5.14 Vacuum tube collectors with two functions: production of DHW and solar shading system (*Source* HFT Stuttgart)

due mainly to the lack of thermally driven chillers in the range of small power and the lack of space available for the equipment (solar collectors, heat rejection devices…). Therefore, the façades and the roof are covered with PV modules in order to provide the electricity needs of the house and inject the rest into the grid.

A classic solar thermal system will provide the domestic hot water needs of the building and to heat up the heat sink tank in winter when needed. The evacuated heat tubes are integrated in the building envelope as sun shading elements at the roof the glazed gaps (Fig. 5.14).

Table 5.1 Priority list in the control strategy

Priority	Subsystem
1	PCM ceiling
2	Ventilation tower (natural evaporative cooling, if possible)
3	Cross ventilation
4	Low energy cooling system (free cooling mode, if possible)/radiant floor
5	Indirect evaporative cooling
6	Reversible heat pump/radiant floor



Figs. 5.15–5.16 Distribution of cooling energy in the house and cooling energy distributed via the activated floor (*Source* HFT Stuttgart)

5.3.5 Control Strategy and Simulation Results

To control the complex hydraulic system described above, a sophisticated building automation is essential. Once we know all the components able to meet part of the cooling demand of the house, one needs to define the order of use of these elements in order to meet the required cooling demand. Passive technologies will be used with the highest priority and then the technologies that require low parasitical energy will have the priority. Table 5.1 shows the priority given for each subsystem in the control strategy.

The simulations for the HVAC have been done with TRNSYS (2006) for the climate in Madrid. The results show that the cooling demand is covered to 27 % by the PCM ceiling, 23 % by the indirect evaporative cooling and to 6 % completely passively by the ventilation tower. The radiant floor covers the rest about 44 %, this cooling energy has to be separated in the free cooling mode with low energy consumption and the reversible heat pump (Figs. 5.15 and 5.16).

5.4 Conclusion

Through the interdisciplinary work over two years it was possible to take under consideration all the aspects of the building beginning with the architecture, the building materials and the energy concept and minimizing the electricity demand of cooling or heating purposes. The Solar Decathlon Europe 2010 was not only an improvement for the science but also for every team member.

Due to improvement of the whole concept of home^{+} it was possible to make an excellent 3rd place in the competition Solar Decathlon Europe 2010 and to take further prizes in five of the ten contests, for example first place in “Engineering and Construction” and Innovation” and second place in “Sustainability”.

Acknowledgments The HFT-SDE-project home^{+} has been substantially funded by the German Federal Ministry for Economics and Technology (BMWi) as part of the framework “EnOB (Forschung für Energieoptimiertes Bauen)” (http://www.enob.info/).

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Chapter 6
Membrane Structures

Principles, Details and Projects

Bernd Stimpfle

Abstract The point of view of designers and suppliers. Ten membrane experts founded formTL in April 2004 with the aim to design light covers and beautiful structures. The company is constantly looking for the clarity of the plain detail and the logical structure of the project. The chapter contains a series of lightweight architectures realized with textiles and foils.

6.1 Introduction

Membrane structures are often used when large spans need to be realised in short time with a reasonable budget. In the majority of the cases, short realisation time means that the design process is parallel to the realisation, a high level of prefabrication and short installation time.

The limitation to a few suppliers and interfaces is an advantage for timing and costs. With reduced requirements on insulation values, cost optimised structures can be realised. These structures are extremely light, starting with approximately 2 kg/m^2 above foundation. High tension forces cause a higher foundation effort.

6.2 Theory

Membrane structures carry their load as tension in the plane of the membrane. Every applied load needs therefore a change in geometry to reach a new equilibrium state. Loads are carried biaxial in the membrane. To guarantee the biaxial load bearing behavior and to avoid slack areas, the membrane is pretensioned in both directions. We differentiate between mechanically tensioned structures with

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anticlastic curvature and pneumatic structures with synclastic curvature. With design parameters we can develop typical construction principles (Tables 6.1 and 6.2). Most tensile structures can be classified with the following categories or a combination of them:

Table 6.1 Design parameters for lightweight structures (*Source* Courtesy formTL)

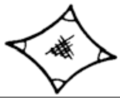
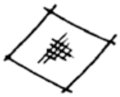
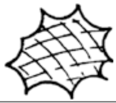
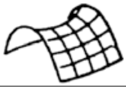
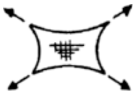
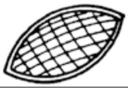
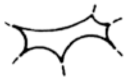
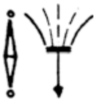
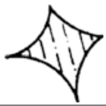
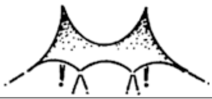
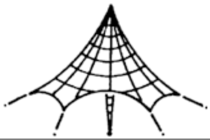
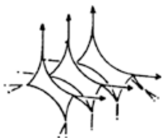
Surface, open or close	Net		Membrane	
Loads, wind and snow	Flat surface		Spatially curved surface	
Surface, form	Saddle = anticlastic curvature		Pneu, cushion = synclastic curvature	
Method of prestress	Pull borders outside Pull weft of membrane to prestress warp		Air pressure	
Border	Fixed boundary		Free boundary (e.g. cable)	
Additional supports	Point − highpoint − lowpoint		Line − cable − linear profile − arch	
Cutting pattern	Radial pattern		Parallel pattern	

Table 6.2 Types of tensile structures (*Source* Courtesy formTL)

Spacially curved and tensioned membrane		Pneumatic structure	
Spacially curved and tensioned cable-net with cladding		Shell	
Cable supported membrane structure			

- Hypar surface;
- Arch membrane;
- Cone structure;
- Ridge and valley cable membranes (folded plates);
- Cushion;
- Bubble;
- Cable girder.

6.3 Detailing

Characteristic is the concentration of membrane-stress in border-, ridge- or valley-cables. These cable forces are collected in individual nodes, redirected and anchored in the ground or in neighbour buildings.

6.3.1 Typical Details

An important for achieving strength is the joining technology.

Furthermore the seam layout plays an important role in the architectural appearance. Typical details are:

- Welded seam
- Clamping joint (Fig. 6.1);
- Cable cuff (Fig. 6.2);
- Clamped border line (typical for PTFE-glass);
- Fixed clamping;

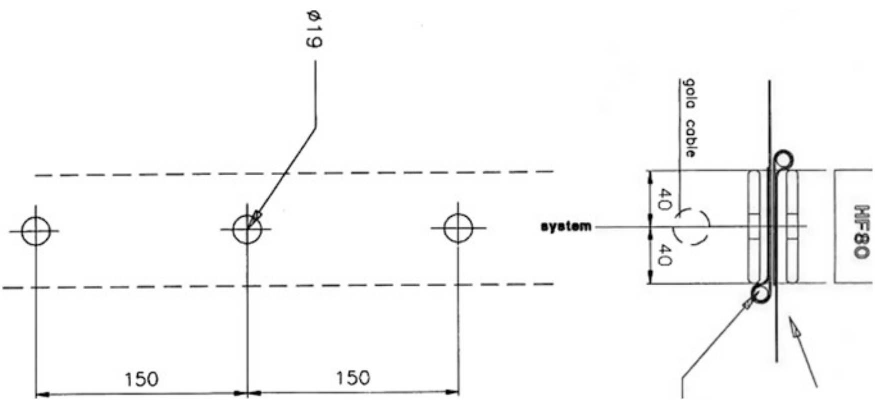


Fig. 6.1 Clamping joint (*Source* Courtesy formTL)

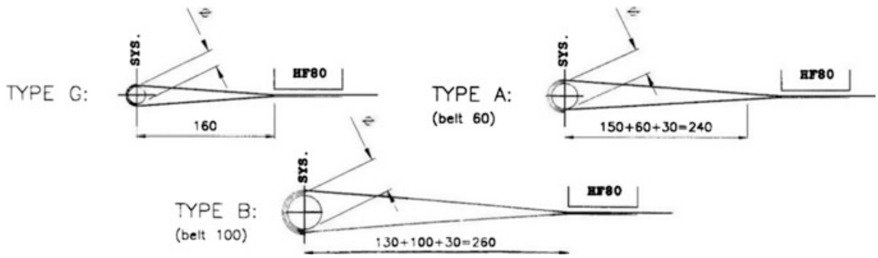


Fig. 6.2 Cable cuff (*Source* Courtesy formTL)

- Cone rings;
- Membrane tips;
- Cut outs.

6.3.2 Cutting Pattern

To generate the double curved shape the membrane needs to be cut along predefined cutting lines (typically geodesic lines). The pattern width is to be defined in accordance with the allowable distortion and the material width (Fig. 6.3).

