

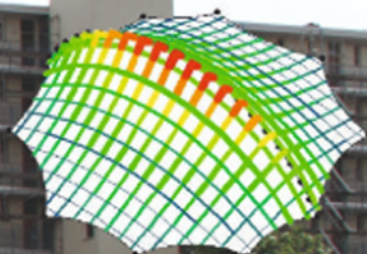
Textile Roofs 2025

The 27th International Workshop on the Design and
Practical Realization of Architectural Membrane Structures

May 25th - 27th, 2025

Aedes - Architecture Forum Berlin, GERMANY

Scientific Supervision: Prof. Rosemarie Wagner (KIT)



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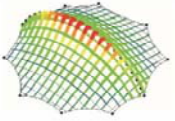
2025, May 25th - 27th
Berlin - GERMANY

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TEXTILE ROOFS: BUILDING SYSTEM OR ARCHITECTURE?
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1 Definitions	6 Contradictions – Paradoxes
2 Antecedents	7 Historical summary
3 Architectural characteristics	8 Conclusions
4 Building system	9 Bibliography
5 Urban characteristics	10 Announcements

1

Summary

Most literature and contributions referred to surface tensioned structures deal with engineering issues as if they were only a building system.

Form finding, computer modelling, patterning, energy consumption, life cycle analysis, materials or project descriptions are preferred topics.

But the architectural characteristics have been very little addressed which does not favour appropriate applications, to the point where the paradox of heavy lightweight structures occurs.

Therefore, the architectural and urban characteristics of the tensioned surface structures are reviewed, illustrated with references to the history of architecture and works completed to date.

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BASIC DEFINITIONS

Architecture: the art and technique of configuring the space

Building system: a set of elements and materials that partially or totally materialize the building.

Building systems:

- **foundations** transmit the loads to the earth
- **structure** allows the building to stand
- **envelope** or what is visible form outside including roof and external walls
- **interior** or what is visible form inside including ceilings, walls, partitions, finishes, furniture and equipment
- **services:** air conditioning, heating, ventilation, power, water, waste, fire safety, security control delivered through ducts, conduits and pipes.

Notes:

- they are usually solved with different additive systems
- interior and envelope are usually interdependent, as is the case of envelope and interior.

TEXTILE ARCHITECTURE

The space is configured by a lightweight pre-stressed three-dimensional membrane.

Surface tensioned structures unify structure, envelope, interior and configure the space

TEXTILE ARCHITECTURE – Josep Llorens – ETSAB/UPC

2

Corollaries

Architecture is textile if the space is configured by the membrane.

As it is necessary to support the membrane on other structural elements, it sometimes happens that they take the role of configuring the space according to their own rules. It is the case of metal trusses and space frames. The membrane becomes an envelope or cladding system and it is not about textile architecture.







It can be avoided by using structural support elements that do not compromise the spatial configuration such as masts, cables or air pressure. So the unsupported span of the fabric itself does not have to exceed 15 meters, (a distance that can be increased if the membranes resistance increases).

Near flat surfaces supported at close intervals and those with a complex support structure are prone to become heavy lightweight structures that configure the shape and the space.

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BASIC REQUIREMENTS OF ARCHITECTURE

<p>1 Only <i>firmitas</i> and <i>utilitas</i>. Deterministic functionalism</p>  <p>Animal construction</p>  <p>Most of engineering construction. The design only requires technical knowledge</p>	<p>2 <i>Firmitas</i>, <i>utilitas</i> and <i>venustas</i> integrated.</p>  <p>Architecture without architects</p>  <p>Textile architecture. The design requires technical knowledge (not only)</p>	<p>3 Only <i>venustas</i>. Free forms and de-constructivism</p>  <p>Free-form. Cloud or potato?</p>  <p>De-constructivism. The idea does not require technical knowledge</p>
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The three classic requirements of the architecture according to Vitruvius (1st century BC) were:

- *firmitas* (strength),
- *utilitas* (utility)
- *venustas* (beauty)
- now we could add: sustainability.

Some ways of approaching the relationship between architecture and construction according to these requirements are:

1 Only *firmitas* and *utilitas*: the constructions of the animals (genetic knowledge) and some engineers (acquired knowledge).










2 *Firmitas*, *utilitas* and *venustas* are integrated. The technique is a condition of the form, (but not the only one). Therefore technical knowledge is needed, acquired directly or indirectly by experience, direct transmission or education.

3 Only *venustas*. The autonomy of the free forms and de-constructivism of the contemporary media architect unconcerned about the resources.

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TEXTILE ARCHITECTURE

 <p>1990</p>	 <p>1992</p>	 <p>1993</p>
 <p>1999</p>	 <p>2006</p>	 <p>2006</p>
 <p>2011</p>	 <p>2015</p>	 <p>2019</p>

TEXTILE ARCHITECTURE – Josep Llorens – ETSAB/UPC 4

According to these definitions, textile architecture occurs when the membranes configure the space.

1990 FTL Associates with Buro Happold: “Pier 6 Concert Pavilion, Baltimore”.

1992 J.M. de Prada, 1992: Palenque public square, Expo Sevilla.

1993 Llorens & Soldevila with IASO: Birth Show Auditorium, Port Aventura.

1999 Ackermann und Partner with sbp: “Truck depot. Office for Waste Management”, Munich (replaced).

2006 M.Guislain with M.Malinowsky, Groupe Alto: Roller Skate Parc, Paris.

2006 form TL with Canobbio: National Stadium Velodrome, Abuja.

2011 gmp with sbp, formTL, Hightex and Bridon: Kiev Olympic Stadium.

2015 Tensile Evolution with J.Lienhard, St.ructure Engineering, R.Roithmayr and Sefar: Velden Gemonaplatz.

2019 Buildair: Hangar H75, Jeddah

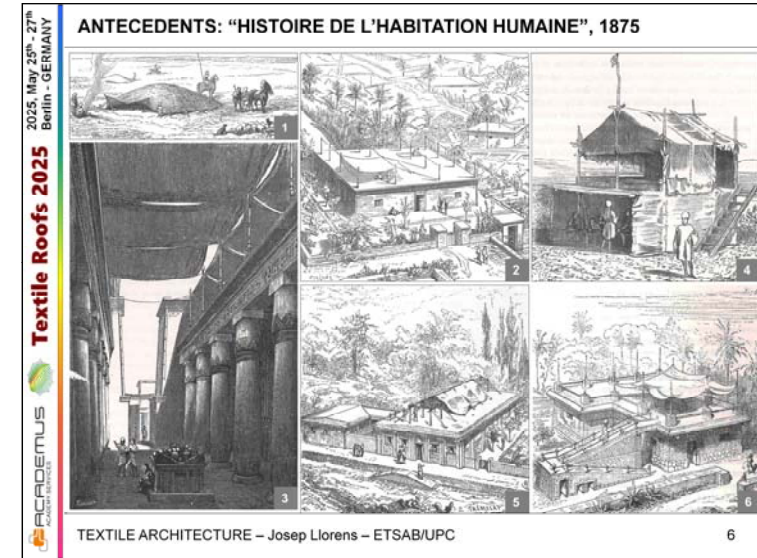


Membranes can completely configure the architectural space but they can also participate in its configuration combining with other construction systems or complementing them as enclosure or cladding.

1 Shigeru Ban et Jean de Gastines with C.Balmond and Arup, 2010: Centre Pompidou-Metz. The roof structure is composed of glue laminated timber hexagonal modules, resembling the cane work of a Chinese hat. This latticework makes it possible to span 40 metres, resting on just a few supports. It is covered with a waterproof membrane made of fibreglass and PTFE (Poly-Tetra-Fluoro-Ethylene), white in colour.
(<https://www.centrepompidou-metz.fr/en/centre-pompidou-metz/architecture>)

2 Foster + Patners with Arup and seele, 2015: the Crossrail Station Canary Wharf, London, showcases the combination between traditional timber and 780 triangular ETFE cushions

3,4 Textile Halls are defined by the aluminum frames. The flat surfaces of the membrane require supports at close intervals, materialized with frames and purlins that configure the shape and the space. They are not strictly textile architecture.



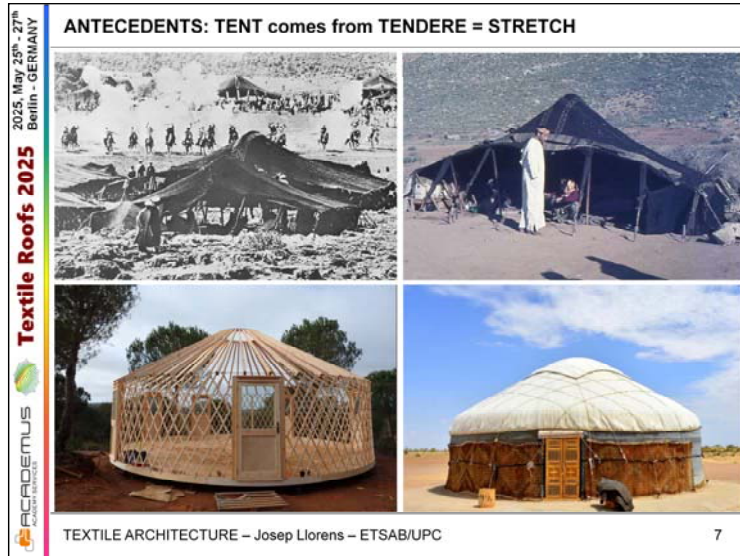
INTRODUCTION. Some antecedents to get into the subject.

The histories of architecture do not usually refer to textile construction. This type of structures have gone directly from the primitive solutions of the nomadic peoples to the high-tech realisations of the last fifty years. The limitations of the available materials only permitted the construction of temporary and ephemeral constructions, which have not been the subject of analysis due to their lack of permanence and durability.

But the rise of durable and resistant materials and the use of computers in the analysis of complex shapes, have led to the use of structural membranes in a wide variety of locations for a variety of purposes. Therefore, it is appropriate to consider them from an architectural point of view.

A pioneer was Viollet-le-Duc who included them on his "Histoire de l'habitation humaine depuis les temps préhistoriques jusqu'à nos jours", 1875: **1** Central Asia desert - **2** Nile Delta - Egyptian palace - **4** Great steppes - **5** First dwellings of the Aryans established in Upper Media (Iran) - **6** The Assyrians.

Textile roofs appear as nomadic or seasonal complements to permanent constructions.

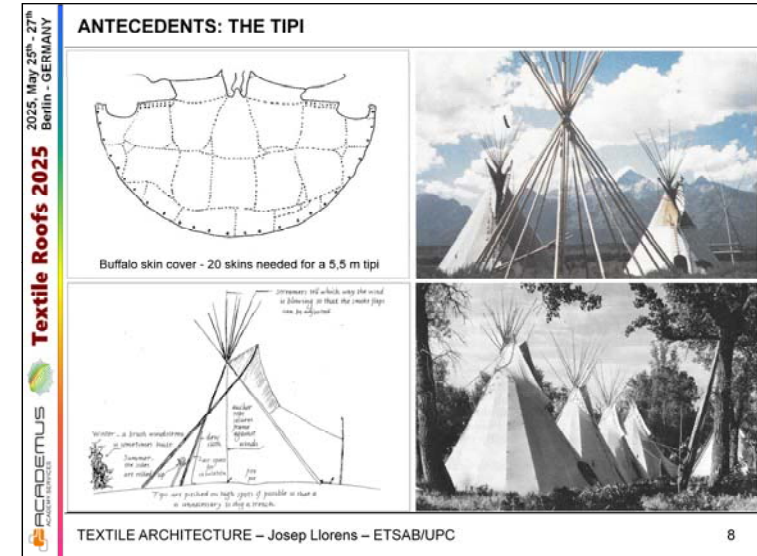


Nomadic tents are at the origin of textile architecture. The etymology of the word “tent” comes from the Latin “tendere”, that means “stretch”, indicating that it is a tensioned surface structure.

Several applications can be distinguished from the very beginning (G.Cataldi, 1986):

- a) Top: the “proper” Bedouin jaima tent stretches a woollen sheet raised on posts by means of ropes. The fabric plays an active role. A rectangle made of structural woven goat’s hair together with poles and ropes.
- b) Bottom: the “improper” yurt tent employs a pre-fabricated portable sheet laying inactively on a wooden structure. It uses a single layer lattice grid shell for the walls and a timber domed structure for the roof, both clad with woollen fabric.

Both respond to the lightness required by the ease of transport with the available materials.



The semi nomadic tribes of the North American Plains become full-time nomads because of the arrival of horses and the pressure of white advance.

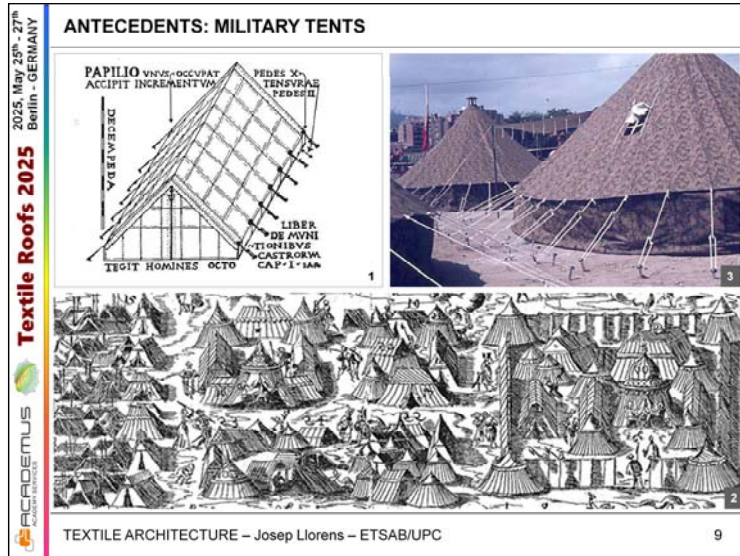
They used the tipi, a conical tent, based on a buffalo skin covered conical frame of poles, wind resistant and able to be erected quickly. The poles are tied together at the apex and pulled down to a peg at the centre.

In addition, the cone tilts against the prevailing wind for bracing and so the hearth can be moved forward of centre, which permits head clearance in the rear of the tent.

However, the greatest innovation of the tipi is the ventilation system. It does not become smoke filled when there is a fire inside it. The main device for clearing the interior of smoke is the smoke flaps which channel the wind in such a way as to draw the smoke out of the tipi. The smoke flaps are attached to poles so that they can be adjusted according to the wind direction.

In addition, the interior ventilation is aided by a lining that hangs from the tent poles, runs around the interior of the tent, insulates, prevents drafts and keeps out rain that runs down the poles.

(T.Faegre, 1979)



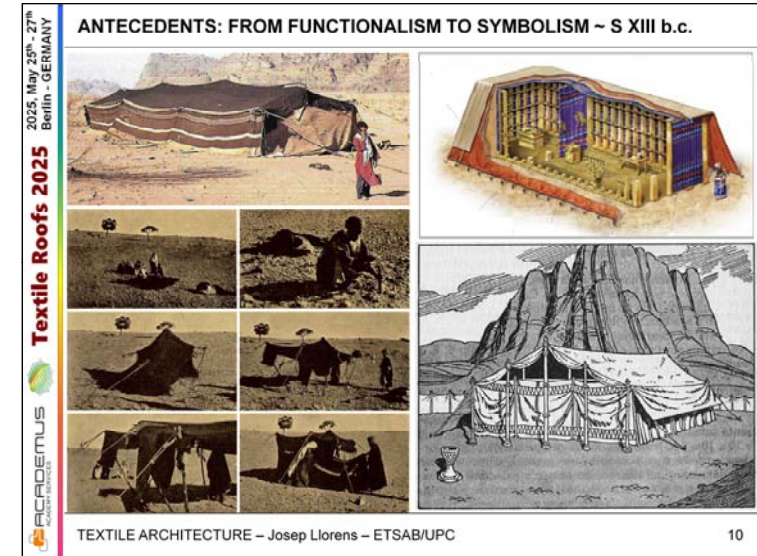
1 The Roman military tent was made of leather, enrolled from a 2 m high central ridge supported by two uprights. It was made from standard 0,5 m rectangular pieces of 2 mm thick calf leather that were assembled lengthwise in six parallel strips consisting of seven standard panels each, avoiding a seam on top.

Both slopes were inclined 45° from the central ridge centred on a 3 x 3 m square in plan. Additional 0,3 m on each side produced a tent wall that could be lifted for ventilation.

(from Ph.Drew 1979: "Tensile Architecture". Granada Publishing Ltd. Frogmore, St.Albans).

2 An army camp (Jost Ammann, XVI th century). The whole city is built with tents. Individual quarters, a market and the area with the army commander's tent complex were grouped together (IL 14, pp.80-81)

3 Contemporary military camp.

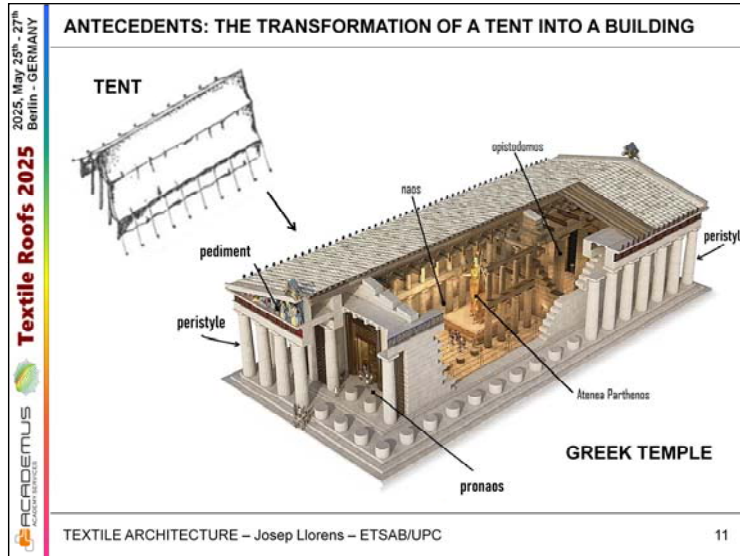


The lengthening of the jaima becomes the black Bedouin tent, source of inspiration for the Tabernacle, the first building to be specified in writing in detail. Its description is contained in chapters 25 to 31 of Exodus. It is part of the set of instructions given by God to Moses during the 40-day retreat on Mount Sinai (13th century BC) and was built by the craftsmen Bezalel and Aholiab. It was a rectangle (15 x 5 m) of prefabricated wooden panels braced with cross beams of the same material.

A longitudinal ridge rests on the beams which supports the multi-layered wool and leather roof. The wool on the inside insulates and ventilates, while the leather is responsible for the appearance and waterproofing. This is the black Bedouin tent transformed into a removable sanctuary, but the shape no longer corresponds to that of a textile construction because the canvas is only used for enclosure and partitions.

The representative aspects prevail because the attempt is made to adapt the mythical Jerusalem temple to nomadism, a symbol of a stable and prosperous society that is preserved in historical memory and which it is desired to recover.

Gottfried Semper in 1860 has already observed the tendency since ancient times towards the wrapping of the structural parts of the building (G.Semper, 1860: "Der Stil". Frankfurt am Main)



This transformation of the tent into a building, with a stable and representative appearance, is at the origin of the classical idea of Western architecture, since it already develops many of its fundamental concepts such as geometric composition, symmetry, axes, hierarchy and proportion.

The interior space divided into two parts by four columns and a curtain can be interpreted as the origin of the division into naos and pronaos of the Greek temple.

The surrounding space protected by the slopes of the roof would be the origin of the peristyle and the front elevation announces the portico, although the proportions vary, since those of the Tabernacle still correspond to those of wood.

In both cases the use has already transcended that of the original artificial shelter and does not shelter man, but divinity.



Conditioning streets, squares and public spaces with textile roofs has been and is still used.

1 Vela roof of the Colosseum (80 AD) by J.L.Gerome, 1859.

2 Corpus Christi procession, San Francisco square, Sevilla. In addition to sun shades over market stalls and temporary stages, there are also awnings to mark the path of a procession protecting participants and passers-by from the sun.

3 Large awning erected for the visit of the Pope to Terracina, 1795. It was anchored to the building at five points and tensioned by four cables.

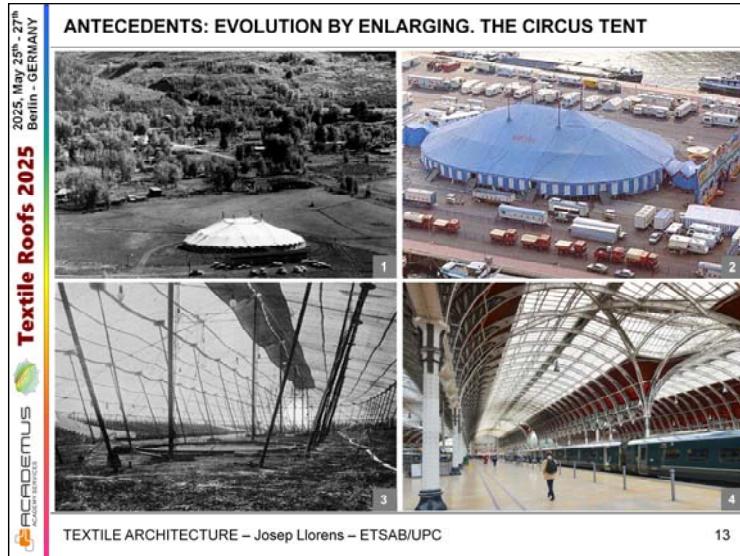
4 Ericeira beach. A considerable area is covered with individual modules that can be operated by a single person.

5 Market square, Lausanne. The awning unifies the dispersion of different individual elements

6 Procession of the "Virgen de los Desamparados", Valencia. The space-creating effect comes into its own on such festive occasions

7 Fondamenta Furlani, Venezia

8 Roofs over streets, Jaén. The cloth strips hang from rings on cables which are strung across the street.



1 E.Saarinen, 1949: Aspen music tent – 2 Circus Krone
3 Ringling Bros, Barnum & Bailey big top – 4 I.K.Brunel,
1854: Paddington Station, London.

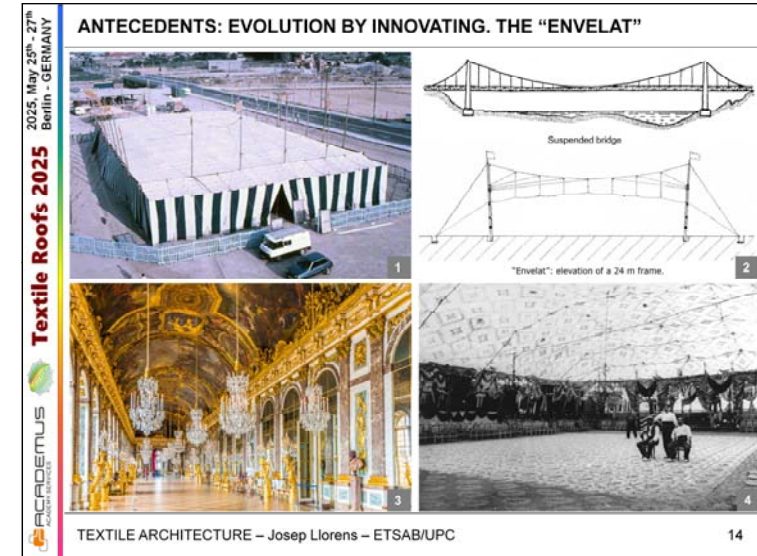
The circus tent culminates the process of enlarging the dimensions of the tent. Its design is optimized according to the needs of a brief, easy assembly and transportation over short and long distances.

