Chapter 1
Designing with Lightness

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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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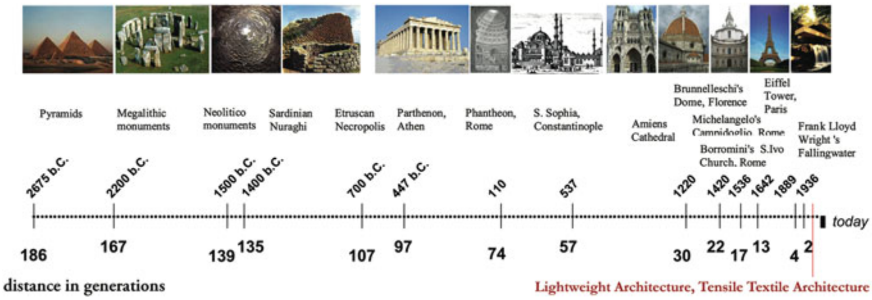

Fig. 1.1 Timeline of the esthetical and technical abilities of man (sketch of the author from the sources: Zevi 1997 and Sarger 1967)

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

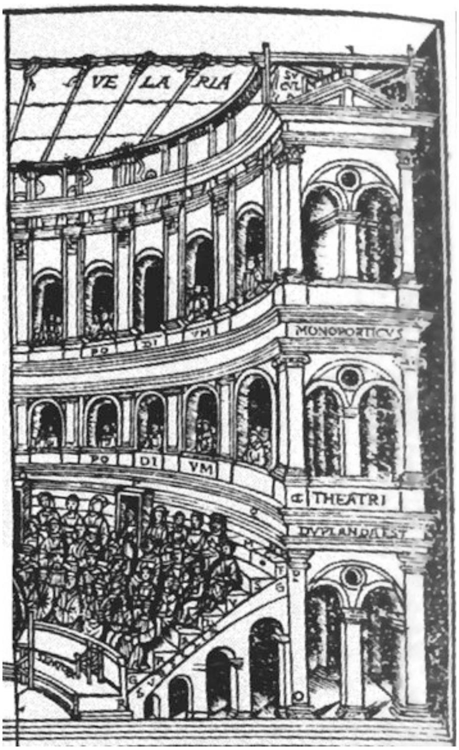

Fig. 1.2 Caesar Cesariano, 1521: detail of an incision about the form of the classical theatre according to Vitruvio (*Source* Ricci 1971)

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).

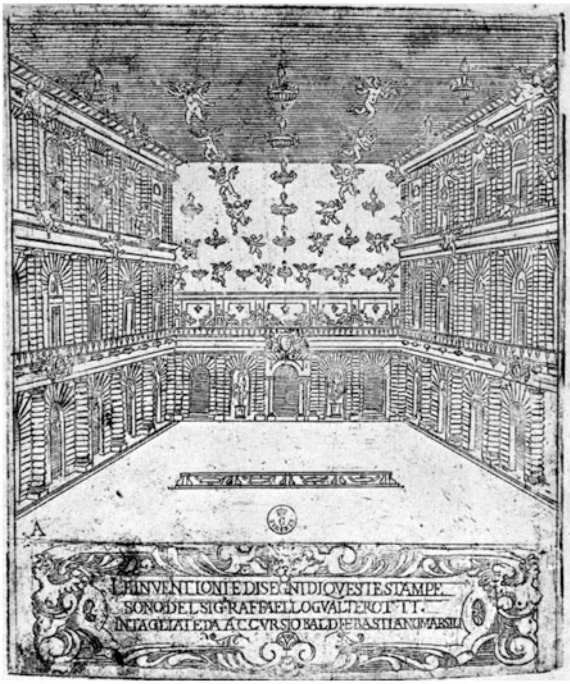

Fig. 1.3 View of the courtyard of the Pitti Palace with the apparatus for the "bar games" built in 1579, Florence, drawn by Accursio Baldi, Sebastiano Marsili (*Source* Zangheri 2001)