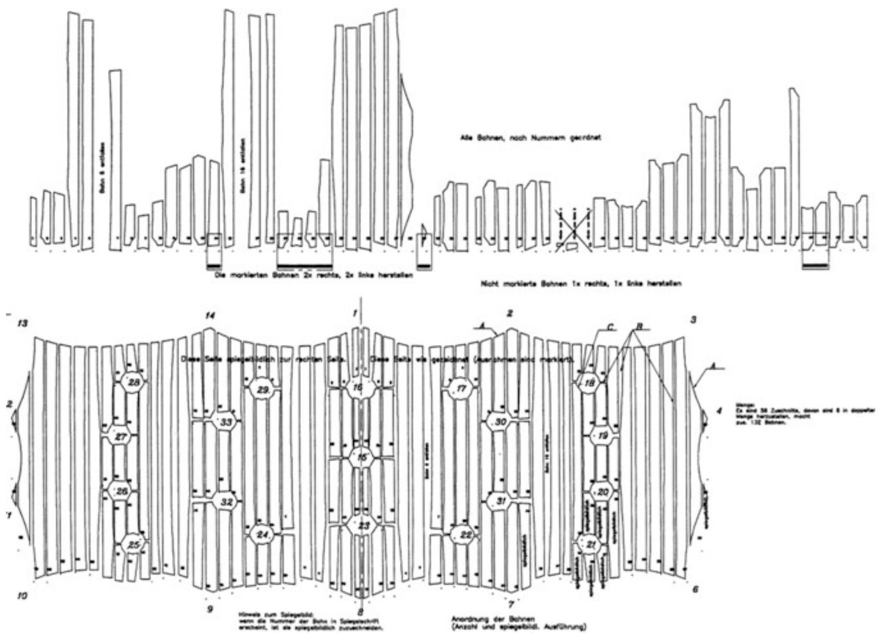


Fig. 6.3 Sample of a seam layout (*Source* Courtesy formTL)

Fig. 6.4 Forum Kirchberg (*Source* Courtesy formTL)

Fig. 6.5 Velodrome Abuja (*Source* Courtesy formTL)

Fig. 6.6 Nouvelle DestiNation (*Source* Courtesy formTL)

Fig. 6.7 GEK Travelling Exhibition (*Source* Courtesy Schienbein + Pier)

Fig. 6.8 Tropical Islands (*Source* Courtesy Ceno Tec)

Fig. 6.9 Kongsberg Jazz-festival (*Source* Courtesy Canobbio)

Fig. 6.10 Weltjugendtag Köln (*Source* Courtesy formTL)

Fig. 6.11 Bancoposta, Italy (*Source* Courtesy formTL)

6.4 Projects

The following projects show the great variety within the field of textile architecture.

The atrium roof for the Shopping Mall Forum Kirchberg in Luxembourg has been developed to bring sufficient daylight into the high mall, with still a reasonable shading, so that the cooling energy can be reduced (Fig. 6.4).

After the failure due to a thunderstorm, the Velodrome in Abuja has been rebuilt as a redundant system with a primary cable net, that is still stable even if in the future one or more panels should be damaged (Fig. 6.5).

The project Nouvelle DestiNation was one of the federal pavilions on the Expo in Switzerland in 2002. The concept was a breathing air supported hall with noticeable deflections (Fig. 6.6).

For a road show through Germany the health insurance company GEK needed an adaptable exhibition space for indoor use that would fit for whatever location in different cities (Fig. 6.7).

The former Cargo Lifter Airship hangar was converted into a leisure area with a 20,000 m^2 transparent cushion roof on the south side (Fig. 6.8).

Fig. 6.12 NTC London (*Source* Morley von Sternberg)

Fig. 6.13 Zenith of Strasbourg (*Source* Courtesy Canobbio)

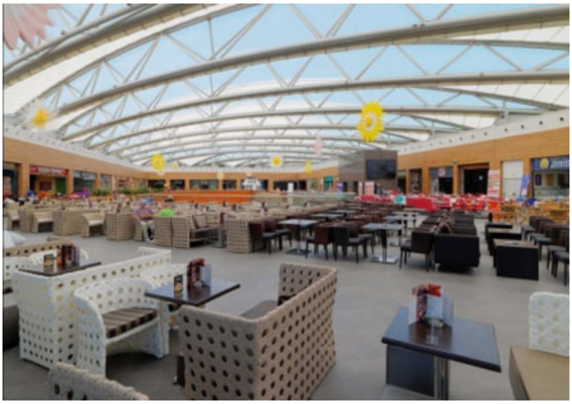


Fig. 6.14 Athens Heart (*Source* Stelios Tzetzias)

Fig. 6.15 The Modern Teahouse (*Source* Courtesy Museum für Angewandte Kunst, Frankfurt/Main)

The stage roof for the Kongsberg Jazz festival is an example for extreme variations in radius over the roof surface. The long cutting pattern varied from full width down to a few centimetres back to almost the full width (Fig. 6.9).

To celebrate the mass one night at the World Youth Day 2005, an altar was realised sitting on a hill and covered with an illuminated cushion, glowing like a bulb (Fig. 6.10).

The pneumatic sphere for Bancoposta was used for a road show through Italy. Inside is a stiff steel structure, so that no airlocks are required (Fig. 6.11).

For training purposes the LTA in London built a temporary roof over a clay court, so that the training is also possible from autumn to spring (Fig. 6.12).

The façade of the Zénith de Strasbourg is made of 12,000 m^2 highly translucent orange membrane (Fig. 6.13).

The atrium of the shopping mall Athens Heart is covered with the combination of a retractable roof and ETFE cushions towards the north (Fig. 6.14).

As a present from Japanese companies the city of Frankfurt/Main received the Modern Teahouse, a double layer inflatable roof, used for tea ceremonies (Fig. 6.15).

Part II
Lightweight Landscape

Chapter 7
The Cultural and Environmental Context

Luigi Spinelli

Abstract "Città Studi", Milan. If the name can simply reduce to the idea of a university and research district or 'work zone', this area encloses a series of historical signs that represent its environment. The context of the LLAW workshop was a pedestrian street of the Polimi campus that serves several departments and sport activities that have been studied through several interpretations, such as relationship, experience, imageability, identity, association, perception, knowledge and variability.

7.1 Introduction

The specific context being studied in this workshop is a section of the city where the individual buildings represent – but do not construct – the urban landscape.

What are the "rules for acting" in such a heterogeneous urban setting, made up by numerous and different buildings? How can such seemingly disconnected information help to build knowledge that can be used to benefit any work done in this city fragment? I will endeavour to provide various interpretations of the surrounding environment based on my experience and on observational expertise that goes well beyond simply *looking*.

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7.2 Relationship

Each structure in the setting must be viewed in relation to the other structures and not independently. Analysis in this section of Milan shows “the diversity of the urban landscape (…), the territorial presence of university faculties in the Città degli Studi district and the related large sports facilities (…). The Città degli Studi district is located in an additional peripheral area of urban expansion to the east of Milan. It created a less densely built up space in the compact surrounding city both because the blocks that form the original heart of the district were modelled on one or two story pavilions, as is common for complex services, and because the area became a sort of university campus with the space – as happened – to build future scientific buildings” (Boriani et al. 2007, pp 215–217).

It seems that, in this case, we can use the theory of relations between buildings introduced by Gordon Cullen in *Townscape*: “One building standing alone in the countryside is experienced as a work of architecture, but bring half a dozen buildings together and an art other than architecture is made possible”. It is an idea that is echoed by Alison and Peter Smithson in their studies on urban structuring: “Forty or fifty houses make a good street” (Cullen 1961) (Figs. 7.1 and 7.2).

Fig. 7.1 The development of the Città degli Studi disctrict would require some fixing, at least as for the spaces between the different buildings are concerned (*Source* Luigi Spinelli)

Fig. 7.2 The landmarks of the red eaves created by Caccia Dominioni and of the chimneys designed by Magistretti and Soro (*Source* Luigi Spinelli)

7.3 Experience

Every situation must be assessed autonomously in relation to the context.

Ernesto Nathan Rogers introduced the idea of pre-existing structures in dealing with the issue of how to manage connective spaces, focusing on a "case by case" approach based on experience, rather than on setting out rules. "The laws, rules and restrictions of each genre are necessary – nobody can doubt this – yet they are only effective if they tend to establish continuity between the past and the present, that is, if they favour the harmonious integration of new structures with existing ones (…) There are emerging values that can easily be classified and defended (such as genuine monuments or some special landscapes), however the real problem is getting into the connective environments between these new emerging values" (Rogers 1957, pp 255–256).

In 1927, in a vast space in a section of the outskirts known as "cascine Doppie" – now Piazza Leonardo da Vinci – the Città degli Studi university district was inaugurated. This followed a lengthy process commenced in 1913 that "represented a real expansion policy, a change in dimension. Milan expressed its modernity, in the sphere of higher education, through a decision to focus on facing future development needs, but also by following the contemporary trend of specialising the city according to district (…) From the very beginning, the chosen urbanization mode was low-density, pavilion-style architecture. In other words, each science faculty had its own structure. The recognisability of the Città degli Studi district as a 'science district' aimed to achieve just such a layout and to provide a textbook-like eclecticism of shapes. In the years that followed – and still today – the development of the Città degli Studi district was certainly not under central urban planning or architectural control. The combination of similar realities (…) produced excessive effects on the overall setting that (…) can no longer be identified as a part of the city. It would require some fixing, at least as far the spaces between the different buildings are concerned" (Boriani et al. 2007, pp 223–224).

7.4 Imageability

The environmental context can clearly be read. An observer can easily recognise its features and various sections because they are organised in a coherent system. Kevin Lynch coined the term "imageability" in 1960 to signify that quality of a physical object that gives an observer a strong, vivid image. "A good environmental image gives its possessor an important sense of emotional security. He can establish an harmonious relationship between himself and the outside world" (Lynch 1960).