It results in a very large tent supported on central masts and intermediate poles that shorten the spans and tighten the whole. The maximum height in the centre focuses the interior space on the ring or rings where the show takes place.

The exterior volume is circular and neutral. For this reason it easily adapts to urban locations or open spaces with the circus caravan filling the leftover corners.

Particularly interesting are the construction details related to the assembly such as the joints, bracing, lightening, local reinforcements, unions and fastening devices.

It can be considered the textile parallel to the spaciousness of iron architecture developed during the 19th century, tested in world exhibitions and applied to large public spaces such as markets, galleries and railway stations.



1 The "envelat" or Catalan marquee was a large rectangular tent (24 x 36 m) and a height of 4.5 m that was used to celebrate patron saint festivals in most towns in Catalonia, Spain.

It was an invention because it did not result from the extension of the tent.

2 Instead of resting on the structure, it hung like suspension bridges. In this way it succeeded in eliminating the interior poles creating a diaphanous large hall suitable for dancing, performances, large celebrations, gatherings or special events.

It was a precedent for current hanging roofs.

3 The decoration of the walls, ceiling and floor tried to reproduce the atmosphere of a dancing room inspired by the Versailles Hall of Mirrors, giving the building a secular symbolism of wealth and luxury.

4 Note how the interior is carpeted, under a clear patterned roof and surrounded by dark curtains framing repetitive decorations.



We come to the year 1954 when “Das hängende dach” is published.

It represents the explicit formulation of the tensioned surface structures as a building system and the starting line for incorporating them into architectural projects.

Therefore, the prehistory of textile architecture can be considered complete. It has been documented in the literature relating to tents and awnings:

D.Couchaux, 1980: “Habitats nomades”. Alternative et Parallèles, Paris

Ph.Drew, 1979: “Tensile architecture”. Granada Publishing Limited, Frogmore.

T.Faegre, 1979: “Tents. Architecture of the nomads”. John Murray, London.

E.M.Hatton, 1979: “The tent book”. Houghton Mifflin Company, Boston.

F.Otto, 1954: “Das hängende dach”. Bauwelt Verlag, Berlin.



Enough works have made textile architecture a reality. Some highlights:

1957 F.Otto and his team: Dance Pavilion, Cologne. A masterpiece of a structure that becomes architecture.

1960 V.Lundy & Bird Structures: Atoms for Peace exhibition. An early inflated structure sheltering a non pressurized interior space.

1973 The Shaver Partnership with B.D.Campbell & Co: La Verne Campus Center. A pioneer in the USA.

1981 SOM with Geiger Berger Associates: Haj Terminal, Jeddah. The world’s largest fabric roof

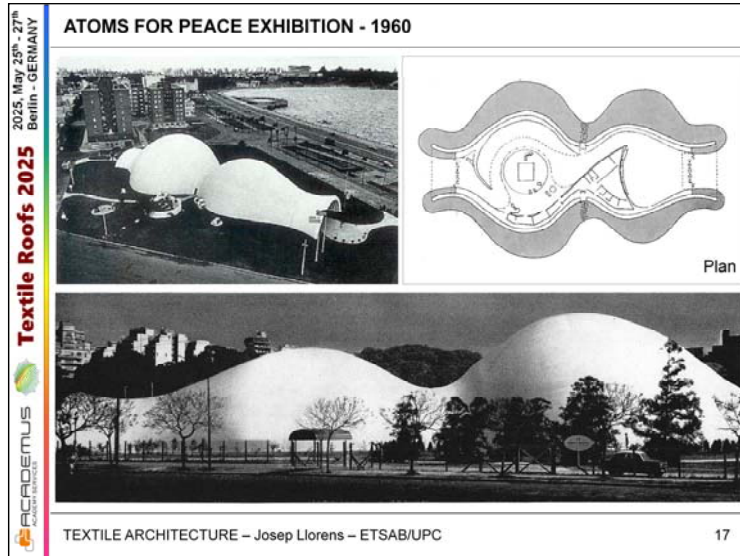
1986 Space Group of Korea with Geiger Associates: Gymnastics Hall, Seoul. The first cable dome.

1990 Studio Tecnico Majowiecki: Roma Olympic Stadium. The spoke wheel reappears after two millennia.

2001 N.Grimshaw with A.Hunt and Vector Foiltec: Eden Project. A breakthrough for its size, frames and nodes.

2014 Vehovar & Jauslin with Vector Foiltec: Aarau bus station. An 1.055 m² ETFE cushion for a urban public space.

2024 L35, GMP and Ribas & Ribas with INES and IASO: retractable roof of the Santiago Bernabeu Stadium, Madrid. A colossal metal and concrete structure covered with a membrane.

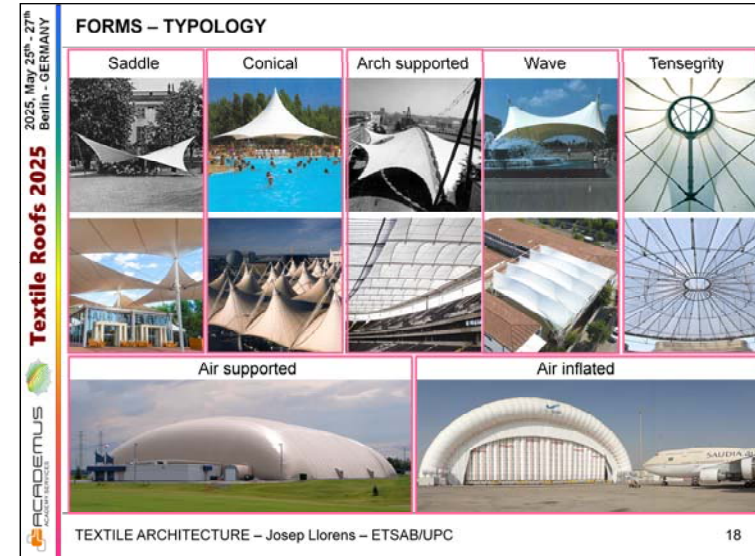


It is particularly noteworthy the case of the “Atoms for Peace” pavilion by V.Lundy & W.Bird, 1960. It was a demountable pavilion designed for the US Atomic Energy Commission, noteworthy for unifying structure and form resembling a puffed-up Henry Moore sculpture, its early date, size, complexity and open form on plan. It was an open-ended vault deformed to produce two hemispherical spaces joined by a central neck and entered by means of arched porches, about the same diameter as the neck (R.Banham, 1969).

The building was 91,44 m long with a maximum width of 38,41 m and maximum height of 16,31 m, weighing 28 t and packed into a standard railroad box car.

The perimeter walls were a double skin of vinyl-coated nylon separated by a 1,22 m airspace which provided insulation as well as the possibility of maintaining different levels of pressure in the inner and outer skins to absorb steady winds and gusts. The different internal pressures marked a major advance in the development of air inflated/supported structures. (S.Bieber, 2019)

“With this construction, a significant architectural achievement appears for the first time in the field of pneumatic construction” Frei Otto, 1962.



The form of tensioned surface structures is one of their main characteristics because it does not follow that of the traditional construction. It derives from the structural function ruled by the principles of only tension, funicularity, curvature and pre-tension.

They result in 3D surfaces that rely on form and flexibility instead of rigidity and weight.

3D curved surfaces in a world of right angles and straight lines attract attention and do not go unnoticed.

Furthermore, they not only clearly show the flow of forces, but also reflect the traces of the manufacturing through the seams.

The repertoire is based on double curved basic surfaces such as saddle, conical, arch supported, wave and tensegrity shapes and their combinations. A formal repertoire has been summarized by M.Mollaert at Textile Roofs Berlin 1999, available at:

https://www.academia.edu/25858675/Membrane_structures_understanding_their_forms_Membrane_structures_understanding_their_forms



Tensile structures are continuous surfaces of variable height perceived as light due to their small constant thickness and curved edges that contribute to the smoothness. The idea of lightness is reinforced by the easiness of erection and (hopefully) the lack of heavy materials and massive supports. The overall shape and the special visual qualities determine a formal primacy, attracting people's view and emphasizing the significance of the function.

What you see is what it is. The shape clearly expresses the construction system of both the structure and the enclosure because they are the same and visible, without cladding or overlapping disguises. One integrated structure does most of the things which in conventional buildings require many additive elements. The structure becomes its architecture.

Constructive clarity is further reinforced by:

- There is no room for mechanical systems
- The connection details are visible, often within the reach of users
- Construction inaccuracies appear as wrinkles. Every patch in the skin can be seen and every seam is exposed.



Non planar geometry appears to be much lighter.

Curvilinearity and scalloped edges are inherent to tensile surface structures.

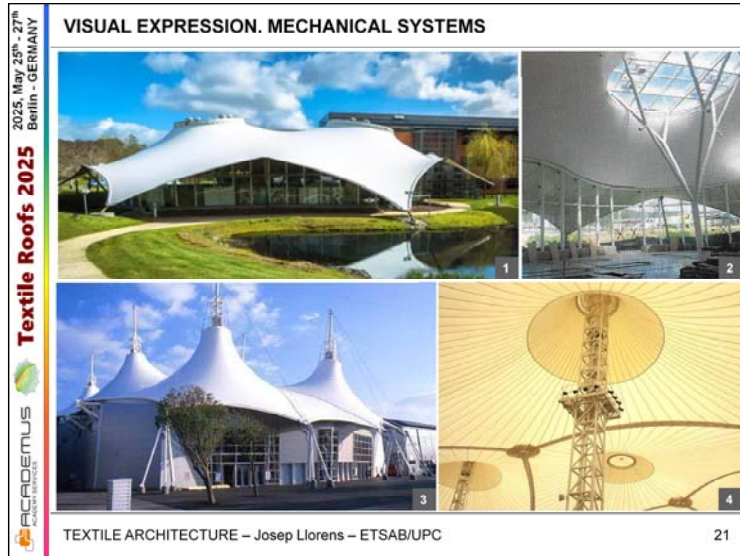
It is recommended to exploit rather than avoid them.
(R.Scheuermann & K.Boxer, 1996)

1,2 Llorens & Soldevila, 1981: Sport Facilities, FASA Renault, Valladolid. The tent for the sport facilities of the Renault factory in Valladolid is integrated into the forest avoiding the trees by means of the curved edges.

Nevertheless, the height of the central mast, the size of the roof and the difference in colour mark sharply the location.

3 IPL Ingenieurplanung Leichtbau GmbH with form TL Ingenieure für Tragwerk und Leichtbau GmbH, 1988: Expo Brisbane.

On a much larger scale, membranes were used for the overall roofing of the venue at Expo 1988 in Brisbane in which the uniqueness of form is one of the requirements



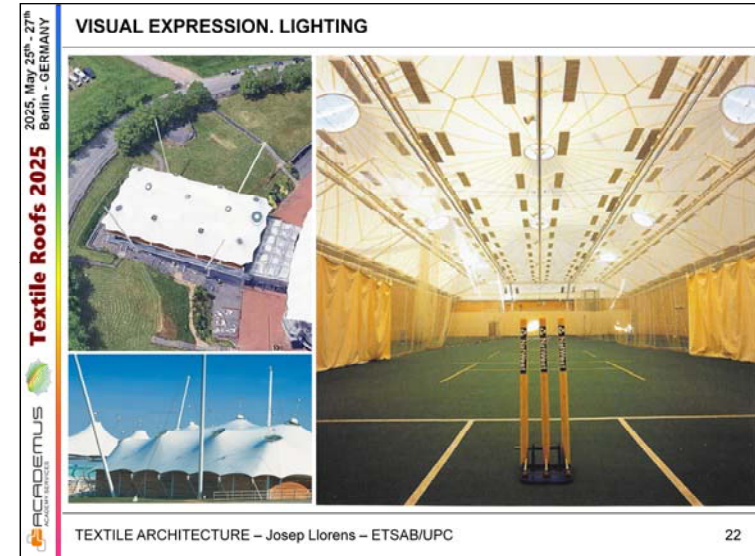
Structural, lighting, fire safety, and other elements remain exposed as there is no room to hide ducts or lines. Lighting and fire sprinklers can often be hung directly from roof cabling or otherwise detailed so that they complement rather than compete with the curving roof form.

Alternatives are the perimeter and the high points, integrated into the structural supports. It is essential to consider them at an early stage of the design in order to provide sufficient room for these components within the structural elements and to integrate them fully into the architectural design (B.Forster & M.Mollaert ed.2004).

1,2 Vodafone Pavilion, Newbury Campus: extractors are integrated in the skylights.

Heating is required (if any) at low level but membrane envelopes encourage warm air to rise into the roof space. While this effect is desirable during the warm seasons, it may cause excessive heat losses through the roof during the cold seasons. Therefore, destratification systems are designed.

3,4 S&P Architects with Buro Happold, Architekten Landrell and Serge Ferrari, 1998: Butlins Skyline Pavilions. Destratification fans blowing downwards are installed on the masts.



Lighting hung directly from roof cabling.

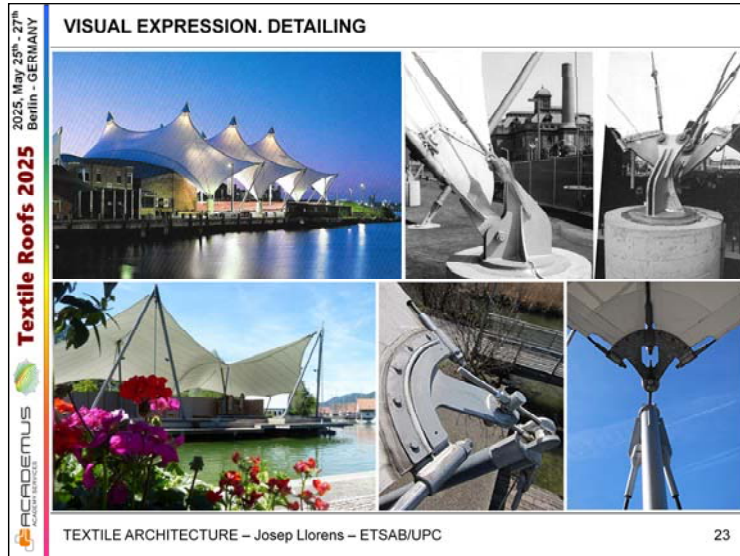
M.Hopkins with Architekten Landrell 2001: Hampshire County Cricket Club, Southampton. When Hampshire County Cricket Club decided to redevelop their home ground, they opted for an awe inspiring and iconic structure to cover their pavilion buildings.

By starting with a virgin site, architects Hopkins & Partners were able to design the ideal environment for training and playing cricket at the highest level.

With a strong background in the design and manufacture of tensile canopies, and experience in building for the sports industry, Architekten Landrell was appointed to develop and construct the tensile structures forming the key buildings at the new venue and a stand for 12,000 spectators and a naturally lit cricket academy.

The white fabric buildings, created from PVC coated polyester, provide an elegant home for this traditional Summer sport and act as simple sculptural elements within the landscaped parkland setting.

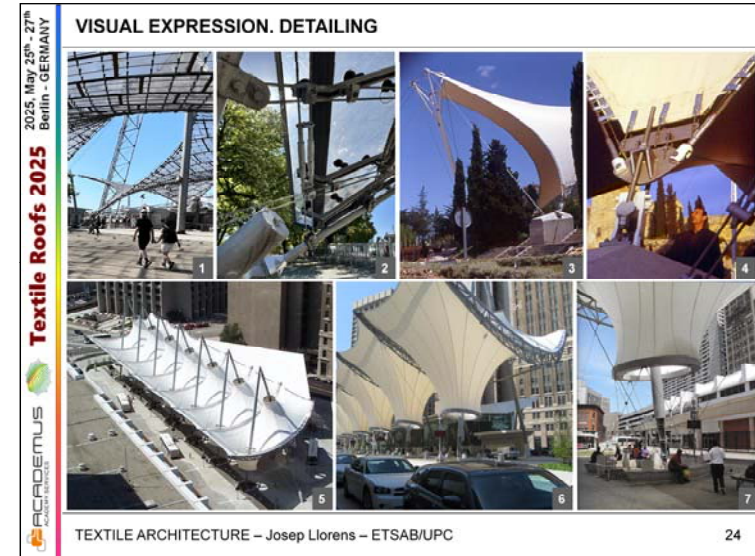
<https://www.architen.com/projects/hampshire-rose-bowl/>



Furthermore, the exposure of structural connections in the finished structure makes the detailing an important part of the structure's appearance, so that visually "clean" connections adapted to the profile of the surface have to be provided expressing the transfer of forces.

Top: FTL Associates with Buro Happold, 1990: "Pier 6 Concert Pavilion, Baltimore". Connections become focal points that can easily result in a clumsy appearance. In the design of the Pier 6 Concert Pavilion low points, extra care was taken to ensure that the shapes respond to the curvilinear nature of the membrane. Note also that the low points are separated from the ground by concrete plinths, so that inclined cables do not interfere.

Bottom: form TL, 2023: lake stage, Immenstadt. The membrane corners are solved with plates that collect the membrane clamped between the plate and a curved strap. The stresses perpendicular to the edges are collected by cables that run into cable cuffs welded to the reinforced membrane. The cables are adjustable by means of swaged threaded ends. Note also the adjustability of the whole corner assembly and the ridge cable. It is also worth noting that the corner is hinged in both directions and that the contour of the plates allows the adjustment of the threaded ends.



Even more attention must be paid when the connection details are within the reach of users.

1 Munich Olympia park, 1972: roof enclosure over the walk to the stadium.

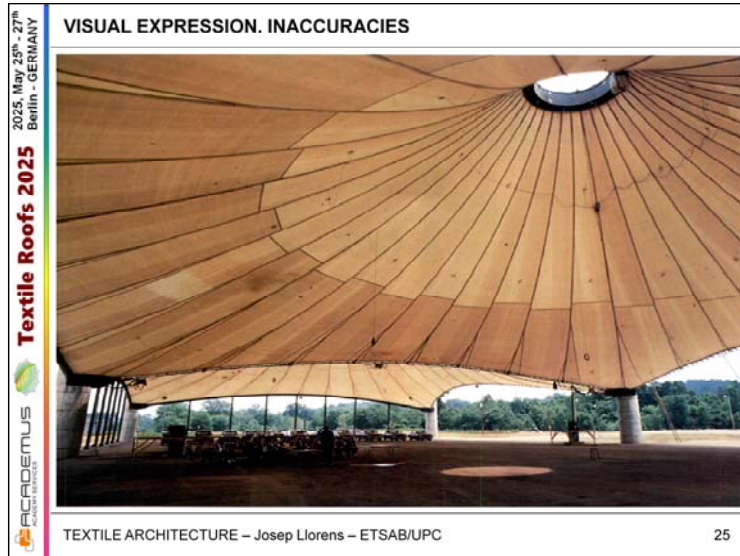
2 "Even if geometrically and structurally sufficient, visually reasonably well-balanced and remarkably accomplished, they seem blunted in feeling and perception" (T.Dalland, 1992).

3: S.Bertino, 1992: Camp de Mart Auditorium, Tarragona. A central A shaped mast together with 4 lateral V shaped masts and six low points provide double curvature and drainage.

4: The proximity of the lower corners to the ground brings them nearer the pedestrians, changing the perceived scale. The dimensions are well proportionate to the surface of the roof and spans but they look over-sized and complicated when seen from a human-body scale.

5 FTL Design Engineering Studio, 2009: Rosa Parks Transit Center, Detroit.

6,7 The low points look proportional to the magnitude of the roof and cars, but are perceived gigantic by the pedestrians



SOM with Geiger Berger Associates, Birdair and Owens-Corning Fibreglas Corp. 1982: Haj terminal of the Jeddah International Airport

A full-size mock up of the Haj terminal tents comprising two full-size units was installed to simulate actual roof installation procedures and to test the structure under a number of adverse conditions.

Though a centre-column support system would have been more efficient, the perimeter pylon system was chosen to gain free space.

In addition this approach simplified the erection because the fabric could be laid out under the centre support rings that provide venting.

It also allowed the structural engineers to check the reliability of the computer programs used for analysis.

Note the translucency that reveals differences in tone and patches.

(“Tent structures designed to endure”. *Architectural Record*, August 1979, pp.86-93).



At night the roof is transformed into a glowing beacon due to the interior lights of the building that shine through the translucent membrane.

1 C.W.Fentress, J.H.Bradburn and Associates with Severud Associates, H.Berger and Birdair, 1994: Passenger Terminal, Denver International Airport.

2,3 FTL Design Engineering Studio with Pei Cobb Freed & Partners, 2009: Skysong at ASU Campus, Scottsdale

4 FTL Design Engineering Studio, 2010: United Nations Porte Cochere.

5 K.Kuma with form TL and Canobbio, 2007: Modern Tea House, Frankfurt am Main.

6 Z.Hadid, 2013: Serpentine Sackler Gallery, London.

7 SOM, 2014: Denver Union Station.

8,9: Kugel Architekten with str.ucture, 2014: Convertible membrane roof, Metzgergasse, Buchs.



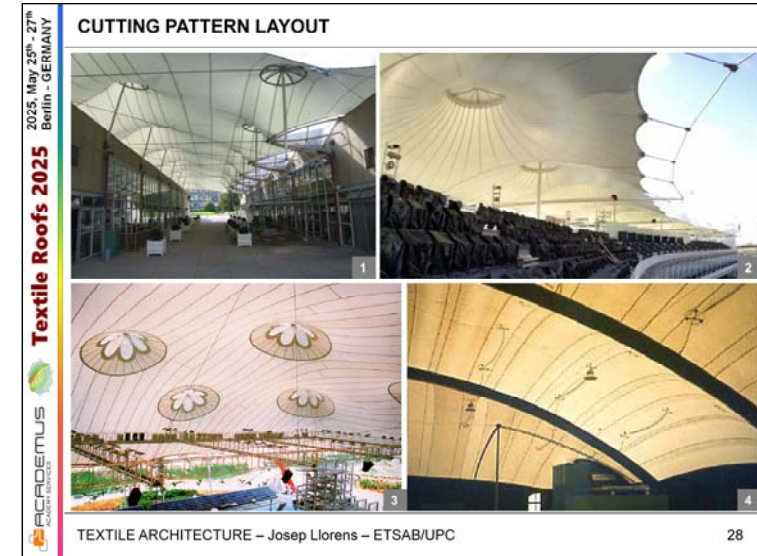
The interior space is characterized by the lighting, the shape and the construction elements that complement them. The light transmission coefficient is high, enough to do without artificial lighting during the day.

Therefore, the cover acts as a diffusing ceiling that gives the space a general luminosity. On the other hand, variations and nuances occur according to the curvatures and slopes that modify the angle of incidence of the light.

The configuration of the space is also influenced by masts, arches, beams, trusses, services, drainage, enclosures, catwalk and joints. They must be taken into account because they can easily distort and confuse the characteristics already described.

Note that if the membrane is opaque, some of the above characteristics are distorted. The perception of the shape is more difficult, resulting in a somewhat featureless interior,

1 Homebush Sports Centre, Sydney. **2** New York Aquarium, Boardwalk, Brooklyn. **3** USA pavilion, Osaka 1970. **4** Plaza Nueva, Bilbao. **5,6** Roof for Olavinlinna Castle. Opacity responds to the requirements of the stage designers and producers.



