# *Tensile architecture and sustainable approach*

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***keywords***
*Frei Otto*
*tensile structures*
*gridshells*
*conception of tensile structures*
*construction system*

**Introduction: Temporary Architecture and tensile membrane structure**

«In architecture, permanence is mainly associated with the endurance of material and durability of construction. Temporary architecture, on the contrary, has a predetermined and brief life span. […] Investigating the permanent and temporary qualities of architecture, Bernard Tschumi states that architecture is not meant to be permanent; it cannot be related to a limited time. Tschumi re-examines the Vitruvian trilogy of "*venustas, firmitas* and *utilitas*", describes "*firmitas*" as a "structural ability" and discovers that three qualities have remained obsessively in thoughts for centuries. He asks if these architectural constants did not exist, how would architecture be? Moreover, he underlines the fact that the permanence of architecture can be a bad mental habit and is a result of intellectual laziness that has been observed throughout the history.
Jean Nouvel, on the other hand, like Peter Zumthor, asserts that architecture is related to light constructions that are "not heavy", "changeable", "permanent", "dematerialized" and "not matter bounded". There are several forms of designing temporary architecture such as exposition, exhibition and pavilion. […] The architects of the temporary structures experience new ways of architecture, all the while questioning what the future of architecture

might be and how their experimentation can be represented. This small-scale and time-limited practice can be the key to the future of architectural practice»[1].

These words are essential to introduce the small notes that follow, in which the reason for studying again the great technological innovation of architecture in the XX century, the tensile systems, can be hopefully clarified. If at the beginning this innovation had the goal of creating astonishment, of reducing space and time for constructing, of easing the structural heaviness of the architecture and engineer's works, now the goals are completely different: as in fact Ahmed El Seragy and Amira El Nokaly declare, «[…] today, with the vast technological progress and the deep understanding of our environment, and the insisting need to reduce energy consumption to save our natural resources, there have been a shift in thinking and the need for a sustainable environmentally friendly architecture has evolved. The need of new materials and structures that fulfil the occupant's needs and comfort, the architectural beauty and attraction and being environmentally friendly have become mandatory. Although tensile membrane structures are relatively new as a structural material, they have been widely used in many architectural projects that were mainly considered as architectural statements and landmarks. Form finding and structure analysis of such structures has become an established discipline, however, their environmental understanding and behaviour are still in its infancy»[2].

Standing this situation, the studies which have been carrying out by the international research team (Italian, Rumanian, Greek and Portuguese experts) in the field of a peculiar technological innovation of the XX century, the tensile membrane structures, did actually proceed in the direction of a development of solutions able to minimize the negative effect of climate change and to avoid any bad effect which the weathering can provide to people employing the temporary spaces and environments built with these tensile structures. Some studies were in the direction of a structural discover of the physical laws that govern these systems, some others go in the direction of an architectural debate, some are focusing on the technologies employed for such systems and innovations, some others deeply analyse the design experience when these systems are part of the decision process, and how the digital tools can be used so as to aid the designer for such a complex task.

Here I would like to focus the subject of the tensile structures as far as their bioclimatic and bioregionalist possible characters are concerned. It is natural that, given the fact that they are used for covering open air activities and their characteristics of «[…] lightness and transparency, the membrane can be considered more as a filter than as barriers between the outdoor flows from outside and vice versa.

Consequently, thermal and humidity performances which they are able to guarantee, can hardly be compared with those provided by massive constructed elements. First of all the conductivity resistance of a generic texture for a membrane in glass fibre and PTFE is equal to 0.0042 sqmK/W, in comparison with the concrete's one (0,015) and of the glass (0.01). If in the past this limitation could have been considered a neglectable detail, due to the temporary nature of these membrane structures, now instead, that the recent utilizations show permanent character, the capacity of previewing not only thermal but also lighting and acoustic performances becomes fundamental»[3]. One of the first goal to be achieved by a temporary structure is that created in the city, mainly in the historically areas of the European city. Avoiding to build new constructions as well as employing a few amount of materials while achieving a good and beneficial result for the population can be guaranteed by a temporary structure. Comparing a temporary system, in a public space at open air, with other possible solutions for equipping an exposed space for laying out shows of various nature, can actually easily demonstrate the first as the best answer, in terms of performance, of appreciation by the audience and/or the public and as far as the most important goal to achieve is concerned, i.e. that of protecting people underneath it by cold, rain, wind, sun and overheating.