In the terms we have been talking about, the most immediately recognisable image is the stand of the Giuriati sports facility. The Politecnico's sports facilities date from the early 1930s and were the work of an engineer called Luigi Lorenzo Secchi, who worked for the municipality's technical office. Starting in 1927, he was involved in numerous projects to create sports facilities for the city.

The Guido Romano swimming pool, on via Ponzio, to the north-west of the project area, was designed in 1928 and opened in 1929, becoming the city's first outdoor pool. The plot is located "in a Sironi-like landscape, amid fields, newly mapped roads and sections of peripheral building (…) The presence of multi-storey buildings is very limited given the surface area and would be insignificant if it were not for the linguistic choice to light-heartedly and elegantly adopt the ways of the Milanese 20th Century (…) While digging was under way for the pool on Via Ponzio, a sports pitch was being prepared nearby, more precisely on Via Pascal (…) and would be used immediately" (Ferrari 1999, pp 50–53).

The Mario Giuriati sports pitch, with the entrance on what used to be Via Pascal, was opened on 30 May 1932, without the open stand and facilities that were opened on 18 April of the following year. In addition to designing the stadium, Secchi also directed the work, experimenting with a "prototype of a local facility, to be used in the most working-class and peripheral city districts. An uncovered section of the stand, with a seating capacity of 1800, marks the entrance to the field and covers the changing rooms and the gym, while the two lower sections, lining the two sides of the stands, contain the toilets and the showers. The basic template does not change, but the identity of each pitch comes from variations in decorative style, which elegantly and with a lightness of touch, draws on the same means adopted for the pool buildings on Via Ponzio" (Ferrari 1999, p 54).

The Giuriati ground is the historical home of rugby in Milan. Matches in Italy's top rugby league are played here and it was the setting for a number of triumphs by Amatori Rugby Milano on their way to winning Italy's top tier rugby league, which it last won in the 1990s. This facility has also witnessed legendary feats in athletics, such as the two world discus records by Adolfo Consolini, in 1941 and 1946. He would go on to win Olympic gold in 1948. In June 2008, Politecnico di Milano was granted free use of the facility for 35 years. It is managed by CUS (University Sports Centre), which is planning refurbishment and improvement work using other European and American campuses as a model.

7.5 Identity

The ability to identify a clear identity, which is unique and discernible from other environments, is a fundamental quality for any setting.

In such a context, the perception of those who are inside the area, without any compact limitations, is that of looking for known landmarks in the city skyline and looking out in different directions. This attempt is met by the presence of certain buildings with silhouettes that have come to form part of the city's historical and architectural memory.

Looking west, one sees the two spires of the Giuliana Ronzoni Institute of Industrial Chemistry, on Via Colombo, designed by architect Giacomo Carlo Nicoli between 1924 and 1927. This building marks the border between the Città degli Studi district and the rest of Milan. The Writer Carlo Emilio Gadda described it in his novel *L'Adalgisa*, looking at the city from the train, as a "very theatrical building, with spires and very solid, but above all, very silly; it is informally called the Kremlin". Looking north, at the corner with Via Ponzio, one finds the metaphysical skyline of the Santa Monica church and the monastery of the Augustinian nuns designed by engineer Giuseppe Invitti in 1934. The monastery was moved here from Porta Vittoria, where they built the imposing court complex known as Palazzo di Giustizia. On the opposite side, on the south-eastern corner of the urban area and beyond the Giuriati sports centre, one can see the chimneys of Milan university's biology faculty, designed by Vico Magistretti and Francesco Soro between 1978 and 1981, on the corner of Via Golgi and Via Celoria. An image that "is emblematic of the capacity to make a piece of architecture easily recognisable, through the expressive use of some iconic elements" (Ferrari 1999). Looking eastwards, quite close to Via Golgi, the red outline of the eaves of the administrative buildings created by Luigi Caccia Dominioni (between 2004 and 2007) is another landmark.

Finally, there is the presence on the north-eastern corner of the twin guest-houses on Via Bassini, by Luigi Moretti. In an early version, they were supposed to be located where the administrative buildings are, as the plan was to build seven tall residential buildings, plus a utilities building. In the end, only two were built, between 1947 and 1950. They were placed in a fishbone layout, compared with Via Bassini, and the height was limited to make them fit into the Città degli Studi district better.

7.6 Association

There is a need for all of us to associate with our reference environment, and this image is rich in memory, familiarity and meaning.

Let me now return to the contribution by Alison and Peter Smithson on the legibility of an environment. This concept was introduced when they started regularly visiting the sociologist Judith Henderson and her husband Nigel, a photographer, at their home in Bethnal Green. Nigel's shots showed models for association and identity "for which no equivalent form has yet been discovered (…) a true 'street aesthetic' (…) assigned the role of element unifying the structure of the city" (Spinelli 2008, pp 74–81).

In the very same areas as those being used for workshop projects, a neorealist film entitled *Miracle in Milan* was shot in 1950, under the direction of Vittorio De Sica and using a script by Cesare Zavattini. Various scenes show those elements in the skyline that define these spaces. The film is about an alternative city, with makeshift architecture, pushed to the margins of Milan and threatened by building speculation. It is a film that should have had another title: *The poor are a nuisance*. It should also have another finale: not the flight on broomsticks from Piazza

Duomo, but rather an eternal diaspora of shantytown dwellers across the skies of the world looking for a place without any "Private Property" signs. However, the Director of Enic (National Body of the Cinema Industry), which funded the film, considered such a title and an ending too dangerous in the cold war (Fofi 2010) (Figs. 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 7.10, 7.11, 7.12, 7.13, 7.14, 7.15, 7.16, 7.17 and 7.18).

Figs. 7.3–7.6 Miracle in Milan, Vittorio De Sica, 1950: various scenes show the elements in the skyline that define these spaces (*Source* Mereghetti and Fofi 2010)

Figs. 7.7–7.18 Serial Visions: the reaction takes place through a sequence of surprising aspects and a recording of sequences (*Source* Luigi Spinelli)

7.7 Perception

An image of the environment causes a reaction in our visual perception and memory of past emotions. This reaction takes place through a sequence of surprising aspects and a recording of sequences. It is what Gordon Cullen calls "serial vision": "Our original aim was to manipulate the elements of the town so that an impact of the emotions is achieved (…) The human mind reacts to a contrast, to the difference between things, and (…) it comes alive through the drama of juxtaposition" (Cullen 1961). Each relationship with our environment must also be assessed considering our physicality, that is, the position of our body in relation to the space and what it presents.

The sense of position is an instinctive automatism that is an indicator of where we are in relation to our surroundings. The existence of spatial compression or rarefaction, being inside or outside of a place, feeling constrained or feeling well, and above all the sequence in which these opposing conditions occur – since one cannot occur without the others – must form part of the project content. Gordon Cullen again defined this concept as the "art of relationship". He goes even further to analyse the space created between grouped buildings, arguing that this space has "a life of its own over and above the buildings which create it" (Cullen 1961).

Let's now take a look at the buildings in sequence along the northern section of this area.

Building no. 19, compact with a steel structure clad with clinker bricks, is home to the nuclear engineering faculty. It is dedicated to Giuseppe Bolla, who arrived in Milan after the war to hold the position of Professor of Higher Physics. He soon started focusing on nuclear physics and its applications for industry and energy. He promoted – working with some of the leading companies of that time – the Information Studies Experiences Centre (CISE) in order to create an experimental low-power battery using uranium and heavy water. In 1957, he was behind the creation of the Enrico Fermi Centre for Nuclear Studies (Cesnef), equipped with a reactor for teaching purposes. He was the director of this institute until 1973. Today, this building houses the Micro and Nano Materials labs. Building no. 20, with a long south-facing four-storey façade, clad with dark framed cement panels, houses the IT and electronics department (DEI). This is one of Europe's leading ICT departments, as well as being among the biggest. The building is dedicated to Professor Ercole Bottani, who in 1940 began studying electrical networks to perform automated calculations. In 1999, the building was hit by a fire. Behind the 19 bays on the ground floor, one finds meeting rooms, offices, classrooms and laboratories. On the right of the entrance hall, off centre, there is a large lecture hall. Since 1927, the tall building at no. 21 Via Golgi, behind the utilities room, has housed the Politecnico's Institute of Chemistry and Physics-Chemistry, designed by Giovanni Bonicalzi. The imposing fire escape creates an architectural sculpture, backed by four chimneys.

7.8 Knowledge

The environmental context must be viewed in light of traditions and available materials, the local cultural, geographical and weather features, the specific landscapes and the relevant orientation systems.

This diversification needs the type of input that comes not only from urban subjects, such as sociology and politics, but also from contemporary aspects of evolution, such as those studied in anthropology and ecology. Reading the context entails a cultural choice because "it is closely linked with the choice of the 'means', that is, the organization that makes the architecture 'communicative' (…) To see a shape means to choose a category of 'means' or 'canals' and ruling out others" (Cerasi 1966).