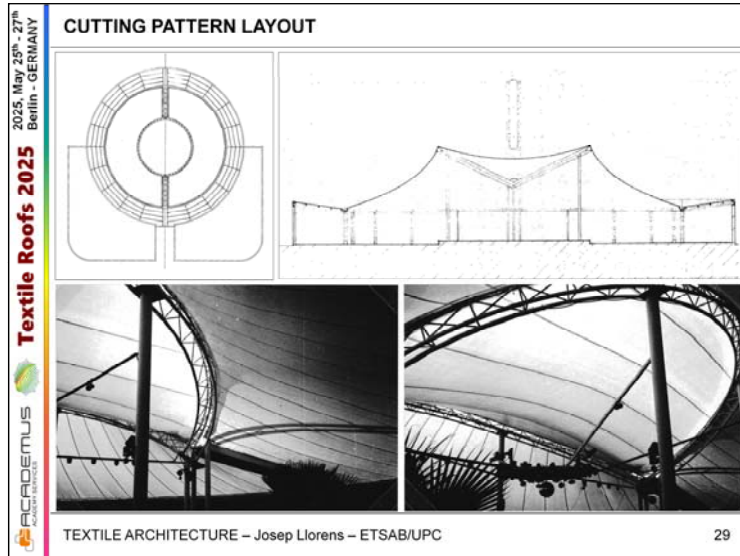
Since the membranes are translucent the shape can be read from the cutting pattern due to the seams that are visible against the light and which also reflect the manufacturing process. They describe the 3D shape of the surface. Therefore, the layout of the seams is not only a technical problem. Care must be given so that the perception of the overall surface is consistent with the spatial configuration.

1 R.Piano & P.Rice, 1984: Schlumberger Factory, Montrouge, Paris. The longitudinal cutting pattern forms continuous strips to maintain the sense of longitudinal continuity.

2 M.Hopkins & P.Rice with Koit High-Tex GmbH and Serge Ferrari, 1987: Lord's Cricket Ground, London. The radial pattern emphasizes a sense of individual space underneath each canopy.

3 Schlaich & Bergemann, 1998: National Swimming Pool, Kuala Lumpur. The parallel membrane strips running towards the edge reflect the distributed stress caused by wind suction. The radial pattern of the high points reflect the concentration of loads due to snow.

4 The layout of the patterns minimizes the waste but the result is messy and confusing.

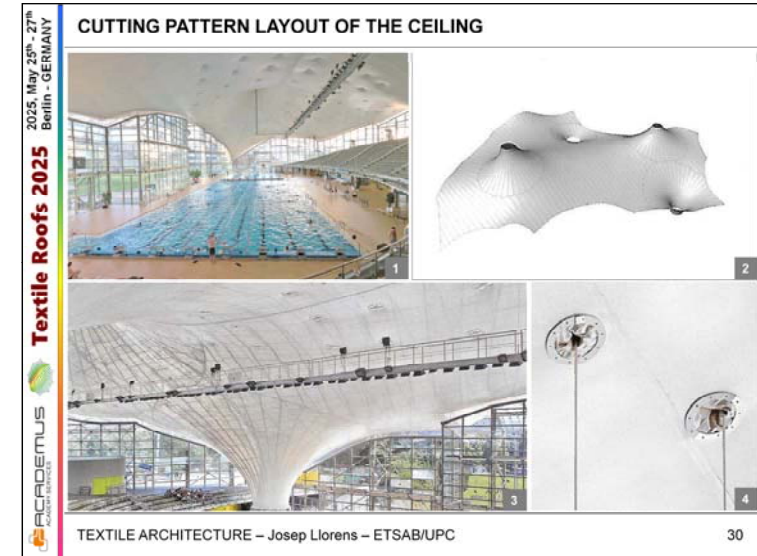


The “Castle” Disco in Santa Pola, Alicante is circular in plan, 35 m in diameter, including a central dance/stage floor, surrounded by a circular porch with tables, benches and seats. An intermediate space in between provides either complementary seats or a central dance/stage floor extension. Main entrance, services, bar and other facilities complete the whole scheme.

Textile roofs were envisaged for the central dance floor and the intermediate space. The central dance floor is roofed with a double curved surface, stretched against a spatial ring, 12m in diameter.

The intermediate space, 26 m in diameter, runs between the arches and the porch. It completes the space directing the shape towards the centre, assisted by the seams resulting from the cutting pattern. Notice that the cutting pattern is not only a concern for making the form, but it also contributes significantly to the perception of the surface, in this case, directed towards the central dance or stage floor, emphasizing that something (or somebody) important is going to happen there.

The steel structure is also relevant. There are 4 single CHS masts and 2 three-fold CHS masts supporting the trussed arches. The porch is delimited by a series of 20 double CHS in order to be self-supporting and avoid ties between tables and seats.



Behnisch & Partner with F.Otto and Leonhardt + Andrä , 1972: Olympic swimming pool, Munich. Its roof is a thermal envelope with insulated suspended membrane ceiling that required refurbishment in 1974. 30 year later, the membrane’s strength had become compromised due to the moisture and chlorine. Bergemann und Partner together with Auer + Weber were commissioned in 2003 with planning the refurbishment of the suspended ceiling and the lighting bridge.

1 The design for the new suspended ceiling of the Munich Olympic Swimming Pool called attention to the different curvatures of the respective areas.

2 At the extremities (apexes and nadirs) the arrangement is radial. In the flatter areas between them the arrangement is parallel running perpendicular to the length of the pool.

3 Another concern was the location of the services, in this case the lighting bridge, since the opportunities to locate services in tensile surface structures are reduced.

4 Penetrations for the cable suspending the lighting bridge: no stresses transferred to the ceiling.

(DETAIL 5/2008)



Can tensile surface structures be decorated?

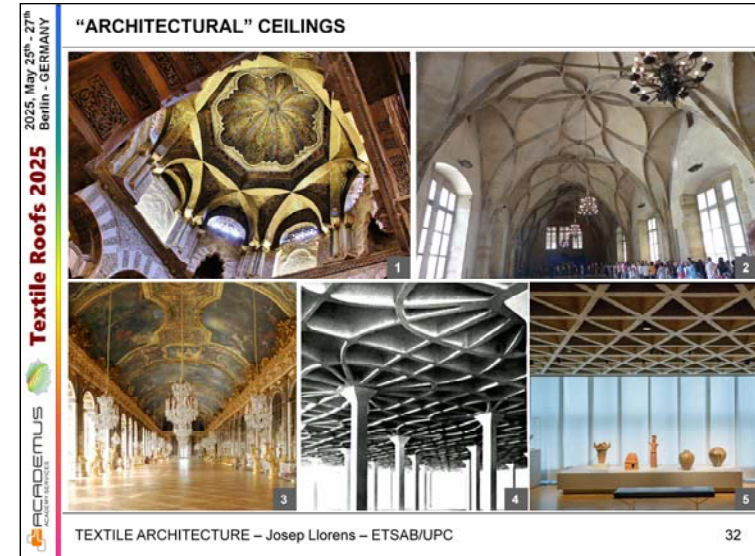
SL Rasch, 2011: Convertible umbrellas, Medina. Based on its design for the courtyards of the Prophet's Mosque, a new type of umbrella that features an innovative folding arm system with six hinges was developed. Besides providing lasting protection from the weather and UV radiation, the Teflon fabric is high resistant and dirt-repellent. The material is also extremely smooth and supple and falls in attractive folds. The tapes and seams are accentuated in colour to add a floral quality to the funnel-like membranes.

Great care had been taken on the layout of the seam lines that develop an ornamental pattern.

At the point where the membrane approaches the central mast, the seam lines intersect with each other, the pattern becomes more lively and a double-membrane layer is incorporated to increase the strength of the material, which is necessary due to additional stress accumulation at this point.

The seam lines combine structural necessity and decorative value.

<https://www.sl-rasch.com/en/projects/u-26-piazza/>



In fact, the ceiling has been repeatedly used for the configuration of interior space.

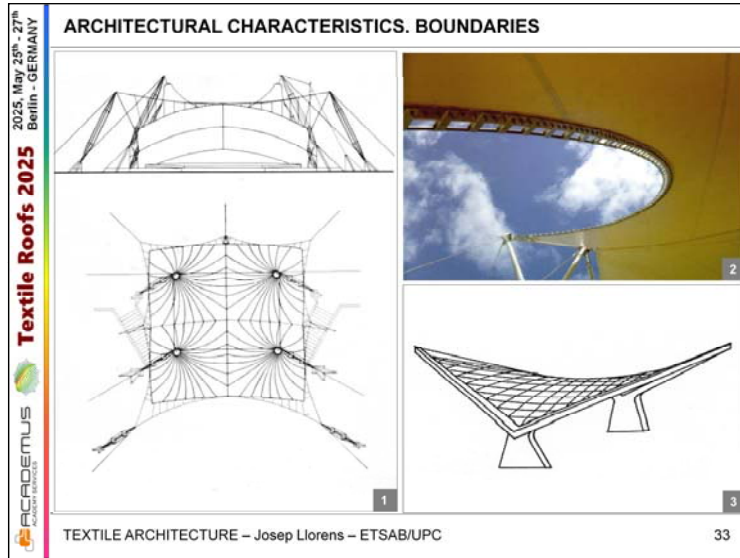
1 Abderramán III, 952: Mosque of Córdoba: Mihrab.

2 B.Rejt, 1502: Vladislav Hall, Prague Castle. The ceiling pattern is clearly apparent. It unifies the space create an undulating surface just as the seams do.

3 J.H.Mansart & Ch.Le Brun, 1648: Hall of Mirrors, Versailles. The ceiling is decorated with nearly 1.000 m² of paintings glorifying and featuring the king Louis XIV in large compositions.

4 C.Cestelli & P.L.Nervi, 1951: Gatti Wool Factory, Roma. Curved forms of ribs along the isostatics of the principal bending moments loose the rigidity of straight beams.

5 L.Kahn, 1953: Yale University Art Gallery. The concrete tetrahedral slab ceiling carries the principle that buliding's elements can be both sculptural and structural.



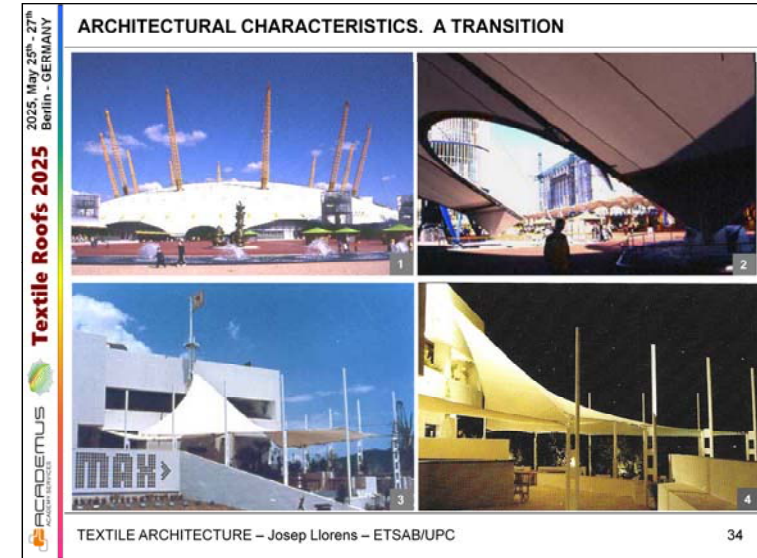
The form of a tensioned membrane flows directly from the geometry of the boundaries. Boundaries can be:

a) Flexible and open: cables with sag, ropes and strips, usually non self-balancing. The stresses in the structure must be directed off into the ground. It is the boundary characteristic of the surface tensioned structures. Edges can act as intermediate spaces.

1 Pinar del Rey auditorium, Madrid, 1986, J.M. de Prada, Architect. The edge cable is connected to the membrane by means of secondary cables. In this way the perimeter of the roof is flexible, avoiding stiff sections, and straight to follow directly the plan. Funicular curvature is transported outside.

2 Camp de Mart Auditorium, Tarragona, 1993. S.Bertino & C. Celeste, Tensoforma. Edge cable is outside the membrane and connected intermittently with allowance for independent elongations.

b) 3 Rigid and closed: beams, arches and walls, usually self-balancing. All stresses are contained in the structure. Exterior enclosures do not have to be connected directly to the membrane and ground anchorages are avoided. It is characteristic of hybrid structures and claddings.



Flexible and open edges project the boundaries as extensions of the roof. They create a continuous intermediate space, a transition between outside and inside with floating canopies, without side enclosures, contributing to the feeling of staying under cover more than being inside. Therefore, intermediate spaces very suitable in mild climates can be created to project the building towards the exterior through environmental filters that soften the environmental and formal transition. The edges act as intermediate spaces as porches that extend the roof outwards. As is the case with:

1,2 R.Rogers with Buro Happold and Birdair, 1999: Millennium Dome. 25.000 m² of projected area around the closed space.

3 Charly Max Discotheque – Eivissa. The terrace is protected by a textile roof, triangular in plan. Two sides are open to the sea view and the third is closed by the building. The horizontal borders frame the view improving the perception of distance and depth. The masts are made of double CHS in order to avoid ties. Scalloped edges act as intermediate space, creating a smooth transition and increasing openness.

4 The main function of the roof as a night dew shelter is complemented by its eye-catching effect, attracting consumers who can easily recognise the place (*TensiNews* 11, pp 8-9)



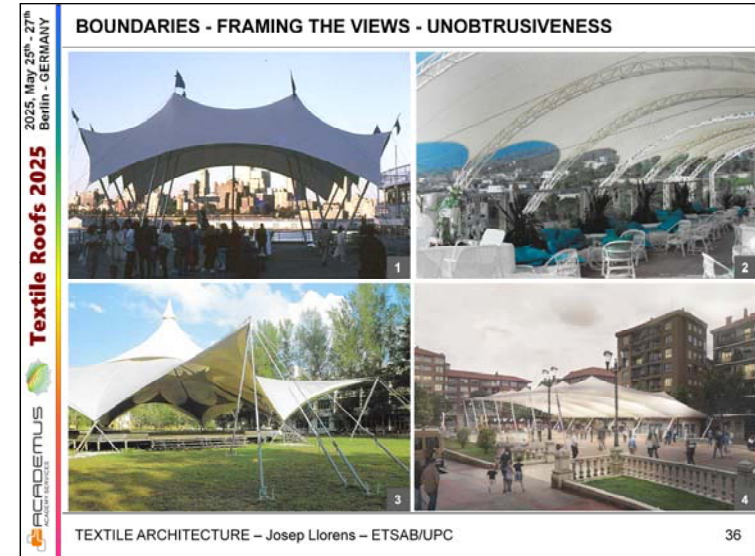
The edges act as porches that extend the roof outwards.

1 Llorens & Soldevila 1986: La Balsa Restaurant, Barcelona configures a complementary space with intermediate conditions. It acts as a visual filter and can also be used as a dining room. The design created a row of modules divided into two awnings: the biggest one draining through only one lower point and the smallest placed above, completing the surface to be sheltered, following the horizontal line of the perimeter. In this way, the usable volume is not entirely disturbed by, the slope and the profile of the building is maintained. The result extends the area towards the exterior and acts as a filter for the transition from the open air environment to the indoor conditions.

2 FTL Design Engineering Studio with Birdair, 1998: architectural wrap for the Cirque du Soleil, Orlando. It shelters the entrance from the rain, provides passive solar shading and allows diffuse light to enter and draws in cool air from the ground and pulls it upwards, creating a passive suction

3 Architen Landrell, 2001: Montage Mountain Amphitheatre, Lackawanna County.

4 Architen Landrell: London Eye entrance canopies.



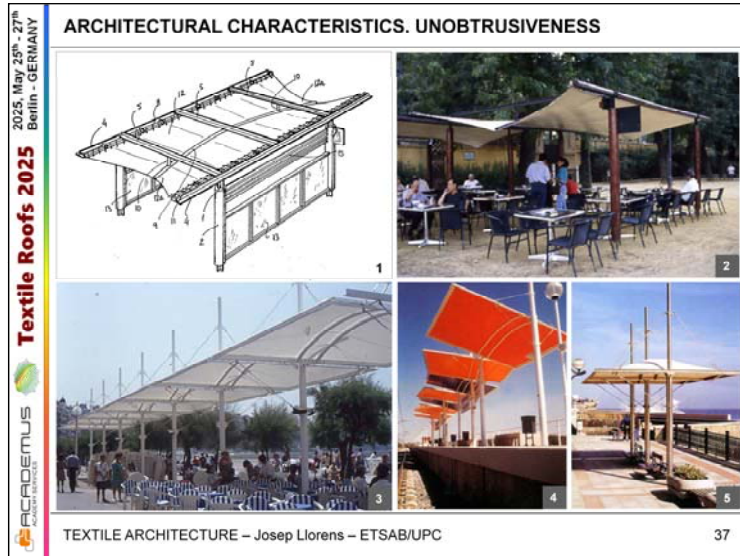
Most tensile structures are not surrounded by a wall. So the views are not restrained to the roofed space and visual communication with the surroundings is allowed. They are framed between the edges of the roof, the structural elements and the ground, improving the perception of distance and depth.

1 This is the case of the South Street Seaport Museum pier, NYC. The sheltering roof clearly indicates the location of the pier while not obstructing the views.

2 Llorens & Soldevila, 1984: Ku Restaurant, Eivissa. A continuous vault stretched against arches was designed. The view towards the surroundings is opened and framed by the curved edges of the membrane. The structure is solved with latticed supports and arches independent from the existing building.

3 SL with F.Otto and Canobbio, 1998: Asembly Tent with large openings at the sides that avoid the feeling of being enclosed.

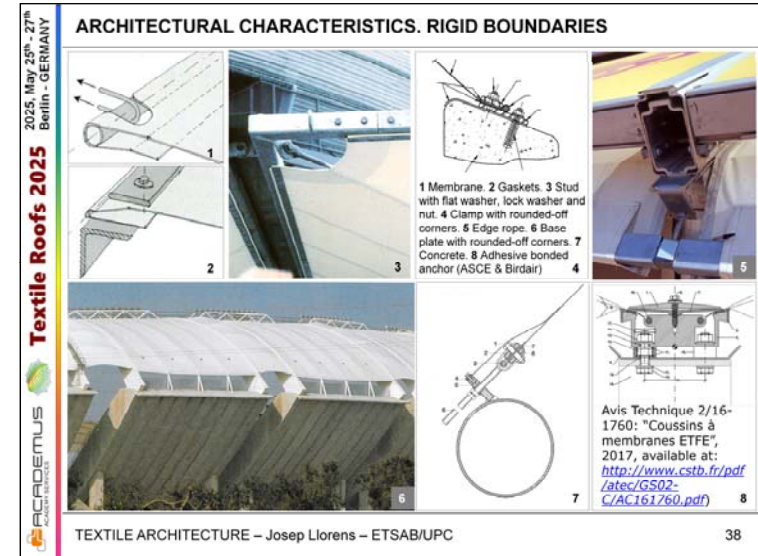
4 Queralt Suau Studio with J.Llorens, 2016: the San Pedro Square roof, Sestao, does not interrupt visually the urban continuity and adapts in height to the widths of the surroundings leaning towards the narrowest street.



Unobtrusiveness is a concern in urban or natural spaces in which visibility must be preserved. Two cases commissioned by the respective city halls:

1,2 The “Lleida” prototype was designed in order not to interfere visually. It is a 6 x 4 m self-supported canopy formed by two frames united by T shaped cross beams. The beams hold a longitudinal CHS arch that pushes down the roof made of a membrane tied up to the frames by means of elastic rope. The two surfaces included between the frames and deformed by the arch are anticlastic, resistant to the wind and they drain properly. There are no inclined planes, slopes nor vertical faces that obstruct the vision.

3,4,5 Another solution with the same purpose is the “San Sebastián” prototype. The design is based on a 4,70 x 4,70 m self supported module composed by a horizontal steel frame hung from two masts. The frame is completed by two low arches and braced by cable-ties. The roof itself is made of PVC coated polyester fabric resting on the arches and stretched against the frame by means of elastic rope. The overall shape is perceived like a horizontal flat surface smoothly curved. It is stable because it’s curved in two opposite directions, drains properly and arrives horizontally to the edges, avoiding vertical surfaces, pitched roofs, leaning planes or obstructive volumes.



3 Rigid and closed: beams, arches and walls, usually self-balancing. All stresses are contained in the structure. Exterior enclosures do not have to be connected directly to the membrane and ground anchorages are avoided. It is characteristic of hybrid structures and claddings. Rigid boundaries are more critical than flexible boundaries because allowances for movements due to loads and creep are needed. The difficult connexion between a light flexible membrane and a rigid boundary, be it a section or wall, can be solved with continuity.

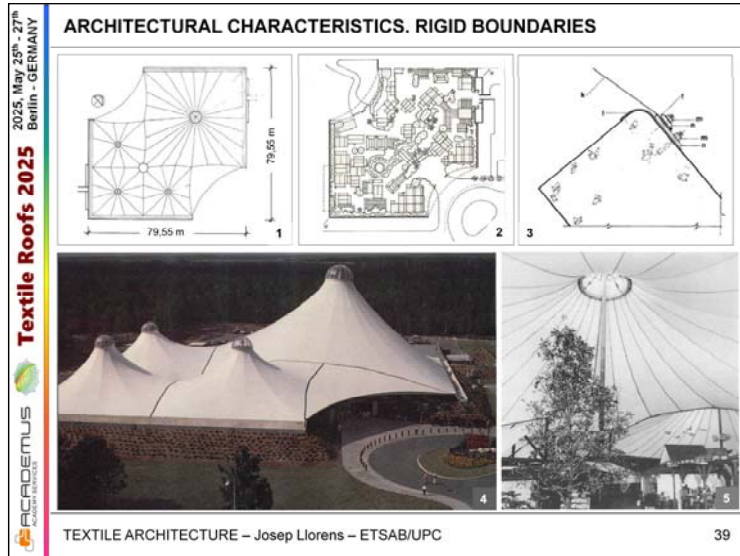
1,2,3 Rigid edges held continuously the fabric by a supporting structure having much greater lateral stiffness compared with that of the fabric, a contradiction that may be easily underlined.

4 In air supported structures adjustability is not needed because the pre-tension is controlled by air-pressure.

5 Extruded aluminium RHS with rails to accommodate keders.

6,7 R.Piano with Ove Aruo, 1990: San Nicola Stadium, Bari.
1 Overlap membrane welded to main membrane - 2 50/3 mm stainless steel stirrup - 3 Ø 12 mm edge bead - 4 15/3 mm aluminium extruded section - 5 60/15 mm stainless steel section - 6 screwed bolt cut off after tensioning - 7 neoprene strip 2 mm thick x 50 mm long - 8 40/8 mm aluminium extruded section (DETAIL 6/1994).

8 Typical section to clamp ETFE air inflated cushions.



R.L.Hart with Geiger Berger Associates, 1980: Florida Festival, Orlando.

It contains entertainments, shops, restaurants and subtropical plants under a fabric that behaves like an artificial sky. A striking form and light interior spaces resulting from the translucency of the membrane.

The Ø16 mm cable reinforced fabric is stressed between peripheral concrete walls, a 32 m high lattice steel mast, three 19 m high tubular steel masts, a low point in the middle and two catenary cables over the entrances. At each peak the fabric is clamped to a steel ring covered by an acrylic plastic dome.