**Temporary structures**

The temporary spaces show a flexibility in the use and in geometrical definition which allows them to be responsive to adequate their configuration to various requirements and needs.
In order to define a temporary space, a number of construction systems can be adopted, which should be easily dismountable, and therefore made up with light materials and flexible technologies, such as for example the membranes. Usually they define the envelope of the construction, for no other systems are needed, and are made up with peculiar structural technology: the tensile system.
The study of temporary spaces is now pushed from the aforesaid present items, but the idea of building such spaces at the beginning represented only a transitory phenomenon, very quickly abandoned, except for those peculiar environments, like circus, and then it seemed destined to disappear.
The new need for flexible systems is dictated by the more and more increasing mobility of the present life, but if initially the novelty of tensile systems did not contemplate the guarantee of environmental comfort for they had a provisory character, today when these systems are often employed for more lasting periods and the need for good internal conditions had become urgent and no longer delayed and neglectable, the design pushed towards finding new bioclimatic solutions.

As far as the flexible systems are concerned, the complexity of the subjects allows, from the architectural viewpoint, a spatial topic open to a multiplicity of solutions, at their turn exciting according to the various shaping choices. Moreover a system of this kind results mainly responsive to different experimentations, and eventually to different utilizations. Some of these temporary spatial systems, being joined thanks to their characters of flexibility and lightness of the relative structures, can in fact be completed with the tensile structures and some others with the pneumatic systems.
The first one is based on the property that the stretched ropes show, as well as the membranes, of transferring tensions. The system then works thanks to the pre-tension of the ropes themselves: it is easily mountable and dismountable, mainly if it is adopted as roof, so allowing a great degree of freedom to the lateral space's surfaces.

**Tensile systems: a starting point**
With the aim of introducing the subject of the membrane, the tensile structure theory is briefly mentioned, starting from the well-known physical and geometrical assumptions. In order to mention the pre-stretched structures, it can be advanced that, as it is known, the capacity of transferring strengths and moments can be found in the micro- as well as macro-cosmos, also in the plants and in the animals.

In particular we know how a rope is capable of transferring tensions, for the structures are means of transmission. Since constructing is, eventually, a process of assembling, the tension phenomena can be observed, and in particular are provided on purpose, also in the technical structures build by engineers.
Another concept to recall is that which classifies the structures, those built by men, according to the technologies which, thanks to the various materials, succeed to transfer strengths and moments, due to various effects: tension, flexion and compression which depend exactly on the applied strengths and moments; in particular the strengths are represented by attraction, repulsion or rotation, and the effects by them provided are considered those of tension, compression and torsion.
In fact, quite according to the direction of the stress, the systems can be classified in:
Mono-axial: when the stress is linear in one direction (the ropes are generally stressed mono-axially); Bi-axial: when the stress is superficial (such as for example a drum); Tri-axial: when the stresses are in any direction. As far as the first systems are concerned, when a dimension is prevailing above the others, they are called linear, such as for example a flexible rope, stressed by traction; a beam, stressed by flexion; columns, stressed by compression: they are all mono-dimensional structures stressed mono-axially.

Regarding the second class, the bi-dimensional systems, they can also be called superficial structures and have two big dimensions and one small. The surface can be flat, but can also be provided with a single curving (and they are called *Synclastic*), or a double curving (and they are called *Anti-clastic*), or finally they can be angular. To give an example of the kind of stress that can be impressed on a structure, various systems can be stressed mono-axially, such as a wall (compression), a steel net (traction) or reticular beams (traction and compression). As far as the bio-axial stresses are concerned we can find the membranes (traction), the slabs (traction, compression and flexion according to the plan), the vaulted ceilings (compressed orthogonally to the surface), the geodetic dome (compression along the axis) and the shells (reticular superficial and rigid curves stressed by traction, compression and moments).
Regarding instead the three-dimensional systems, they have the same big size in the three dimensions, they can take any shape and can be subjected to mono-, bi-, and tri-axial stresses. They can be discontinuous, or made up with linear elements, in any direction, such as for example the web structures, such as the ancient roofs, or spatial rope nets, or aerostatic pneumatic balloons, or even the human skeleton. Coming now to the core of these notes, the Tensile Structures, we know that they can transfer strengths and moments due to their pre-stretched materials.