It is common in Italy to find signs of the past and Milan is no exception here, with a small memorial garden next to the fence around the sports centre. The tombstones speak volumes.[1]

The city's historical memory is also represented by the Carlo Besta Neurological Institute, on the corner of Via Ponzio and Via Celoria, overlooking the western side of the Giuriati sports field. The current building is the result of many extensions and additions. The complex, equipped with cutting-edge devices for the study and treatment of nervous system diseases, was opened in 1932. After the bombing in

[1]"Folli Attilio, 18 years old, Giardino Roberto, 22 years old, Rossi Luciano, 22 years old, Botta Renzo, 21 years old, Ricotti Roberto, 21 years old, Serrani Giancarlo, 18 years old, Bazzoni Sergio, 18 years old, Capecchi Arturo, 19 years old, Rossato Giuseppe, 21 years old, shot here on 14 January 1945, the blood you split here helped created Italy's new destinies. This Resistance Memorial Garden, dedicated to the 14 partisans who were shot here in January 1945, was inaugurated on 20 April 2009 following restoration work supported by Sezione 'ANPI' 25 Aprile in Milan Città Studi and local citizens". Plus: "On 2 February 1945, the following fell in the name of liberty: Campegi Luigi, Volpones Oliviero, Mantovani Venerino, Resti Vittorio, Mandelli Franco".

1943, the building was rebuilt and one floor was added, to house the paediatric neuropsychiatry ward. New buildings were added in the 1960s. At present, the possibility is being looked into to relocate the building, given the safety and equipment needs.

7.9 Variability

The environmental context changes constantly over time, appearing fragmented and partial.

The environment is the result of work done by multiple and different subjects: engineers, sociologists, politicians, demographers and communication experts. Their work constantly changes the structure of the city, even though these changes are visible only in the long run, and the perception is fragmented and confused, with contradictions brought about by new assessments. Fortunately, people live in cities and go about their business, adding mobile elements that have the same importance as the fixed ones. It is this second presence that ensures the openness and constant transformation of the environment and the vital evolution of its image.

In this sense, the presence of a children's playground offers some dynamic possibilities and potential for use. Let us now turn to a milestone in the history of architecture, namely the playgrounds designed by Aldo Van Eyck immediately after the war on areas that were considered "lost". At that time, he was working for the city's Development Department. From 1947 to 1955 Van Eyck designed some sixty playgrounds in the most densely populated parts of Amsterdam. In this example from the Netherlands, these grounds had the potential to build networks, although this is not the topic we are currently looking at. What is of interest to us is how he explored these places with small projects, adopting a "theory of relativity", which acknowledges the importance of the elements in a playground, where there is no hierarchy, but an interdependence of the overall composition. Above all, it is interesting for us to note his way of seeing the city as an object of planning that evolves and adjusts because users are left free to imagine these spaces, which were deliberately left simple so that they could be constantly re-invented by the imagination of children. "Such suitable places already existed and were awaiting (just like many of those places or similar places in any city in the world), forgotten,

Figs. 7.19–7.20 People live in cities and go about their business, adding mobile elements that have the same importance as the fixed ones (*Source* Luigi Spinelli)

Fig. 7.21 It is this presence that ensures the openness and constant transformation of the environment and the vital evolution of its image (*Source* Luigi Spinelli)

useless and dead (…) These children playing demonstrate the latent possibilities of urban renewal in general (…) places where children and parents meet, true extensions of the doorstep – for it is on the doorstep that the outside and inside worlds meet, the spheres of collective life and of individual life, intersect" (Van Eyck 1959, pp 34–37). Taking on board these words by Van Eyck, and even though it is currently considered as an attachment to the Giuriati pitch, a playground for children, inside the campus, could trigger far more interesting dynamics than leaving it all up to the university's management (Figs. 7.19, 7.20 and 7.21).

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Chapter 8
…Where to Place the Voids

Designing the Context: Morphological and Cultural Issues

Arantza Ozaeta Cortazar and Álvaro Martin Fidalgo

"The art of structure is how and where to place the voids.
If you think about the void, instead of working
with solids elements, the truth emerges"
(McCleary, Iglesias, 1997).

Abstract This chapter offers multiple keys for unveiling, representing and constructing the context, figured out in between architectural and landscape design. Context becomes a multi-scalar Latent Environment that is made visible -and transformed- with Diagrams and Cartographies. Context, understood with reference to time as and interactive and living organism, drives us to design architectural successions of Landscape Events.

8.1 Introduction

Robert Le Ricolais (1894–1977) was a curious and experimental engineer who taught us to reflect on the voids. After an insightful observation of the human skeleton, which weighs five kilos but can support twenty times this weight, he proposed to build structures by defining their holes or with hollow elements. This apparent paradox ("*strength without weight*") triggered a new frame work that diverged from the deterministic outlook common to engineers at that moment.

In the same way, the musician John Cage composed his most famous piece 4′ 33″, four minutes and thirty three seconds of silence. After visiting an anechoic chamber, he realized that he could hear his own blood circulation and nervous system, so silence is audible – it doesn't exist (Cage 1999). With this idea, he amplified the context of music by utilizing random and "non-desirable sounds" (noises) in addition to "desirable sounds" (notes correctly played).

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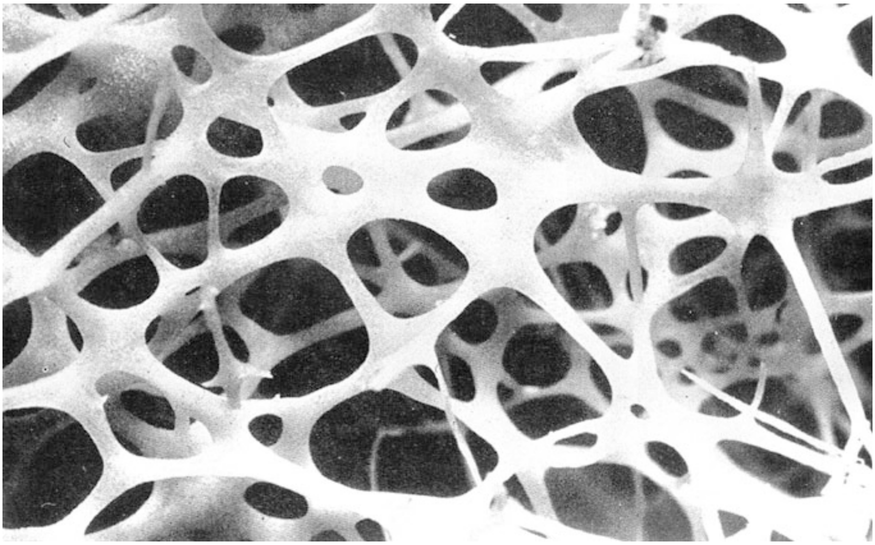

Fig. 8.1 Microphotography of osseous tissue (*Source* McCleary and Iglesias 1997)

These important figures redefined or amplified the context of a discipline (structural engine or music) by paying attention to the apparently non-visible characteristics of reality (voids and noises). They gave importance to events that previously hadn't been taken into account and as such proposed a new framework that triggered new opportunities (Fig. 8.1).

8.2 Constructing the Context: From Landscape of Events to Latent Environment

Looking at the dictionary, we have re-appropriated different and objective notions of Context and created our personal definition[1]: Context is "an environment that determines the meaning and value of an idea, a project or a construction". This Environment refers to "the set of extrinsic conditions that a system needs to run". But these conditions are not ideal or static anymore, they change, so current reality becomes a *Landscape of Events*. It is a hyper-place constituted by dynamic, unfinished and evolutionary situations that offer a multiplicity of interpretations. It is not only a result of the topography, climate and property boundaries, but it is also a consequence of population statistics, sociological data, cultural information,

[1]Interpretation of different notions of *Context* and *Environment* from "Dictionary of Spanish Real Academy".

meteorological and geographical conditions, urban regulations, territorial claims, economical management, technological arrangement and aesthetic coherence.

Therefore, a context embraces numerous environments and situations that, as architects, we have to learn how to track, represent and interpret exhaustively and precisely, because reality is not simple. So, with the same context, several individuals select a different set of parameters which are considered as "architectonical conditions of opportunity". By them, we are activating a *Latent Environment* that constitutes a new and concrete reality where we place our project. In this way, the context of a project will be always a personal environment, interpreted through our experience – references, knowledge, images, memory.

8.3 Context Is Multi-scalar

An apparently small event, such as the official launch of a technical device celebrated in a small auditorium in San Francisco, can have an instantaneous and widespread effect in the world economy. So like an electrocardiogram, the NASQAD (National Association of Securities Dealers Automated Quotation) measures the impact of Steve Jobs' words during the launched Ipad2 in real time: Jobs' greets the audience, shares go up $2.77; Jobs says that he has 90 % of the market, shares shoot up, $3.67; Jobs leaves the stage and another executive goes on with the presentation, half of the increase is lost; Jobs comes back to the stage, shares go up $2.93 (Martin 2011, p 60).

Because we live in a global world where the most distant architecture can sometimes be more familiar than the closest local event, we can't assume anymore that context refers only to our closest surroundings (Soriano 2009). If we want to understand the real magnitude of a context, we must take into account data on any scale, from the global economic situation to physical restrictions of a piece of land.