8.360 m² of PTFE coated glass fabric (1,5 kg/m²) cover a surface of 6.500 m² (ratio: 1,29) with a 18% of light transmission. The whole tent fabric was made in 6 pieces which were joined by bolting between aluminium strips along the valley cables.

1,2 Plan - **3** Connection to concrete edge: **k** fabric; **l** neoprene layer; **m** ½" stainless steel bolt at 8" centres; **n** aluminium plate. - **4** View of the tent - **5** Top of small mast.

(A.Orton, 1988)



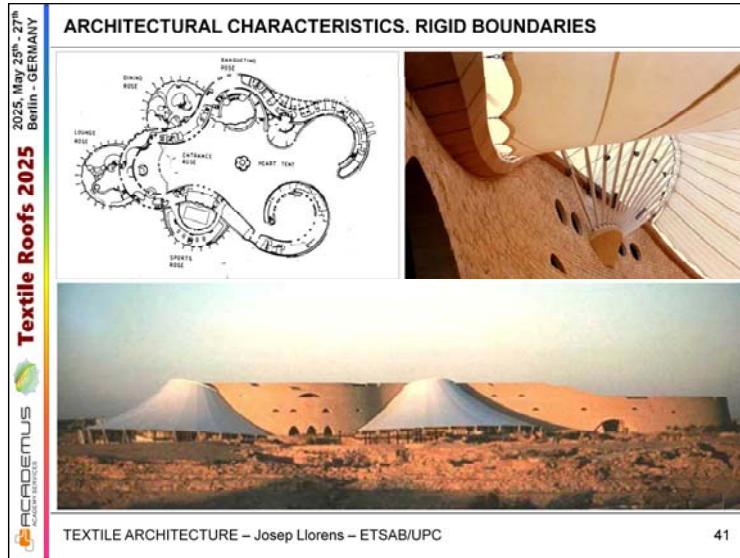
The connexion between a light flexible membrane and a rigid boundary can also be solved by leaving a gap, preventing a collision or at least an obvious contradiction between such different materials.

1 Three 20x20 m. tensile arcade, Avenida de los Descubrimientos, Sevilla, 1992. F.Escrig & F.Duarte, Architects. The perimeter is solved by means of a stiff hollow steel section. It contrasts with the 1 mm thin membrane despite the gap between them.

2, 3 Rigid adjustable edges of the arch-shaped door entrance to the Kelebekia Residential Development.

4,5 Australia Pavilion, Sevilla, 1992. The membrane was fastened with rope. Tension adjustments were possible by means of threaded rods screwed into the structure.

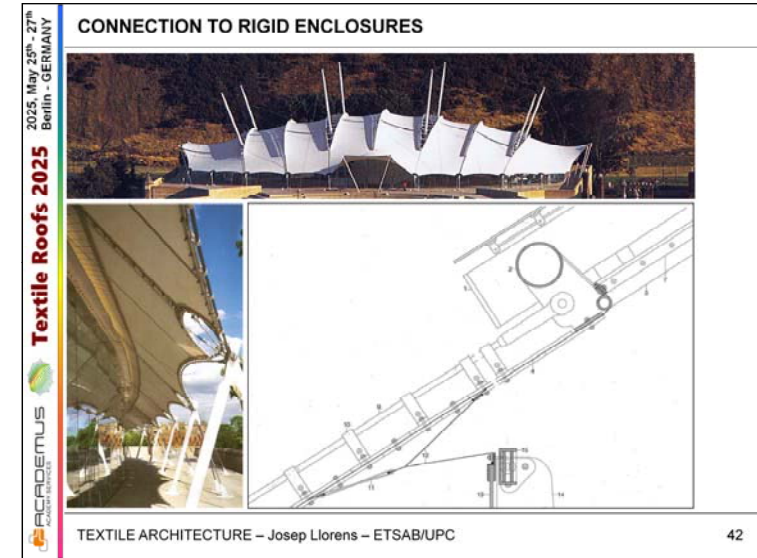
Note that the edges can be used to achieve a strong appearance. Are straight edges the right solution for a curved surface? Surface tensioned structures create highly plastic forms without struggle or distortions. This means scalloped edges rather than straight ones. However, curved edges, although rigid, fit better with the membrane.



A third way could be through a mediating element filling the gap, such as glazing or polycarbonate elements between the scalloped edges and the rectilinear structures.

Omrania with F.Otto and Buro Happold, 1986: Diplomatic Club Tuwaiq Palace, Riyadh, where convex shapes provide an attractive contrast to the heavy masonry of the walls. The complex is composed by:

- a sinuous masonry building as a “wall” organizing it all, housing functions that require greater environmental control.
- the free-standing heart tent in the middle is a Bettina Otto hand painted glazed canopy supported by a cable-net around a single trussed central mast.
- two structures employing cable-nets (entrance and banqueting suite) covered with timber boarding insulation, insulation, weatherproofing and blue ceramic tiles.
- three translucent PTFE coated glass-fibre membrane structures (dining suite, recreational lounge and sports facilities) conical in form with radial support cables. They are anchored to the masonry touching only in a few places, exploiting the scalloped edges for direct light sources. As a result, the conical and saddle-shaped roofs are satisfactorily connected to the curved inhabited wall in both structural and aesthetic terms. (R.Scheuermann & K.Boxer, 1996)



M.Hopkins, 2010: In the Dynamic Earth Centre, Edinburgh, the membrane roof is attached to the glass façade. The side walls are in glass to establish a relationship with the surroundings. The FLEXIBLE membrane has to be connected to the RIGID vertical enclosure and therefore three highly demanding requirements must be attended: 1) air-tightness, 2) allowance for movements at one side only and 3) geometric tolerance to accommodate the irregular intersection.

They have been solved filling the gap between the glass and the fabric with a folded strip of membrane.

Joint between glazed façade and roof. **1** Ø273x10 CHS – **2** Ø193,7 CHS – **3** Ø60x3 CHS – **4** PTFE-coated glass-fibre fabric roof membrane – **9** Ø26 mm steel cable – **10** Sheet steel strip bent to U-shape – **11** Elastic polyester cord for tautening membrane – **12** Membrane “hinge” to absorb roof movement – **13** 12 mm laminated safety glass façade – **14** 19 mm laminates safety glass fin – **15** Peripheral channel section. (Courtesy of DETAIL).

Nevertheless, the strip interrupts the visual continuity of the roof and emphasizes the presence of the vertical enclosure, disturbing the intended transparency of the wall.



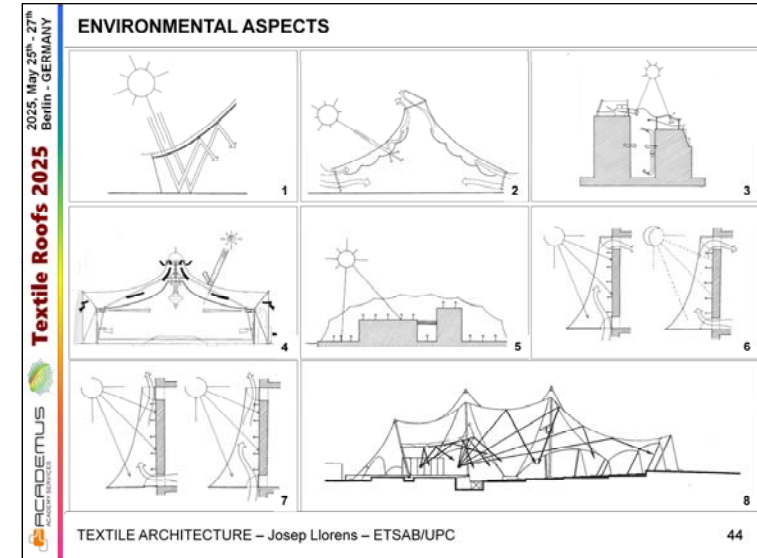
Allowance for movements in one side only and geometric tolerance are usually accomplished through the use of looped cords or adjustable devices and air tightness is provided by closing the gap, overlaps or channels. Alternatively, air-inflated tubes whose size varies along the length of the interface are also used.

1,2 The idea of curvilinear elements obeying the tensile roof structures was applied to the glass walls of the Munich Olympic Swimming Pool where the glazed perimeter follows the scalloping boundaries. There is no the usual straight boundary line.

3,4 Büro Herbert Kochta with Büro IPL Ingenieurplanung Leichtbau, KOIT High-Tex GmbH and sbp, 1995: House of carnivores, Munich Zoo. The foil inflated cushion fulfils the 3 severe requirements: air tightness, allowance for movements and geometric tolerance.

5,6 Sobek und Rieger with D.Wakefield, 1995: BMW Pavilion, Frankfurt. Two inflated cushions are used for the façade. They close the gap between the roof and the frame.

(DETAIL 8/1996, H.J.Schock, 1997 and DETAIL 5/2008)



Tensile surface membranes can be considered as filters to the weather regulating the external climate. Several options have been tested:

- 1** Greenhouse effect
- 2** Movable sunshades and thermal stack to prevent overheating
- 3** Daylight transmission and re-circulators
- 4** Exterior shading layer + white PVC outer layer + 75 mm of mineral wool insulation + white PVC inner layer with a large air gap and natural ventilation
- 5** The membrane roof creates an intermediate climate which reduces energy requirements
- 6** Left: pre-heating fresh air. Right: re-heating circulated air venting
- 7** Left: venting off used air. Right: getting rid of excess heat
- 8** Acoustic diagram

(R.Scheuermann & K.Boxer, 1996)



Tensile structures can allow large quantities of light to penetrate the building. The light transmitted depends on the range of translucency and is highly diffused, resulting in poor contrast and the absence of marked shadows. If 3D vision and shadows are necessary, additional direct light sources via transparent glass or ETFE surfaces have to be provided.

1 M.Hopkins and Partners with Ove Arp, 1994: “Inland Revenue Centre”, Nottingham. Glazed elliptical ladders trusses generate the main roof form, solve the location of mast penetration and provide a way of joining the glazed end walls to the roof. They also capture slivers of sky, enhancing a combination of diffused and direct light.

2 M.Hopkins 1998: Saga Group Pavilion, Folkestone. Curved and tapered eyebrows of vertical glazing fill the gaps between the pairs of steel arches and provide direct light.

3 R.Piano with O.Arup, 1992: Il Bigo, Genoa, was an exhibition hall converted in a public piazza, performance place, skating ring and soccer games for children. Glass lenses close the gaps between the 5 panels into which the roof is subdivided, provide direct light sources that enrich the light spectrum and cast shadows that make the space more intelligible.



If some areas need to be private or fully enclosed while others can be public and semi-conditioned, there is the possibility of covering the entire building, thus creating an intermediate space.

The envelope can be sufficiently separated avoiding the problem of joining the flexible three-dimensional roof structure with the rectilinear construction.

1,2 Samyn and Partners, 1991: M&G Ricerche, Venafro. A single skin membrane, supported by six steel horseshoe arches, envelopes a combination of offices, laboratories and test rigs. Conventional concrete and block work construction is used to form separate enclosures within the membrane envelope. Glazed screens and transparent PVC provide direct light through the scalloped edges and steel arches respectively. Note the lake surrounding the building that helps to lower the outside temperature. (R.Scheuermann & K.Boxer, 1996)

3,4 R.Rogers and Buro Happold, 2000: Millennium Dome rebranded O2 in 2007. Various buildings are housed within the dome including the O2 Arena, Indigo, Hollywood Bowl, Cineworld, Virgin Media Gamepad and Entertainment Avenue consisting of restaurants and bars.

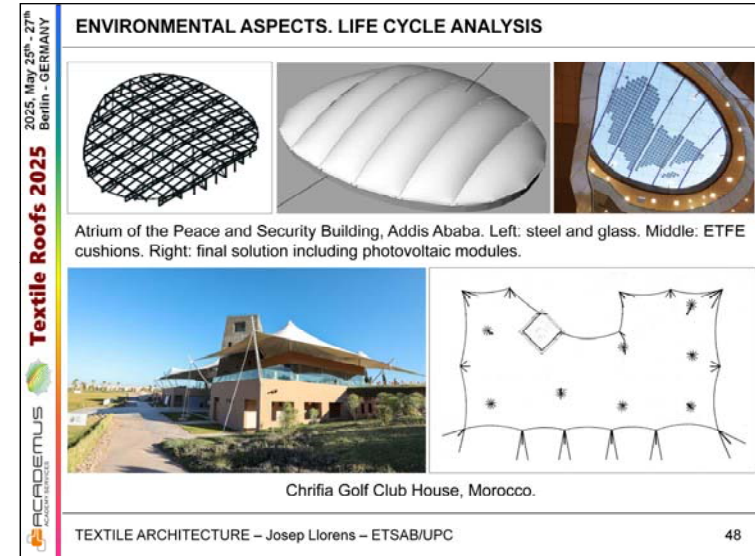


Foster + Partners with Buro Happold, 2009: Khan Shatyr Shopping and Entertainment Centre, Astana.

The Khan Shatyr Entertainment Center was designed to provide the city with a range of civic, cultural and social amenities all sheltered within a climatic envelope - 'a world within' - that offers a comfortable microclimate all year round, whatever the weather.

The building's tented structure has great resonance in Kazakh history as the tent is a traditional nomadic building form - Khan Shatyr translates as 'the Tent of the Khan'.

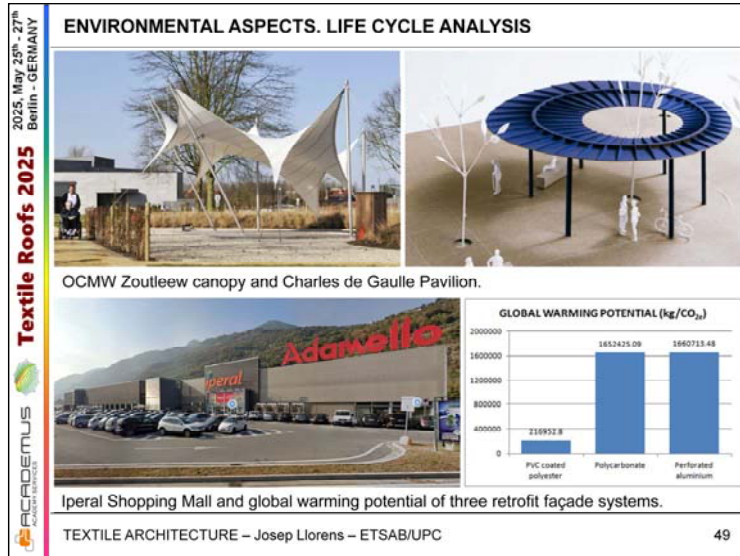
The tubular-steel tripod structure supports a suspended net of steel radial and circumferential cables, which is clad with a three-layer ETFE envelope, formed as 3.5 x 30-metre cushions. The translucent material allows daylight while sheltering from weather extremes. The open circulation areas are environmentally tempered, with target temperatures of +14 degrees Celsius in winter and +29 degrees in summer. Low-level jets direct cool air across the space, while vents at the apex induce natural stack-effect ventilation. Ice forming on the inside of the envelope is avoided by a combination of temperature control and directing warm air currents up the inner fabric surface, a strategy that also prevents downdraughts.



In order to highlight the advantages of membranes from an environmental point of view, several comparisons have been made.

Bögner-Balz, Von der Weth and Moritz, 2023, compare the pneumatic ETFE cushions with steel and glass of the 430 m² oval-shaped roof for the atrium of the Peace and Security Building of the African Union in Addis Ababa. The initial solution envisaged a steel and glass roof but an alternative proposal consisted of 2 layer pneumatically pre-stressed ETFE cushions. At the material level, the same area can be covered with ETFE cushions with approx. 60% less CO₂ emission than with glass (without the frame). At the system level, the glass option weighs around 15 times more. At the building level, ETFE foil cushions can also offer the possibility to include photovoltaic modules and control the solar transmission and energy transfer into the building to reduce mechanical air conditioning but still allowing enough light to pass through and thus saving energy.

Bonneville, 2023, compares the textile roof of the Chrifia Golf Club House in Morocco with a conventional metallic roof. The membrane roof performs much better because it weighs 4,5 kg/m² and has an embodied carbon value of 21 kg CO_{2e}/m² against the 45,2 kg/m² and 75 kg CO_{2e}/m² of the metal option.



Eryuruk et al., 2023, compare the global warming potential (GWP) of the membrane OCMW Zoutleew canopy with the steel/aluminium Place de Gaulle Pavilion, Eure. They have been analysed by means of the tool OneClickLCA.

As a result, the membrane solution is better positioned in terms of environmental performance except for the end-of-life scenario, (because the fabric will be incinerated). Note however that, although the projects are quite different, it is advisable to design the shape and to choose the materials considering the criteria of environmental performance.

Procaccini and Monticelli, 2023, compare three different façade retrofit designs based on similar approaches but achieved with different materials. The three solutions chosen are PVC coated polyester, polycarbonate and aluminum perforated panels so that all three cases are translucent and require a similar substructure.

The three options exhibit a considerable difference between the Global Warming Potential. As a result, the PVC coated polyester deploys 216.952.8 kg/CO_{2e}, polycarbonate 1.652.425,09 kg/CO_{2e} and perforated aluminum 1.660 713,48 respectively.

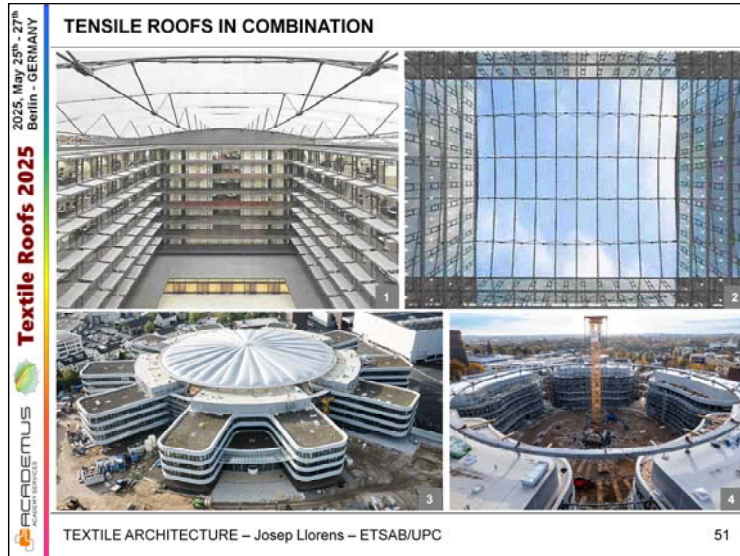


Variability of form is a hallmark of tensioned fabric construction to fit a wide range of building footprints. On the other hand, a possibility to achieve subdivision in a building is to roof only the large and outstanding spaces with tensile structures. Under utilitarian aspects it is much more feasible to use conventional structures for the surrounding parts which take care of the smaller spaces.

1 M.Hopkins with O.Arup, 1992: Research Facilities for Schlumberger, Cambridge. A three-bay large membrane roof is attached to rectilinear frameworks. The suspension of the membrane is achieved from outside by means of steel cables hung from eight pairs of tubular steel masts.

2 C.W.Fentress, J.H.Bradburn and Associates with Severud Associates, H.Berger and Birdair, 1994: Passenger Terminal, Denver International Airport The main concourse of the new airport terminal has been covered with a large tensile roof.

3 Foster & Partners with form TL and Canobbio, 2013: University Building Roof, Torino. Its unifying element is a cantilevered membrane roof which gives appearance of floating
<https://www.form-tl.de/en/project/membrandach-campus-turin-i/>



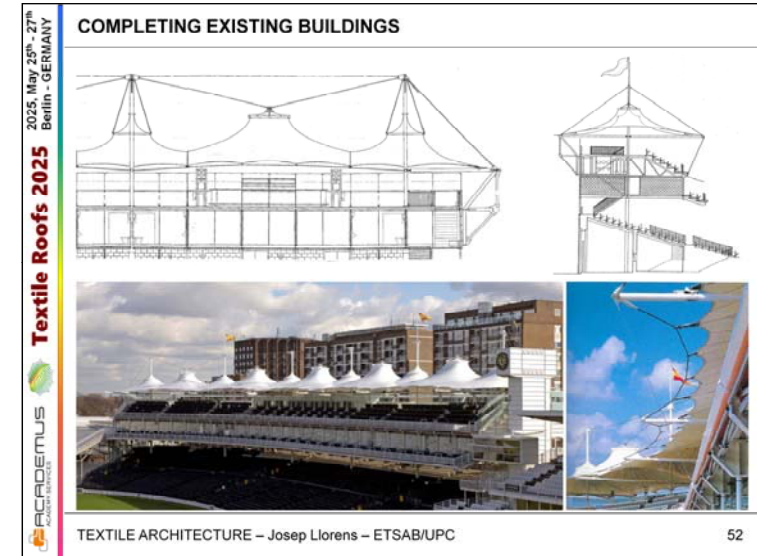
1,2 Jabornegg & Pálffy, 2008: Bank, Bratislava.

Transparency is the primary design feature of this nine-storey structure in the form of a square perimeter block around a covered courtyard. Above the topmost floor, air-filled cushions made from transparent ETFE foil span across the open inner courtyard in the form of pneumatic tubes 4,5 x 46 m fixed to parallel steel cables supported by transversal cable-beams. (J.Knipppers et al. 2011)

3,4 H.Hartmann Architects BDA with form TL and Pfeifer, 2023: Inner courtyard SMS Campus, Mönchengladbach.

In the newly created campus, the central roof of the inner courtyard is supported by a total of 5 office buildings at a height of 20 m above ground. The Geiger Dome, with a diameter of 82 m and a covered surface area of 5.100 m², is spanned by 40 radially aligned air-filled cushions made of ETFE foil panels. It looks very light. The rope support structure is held only by the outer self-balancing compression ring resting on the surrounding buildings. It does not need any further support.

<https://www.form-tl.de/en/project/inner-courtyard-roofing-sms-campus-moenchengladbach-d-2023-2/>



Tensile structures may be related with existing or new buildings that affect strongly the design of the shape, joints and complementary elements.

For example, the Mound Stand, Lord's Cricket Ground, London 1987, is an extension of the existing stand. The extension is based on a steel frame and only six masts, for a length of 102 m passing through the building.

To cover the entire length, given the proportions of the grandstand, 11 cones were needed, so the five cones that do not have a mast are hung from their neighbours to minimize the intervention in the existing building.

From each of the masts horizontal booms project forwards and backwards beyond the edge of the fabric roof. The front booms are tied down by cables while the rear booms are connected to triangulated frames which project up in cantilever from the rear. From the extremities of the booms, the edge cables are pulled into a horizontal catenary by the tension of the fabric, whose 3,66 m scallops give the roof its festive wavy edge. Valley cables pass over the fabric from the front to the rear catenary between the pick up rings and pull the fabric into a shape with the curvature needed in these areas



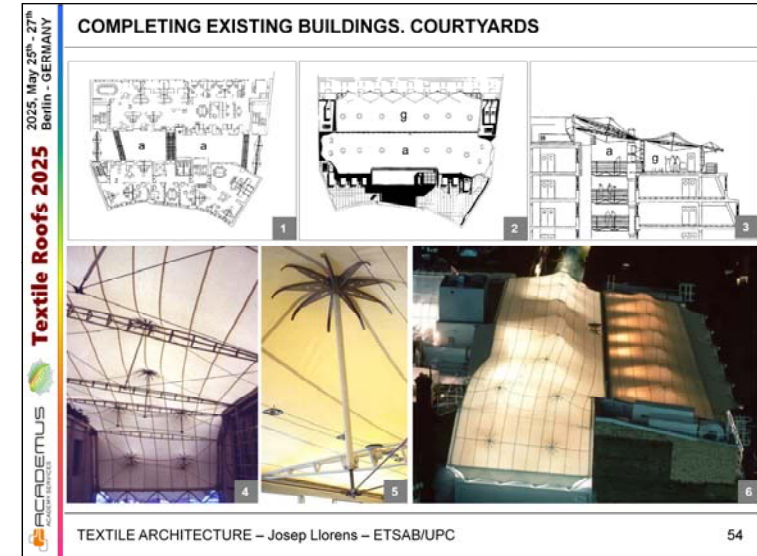
Structural membranes are suitable to add new roofs, that is to say completing buildings setting up new space and conditions.