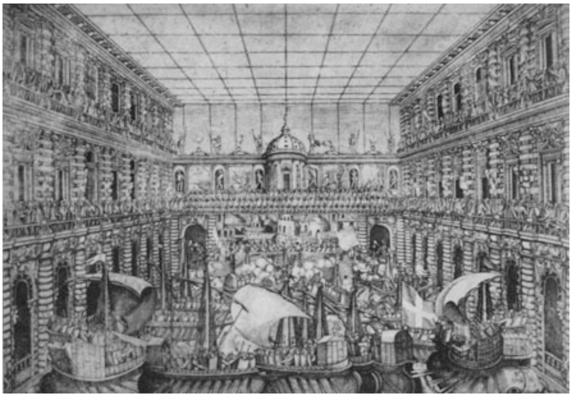

Fig. 1.4 Orazio Scarabelli: the apparatus of Naumachia games designed by Bernardo Buontalenti in the courtyard of Pitti Palace, Florence, 1589 (*Source* Zangheri 2001)

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

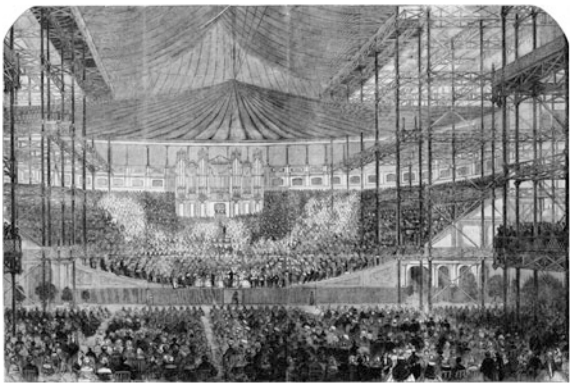

Fig. 1.5 Acoustic membranes for performances inside the Crystal Palace during the Haendel Festivals, London, 1859 (*Source* Forsyth 1985)

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).

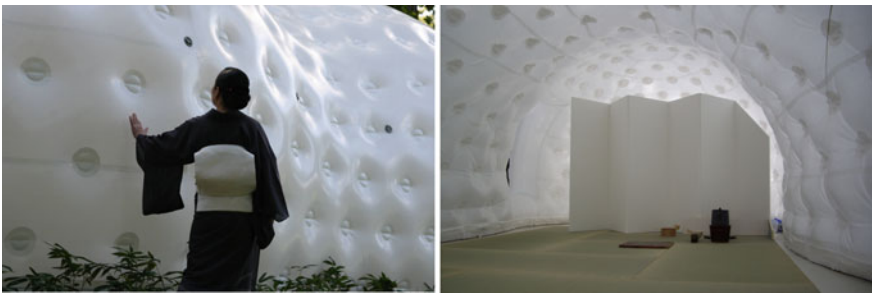

Fig. 1.9 *The soft form*. Kengo Kuma Architects: Temporary Tea House, made of two textile membranes stabilized by inner air pressure. A perimeter steel U profile connects the two layers of membranes and also works as a temporary foundation (*Source* Courtesy Form TL Archives)