Information constructs a Project. Everything becomes data or can be used as data: documents, numbers, interviews, images, journalistic articles, photographs… We must be exhaustive and precise, and we should avoid being guided by appearances. We need to understand context in its entirety so we can act precisely and position our projects in a determined place, with a determined economy and a determined program (Soriano 2010). That is why we propose Acupuncture (Lerner 2005) as a system by which projects are inserted in reality. A simple action that helps to create a chain of positive reactions that will provide vital energy to a place. This approach is a process, it is successful when an organism finally takes charge of its own revitalization. This requires speed and precision, introducing a needle slowly and painfully is meaningless. We quote Jaime Lerner, author of the reference book Urban Acupuncture, in view to explain how we want our projects to work: "We know that this approach is a process. It doesn't matter how good it is if it doesn't cause an immediate transformation. Mostly it is a spark that starts an action and its subsequent spread. That's what I call good Acupuncture, real Acupuncture".

8.4 Representing a Context Is Starting Its Transformation

These are the first and second representations of the surface of the moon (1609). After the discovery of the telescope, scientist Thomas Harriot could look at the moon in detail and draw its first cartography: a rough line that separated light and dark. But he was not able to interpret it. A few days later, Italian astronomer Galileo Galilei, by using a new pictorial technique of representation (*chiaroscuro*), was able to interpret the shadows of this satellite and revealed the moon in relief (Castro and Marcos 2010). The transference of a technique of representation between different disciplines – from art to science, in this case – provided a relevant discovery for contemporary science: the moon is not an ideal and smooth sphere, but change and imperfection are part of its nature (Fig. 8.2).

As designers, architects work with every kind of data detected in context by turning them into parameters of our architecture. Firstly, we allow ourselves to get impressed by the reality, looking at everything with the same intensity. Then we choose and activate that part that we call *Latent Environment* which constitutes our personal impression of the place, our starting point. In a second round, we focus on the registration of data: not proposing anything but describing the face of reality in which we are interested. This record should be as objective, precise and complete as possible, only in this way can different data become compatible and therefore handled and transformable. So we are interested in representation techniques that provide exchange and dialogue between different kinds of information. The project is considered a living experiment, so we need to work with open documents that are transformable and implementable. At the same time, as reality is a *Landscape of Events*, it is a dynamic phenomenon so we look for techniques of representation of dynamic processes, which explains the fluent condition of a context with statics and plain drawings. Traditional techniques can be implemented with transferable ones from other disciplines. Good sources of representation systems are meteorological graphics, hydrological studies in flood risk areas, thermal maps, predictions of

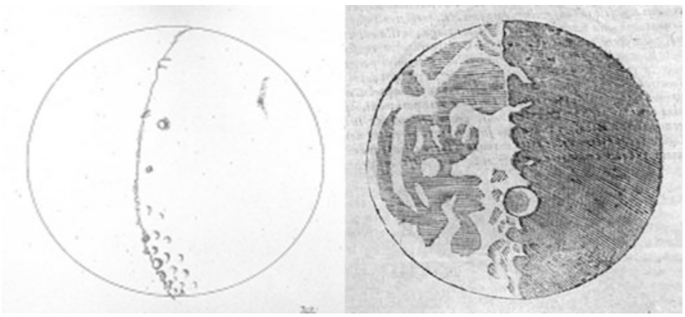

Fig. 8.2 Representations of the moon made by Thomas Harriot and Galileo Galilei respectively (*Source* http://www.nature.com/nature/journal/v467/n7314/full/467398a.html)

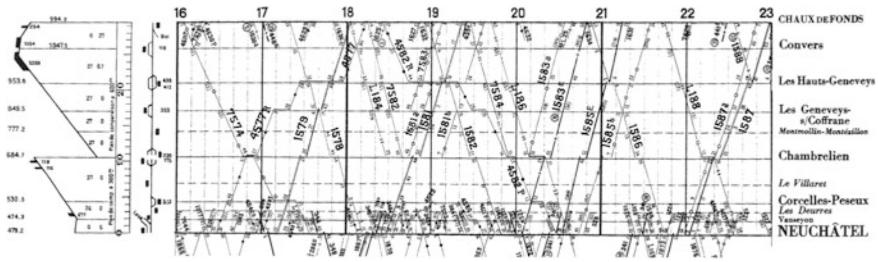

Fig. 8.3 *Cartography* train schedule which visualizes the velocity and stops of the different trains over a single track compared to the profile (*Source* Tufte 2001)

useful life of materials, morphological studies of crystals according to temperature and saturation, comfort climographs, maps of ocean currents, drawings of migratory routes of animals, analysis and graphics of the market, etc.

8.5 Revealing Context with Diagrams and Cartographies

At this point, two concepts are introduced in relation to representation of context: Diagram[2] (“representation of a process”) and Cartography[3] (“representation of a process in/of a place”) (Fig. 8.3).

On one hand, Diagrams (Soriano 2002) are precise and concrete drawings; they are syntheses of information, not reductions. This instrument is a procedure in itself and we construct them. It provides a precise but open, exact but diffused control of data, providing links, variations, alterations, assemblies, etc. Diagrams are understood here as thinking mechanisms because they do not only represent but also produce situations.

On the other hand, Cartographies are “geographical maps of a place”, but we would like to redefine them as “*geological maps of a place*”. This geological character would add a reflection on terms like transformation, evolution, growth and change. It turns cartographies into “representation techniques which show measurable and descriptive relations of a place dealing with its composition, internal structure and generative process”.

We use diagrams to describe reality and we apply them in the construction of new cartographies that represent the *Latent Environment* of a place. These are representations of what is possible, what is real and what is needed.

[2]Definition of *Diagram* in Dictionary of Spanish Real Academy.

[3]Interpretation of different notions of *Cartography* from Dictionary of Spanish Real Academy.

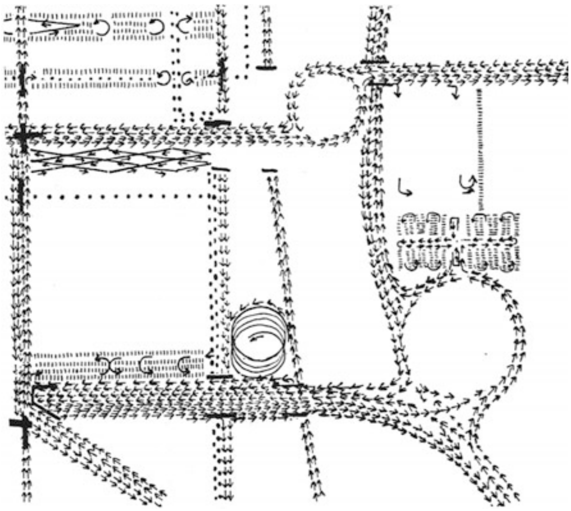

Fig. 8.4 Traffic Map in Philadelphia, by Louis Kahn (*Source* Soriano 2002)

The importance of representation techniques was stated by Deleuze: "each representation system can be ascribed to a different organizing capacity of the world". And the map of Philadelphia made by Louis Kahn in 1953 illustrates perfectly this idea. He used arrows, dashes and crosses in order to mark the path and speed of cars, buses, trucks and streetcars with varying speeds and destinations. However, the physical infrastructure of the city was not depicted. Rather, the street grid was only implied as a reversal of the use patterns of those who travel through it (Ábalos, 2005). This cartography implies a determined order of the place in terms of flow, speed and movement, where expressways are understood as rivers and streets as canals, so we will operate with harbors and docks (Fig. 8.4).

8.6 Project and Context as Interactive and Living Organisms

A fisherman by the river, sitting with his TV and an ice box, with a car behind him, all neat. This image illustrated the project "An Experimental Bottery" designed by David Greene (Archigram) in 1969. Here Nature becomes architectural material, which can build new and complete realities together with technical devices. It represents a temporary place, "an architecture that exists only with reference to time". Everything can be removed and just a slight footprint – squashed grass – will be visible in the near future. Some sophisticated and portable technical elements – hardware – transform this space into an instant place, an ephemeral environment that allows us to think that "the world will perhaps again be a garden" (Cook and Webb 1999). We are interested in this incorporation of adaptability to architectural objects, in the possibility of designing architectural "moments", which implies an idea of transformation, flexibility and dynamism.

The aim of a complete understanding of Context is its transference to our working process and so the integration of our projects into their concrete reality. In order to get that active presence of the Context into the project of Architecture, we propose to design like "Gardeners" who, with a deep knowledge of (architectural) working material, operate from experience, thinking about different states of project along its life and about how it will be related with its changing environment. Thus, an Architect will "interpret material and Context as interactive living organisms, and design a succession of future events".

With the new technologies, Architects are able to represent dynamic processes and work on dynamic fields, therefore we should adapt our methods and techniques

Fig. 8.5 LAWUN. Project nº1. An Experimental Bottery 1969, David Greene (*Source* Cook and Webb 1999)

Fig. 8.6 Profile of a forest plot 20 × 30 m at Montagne La Fumée, French Guiana: trees of the present in thick lines, trees of the future in *dotted lines* and trees of the past in *thin lines*. Roel of A.A. Oldeman (*Source* Ishigami 2010)

to this professional reality. According to the professor Iñaki Ábalos, disciplines such as Landscaping and Environmental Sciences become references in this field, "not because of their scientific principles of ecology, but because of their methodological and creative dimensions. By working with phenomena of biological change and succession, they give consistent responses within a Context simultaneously natural and artificial" (Ábalos 2009). On this way, we could talk about Architecture in terms of dynamic understanding of elements, growth models, erosion, useful life, methods of ecological control, dynamics of occupation and levels of integration (Figs. 8.5 and 8.6).