1,2,3 Berlin Olympic Stadium new roof, gmp Architects with Schlaich, Bergermann Partner, 2004. The transformation of the 1936 Berlin Olympic Stadium into a modern arena has been reconciled in accordance with conservation constraints. The most important change is the new lightweight roof that plays down the politically motivated heaviness of the stone. Some fans object to the slender columns in the upper tier of stands, but, as a result, the old stadium has been recycled and upgraded.

<https://www.sbp.de/en/project/olympic-stadium-berlin/>

4,5 IDOM with Maffei, Taiyo and Ferrari, 2020: new roof for the Levante Stadium (1969) in Valencia. A lightweight membrane cable roof with spans up to 40 m has been chosen, in order to minimize the overall weight of the structure. The roof design is derived from the bicycle wheel principle, with two inner tension rings and an outer compression ring. The ability to support the new cantilevered roof independently from the existing structure and with minimal intervention have been the key factors in choosing a roof of this type.

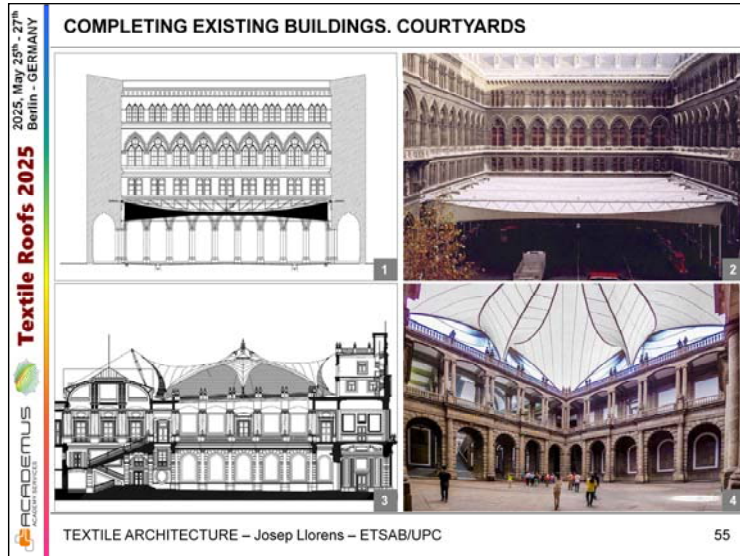
<https://www.sergoferrari.com/references/levante-stadium>



R.Herron with Buro Happold, 1989: Imagination Headquarters, London. Two separate wings of a building have been united by a lightweight single-skin membrane stretched across the space at roof level continuing over the exterior terrace situated on the upper level at the rear of the building. The geometry of the tensioned surface structure has been adapted to the rectilinear geometry of the building.

1 Typical floor plan. **2** Roof plan. **a**: atrium. **g**: gallery. **3** Section through the atrium **4** A glazed roof had been considered but the membrane roof cost a third and weighed sixth of the glazed alternative. **5** The fabric is supported by a steel frame which has been added to the original building and stressed by adjustable perimeter rods in cable cuffs and flying masts at mid span. **6** The night-time effect of the interior lighting is remarkable. Artificial lighting turns the cover into a glowing lantern. The seam lines are clearly readable and support the perception of the surface.

This intervention in an existing building shows how a tensile covered space can be subdivided to suit situations where a variety of functions take place or where hierarchy of spaces is required. Note also that the use of membranes to cover courtyards, which has been traditional in southern countries, is currently one of the most widely used applications.



1,2 S.Tillner with sbp, 2000: retractable roof of the courtyard City Hall, Vienna. The wave-like shape of the membrane is determined by upper and lower cables, which hang from four multi-chord truss girders. On two sides of the courtyard, longitudinal girders are fixed to the building and serve as tracks that allow the cables and trusses to move. In order to protect the membrane from soiling and to prevent the valleys from being affected by snow) the folded roof (4 m thick) is covered under a glass canopy.

3,4 J.G.Oliva et al. with Carpas y Lonas El Carrusel SA, 2002: textile roof for the “Palacio de Minería” courtyard. Mexico City. It was designed under the requirement of not altering neither the existing structure nor the external look, meaning that no structural elements of the roof might be seen from the streets. Therefore the intervention had to be very light and the height of the masts limited. As a result, the historic building has been enhanced by the functionality of the membrane designed taking into account the formal guidelines of the Palacio to preserve its architectural configuration. The membrane is easy to erect and dismantle, light enough to rest on the existing structure without special reinforcements and flexible to admit the irregular sinking of the site (a former lagoon). In addition, if the roof is removed, all its elements would disappear and the courtyard would return to its original situation.



Eiffage Métal with IASO, 2020: “Le Polygone” shopping centre, Montpellier. The refurbishment of “Le Polygone” shopping centre includes a complete replacement of the roof to bring natural light into the complex while ensuring the necessary protection against bad weather.

A large roof (150 m x 16 m and 24 m) has been incorporated, consisting of a lightweight metal structure supporting a total of 49 diamond-shaped ETFE cushions and 57 triangular-shaped cushions. In the transverse section, the cushions are placed on arcs of variable radii, while in the longitudinal section the structure describes various waves that are reproduced by the cushions. This configuration is divided into 5 blocks separated by expansion joints, covering an area of more than 3.000 m².

The ETFE cushions consist of 3 layers, with an IR-CUT treatment on the top layer that prevents the passage of infrared rays, as well as a variable in density surface screen printing that filters the passage of light. The dynamic night-time lighting system incorporated in the project further enhances the translucent-transparent nature of the ETFE cushions.

<https://www.iasoglobal.com/en/projects/le-polygone-montpellier-shopping-centre/>

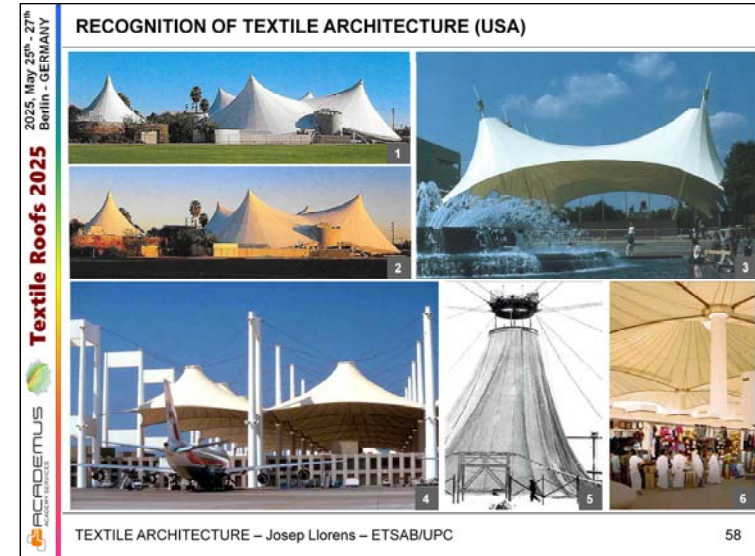


The acceptance of textile architecture for department stores in the USA: EPR Architects with Geiger-Berger and Owens-Corning Fibreglass Corp., 1978: San José Bullocks department store. Its 1.672 m² fabric skylight was conceived late in the building design and replaced a more conventional solution. When the store opened in the fall of 1978, it pioneered the use of the fabric roof in a retail store. It took advantage of several material properties:

- The translucence of the fabric created an "outdoor-like" space in which plants could grow.
- The material's reflectance helped to reject solar heat gain from without and simplified night lighting from within.
- The Teflon surface reduced maintenance.

Fire code officials in the San José area called for a double layer of fabric. The interior layer is non structural and drapes into the space. The additional layer also absorbs about 75% of the sound which reaches it, creates a thermal insulating air space with the outside fabric, and reduces the translucence of the roof. The variation in translucence provides a richer ceiling surface visually and helps to define the space.

(Architectural Record, mid-August 1979, p.86-93 and Progressive Architecture, June 1980, p.110-125)



1,2 The Saver Partnership with B.D.Campbell & Co, 1973: Campus Centre, University of La Verne. Because **economic** and **flexible** facilities were needed, a membrane instead of a conventional structure was chosen. It happens to be the first project in which the membrane is a permanent material and structure. Note the **variations produced by sunlight** (K.Ishii, 1999).

3 H2L2 with Geiger Berger Associates and Birdair, 1976: Independence Mall Pavilion, Philadelphia. **The surface in equilibrium is apparent.** The masts are balanced with the fabric because they are sloped outward bisecting the angle of the cones.

4,5,6 SOM with Geiger Berger Associates, Birdair and Owens-Corning Fibreglas Corp., 1981: Haj Terminal Jeddah. **136.640 m²** had to be covered to serve 80.000 people a day. An enclosed building was **too expensive**. Concrete and metal roofs were abandoned because they absorb **too much heat** and the fabric roof for the Bicentennial in Philadelphia had proven effective in improving comfort on hot days. 10 modules, each consisting of 21 tent units with a plan dimension of 45,75 x 45,75 m, cover 320 x 137 m. Note the double centre support open ring for easiness of erection and ventilation (K.Ishii, 1999).



Structural membranes are particularly suitable for the rehabilitation, refurbishment, protection, completion and improvement of monumental heritage because they are lightweight, flexible, and translucent. They do not alter the architectural character, are clearly distinguishable from the original elements, and can be easily removed. Different strategies are established according to the value of the pre-existing assets and the objectives of the operation.

1 O.Häuselmayr with IF and Birdair, 2000: roof of the Ephesus Roman Terrace Houses.

2 F.Vizioso & N.Bordas, Architects with IASO, 2013: Corbera d'Ebre Church restoration. Integration into the existing building or urban space is the most conservative option.

3 J.A.Martínez Lapeña & E.Torres with J.Llorens & A.Soldevila, Architects, 1989: Awning in Palma de Mallorca. The dialogue between pre-existing conditions and intervention. This is often the pragmatic option in most cases.

4 The Nomad Concept, 2008: Julianus Shopping Mall, Tongeren. The intervention is imposed by juxtaposing a completely new and independent form, which is the riskiest option, difficult to assume in most cases.



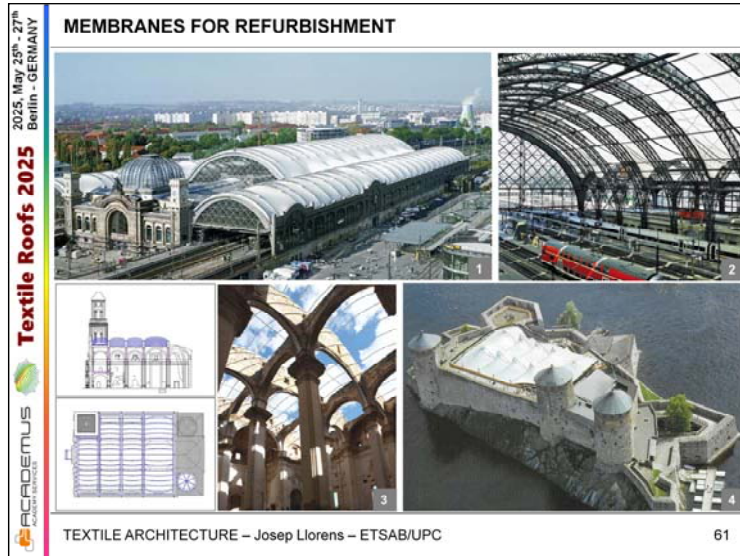
Difficult additions to historic untouchable buildings.

1,2 Removable roof for the Arena, Nîmes (100 AD), 1988. F.Geipel & N.Michelin, Architects with W.Sobek, Engineer.

The roof for the Arena in Nîmes is an inflated cushion encircled by a ring beam and connected to the old Roman building by steel columns. It is totally included inside the Arena in order not to be seen from outside, because the monument is a landmark and its aspect untouchable. The roof is installed each winter and dismantled in spring in three weeks.

3,4 Gerkan, Mark and Partners architects with Schlaich, Bergermann and Partner, 2017: Convertible membrane roof for the Verona Arena (30 AD).

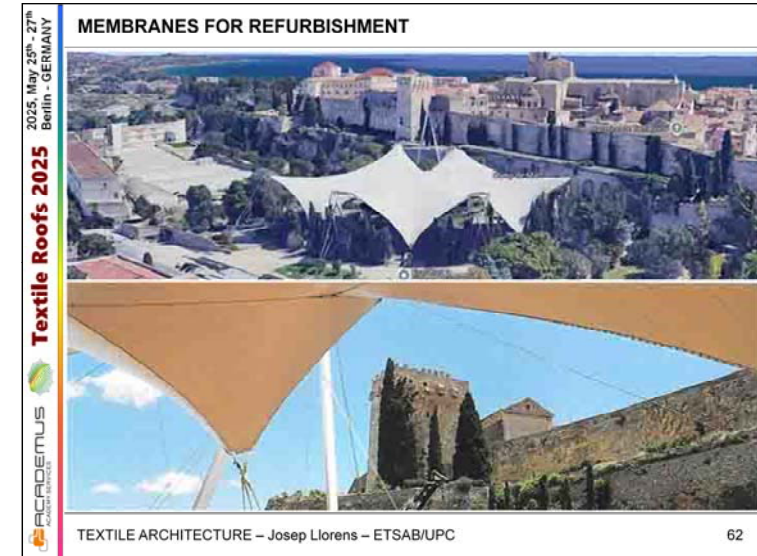
It would be similar to that have been realized for the stadiums of Warsaw, Bucharest or Frankfurt am Main. Nevertheless, the Arena di Verona would have a new feature. The network of cables would not be static. They would be completely hidden in the supporting ring in one of the narrow ends of the ellipse when the roof was open. When the roof was closed, the cables first would move along the compression ring and once they would have reached their final position, the membrane would be radiated out along the cables.



1,2 N.Foster & B. Happold, 2006: Dresden Station refurbishment for the preservation and enhancement of the historic building. The new translucent roof consists of PTFE-coated glass-fibre fabric. The daylight filtering through the roof and the low sound reflectance create a pleasant atmosphere within the station. Membranes are not the primary structure but contribute significantly to the space configuration (J.Knipers et al. 2011).

3 Ferran Vizoso & Núria Bordas, architects, 2013: Corbera d'Ebre Church restoration. The completion of the ruins of the Corbera d'Ebre hilltop roofless church is an outstanding example of recovering the use of the building while preserving its architectural character. A new transparent ETFE roof was envisaged, instead of rebuilding the previous one to maintain as far as possible the character of the ruin preserving the feeling of being outside and keeping it open to the sky and illuminated by the sunlight. And the idea of being light (made of ETFE instead of glass) was intended to affect as little as possible the existing walls.

4 The removable roof for the Savonlinna Castle had to harmonise with the monument. It was not permitted to fix new insertions to the old walls and it had to be hidden from outside. (K.M.Koch, 2004)



S.Bertino with Tensoforma and Serge Ferrari, 1992. "Camp de Mart" auditorium in Tarragona is a 3.000-seat open-air amphitheatre located close to the city's Roman walls in Tarragona.

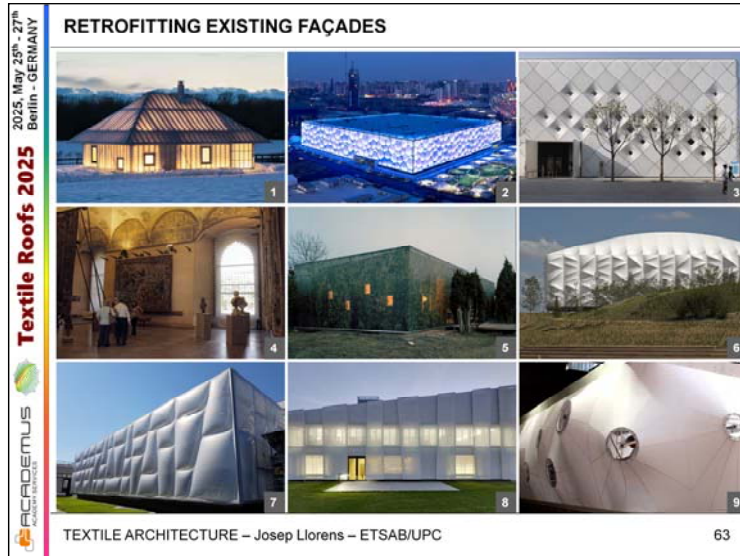
The proximity of the historical enclosure was of great concern.

The local – historical – archaeological authorities interrupted the works, because they were not able to accept such a combination of contemporary styles, materials and technologies.

But in the end, the possibility of dismantling it easily, its openness, light weight, translucency and the fact that it did not interrupt the visuals towards the Archbishop's Tower and wall, convinced the city's historical heritage protection authorities.

The installation was difficult due to the terrain and weather conditions. The masts and membrane had to be erected with mobile cranes from the outside, as the stands were not suitable for heavy vehicles. The initial tensioning of 300 kg/m was achieved by tilting the masts outwards and reducing the length of the perimeter cables by means of adjustable fittings.

(Hans-Joachim Schock, 1997)



1 Meme experimental house – 2 Watercube – 3 UBPA b3-2 Pavilion – 4 Textile hybrid, Castello Sforzesco – 5 Juniper House – 6 London Basketball Arena – 7 Sacmi New Auditorium – 8 Forschung Sedus Stoll AG – 9 Maco, Textiles Hub.

The retrofitting of existing building façades is a crucial intervention strategy in the construction industry to improve energy efficiency, reduce environmental impact, and enhance the aesthetic and functional value of buildings.

Conventional retrofitting techniques often involve rigid and heavy materials, leading to significant structural constraints and cost implications. Membranes represent an innovative alternative thanks to their lightweight nature, adaptability, and multifunctional potential. These materials allow for a less invasive application process, minimizing time and cost of building processes and the amount of use of construction materials.

Nine textile façade retrofit strategies have been identified of which covering, wrapping and double skin stand out thanks to their ability to enhance the thermal performances by adding a sun-shade element and creating an additional air gap

(G.Procaccini, TensiNews 48, April 2025, pp.7-9)



Membranes can also share the space configuration with other building systems:

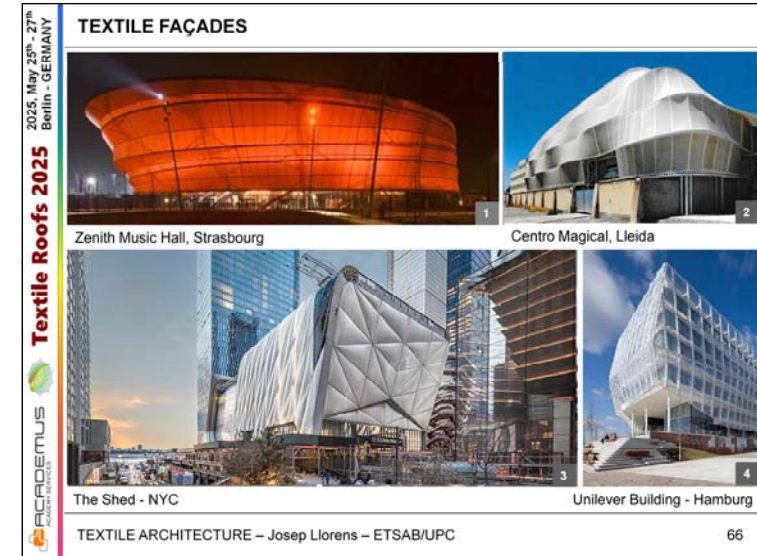
- 1 Textile hall. The main structure is made of aluminium.
- 2 N.Grimshaw, 2001: the Eden Project, Cornwell, is considered a breakthrough in the history of ETFE design and technology in architecture. Inspired by Buckminster Fuller's geodesic domes, the structures were some of the first to be built with synthetic fluorocarbon film. The transparent "windows" in each hexagon and pentagon are made of ethylene tetra-fluoroethylene copolymer (ETFE). Each window has three layers inflated to create a two-meter-deep pillow.
<https://www.edenproject.com/eden-story/behind-the-scenes/architecture-at-eden>
- 3 archi5 with ingerop, Esmery Caron and Serge Ferrari, 2013: Léo Langrage Toulon Stadium is a floating twisted sail made of three main arches of tubular steel sections that span 120 to 150 m. Elliptical-shaped secondary trusses run between them covered with PVC membrane UV-resistant
- 4 Textiles Hub, Politecnico di Milano with form TL and Canobbio, 2019: TemporActive Pavilion is an active bending hybrid structure, combination of ultra-lightweight GFRP bending active arches (produced from a straight unbent shape), a restraining system made of stainless-steel cables and a transparent membrane envelope. It is a considerable improvement.



J.Mingolello with FTL Design Engineering Studio and DUNN with Sheerfill, 2022: Hartford Healthcare Amphitheatre. The Bluefish baseball team moved from Bridgeport to High Point leaving their facility empty.

A covered music amphitheatre has been developed to reuse the old bleacher seating and structure of the facility. The approach was to develop a hybrid structure using a 'tensegrity' mast system with fabric above the orchestra seating and a fabric clad frame system for covering the bleacher seating and interfacing with the existing stadium. A trussed catwalk element unified the two structures providing for lighting, access and a seamless transition. The facility includes a new entry element which acts as a beacon to both the Amtrak trains and the I95 corridor both which pass close to the facility. Fabric Structures can be used as an element to create adaptive reuse projects allowing an old disused facility to be reborn as a new premiere concert venue for the East Coast.

The project combines both the old and the new on a very large scale. It uses both a tensile fabric roof and a fabric clad frame roof creating a hybrid technology which has the clear spans for performances and the integrated frames for connections to the existing stadium. The PTFE glass fabric makes this a permanent new building (N.Goldsmith, 2025).



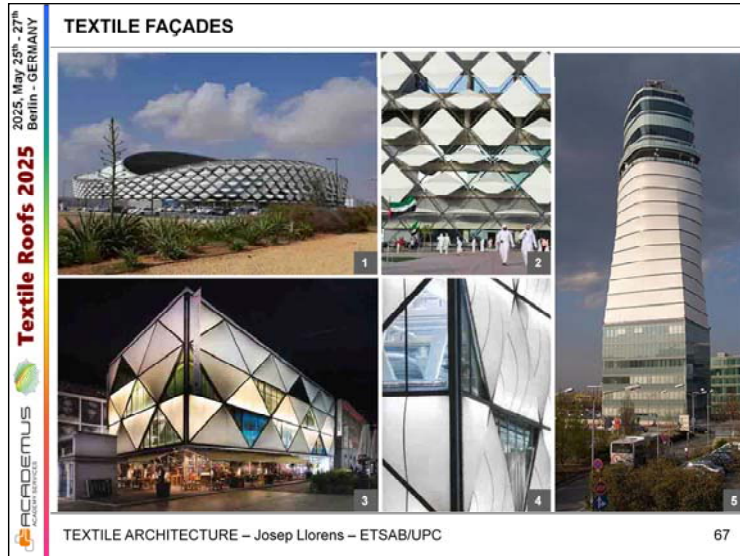
The façade protects and separates the interior and generates the exterior appearance of the building, sometimes creating a landmark. Membrane materials are an alternative to traditional cladding materials that minimize the dead load.