We know that some materials can resist to traction, such as the wood, the natural fibres, the steel, while others – stones, bricks, cement – cannot.
Usually the compression is absorbed by rigid and fixed elements, while the traction instead by membranes, cables, and any flexible elements: in nature usually the animals' body can resist to compression and to tractions, thanks respectively to the skeleton and the muscles.
The spider's web can highly resist to traction. In the human history, apart from the use made out of animals and plants, men have invented the tents, the fabrics for their cloths, the fishing nets, the sails for wind boats, and then the Circus big tents, the suspended bridges […] and so on.
Single elements of tensile structures are the ropes: the simple rope is any supporting element which can be loaded by a tension, but it is flexible, such as chain, bands, threads. Since the rope is a linear system, it is called, as known, mono-dimensional, for its prevailing dimension. A rope can behave differently according to the boundary and strength conditions: if it is a straight line, it transfers tension strengths; if it is hanging between two points and is uniformly loaded (for example with its deadweight), then it assumes the shape of a Catenary (see fig01).
If the rope is uniformly loaded in an orthogonal way to the curve's tangent, then it takes the shape of a circle's arch (see fig02).

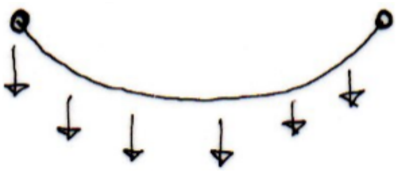


*fig01- A Catenary.*

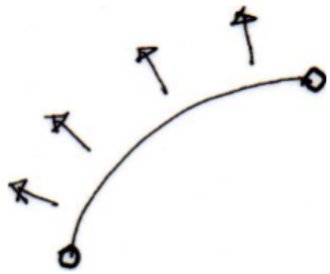


*fig02 - Circle arch shape.*

Finally, if it gets equal loads applied at regular intervals, then the rope create a shape with the geometrical curve of a Parabola (see fig03).

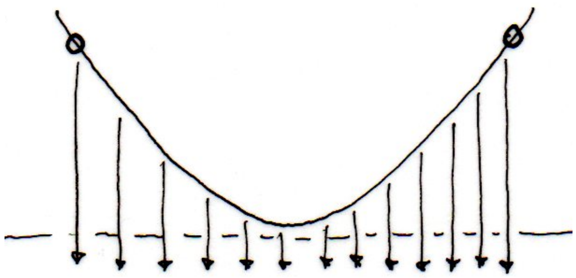


*fig03 - Loaded rope in the shape of a Parabola.*

More complex systems of ropes can be arranged: for example, a vertical rope which has a load transferred by other two caves fixed in two points: this will produce a flat surface with bi-dimensional support (see fig04).

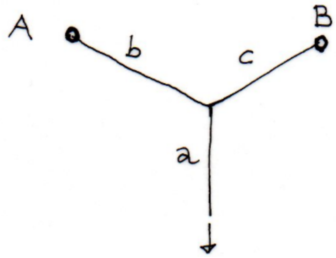



*fig04 - Loads transferred by other two fixed ropes*

Another system of ropes is made up with one single rope fixed and more other vertical ropes hanging: this is the principle of the suspended bridges (see fig05 and fig06).
Then other typologies are produced with freely hanging ropes which shape surfaces; they can be made out of ropes that have the same length, hanging at the same distance between two parallel horizontal lines (see fig07): in this case the hanging ropes shape a Catenary.

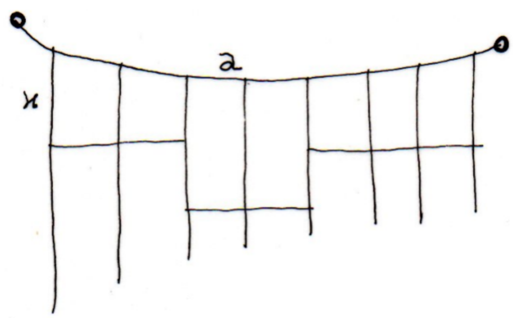



*fig05 - Vertical ropes suspended underneath a fixed one.*

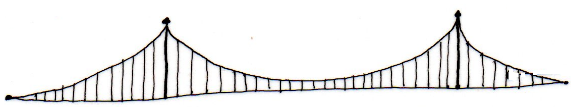


*fig06 - The principle of a suspended bridge.*

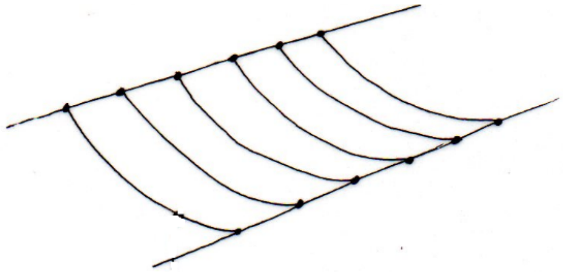


*fig07 - Hanging ropes shaping a catenary.*

When instead also the two equally long ropes are free every rope produce a Catenary (see fig08): these two examples produce a *syn-clastic* surface at unique curvature.