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Chapter 9
The Path: Between Perception and Design

Paolo Pedrali

Abstract A dynamic perception of paths is essential to design a context that takes into account all the relationships between its urban elements. The essay introduces this emotional observation approach to support the rethinking of spaces like architectural promenades.

Every single day we perform actions that enable us to appropriate space and understand the environment in which we find ourselves: we walk, rest, climb, descend, see, hear, touch, etc. More or less consciously, moving our body through space allows us to perceive, to get to know and to recognize our surroundings.

Our mode of travel modifies the quality and type of our perception. It is easy to see how profoundly different the experience of a journey is along the same road on foot or by car. When we walk, we place a much greater emphasis on the details, sounds and smell associated with specific places; we may engage in tactile experiences with the elements around us. On the contrary, in a car distant objects capture our attention, while the relationship with the environment is mediated by the inside of the car. The speed we travel allows us to gain a broader overview of the various sensorial sequences we encounter.

Naturally, to varying degrees this applies to every means of transport. In particular, it is a function of the different relationships between the space traversed and the time taken to traverse it: i.e. speed. We may also say that higher speeds reduce the perceptive value of detail while heightening the synthetic value.

And yet speed is not the only objective factor that influences our perception of space. There is also the observer's physical effort in moving, their position in terms of direction, lighting levels, exposure to atmospheric conditions or the protection afforded by being inside a car, …

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Additional subjective elements also come into play: attentiveness, the reason for making the journey, memory, imagination, culture and more (Desportes 2005).

Perception is a complex cognitive act, one that has garnered multiple definitions over the years in a vast range of philosophical and psychological literature. In the most common definition, perception is conveying sensations experienced by the body in a given space at a specific time, after which consciousness allocates meaning. Some sensations are organized and interpreted, while others do not register in the perceiver's consciousness (Leibniz 1704).

Even so, through recollection this latter category (Condillac 1749) can, in turn, be connected with previous (different) perceptions and generate a new perception associated with memory (Proust 1909).

Historically speaking, the first conscious transformation of landscape was effected by erecting standing stones–menhirs – during the Neolithic age. This generated a new perceptive relationship with the landscape. Placement of these standing stones (and the various meanings attributed to them) designed new spaces connoting territorial proximity or borders, while at the same time describing the territory and its specific characteristics. By the 1600s, how people understand the landscape and architecture had become a literary genre fuelled by travel; space was described and portrayed as a pictorial genre during the Grand Tour (Lassels 1670), as travel became institutionalized as an expression of knowledge.

By the 1900s, the idea of the path was being used as a tool to undermine traditional forms of art. This relatively recent occurrence coincided with an exploration of what the space we inhabit actually is and how it communicates with us, as a result of new impulses and theoretical approaches (Careri 2006).

In 1921, the Dadaists met opposite the Saint-Julien-le-Pauvre church in Paris. This experience, which they referred to as a Dadaist "Visit", was their way of transitioning from Futurist representations of movement to the practice of movement in real space, in which perception becomes an aesthetic experience.

Three years later, in 1924, Surrealists L. Aragon, A. Breton, M. Morise, and R. Vitrac embarked on a new practice that they called 'Deambulation': an erratic wander around a vast natural territory (and, later, the outskirts of towns) without any specific destination for the express purpose of being affected and inspired by the environment (Breton 1924).

In the early Fifties, Letterists (later Situationists) G. Ivain and G.E. Debord theorized the 'dérive' in their writings. Unlike their Surrealist predecessors, the Situationists were keen to cast aside the unconscious and chance in favour of objective exploration. Applying precise rules, they developed the *dérive* in various parts of the city, drawing a psycho-geographical map that represented the surveyors' states of mind. The resulting maps depicted patches of the city, which were represented as islands in an emptiness of urban amnesia (Debord 1956).

With Richard Long, art appeared to re-engage with the erratic path of Neolithic times and the idea of the menhir: a path, a route forged by walking as a mark on the landscape, in which the body serves as a tool for the measurement of space and time. Here, the path is no longer a tool for finding out about places passed through; it is an aesthetic translation of what the artist wishes to convey (Careri 2006).

In what is, more strictly, the field of architecture, the idea that design should take into account the relationship between the layout of elements that make up the space and the emotional reaction they provoke in observers was espoused by Sitte (1889) and later Choisy (1899), though it was only in the writings of Cullen (1961) and Lynch (1960) that the theory was developed analytically: perception of the things we see and that surround us does not occur statically but in a dynamic perception generated by the viewer's movement along a more or less defined path.

While Sitte and Choisy studied the form of architectural space and identified its role as an invitation to movement, Cullen and Lynch proposed the transformation of space into the function of a path, modeling the path as a function of the space traversed (Appleyard et al. 1964). This becomes the main instrument of control through serial vision or the visual sequence, which is tasked with rendering in images what the observer visually perceives as he/she travels along a given path. The landscape reveals itself as a succession of visual pictures and associated space perceptions – nearness and distance, constriction and expansion, entrance and exit – along with the relationship between contiguous buildings, space in light and shade, the different textures of the ground, etc.

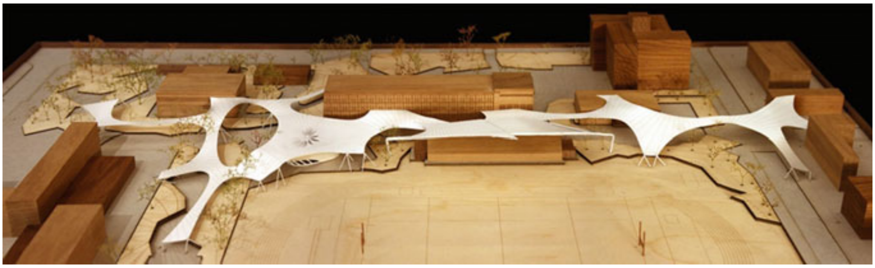


Fig. 9.1 Ramunni E, Silva Trovato S, *Parametric Membrane*. M.Sc. thesis in Architecture, Supervisor Spinelli L, Advisor Beccarelli P, Politecnico di Milano, AY 2012–2013

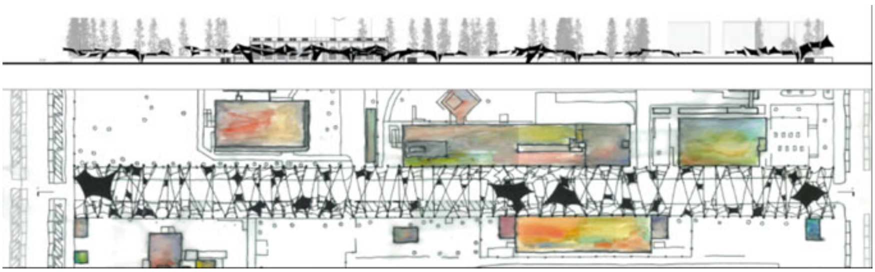
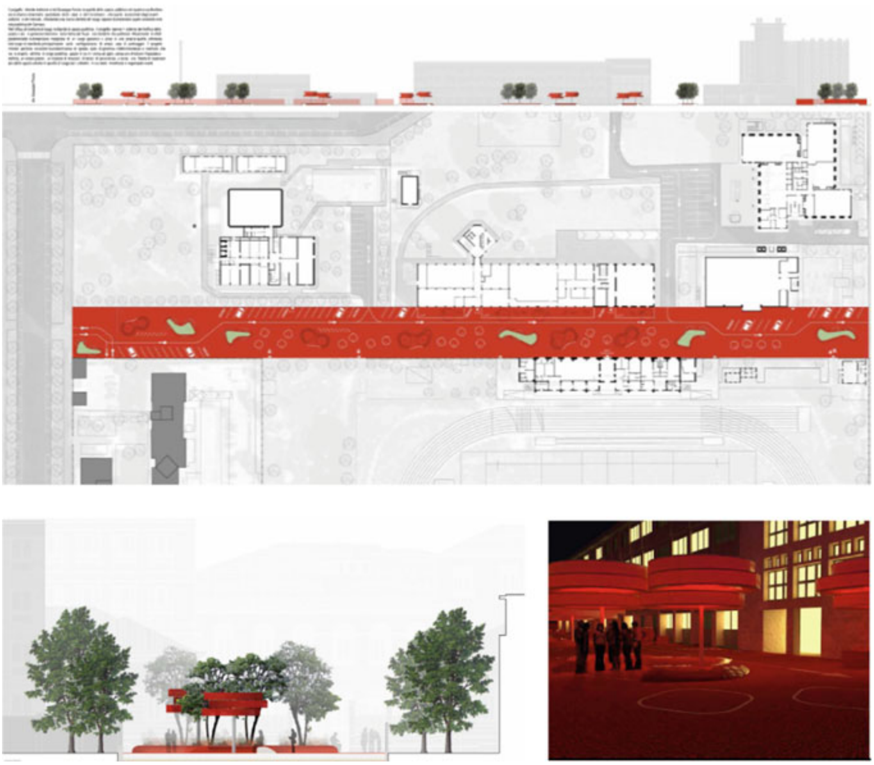


Fig. 9.2 Gorbulin M, Grubova M, Afshari A, Rajabi M, *From Mono to Multi*. LLaw, Politecnico di Milano. AY 2011–2012

If we analyze the compositional structure of many architectural works that are structured as heterogeneous portions, the path or street serves as the unifying element for the whole. Drawing on rhetoric, this approach to design has been dubbed hypotactic (Bricolo 2006); the path therefore acts as a spatial developer that a person can use to situate (objects around him or her) and situate him or herself (among others) (Desportes 2005). Approaching design from this standpoint means placing the path at the center of a narrative structure in which various architectural episodes work together and follow one another in a predetermined order and with compositional weight. It also means being aware that every object/item and every spatial episode that is conceived and designed is not only functional to a project (and, much less, legible from a single position); the elements that make up a design are not a self-referential end in themselves, they are organic to the overall design through visual sequences and reciprocal relationships (Figs. 9.1, 9.2, 9.3, 9.4 and 9.5).