1 M.& D. Fuksas with Form FTL and Canobbio, 2008: Zenith Music Hall. The translucent textile membrane covers the steel-frame and creates magnificent light effects. <https://www.e-architect.com/france/zenith-music-hall-strasbourg>

2 Pich Aguiera, Puigdemasa & Pamias with IASO: Experimental centre for multimedia production, Lleida. <https://www.picharchitects.com/portfolio-items/centre-experimental-audiovisual-magical/?lang=ca>

3 Diller Scofidio + Renfro & Rockwell Group with Thornton Tomasetti and Vector Foiltec, 2019: The Shed, NYC, an art and cultural centre enveloped by an inverted U-shaped steel shell clad with 148 fritted ETFE cushions.

4 Behnisch Architekten, 2009: Unilever Headquarters, Hamburg. An ETFE screen to protect from the wind. <https://www.vector-foiltec.com/fr/projects/zentrale-unilever-state-of-the-art/>



Single layer membrane systems are mainly used as sun screens, wind and rain protection, semi-air-conditioned zones and visual barriers.

1,2 Pattern Design Limited with sbp, 2014: Hazza Bin Zayed Stadium, Al Ain. Its exterior palm bole façade consists of a steel diagonal grid structure with 612 individual orientated membrane panels that achieve maximum shading whilst allowing view points from the inside (<https://www.archdaily.com/604755/hazza-bin-zayed-stadium-pattern-design>)

5 Zechner & Zechner with form TL, 2005: Airport Tower, Wien. The building's base is orientated along the building lines whereas the turret faces the airfield. The 45° rotation between these two segments is externally manifested by means of a membrane covering.

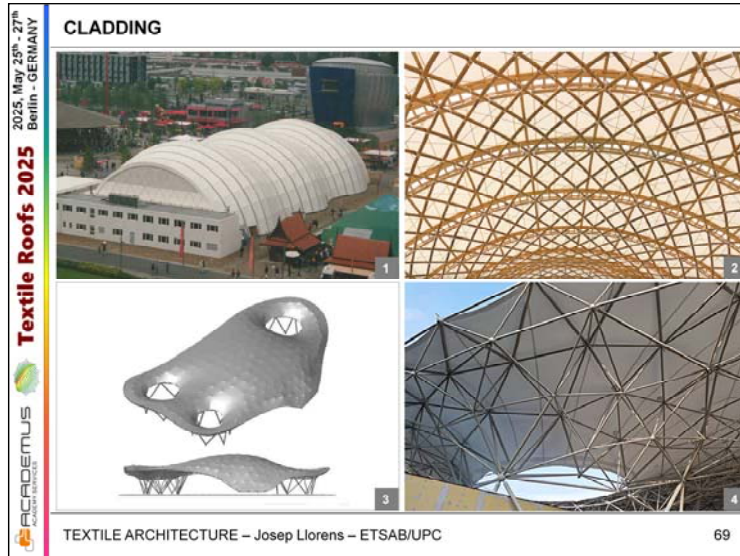
Multi-layer membrane systems provide better thermal performance. They are either inflated membrane cushions or two-layer systems with intermediate insulation.

3,4 B+W Architecture, 2007: La Miroiterie commercial building, Lausanne. It is clad with cushions of translucent membranes that are illuminated at night. This makes the building appear lighter than air while allowing the daylight to shine through. (DETAIL 11/2010)



1,2 Selgascano Arquitectos with Lastra y Zorrilla, 2017: the Plasencia Congress Centre is enveloped by a 0,25 mm thick ETFE skin that veils the inner structure but leaves it recognizable. The skin acts as a means of weather protection, as shading and to scatter the lighting after dark. As thermal insulation, the outer membrane was complemented with single-layer glazing to form a double skin façade. The membrane is white with a light transmittance of 29% and kept taut by a slight double curvature which avoids diagonals that had been rejected by the architects. The surfaces are therefore concave which lends the skin a distortion-mirror effect and softens the angular severity of the volume. (DETAIL 3/2018, p.58-71; Croquis 171, p.218-249)

3,4 S.Radic et al. 2018: Theatre BioBío, Concepción, a six-floor volume (L=114 m x W=31 m x H=28 m) with a translucent lantern-like PTFE skin that envelopes and hides an orthogonal grid frame of concrete columns and beams. In the interior the program is laid out with a high degree of freedom. It occupies the gaps of a labyrinthine spatial grid.



On a more or less conventional structure, dome, grid, or space frame, the space-enclosing element can be a membrane, be it fabric or foil. The space is not shaped by the rules of membranes

1 S.Ban with F.Otto and Buro Happold, 2000: Japan Pavilion, Hannover was a 3D curved grid-shell tunnel arch composed originally of paper tubes Ø 12 cm connected together by fabric tape evoking the Japanese tradition of knots and tying systems. This frame had to be covered by a membrane of fire resistant paper. and reinforced by wooden ladder arches.

2 Nevertheless, the authorities refused to allow a structure made solely of pressed paper tubes held together at the joints with adhesive tape. Therefore, a second support structure made of curved wooden ladders arches was needed to obtain the legal permits. The planned roof material was paper to which it was necessary to add a PVC membrane for fire safety.

3,4 Incide Engineering S.r.l. with Mero, form TL, Canobbio and Serge Ferrari, 2025: Multi-purpose roof, Abano Terme supported by a Mero space-frame. The membrane was produced as a single continuous piece, completely eliminating joints. This solution significantly enhanced the overall aesthetic, giving the structure a smooth, uninterrupted appearance.

(TensiNews 48)



It looks like textile architecture but it isn't.

5 Dar Al-Handasah with Projacs and gmp Architekcten, 2021: Al Bayt Stadium, Al Khor City, Qatar. The 770 x 10⁶ € Al Bayt Stadium in Al Khor City is the most astonishing spectacular height of change of scale.

Its design is based on the Bayt Al Sha'ar, a black and white tent **(1)** used traditionally by nomadic people in Qatar as a welcome symbol of hospitality for desert travelers.

Especially surprising are the dimensions (311 x 273 m), the change of scale with respect to the original model, the trussed steel structure above the reinforced concrete **(4)**, the retractable roof, the 6 different kinds of membrane **(2, 3)** including the one specially customized, and the services, comprising conventional energy-consumer air conditioning.

The steel structure doubles and envelopes the reinforced concrete structure of the stands and air conditioned will be installed even though the model in which the designed is inspired is conditioned without energy consumption

The lack of adequacy to the original model will be revealed by the perimeter ties along with their anchors, which are not necessary at all.

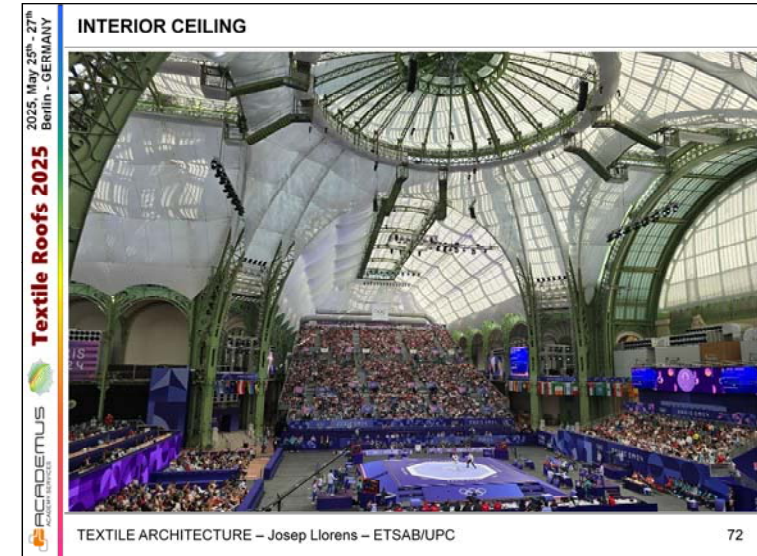


Free-forms require a steel framework and may be cladded with fabric.

1,2 A notable example is the ABB Architects with Covertex, 2001: BMW Pavilion, Frankfurt. (135 m long x 25 m wide x 18 m high). It “accelerated the space around the vehicles to communicate the joy of driving” as the dynamic essence of the BMW brand.

The way to materialize this arbitrary shape consisted of slicing the volume and define buildable flat sections. The space is configured by the metal frames. The membrane is just a cladding. It could be replaced by another material.

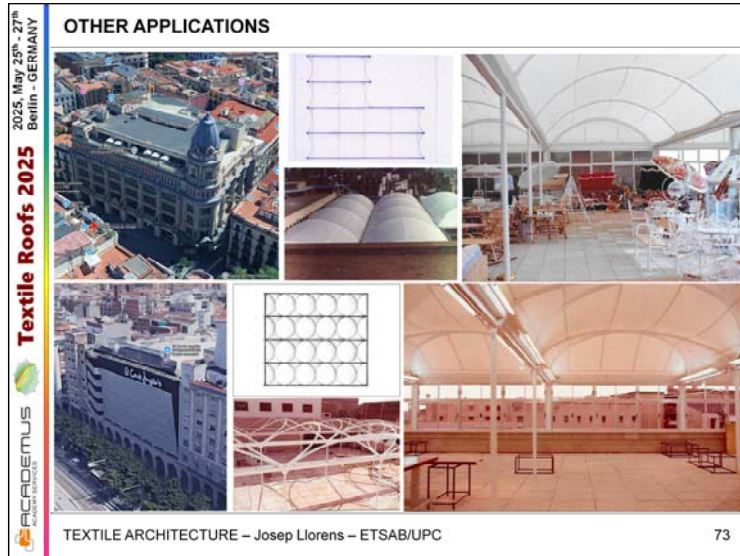
3,4 It contrasts with the Sobek und Rieger with D.Wakefield, 1995: BMW Pavilion, also in Frankfurt, where the tensioned surface structure configures the space according to its characteristics. It is textile architecture.



T/E/S/S with Taiyo and Serge Ferrari, 2024: during the summer of 2024, the Grand Palais, Paris, hosted the events of fencing, wheelchair fencing, taekwondo, and para-taekwondo, all held beneath the majestic glass roof of the large Nef. It was necessary to mitigate and control the light intensity, standardize contrasts, and protect the competition areas from direct sunlight.

The solution consisted of large-scale curved fabric panels. A custom technical approach was developed to respect the architectural unity of the nave and the elegance of the historic structure. The chosen fabric and its installation allow the roof framework to cast shadows on the fabric, preserving the identity of the space while highlighting the heritage of the building.

It had to be considered the lighting levels and light contrasts in compliance with the specifications, design of systems ensuring no direct light on the competition areas in strict adherence to the criteria set by media broadcasters, sporting federations, and the Architecture department of the Project Management team. (S.Aubry et al. 2025: “Temporary membrane cover of the glass roof of the Grand Palais, Paris”. Structural Membranes, XII International Conference, Munich).



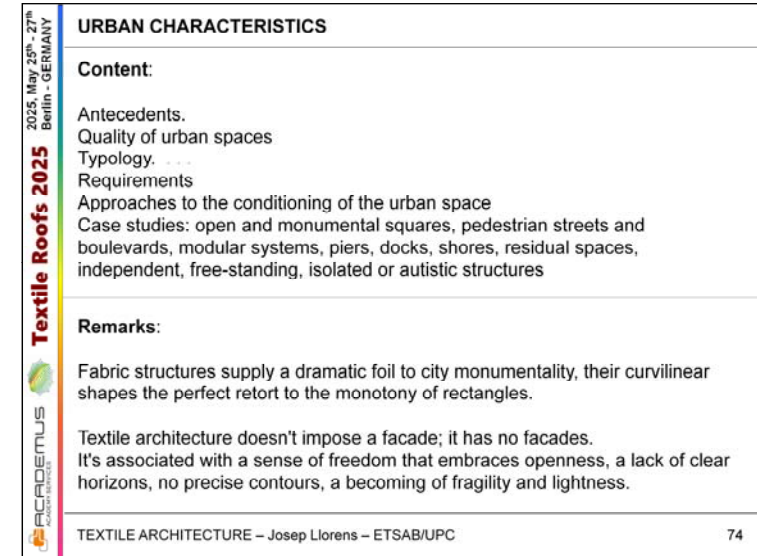
Not considered as permanent construction building system. A building permit is possible where building is not permitted → Jorba.

Department stores require a lot of space, but in urban centers they are heavily restricted by municipal regulations.

A possibility for extension is the roof, that can be covered with an awning, not considered a building by the municipal regulations.

In these cases, the entire terraces were covered with modular roofs of vaults between arches on tubular pillars.

Adding a light aluminum lateral enclosure, an additional floor was achieved.



Surface tensioned structures can be used for conditioning urban spaces as they allow adaptable, flexible, light, open and transparent installations which do not interfere with the continuity of the space of the city. Although there are historical examples, the durability of materials available until the sixties, the lack of tradition and the conditions which the city imposes, limited their use.

Textile conditioning of urban spaces is aimed chiefly to the creation of atmospheres more or less protected against the rain and the sun. The types used most frequently are individual and unique surfaces or repeating, modular canopies, which can be erected free-standing or supported, depending on whether they relate to the adjacent buildings or not.

The options for this type of intervention are conditioned greatly by the urban characteristics of each location in accordance with its use and configuration. For this reason, a typology of urban space is proposed, commented on in accordance with the options which each case presents for the intervention project.

The criteria for intervention associated with the typology of urban space, together with the account of applications and characteristics, can be used to describe, analyse and project structural membranes for the city.



Structural membranes can be isolated, in combination, filling gaps or providing continuation of existing patterns. When used among conventional architecture, they are outstanding. They could be seen as appropriate to create special buildings amongst the ordinary urban fabric.

Their role as intermediate spaces is provided by means of translucency, even transparency, and natural and artificial lighting characteristics.

They can easily create better conditions for outdoor events and lengthening the time spent outdoors by improving physical conditions.

In addition, the curvilinearity of structural membranes facilitates the adaptation to the regular geometry of streets, squares and irregularities that occur in many urban situations.

Soft and curved borders create an open boundary zone that attracts attention and avoids hard lines enhanced by:

- the significance of ceilings
- the mutual correspondence between structure and space and
- the readability of the shape.



1 Textile roofs have been used in cities since their beginnings. In fact, they occasionally date back to the city's origins as demonstrated by the founding of cities from a Roman camps.

Furthermore, camps as cities still exist today.

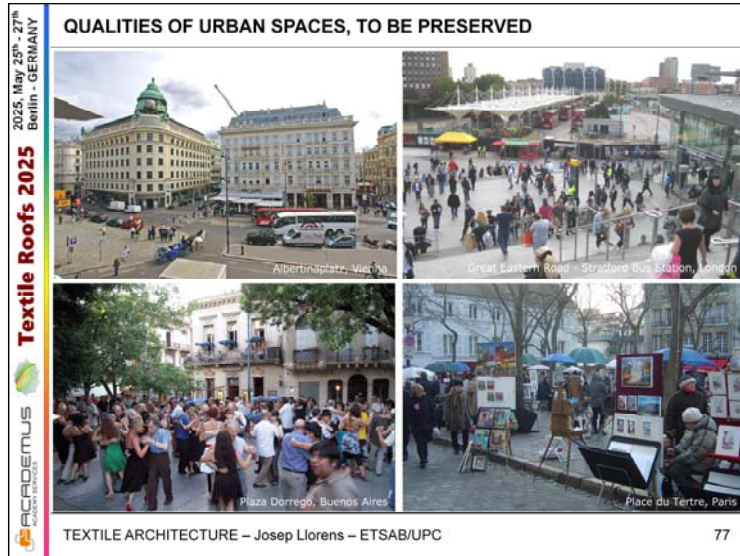
2 Mina tent city

Background examples of textile conditioning of urban spaces which are still in use are open-air markets and fairs, the decorating of streets for celebrations of popular festivals and solar protection.

3,4 Military parades: Florence and Paris.

5 Sevilla Fair

6 Blanes weekly market



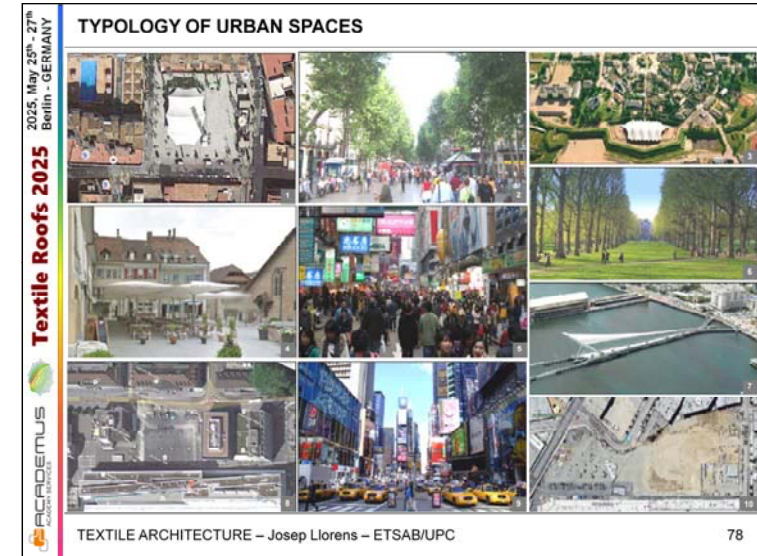
Urban spaces are all types of space left between buildings **usually seen as open and unobstructed**. Their qualities are characterised by:

- the general configuration
- the geometry
- the range of the visuals
- what they are to be used for
- transportation and pedestrian routes
- the surrounding buildings
- the presence of monuments, sculptures, fountains, street furniture, facilities and
- traffic flow.

Urban spaces are places where people socialize. They are the most remarkable areas of the city in terms of both the time of usage and the amount of users.

Activities which take place in urban spaces are multiple: travelling to work, shopping, selling goods, recreation, leisure, sports, etc.

Clearly, geometric urban spaces call for architecture of high quality because any architectural error detracts from the overall visual impression.



However, these features have to be tuned to different situations that occur in the city, so that a typology of urban spaces aimed at the architectural possibilities of being conditioned by structural membranes is established:

- 1 Open squares
- 2 Avenues and boulevards
- 3 Planned open spaces
- 4 Monumental squares
- 5 Pedestrian streets
- 6 City parks
- 7 Piers, docks shores
- 8 Squares open to the traffic
- 9 Streets open to the traffic
- 10 Unplanned, empty, vague or derelict open spaces



The main applications of structural membranes to the conditioning of urban space are the creation of atmosphere, delimitation and protection.

They provide comfort, daylight and lightness providing at the same time an equilibrated contrast between their curvilinearity and the rigorous geometry of the surrounding buildings.

They maintain the space's character because they do not configure fully-enclosed volumes which obstruct visuals, thus interrupting the continuity.

Silja Tillner with sbp and Skyspan, 1999: Urban-Loritz-Platz, Vienna.

The Urban Loritz Square on the Vienna Gürtel (beltway) is a centrally located public space and a major public transportation hub, where several streetcars and subways connect. Transforming the formerly unappealing and entangled traffic hub into an attractive, contemporary urban space, the new design for the Urban Loritz Square heralds the revitalization of the entire Gürtel region.



It is important than transitions between public and private are indicated physically but at the same time it is important that the indication is not so firm a demarcation that it prevents contacts with the outside world.

Public spaces can be inviting and easily accessible. It is a question of how the border is designed.

Flexible boundaries in the form of transitional zones will often be able to function as connecting links, making it easier, both physically and psychologically, for residents and activities to move back and forth between in and out.

On the other hand, being able to see what is going on in can also be an invitation, as children show repeatedly.

1 bmt Architects, with büro für leichtbau 2004: Mainau Inseleingang

2,3 Snell Associates Whitlingham Park Water Activities Centre 2005



In addition, structural membranes can be removed easily leaving no trace, so they do not irreversibly compromise the places where they are installed.

1,2 Catalunya Square, Barcelona. Circus tent. A heavily used public square collapses during the circus's stay, taking over the public space and disrupting it. Instead of a connector, the square becomes a separator, which also obstructs the views.

The urban space is no longer a space left between buildings open and unobstructed.

The advantage is that it disappears completely when the stay ends.

4 Major Square, Vic. **3** Weekly market. Street markets are not so disruptive. The one in Vic has been identified with the city since the 9th century long before the first houses that frame the present-day square started to be built. Note that the scale and arrangement of the stalls permeates the public space and does not interrupt it.

In addition, as in the previous case, it has the advantage that it disappears completely when there is no market.



Conditioning the urban space may be **tailored to the needs of a specific location** (T) or may be adapted for standardized **modular** prototypes (M) planned for different sites that are independent of the location.

On the other hand, there are situations where **the context** is crucial (RC), e.g. the new construction is required to fill in a gap or continue an existing pattern, while others allow for **independent free-standing** solutions (FS).

Combining both criteria, a typology of interventions in the urban space is established:

1 T/RC: Tailored related to the context - Glyndebourne Opera. The foyer is enclosed by two glass walls and a fabric canopy spanning between the main building and the old back stage block, part of which has been converted into a bar, shop and box office.

2 M/RC: Modular related to the context - Rovinj, 1994

3 T/FS: Tailored free standing - Tubaloon. Kongsberg Jazz Festival, 2006

4 M/FS: Modular free standing - Yulara Tourist Resort, 1986



The Almuñécar Aquarium (Arqintegral & J.Llorens, 2007) is an underground installation that shows Mediterranean fauna below the Kuwait Square of the Andalusian town of Almuñécar.

The Aquarium emerges to the surface by means of its control building, staircase and lift, all arranged around an open courtyard.

A textile roof was designed:

- to protect the courtyard from direct sunshine and rain
- to hide the buildings
- to attract visitor's attention.

The openness is enhanced by the absence of side walls and the scalloped edges that avoid a strictly linear boundary line and diffuse the border.

Note that the masts are branched to reduce buckling and spans. The membrane of the 700 m² roof was subdivided into 60 pieces but manufactured in only one panel to avoid joining on site.

(TensiNews 13, p.9)

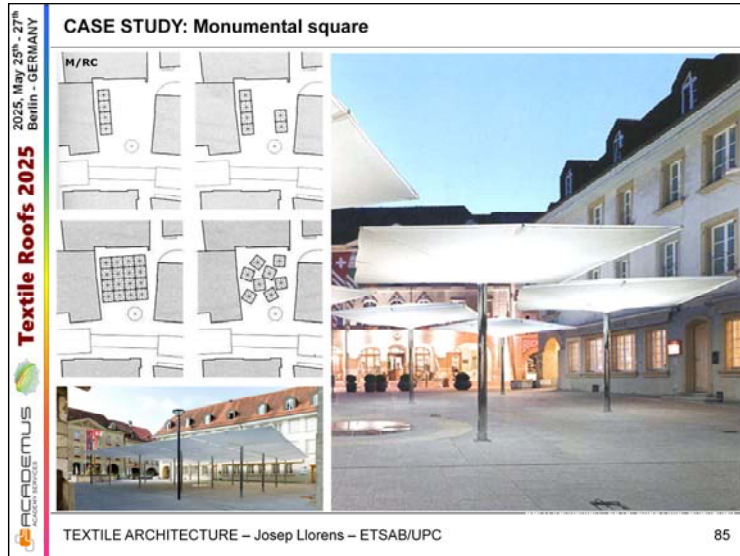


Mossessian & Partners, 2015: Msheireb - Heart of Doha, Qatar.