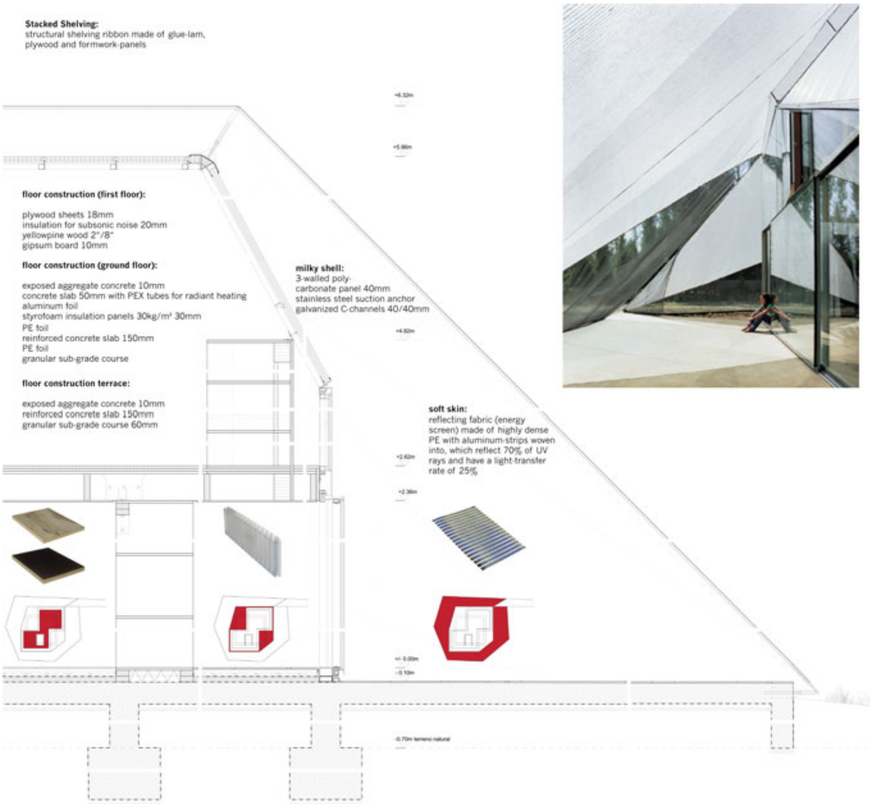

Fig. 1.10 *The adaptive skin*. FAR architects, vertical section of the Wall House and a view of the open air perimeter protected by the soft textile skin (*Source* Courtesy FAR Archives)

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)

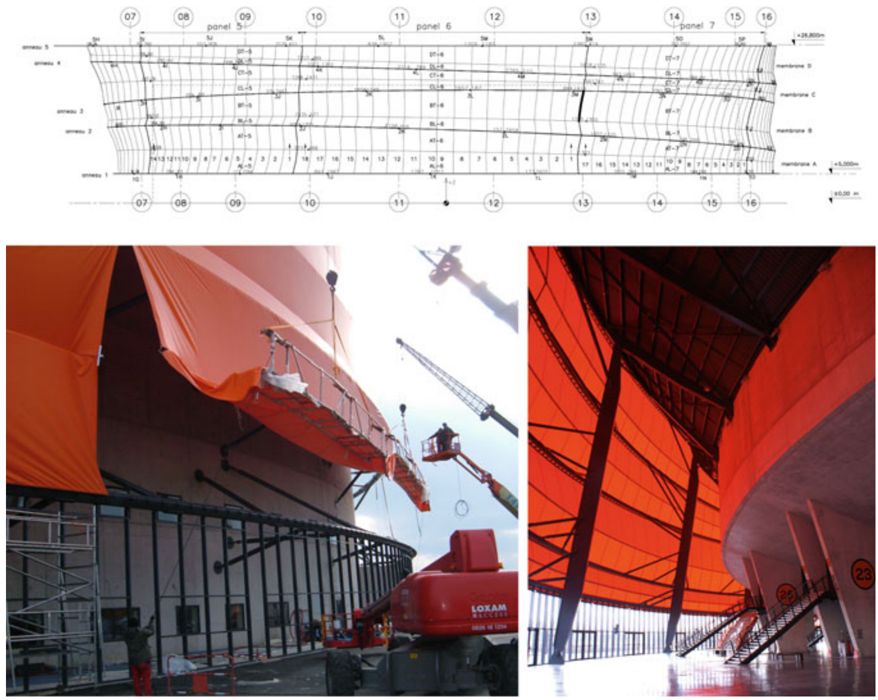

Fig. 1.12 *Textile as a building product*. Massimiliano and Doriana Fuksas, Zenith Auditorium, Strasbourg 2008. The impressive textile skin of this permanent architecture was installed in only ten weeks. The detailed front drawing shows the partition of different big textile panels which were produced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