Figs. 9.3–9.5 Pacchetti M, Panzeri S, *The Red Carpet*. M.Sc. thesis in Architecture, Supervisor Zanelli A, Advisor Beccarelli P, Politecnico di Milano. AY 2011–2012

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Chapter 10
Learning from Djemaa el-Fna

Alessandro Villari

> Learning from the existing landscape is a way
> of being revolutionary for an architect.
> Not the obvious way, which is to tear down Paris
> and begin again, as in Le Corbusier's suggested in 1920s,
> but another, more tolerant way;
> That is, the question how we look at things
> (Venturi et al. 1972).

Abstract The essay explains the role of the urban landscape of fragmented modern cities, and proposes to remove superfluous and unnecessary features built into urban stratifications in order to better remark the original essence of the space. Thus, landscape will still propose the value system of a specific society without any kind of fake or imitation, and public space should overcome its own crisis of identity born with our car civilization and the reduction of spatial distances.

Keywords Landscape · Public spaces · Urban relationship · Community

It is very difficult to talk about landscape and especially about that part which, for a strange reduction and simplification, is called urban landscape. Although it is easy to define the term landscape in forms and types (rural, coastal, urban, etc.), it is much more difficult to attribute to urban landscape its clear and precise specificity.

It is possible to say that urban landscape is the universe that gets together the complex relationships between our city and the society that uses it. It is rather curious to define the open space of cities as *zero volume architecture.*[1] In this sense it would mean that a city is the result of a complex structure made up by a set of architectures with and without volume.

Without mentioning a multitude of definitions and out of every rhetorical criticism, I will try to illustrate how nowadays urban *space-landscape* is leading to redesign a contemporary image of the city, especially at the present state of crisis.

[1]"The architecture ZCA [zero cubic architectures] while not technically an interior space, however, come through a negotiation between the environment and landscape, to set up outdoor space, a field of quality and handling characteristics with its […]". In: Aymonino A., Mosco V. P. (2006) Spazi pubblici contemporanei. Architetture a volume zero, Skira Editore, Milan.

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Urban spaces consist of a catalogue of many complex forms that refer to narratives, stories, sometimes even clichés, and they are excellent places where material and immaterial layers have slowly accumulated and settled. A changing palimpsest, that is enriched constantly by urban patterns and that gradually tends to modify, remove or abandon rituals and social functions, is no longer compatible with the rise of new cultural stereotypes.

The urban landscape design in recent years is set in continuous overlapping and layering of signs and forms, which aim to overcome the lack of identity of places, as stronger and closer to situations of marginality, with a semantic too often redundant. In fact, public space exists if there are people who use it, and thus bear witness of quality and comfort values.

In 1972 Robert Venturi published a book on the city of Las Vegas, which became a reference tool for a whole generation of architects. In contrast with modern architectural theories, founded on a rigorous structuralism and a blind functionalism praising the spatial qualities of architecture against the rhetoric of symbol and decoration, Venturi proposes a reviewing of Las Vegas, trying to show how urban image quality and its impact were the medium between cities and society to assist urban behaviors. New urban paradigms were developing, in the disorder of sprawl city, declaring the new image for the future modern city. Nowadays, visiting Las Vegas is a spectacular and dazzling visual experience, perhaps less interesting than Venturi imagined. Architectures, colorful lighting, events lead people into adventure searching of his place of entertainment, in the glitter of signs.

This does not change the cultural significance of Venturi's research, which elicited a critical reflection on the Forma Urbis, and on the dynamic relationship between architecture and outdoor space.

Venturi proposes a complex of new urban paradigms that, reversing the relationship between three-dimensional space and two-dimensional image of the city, may be useful to read contemporary reality of new cities. Las Vegas became the semantic city par excellence, where image is necessary for communication and interpretation of urban space dynamics. In detail, we can say that Venturi proposes a light but complex system of urban signs as a tool showing a variety of urban functions: events, places and spaces (Fig. 10.1).

This interpretive model of the city anticipates all reflections on modern public space, it emphasis the psychological and physical distance of human beings inside urban spaces and it shows a way to connect men with urban landscape.

Trying to understand the nature of urban landscape is not an easy performance. We know that a landscape, in common sense, is a complex system of phenomena defined by nature and by material actions that people make in a continuous transformation process. The urban landscape however is a place of socio-spatial relationships of people. Therefore it is logical to say that the urban landscape-space exists as a place of human actions. We recognize and testify to a quality value of open space of our cities in relation to the people who live in it: in brief, the square is the people who live in it.

Fig. 10.1 Las Vegas urban sign

Learning from Djemaa el-Fna, the city square inside the Medina of Marrakech, means setting the coordinates to reflect on the spatial organization of the place and on the way of its use to find a possible urban quality.

This "cultural space" was included in 2001 in the UNESCO list of sites referred to as "Masterpiece of the Oral and Intangible Heritage of Humanity".

This medieval square is resistant to attacks and transformations of the medina, but it's hard to find in literary sources, clear descriptions of the history of the place. The first interesting description of the place is dated on 1922, when the Sultan Moulay Youssef included it in the list of monuments and environments to be protected. In fact, for the first time, an interest in the place is being manifested, primarily symbolic and cultural, even if directed at control of the growing Medina and the public buildings proliferation. After the Treaty of Fez and the French protectorate, some buildings with a public function have been realized and they have changed the shape and use of space (Fig. 10.2).

This square records every year millions of visitors from around the world, who come to visit the exciting entertainment show offered by a multitude of actors (acrobats, snake charmers, vendors, doctors…). The current image of the place is the result of a historical process, not always conscious, that has made the square the symbol of the city and Morocco in general.

Watching and analyzing the current spatial conformation of Djemaa el-Fna, we cannot say that it's really a square, but an open space without a clear border, where the vacuum power accommodates a multitude of actions in infinite spatial configurations.

The buildings surrounding the site were characterized by a lack of scenery and by the exclusive use of simple materials drawn from the local building tradition.

The square of Marrakech shows, in significant ways, all complexity of urban places and also the internal conflicts of the modern city. The urban landscape generated is of rare beauty, but it is not immune from the conflicts of the social

Fig. 10.2 Marrakech, Djeema el-Fna square. A simple space for endless and complex social uses (*Source* Alessandro Villari)

structure. Often sites like these are witnesses of unresolved conflicts that sometimes it is difficult to perceive and sometimes clearly stand out.

We must walk around and penetrate the streets of the city of Hebron in Palestine to understand how the social and ethnic conflicts permanently alter the idea of public space, inverting the reaction dialectic between space and society. In Hebron the public space has abandoned the role of indicator of urban and social transformations. It is no longer a place of diversity and relationships but a place of political power (Fig. 10.3).

In contention cities, empty spaces are witnesses of unresolved conflicts. Outdoor space takes on the role of collective vacuum, where usual activities of public space are reduced just to crossing.

There are many places, especially in the South that is not geographical but cultural, as well as being similar to each other, that have many similarities and correspondences with Djeema el-Fna square. In some ways, all souks and North Africans medinas tell of everyday life and of the complex relationships between cities and people. Also in Italy you can find sites that possess all the chromosomes of an urban metabolism, very often of Arab tradition, where sounds, smells and people gives us an n-dimensional space for a sensory experience.

One of these is the fish market square in Catania, one of the landmarks of an ancient culture and a social model. In fact it occupies a void space between the eighteenth century building near the sea and the old city walls. Its transformation into an open-air fish market is not really clear, but its history is deeply established in the memory of the city and its inhabitants. It's a site without form that isn't marked by any obvious morphological structure and it is located in the centre of the city. It's a timeless place, immune to social change and urban transformation. It's the

Fig. 10.3 Palestine, Hebron. The public space becomes eloquent witness of intractable social conflicts (*Source* Alessandro Villari)

place of repeated gestures, without remarkable changes, without stress for crises of modernity during everyday life. The charm of the place is enhanced by the presence, now barely recognizable, of the Amenano river which, although submerged by the last historical lava flow of 1669, is still visible due to the extraordinary trick of a fountain that is the mark of the river and the transition place from the fish market to Piazza Duomo. Moreover, it simulates the entrance to this symbolic place with all its colorful, charismatic and disordered humanity. Here, as in Marrakech, we have an informal public space, without a specific design or architectural connotation, but just a place of intense cultural and social reciprocity.