Based on the old tradition of the "Seville awning", a 90 x 34 = 3,060 m² retractable shade canopy has been engineered by Burns McDonald with sbp New York and Pfeifer in Doha.

Due to the dimensions of the roof, the traditional lightweight flexible solution based on strips of fabric sliding by hand between ropes was converted into a series of stiff, aluminium-framed panels hung from steel strands, and operated by powered engines.

Considering the change of scale (from a private courtyard to the urban square), a 1:1 scale mock-up was tested prior to the installation.



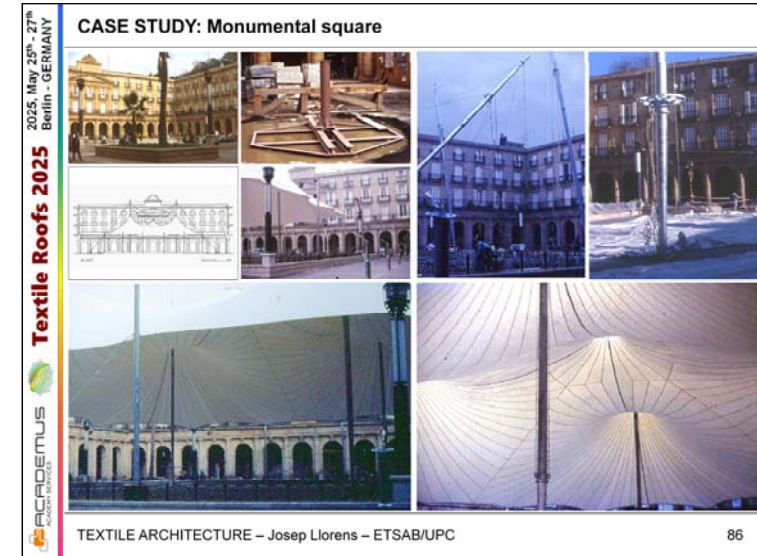
F.Jud, Architekten, 2010: Market Square, Avenches.

A flexible covering was designed for the market square in Avenches based on a repeating module that allows for different configurations according to different uses as café, restaurant, independent stalls or weekly market so that the covered area may vary.

When the umbrellas touch, the water is collected so that it does not spill. Each umbrella consists of two membranes sloping in opposite directions. Rainwater flows from the upper membrane of each element into the lower membrane of the adjoining one and from there into the column and on the drainpipes beneath the square.

In summary: it is a modular solution adapted to the urban context.

(DETAIL 10/2013)



Llorens & Soldevila, 1990 "Plaza Nueva", Bilbao, a building site restricted by arcades

Inaccessible to auxiliary means, the Plaza Nueva, Bilbao, was conditioned by the relationship with the monumental façades, the height of the surrounding porches and the visual continuity.

That's why the roof was designed separated from the surrounding perimeter to avoid interfering with the monumental façades and the height was determined in such a way that views were not obstructed.

Four hinged masts were erected pulling the tops with manual Tirfor machines and the membrane was lifted by means of cables, pulleys and crowns. So that there was no need for cranes, bucket trucks nor scaffolding.

In addition, an underground parking garage conditioned the foundations. Original solutions had to be found for the foundations in the aim of integrating urban furniture, distributing the weight on the parking garage slab and avoiding oblique cables in areas open to pedestrians.



R-Mänttari, 1998: Hamina Central Bastion

The Central Bastion of the fortress was originally designed to serve as bombproof storage facilities 1802-1811.

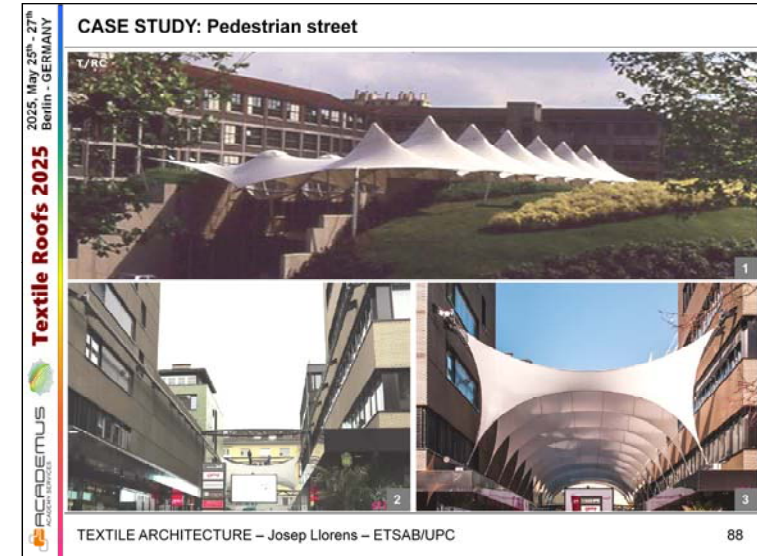
It currently provides a venue for large-scale events with its grandstand (4000 seats) and summertime canopy that fills the urban gap to shelter public events (parades).

The geometry of the military city plan imposed an axial symmetry emphasized by the fabric strips that run lengthwise, underlining the ridge and valley profile of the canopy.

The vision to the bastion has not been interrupted because the flying canopy has been kept unobtrusive and low enough to avoid any competition with the town hall and church spires that dominate Hamina's skyline.

An economical, airy in appearance and easily removable solution has been achieved.

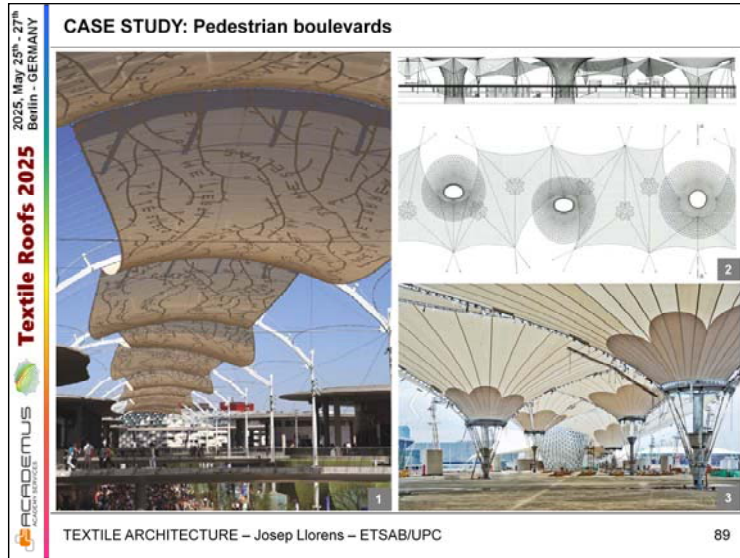
"The contrast between the lightweight translucent canopy and the heavy brick fortification is full of drama". Ph.Drew, 2008.



1 R.Piano, 1984: Schlumberger Research Facilities, Montrouge, Paris.

The Montrouge industrial site renovation is an early example of the possibilities of combining membranes and conventional construction within an urban setting. A newly formed street cuts through a landscaped mound which houses the restaurant and staff facilities. This street is roofed by a translucent lightweight membrane that gives it the characteristics of the traditional European galleria. The undulating curves of the fabric are seen against the green in correspondence with the undulating topography. As a result, the lightweight membrane forms an integral part of the intervention and bridges the gap between the conventional architecture and the urban park.

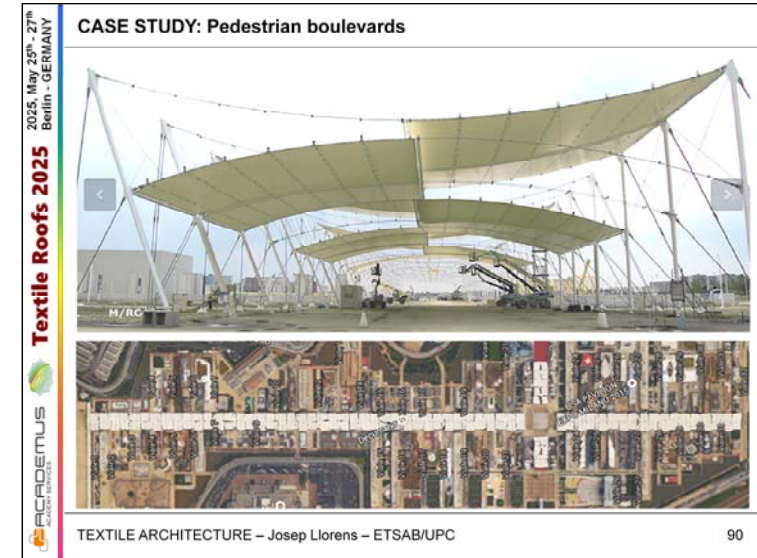
2,3 Kugel Architects, 2014: Metzgergasse, retractable roof, Buchs. A foldable membrane roof spans over a 50 m long and 11 m wide pedestrian street in the center of Buchs, Switzerland to redevelop it as a meeting place for all kinds of events. In the deployed state the membrane takes on an undulating shape, pronounced by sharp ridges and valleys. The retracted membrane is collected under a parking bridge at the northern end and presents itself as the entrance arch of the road. **Even under bad weather conditions, the public space is fully available and can be used for a variety of events.**



World Expos are unique in providing opportunities for textile conditioning of open spaces.

1 The 2008 International Water Expo in Zaragoza was not an exception. Sun protection for the main avenue was needed but several constrains had to be taken into account to avoid visual obstructions to the pavilions, paths and activities. Adjacent buildings could only receive vertical loads. Inclined cables for ground anchors were not allowed because they had interfered with outdoor activities. They were solved by using self-equilibrated arches stiffened by ties underneath (for pressure) and above (for suction) and only 14 vertical hinged supports for the 416 m length of the boulevard.

2,3 The 2010 Expo in Shanghai ran under the slogan "Better city better life". His main boulevard was a large-scale urban operation. It guided the visitors to the national and theme-based pavilions and provided places of relaxation. It was designed as a built landscape with openness and flowing transitions between interior and exterior. To clear up the area, the capacity of dealing with large spans was exploited and structural supports were reduced to a minimum. The translucency of the ceiling made a significant contribution to the character of the space.



M.Majowiecki,,: 2015: Cardo & Decumano, Expo Milano.

Expo Milano 2015 runs under the slogan "Feeding the planet. Energy for life".

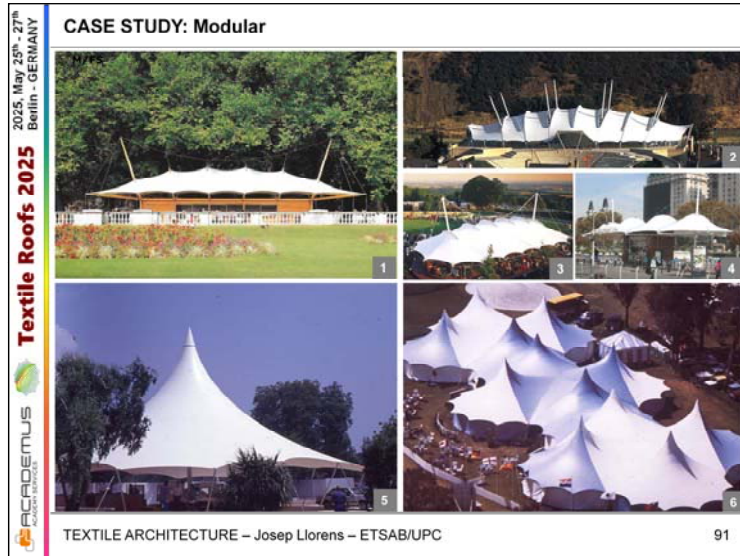
It has also a main boulevard called Decumano, inspired by the Roman camp, and crosses the whole site from east to west with the national pavilions of the participant countries on either side.

The Decumano is covered by a translucent membrane for weather protection and urban identification.

It is supported by pairs of wire ropes composed of upper load-bearing cables and lower stabilizer cables which have the task of pretensioning and resisting the wind suction.

The membrane is placed, on one side, on the upper cables and, on the other side, on the lower ones. And this arrangement is reversed for each module.

This design produces a pleasant aesthetic effect of movement, avoids the tunnel effect that could occur given the 1,5 km length of the boulevard, facilitates the outflow of the hot air and provides direct lighting that balances the uniformity of the translucent skin.



M.Hopkins, 1994: Buckingham Palace Ticket Office at Green park

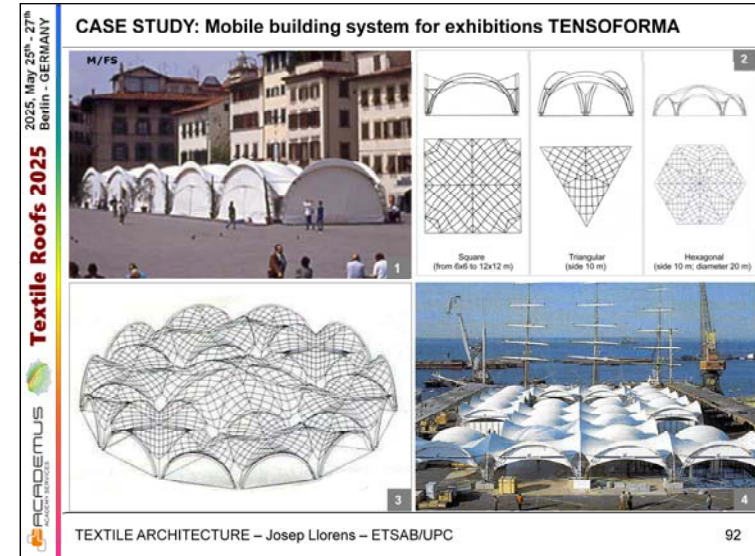
1 M.Hopkins designed in 1994 a ticket office pavilion for Buckingham Palace visitors located at Green Park, London. It needed to be temporary, easily erected, dismantled and put in storage when not in use. The pavilion shelters a closed cabin inside but is totally open at the sides. The roof projects forward the perimeter creating a transition, avoiding divisions and contributing to its ethereal cloud-like suspended quality that reinforces the impression of lightness. As a result, there is not a disruption of the venue where the pavilion is installed.

The ticket office pavilion became a prototype that was applied successively to:

- 2 Dynamic Earth Centre, Edinburgh, 2010
- 3 Summer pavilions, Goodwood Racecourse, 2001
- 4 Puerto Madero Pavilion, Buenos Aires, 2006.

Commercial modular options:

- 5 Permanent installation for a disco on not qualified land (<https://dalo.com/>).
- 6 Anchor Industries combination of modules



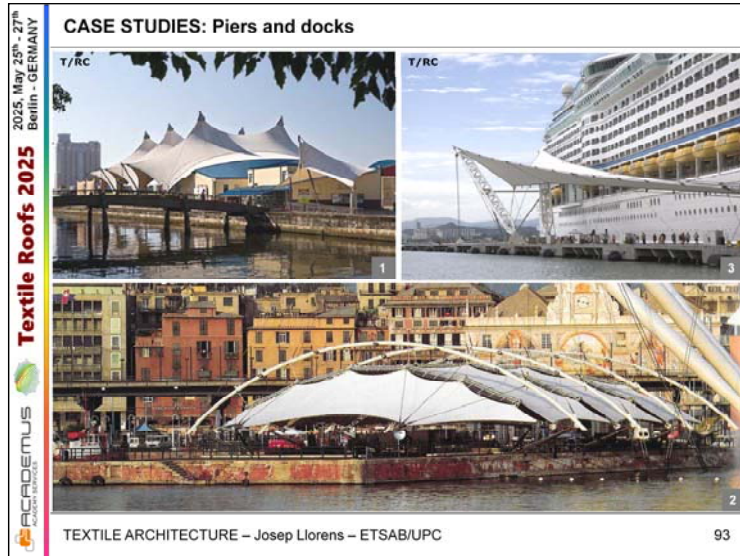
1 Arched tensile structures were developed with the intention of creating a truly modular system capable of resolving multiple needs, promote economic, cultural and leisure time initiatives, faced with the difficulty of adaptation to any environment and surface.

2 Careful consideration has been given to quick and easy assembly, transport, handling, and storage. So that even very large areas can be stored in exiguous space.

3 Aggregation with square, triangular and hexagonal modules.

4 Square Module. This structure is a structural PVC-coated polyester membrane supported by four metal arches and braced with two galvanized steel stabilizing cables. Square module structures are available in four sizes 6x6, 8x8, 10x10, 12x12 mts. The shape is formed by the intersection of a square-base prism with two intersecting hyperbolic paraboloids at right angles.

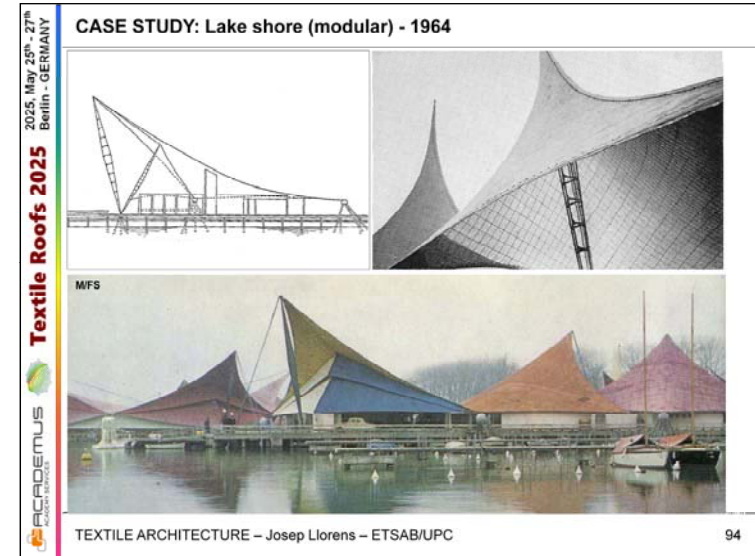
For easy construction, four semi-round arches replace the parabolic boundary arches. The result is reminiscent of the old round cross-vaults but here the barrel-arches have been replaced by two paraboloids and the ribs by stabilizing cables.



1 FTL, 1991: Pier 6 Concert Pavilion, Baltimore. It sets its unique appearance with a tensile-roofed structure supported by six masts that rise 21 m. Its side openings are 9 m high to provide panoramic views of Baltimore's famous inner harbor and the city.

2 R.Piano, 1992; Grande Bigo, Genoa. The former harbour pier was converted in the Piazzale delle Feste by means of the membrane structure. The 30 x 60 m covered arena is open at the sides so that the surrounding walls of the harbour form a visual backdrop. The translucent membrane of PTFE-coated glass fibre provides shade without darkening the space below. Glass skylights close off the gaps between the membrane panels providing direct lighting that balances the uniformity of the translucent skin. At night, the tent functions as a giant lamp in the middle of the old port and thus plays its designated role as symbol and landmark.

3 Pier Walkway, San Juan, 2007. It is considered a fabric canopy that resembles the sails of a vintage sailing ship, accommodates the berthing of cruise ships, provides appropriate shade for passengers and makes a grand architectural gesture to distinguish the pier. It allows to accommodate the largest ships and is intended to attract cruise ship traffic to San Juan.



M.Sauguey & F.Otto, 1964: Swiss National Exhibition, Lausanne

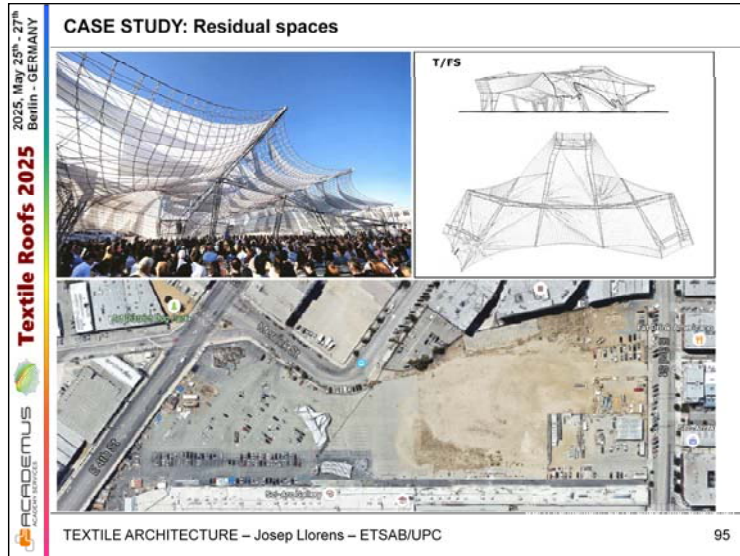
24 Simple shaped four-point sails were arranged around the boat harbour, overlapping and penetrating each other. They configured the spaces for the leisure centre of the exhibition with restaurants, coffee shops, shops, dance clubs and various attractions.

They related the lively waterfront of the lake in the foreground and the green pastures on high rising mountains in the background.

From the constructional point of view they were not really tents but steel cable nets with infilling. Ø 8 mm steel cables were encased in a lipped PVC section which enabled it to be continuously attached by sewing to the tent membrane. Therefore, the membrane in this case served merely as an infilling, while the steel cable nets took up all the main loads as they stretch less than the tent membrane. The compensation of the differences of stretch between the fabric and the cables was achieved employing cables of greater length.

Important experience was gained for the construction of long-span membrane and cable nets.

(C.Roland, 1970)



SOUTHERN CALIFORNIA INSTITUTE OF ARCHITECTURE IN LOS ANGELES

A temporary pavilion is traditionally erected for the annual graduation ceremony to provide shade to 900 people.

The roof slopes towards the west to screen off the evening sun.

A two layer network spans over six steel lattice girders cantilevered on one side.

The position of the pavilion configures the space where the ceremony takes place despite the fact that the plot is residual.



FTL Design Engineering Studio with Fabritec Structures, 2009: Sky Song shade structure for a pedestrian mall on a new campus at Arizona State University.

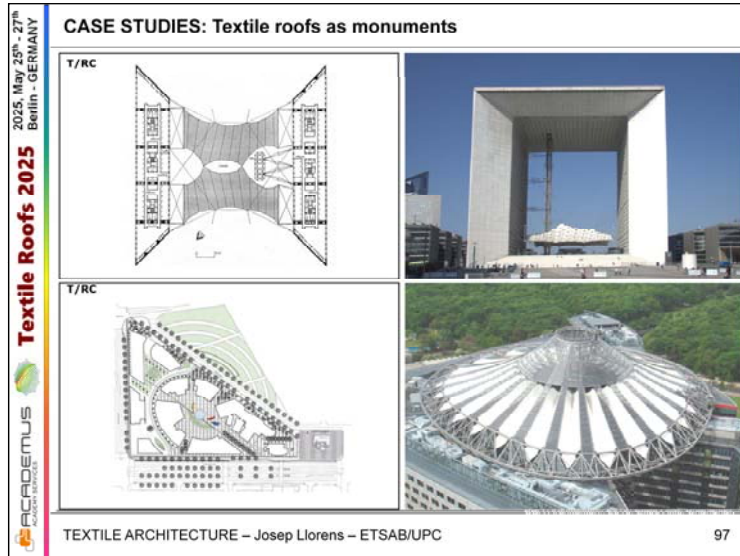
It is a combination of high and low points that clearly shows the difference in the formal repertoire of tensile surface structures with respect to conventional construction.

Although symmetric along four axes, the surfaces feel free and unrestrained because they were found using rotational symmetry rather than a mirrored symmetry.

In addition, the redundant qualities of the rotational symmetry created a simplicity in execution despite the complexity of the form.

Sky Song acts both as an architectural icon and infrastructure element creating shade for the campus, collecting rainwater for irrigation and promoting the use of outdoor space in a warm dry climate.

(N.Goldsmith, 2018)



Structural membranes can be also be envisaged as monuments.

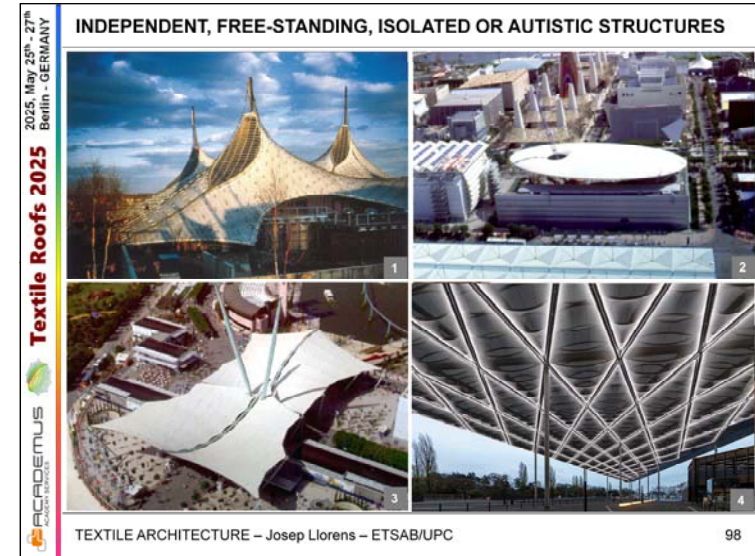
J.O.von Spreckelsen & P.Rice, 1989: La Grande Arche, Paris

It is the case of “La Grande Arche” de La Défense Paris, constructed using a series of repetitive modules instead of a single-spanning membrane. It was designed as a counterpoint to the geometric simplicity of the large cube and intended to be a cloud floating over the open central space. It was materialized as a canopy formed from prestressed cable-beams, translucent PTFE-coated fiber glass membrane and transparent glass discs pushed upwards by flying masts.

H.Jahn, 2000: Sony Centre, Berlin

On the other hand, the central square of the Sony Centre in Berlin was covered by a combination of glass and membranes. They are supported by a unique oversized flying mast that stands in the middle as a the focus of the interior space.

In both cases the membranes go far beyond the urban space conditioning and become monuments by themselves. **Complex devices interfere with a simple scheme instead of solving problems using a minimum number of elements.**



When the building is isolated and there are no limitations coming from the interplay with nearby structures or buildings, the edges can be designed to be open, continuous, attached to different points, stiff or flexible according to the characteristics of the roof itself and the planned relationship between indoors and outside. It is the case of fairs and international exhibitions

1 German Pavilion, Expo 1967, Montreal

2 German Pavilion, Sevilla 1992. The roof was an independent flat cushion suspended at a height of 22 m over an elliptical steel framed ring with a hole for the main supporting mast 60 m high. Contact with the building was avoided.

3 Barqueta Door, Sevilla, 1992. The roof isolated and the edges open and flexible formed a free independent shape.

4 SOP Architects with form TL and Temme Obermeier, 2020: Trade Fair Entrance South, Düsseldorf. The supporting structure consists of a steel grid structure designed in a diamond shape covered with two different fabric materials: an upper roof membrane and a lower membrane with a high degree of translucency. The shape of the two membrane surfaces is spanned by internal steel arches. <https://www.form-tl.de/en/>



1,2 San Francisco Square, Seville

3,4 Cathedral Square, Barcelona

The relevance of maintaining the continuity of visuals and use in order to preserve the area's urban character should be emphasized.

5,6 Otherwise, the intervention converts into a building which reduces and interrupts the urban space.

The urban space is neither improved nor conditioned.

It is rather occupied.

The fully enclosed pavilions for temporary exhibitions or events are not properly urban spaces.

They are closed buildings.



Traditional constructions in the urban space without interrupting it:

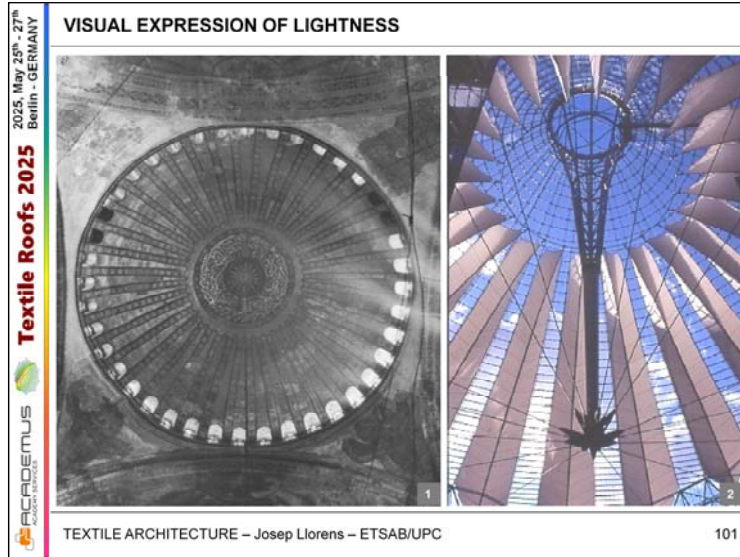
1 B.Brufalt 1587: The "Porxada" (porch), Granollers, was the shelter of the weekly wheat market. It could be used during the rest of the week together with the rest and the square. It didn't interrupt the visuals and continuity.

2 I.Sánchez del Rio, 1929: Milk market umbrella made of reinforced concrete in Oviedo. The milk market is no longer held but the umbrella is intensively used as a public space and night-time entertainment.

Surface tensioned structures can also be used in the urban space resorting to the aforementioned architectural characteristics

3,4 Vehovar & Jauslin with form Tland Vector Foiltec, 2014: Aarau Bus Station. A complex geometrical problem is solved bringing delight. The opposing polarity of the curvilinearity and lightness of the canopy and the regularity and solidity of the urban grid is exploited to create a very strong and inspiring unit because the juxtaposition brings out the qualities of both.

<https://www.form-tl.de/en/project/busterminal-aarau-ch/>



“Lightness does not only signify lightweight or low weight. It is an architectural approach” (Jürgen W.Hennicke).

Lightness also (and mainly) depends on light and proportions, as many outstanding examples reveal.

Fabric structures in architecture are not spared from this principle.

1 Isidore of Miletus & Anthemus of Tralles, 537: Hagia Sophia. Its dome is 31,7 meter in diameter and 55,6 meter high from floor level. It's supported by the arches between piers, called pendentives which were unique at those times. The sunlight enters from the forty windows encircling the base of the dome, relaxing the pressure of the dome on the pendentives. So that even though the dome is made of stone, it looks light because the row of windows puts it suspended in the air.

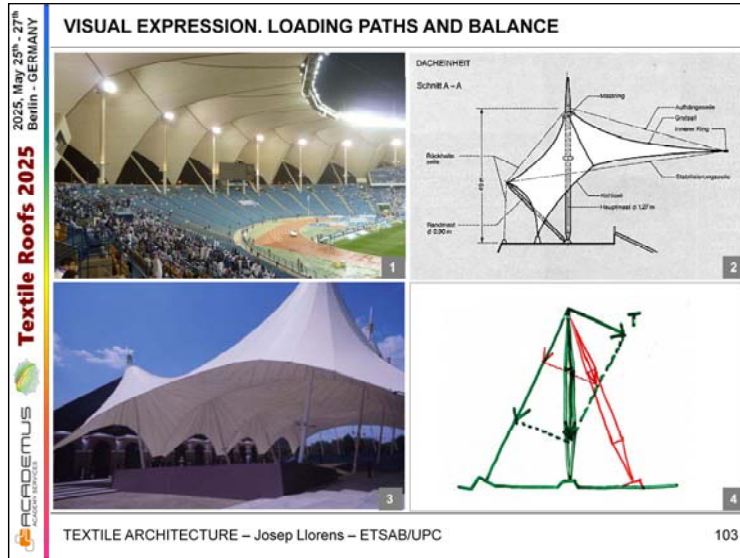
2 Murphy/Jan with W.Sobeck and Arup, 2000: Sony Centre, Potsdamer Platz, Berlin. A pre-stressed cable net supported by an enormous flying mast suspended within an elliptical ring beam. It is clad with glass and membrane panels covering an open space. The unique flying mast looks very heavy because of the contrast with light membranes and transparent glass.



1,2 Masts in the middle interfered. So, the bases were put aside. As a result, the masts do not bisect the seams. The symmetry of the roof is not structural.

3 The plates didn't follow the direction of the cables. An auxiliary plate was needed.

4 Following the load paths: the funicularity is not only a requirement of the surface, it is also needed in edges, corners, cables, ties, fittings, adjustable devices and all elements involved with the tensioned parts of the roof.



Masts are most efficient constructed so that they align with the resultant of the accumulated forces at the peak of the fabric. External cabling to the top of the mast serves primarily to stabilize it in the event of strong wind load or a tear in the fabric.

If the seams directly follow the flow of forces, the structure is easier both to perceive and to understand. The same effect is felt when the directions of cables, masts or boundaries that meet at a point are geometrically balanced.

1,2 Ian Frazer with Schlaich und Partner, Geiger Berger, Pfeifer and Birdair, 1986: International Stadium, Riyadh. The masts do not bisect the angle of the stays.

The resultant of the fabric membrane shape pulls markedly inward at its peak while the mast is vertical in order to satisfy non-structural considerations. The external guy cables must perform the additional function of resisting the horizontal resultant force at the top of the mast. (C.G.Huntington, 2003).

3,4 H2L2 with Geiger Berger and Owens-Corning Fibreglas Corp, 19t6: Independence Mall Pavilion, Philadelphia. Balancing the mast with the membrane expresses equilibrium and reduces loading.



Peripheral joints compensate for the differences in shape and behaviour that occur when membranes are paired with other elements of stiff construction. This is the case with roofed courtyards, squares and streets.

1 Nantes Railway Station, J.M.Duthilleul, SNCF. Heavy reinforced concrete beams follow the curvature of the membrane. Nevertheless, their depth does not fit the lightness and the whole looks odd. Elements that do not fit the essential idea, in this case lightness, weaken or contradict it.

The proportions between parts can be balanced with the whole of the structure, but these may look oversized in comparison with the scale of a human being.

2 Camp de Mart Auditorium, Tarragona.

3 Olympic Park, Munich.

The visual aspect is also related with the structural behaviour. Stiff components and moment resisting connexions increase size and weight. They could be balanced by simplifying, splitting, subdividing, separating or removing. Flexibility and hinges also help.

4 Too much everything. Complexity that is perceived as unnecessary should be avoided.

5 Complexity and concentration of stress in the corner are reduced by tripling it

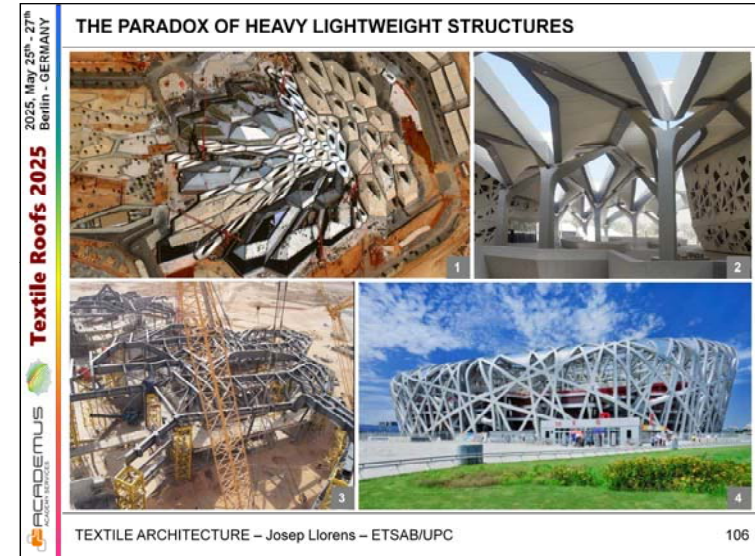


In tensioned membrane buildings *the membrane is the protagonist* of the architectonic space. Understanding this is vital to securing the building aesthetic qualities. Consequently great care has to be taken during the design phase to think how all elements can be integrated within a membrane enclosure, including structure, building services, joinery, furniture and finishes.

Joints and connections are left exposed. Together with the membrane and other structural components, they fashion the appearance of the design as a whole. Care should be taken regarding the coherence, simplicity, lightness, balance, proportion, smoothness and style, because *visual expression factors are not only visual*. They are also indicators of structural, geometric and functional suitability.

Coherence and homogeneity.

Membrane structures are *lightweight and translucent*. Surfaces follow load paths. They express neither thickness nor mass. They use a minimum amount of material. Preserving these characteristics in the details prevents strange and contradictory structures. Care should be taken with rigid enclosures connected to the membrane. Contradictions caused by differences of depth may arise.



The roofs are membranes but they do not look light.

1,2,3 To provide shade and ventilation, a *dramatic sculptural mixture of fabric and steel* was designed for the KAPSARC, King Abdullah Petroleum Research Centre in Riyadh, Saudi Arabia, 2017.

Hexagonally shaped cells of very varying dimensions are arranged in a continuous, organic, crystalline looking layout that spans the major central courtyard area and the streets that are formed between the major blocks of the building complex.

For each cell, a *deep perimeter beam* provides upper and lower boundaries to fix double-skin semi-translucent membranes. The double skin forms an insulation cavity of 0.5 m to 1 m and obscures the seam lines. *It also hides the supporting steelwork* of the central ventilation aperture in a manner that the daringly shaped membranes appear to magically suspend the central openings.

4 In summary, *it is an astonishing, oversized structure, showing once again that structural membranes, if not designed as such, require an imposing steel structure*, as happened at the Beijing Olympic Stadium, 2008.



"Structural membranes, if not designed as such, require an imposing steel structure" Jürgen Hennicke.

Membranes may be part of a roof that does not look light.

The space configured in these cases is not determined by the tensioned surface, but by a heavy steel structure.

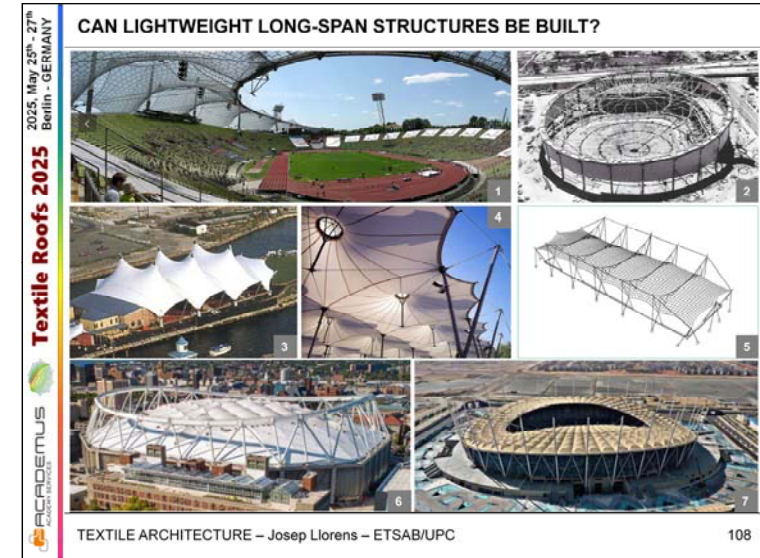
This is not about textile architecture.

1 <https://revistatoldo.com/arquitectura-textil-en-un-teatro-al-aire-libre/>

2 K.Kurokawa with IASO, 2017: Krestovsky, Zenit or Kirov Stadium, Saint Petersburg

3 ACD Girardet & Associés and DVVD Ingénieurs-Architectes-Designers with Ferrari, 2020: Philippe-Chatrier court, Roland-Garros

4 FCC Construcción, 2023: Santiago Bernabeu Stadium, Madrid.



1 Cable nets - G.Benisch & F.Otto, 1972: Roofing for the main sports facilities in the Olympia Park, Munich.

2 Cable domes - D.Geiger, 1990: Suncoast Dome, Saint Petersburg, Florida.

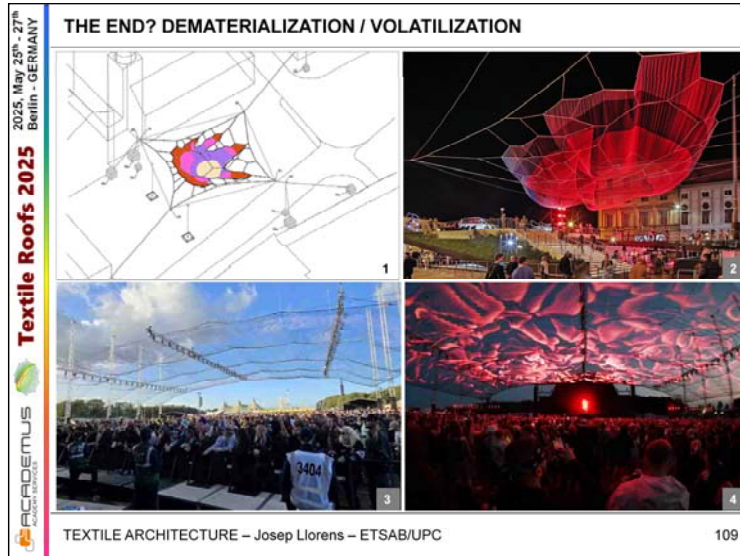
3 Ridge and valley cables - FTL Associates with Buro Happold, 1990: "Pier 6 Concert Pavilion, Baltimore"

4 Flying masts - Ackermann und Partner with sbp, 1999: "Truck depot. Office for Waste Management", Munich (replaced).

5 Cable beams - M.Guislain with M.Malinowsky, Groupe Alto, 2006: Roller Skate Parc, Paris.

6 Suspended roofs. Cable trusses - Geiger Engineers, 2020: Replacement of the JMA Dome (Carrier Dome), Syracuse University, NY.

7 Spoke wheels - SHESA Architects, MJW Structures and Orascom Construction, 2023: Misr Stadium, Egypt



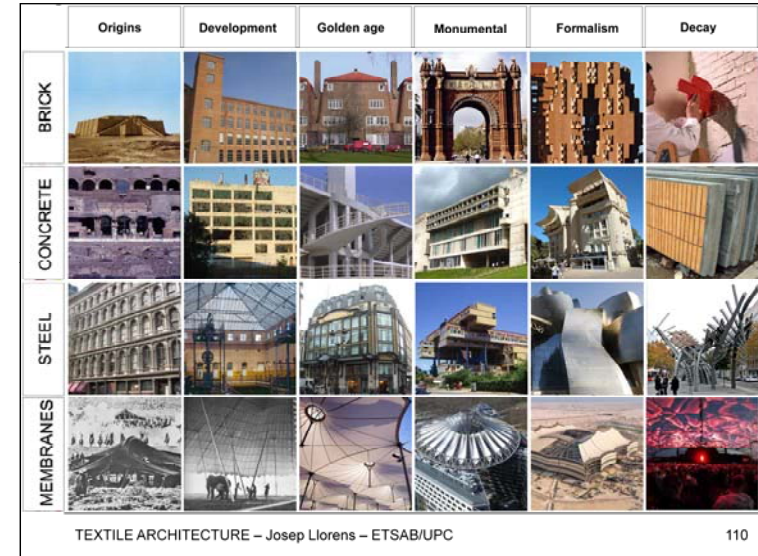
1,2 J.Nerves & J.Echelma with form TL and Mercedes Benz, 2021: Art Installation, Munich's Odeonsplatz.

The sculpture is made of high-strength recyclable polyurethane fibres supported by masts, guy ropes and ballasting. According to the artist "it seeks to heighten our awareness about the way we are all interconnected with one another and our planet. It serves as a symbol of interconnectedness - composed of countless intertwined fibres. Each time a single knot moves in the wind, the location of every other knot in the sculpture's surface is changed in an ever unfolding dance of human-made creation with the forces of nature beyond our control".
<https://www.echelma.com> and <https://www.form-tl.de>

3,4 Special Structures Lab with Rope & Rigging Ltd and Mobile Stadiums, 2024: Chevron Stage, Reading & Leeds Festival: tensioned floating led web of pixels suspended from 60 m span catenary cables rigged to 10 vertical steel perimeter truss masts 25 m in height weighing 2,25 t per mast.

The sky is turned into a dazzling reactive display so called "a terrifying apocalypse" (Financial Times).


TensiNews 48 and
<https://www.specialstructures.com/projectlibrary/chevron>



A historical summary as a conclusion: the history of the application of construction materials develops in 6 phases, that may overlap.

- 1** Origins. Pre-history.
- 2** Development of construction applications to solve practical issues.
- 3** Classical/golden age: development of architectural applications. The material is used not only to solve construction issues, but is also used intentionally to configure the architecture.
- 4** Monumentalization. It is about creating a very striking work, outstanding from a formal point of view.
- 5** The structural function is excluded and the material becomes only cladding or façade.
- 6** Decay. Dematerialization. The material is no longer required to perform any architectural or constructive function but simply complementary or ornamental.

It is an evolution that goes from the practicalities to the beautiful, ending in the decorative and superfluous.

	<h2>CONCLUSIONS</h2>
	<p>The architectural analysis of membrane structures reveals the following significant characteristics:</p> <ul style="list-style-type: none"> • external appearance defined by the surface, color, fabric and the overall shape of the building. • smooth transition from outside to inside through the edges acting as intermediate spaces. • general diffused daylight varying with the geometry of the surface emphasized by the seams. • structural elements contributing to the general configuration. • framed views and uninterrupted visual communication. • integration to the environment completing existing buildings or adapting the shape. • lightness of the whole, elements and materials. • independent elements tend to be modular for easiness of adaptation to different surfaces and sites. <p>The list of architectural characteristics can be extended to describe, analyse and evaluate existing buildings or proposed designs.</p>
	<p>TEXTILE ARCHITECTURE – Josep Llorens – ETSAB/UPC 111</p>

Structural membranes are appropriate for conditioning urban spaces.

They provide atmosphere, protection and delimitation.

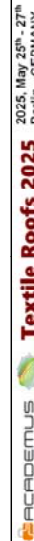
They maintain openness and usefulness.

They do not consolidate closed volumes, because they are easily removable leaving no trace behind.

Urban spaces have been classified according to their requirements and a diversity of solutions has been recognized: tailored, modular, free standing or related to the context.

These directives ought to be considered in the design or the analysis of projects and production.

The construction of closed buildings located in the middle of a street, square or open space, completely ignoring the surrounding atmosphere must be avoided.

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Germany

June 5-6,
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Institute for Lightweight
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"Shaping the pathway to future tensioned membrane design"
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113