If the sites also have symbolic value, as stated by Debarbieux (1995), then we can declare that Djemaa el-Fna and the Catania fish market are "lieux de condensation sociale et territorial", because they express the value system of a society. In this sense, the square more than a space is a container of actions that, from time to time, reconfigure the spatial arrangement of the place by starting a dynamic process of continuous modification of urban relationships.

When space is in direct relationship with the community and in general with the city, it reveals a myriad of spatial combinations, not depending on the shape of the place, but interacting with a continuous combination of events related to each other. In this sense "the square" is no longer a spatial organization of static elements, an involuntary organization of actions that create and produce areas. Something similar happens in the theatre, where actors, as a function of their roles, play and move giving to the scene an image, not static but variable in time, always evolving. Djemaa el-Fna Square is the city's theatre, the mirror of a common identity and so urban landscape par excellence.

By the persistence of places not affected by the processes of modernization, where there occurs continuously a sequence of collective rituals, issues emerge concerning the way we use them (Fig. 10.4).

How are the relationship between people and urban landscape changed?

Regarding collective and spatial interactions, the Danish architect Jan Gehl in 1972 published the results on a systematic study of relationships between people and public spaces. His book *Life Between buildings* is a reference point about public

Fig. 10.4 Catania, Fish market. It is the identity place of the whole community: the central space of collective rituals (*Source* Mauro Moschitti)

space qualities and about the ability to modify and decline the complex interchange between people and the modern city. Gehl proposes a new vision of public space, related to categories of actions performed in open spaces, in strong opposition with the opinion of the fundamentalist city planners. Gehl divides the human activities in the public space into three basic categories (Necessary activities, Optional activities and Social activities) assigning each one a weight and a method of use of public space, quantifying the number of activities and frequency of their interactions.

With a totally scientific approach, he shows that "The more time people spend outdoors, the more frequently they meet and the more they talk". He tends to show that open-air activities and their interactions are influenced by some conditions, and that the quality of the physical urban environment is one of the determining factors together with the environmental and climatic factors. In few words, the best quality of public space leads to a greater quantity and quality of relationships between people. Gehl offers a model of a "Carless city", able of returning to the community adequate cycle and pedestrian spaces. It is no wonder that nowadays Copenhagen is the capital of sustainable traffic with the most extensive net of cycle routes in the world, used by 40 % of the population.

Forty years after the publication of Gehl's book, we must reflect on the relevance of his studies in relation to new behavior models expressed by society and to the complex crisis in public spaces.

The collective dream of a car for every family is gone and "car civilization", claimed by Ford, has been replaced by new questions of conscious balance of urban behaviors and of environmental sustainability. As you know, with the rise of personal transport and the reduction of spatial distance, cities have been able to expand their territory beyond the limits of the compact city. This process of extensive expansion has contributed to the gradual erosion of public life, to the fragmentation of public space in more specialized areas, to the gradual abandonment of urban space and to the disappearance of the functional *mixité* typical of pre-modern cities. The consequence of this dislocation has served to create and disseminate, in the suburbs, new areas of centrality as a substitute for public ones, including the Shopping Mall.

The situation of degradation of the city isn't less important, and people look for a comfortable refuge in their home. A degradation, sign of a lack of civic consciousness and of a disconnection between individuals and public space, that is manifested in the most suburban areas of the city.

Electronic modernization drives us towards a relocation of activities that took place first in urban space, increasing the degeneration and the crisis of public space. The cyberspace has become a social place par excellence, where all the public life of people takes place. Houses have assumed the role of shared and immaterial public space, where there are many of the actions typical of outer space.

In response to this crisis, we must remember that the design of public space has been a status symbol of European society. The strategic plan for specific projects of reconstruction of public space planned and realized in Barcelona has had a dual objective: the first has been to think of the city image in planning the collective space as important elements in urban development policies; the second has been to start a strategy of agreement extended to all social groups, to reduce geographical and cultural differences that had arisen between downtowns and suburbs. In the wake of the Spanish model, many European cities (Lyon, London, Copenhagen) have developed plans to re-qualify public spaces as a topic aspect for a consistent policy of urban renewal.

Currently, urban landscape is more a transitory space, material and immaterial, where human activities mingle in a disorder that cannot be evaluated by categories of default actions. There is no longer a place for work and a place for leisure, but it confirms the logic that tends to mix up our experiences in a continuous process of contamination of events, that are layered on residues of urban collective rituals still standing. In this sense, the urban landscape acquires more and more, the size of the place of the continuous variability of scenarios and of testing of most appropriate processes of negotiation between man and city.

What is the quality of the urban landscape for future cities?

We are heirs to a long tradition, mainly Anglo-Saxon origin, in which the design of public space has always belonged to the sphere of urban design confirmed by a multitude of projects. A result of the project was based on the mechanical assembly of furnishing equipment and plants that gave responses more to requests for quantity of services rather than starting a reflection on the quality of the city. The awful urban furniture has invaded our cities. The poor quality of many realizations has certainly not improved the places, but it caused the confusing overlap of objects and shapes in complete disharmony. This trend is pervasive, not yet completed, and it has to deal with a society that has set its coordinates of development on the political integration man/nature, no longer be postponed.

We are witnessing, more and more often, in designing projects with a strong representation and social impact that is a symptom of analytical difficulties. These projects try to create urban scenes as exaltation of the collective imagination, good to see immune to socio-cultural changing, or they have tried to repair obsolete or outdated rules of life. In this sense, the pedestrian *tout court* in many parts of the city and the exclusion of cars from the most sensitive environments haven't always been the resolution of the widespread phenomenon of urban chaos, and they haven't contributed, in a structural way, to reformulate new ways of use of public space. Without disappointment the consistency of contemporary projects is often associated with the desire to give the community more specialized, attractive and spectacular areas in contrast to the historical roots of public space.

For some years the *paesaggio* or *landscape* or *paysage*, has become the password to start cultural projects of reform of the city. The urban landscape has shared and supported, with architectural projects, the growth of a new urban model according to the wishes, imaginations and expectations of a community studded by the media. It's necessary to filter any adjustment according to a cultural figure that starts from landscape as supporter of the urban quality able to manage with the complex and ever-changing metamorphosis. The new theories of landscape urbanism, based on architecture criticism and on modern tradition planning, claim that only through the proper tools of landscape is possible to rearrange the city and improve the urban life. Although this theory is widely acceptable, we are faced with the nth cultural manifesto of principles that are not always fully implemented in contemporary projects.

Aware that the landscape is a system of phenomena, then we have to imagine that the urban landscape design should find symmetries with natural phenomena and return to the city the natural metabolism that has been forgotten for too long. The city is the ensemble of collective phenomena, made up of codes and languages that have to be interpreted, guided or sometimes rewritten. Cities are increasingly overweight and wealthy, it is urgent to find a solution that would provide a new path in the public space design and that would be able of ensuring environmental and formal quality in relation to new patterns of use.

We must establish a dynamic balance between urban tissues and environmental system, which establishes comfort rules for public space, that does not depend form morphology and from size of the available space, but from the structural quality of the project getting over the limits of the design of the soil.

There is a clear need for a cultural model, in analogy with the natural processes, taking possession of tools to overcome and control the aggression of the territory and the continuous use of land, restoring a physiology of the city able to protect the environmental balance. The car paradox is symptomatic to understand how the community should bear the heavy burden of social emancipation and modernization at low cost. To make transport more comfortable we asphalted all the streets of our cities and, once sealed the soil, higher was the production of cars. The result of this intervention was to have interrupted the natural cycle of water and through the artifice of a complex system of pipes to drain the water, not through the soil, to the sea. Establishing water cycle, expanding the permeable areas of the consolidated city, could be one of the first tasks for environmental restoration and reconstruction of an urban microclimate.

What is surprising is the total absence of organic and systematic projects of public space as we witness the proliferation, according to the rules of a policy not careful to quality but more interested in consensus, of a production of project without a general strategy and of a continued fragmentation of urban space.

The public space is the cultural dimension of the city, where the society has always settled expectations, aspirations and dreams. A place of conflict and convergence, that has for centuries played a decisive role in the structuring of the urban tissues and in the dynamics of growth of the modern city. We can say that the design of the urban landscape is the key to the new strategies of urban regeneration worldwide space.

Learning from Djeema el-Fna or from Catania fish market means to understand the success of some urban landscapes. It means to question the values and qualities of a "landscape without a plan" that exists in relation to its cultural and spatial stratification. It also means to trace the reasons for this social success and to reproduce them in the new urban landscapes. I think that sometimes, more than assembly elements in amazing shapes and figures, we just need to remove the superfluous. Eliminate unnecessary time stratification to return to the essence of space. From the knowledge, editing and rewriting of the codes of public space depends on the opportunity to modify the urban contexts. The project must start in the city, not as a solution of decorum, but it must anticipate and intercept the desires of a society, to interpret the changes, reconfiguring what is there. "The architects chose to change the environment rather than improve what's there" (Gehl 1971).

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