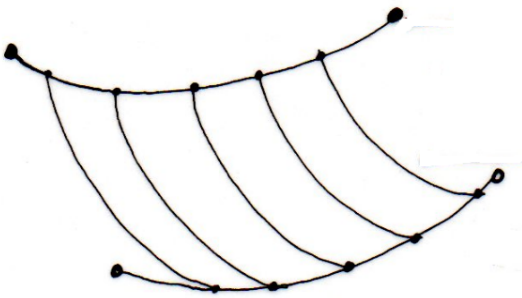


*fig08- A Synclastic surface at double Catenary.*

If instead the bending of the two systems - the two long ropes and the other hanging ones - have different curvatures, then they produce an *anti-clastic* surface (a saddle, or geometrically said hyperbolic paraboloid) (see fig09). Finally a more complex system of ropes can be made up with a certain number of ropes fixed to external caves shaping a border with surface as well as three-dimensional models (see fig10 and fig11).

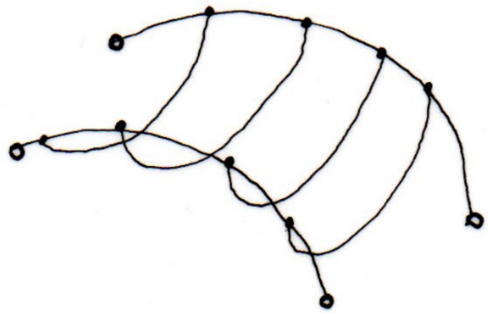
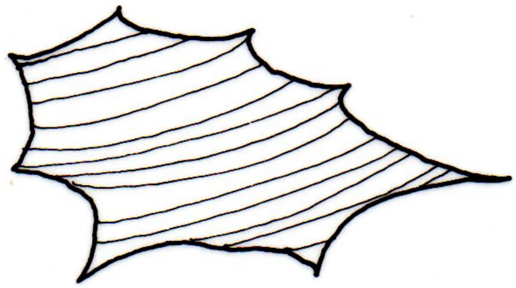


*fig09 - A saddle, an anti-clastic surface.*



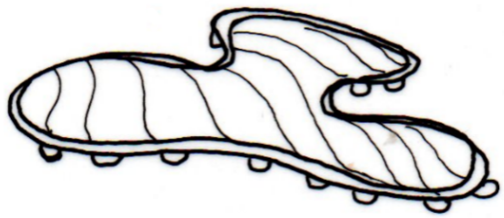


*fig10 - External caves shaping a border.*

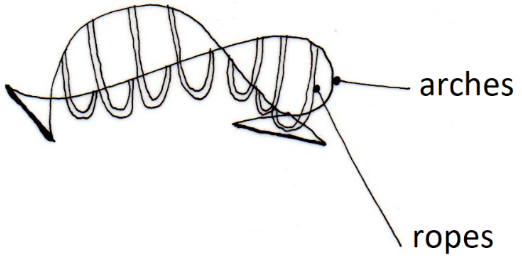



*fig11- Three-dimensional model.*

Other tensile structures can be arranged as single ropes with radial disposition, so shaping a cylinder (with hanging caves at regular intervals around a ring frame) (see fig12).

*fig12 - A cylinder with hanging ropes.*

They can also shape a Catenoid when the ropes are no longer free but hanging in both their two extremities (with a horizontal or tilted suspended plan, i.e. producing respectively a symmetrical or an asymmetrical surface) (see fig13 and fig14). Finally, rising the centre of the Catenary with an additional cave, another shape is possible: the latest is a tensile structure bended anti-clastically (see fig15).

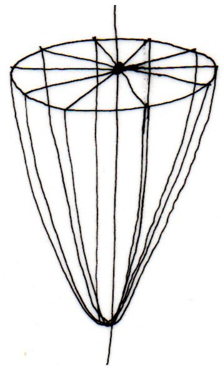


*fig13 - A Catenoid with horizontal suspended plan.*

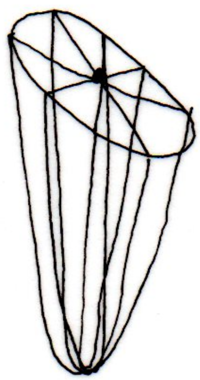


*fig14 - A Catenoid with tilted suspended plan.*

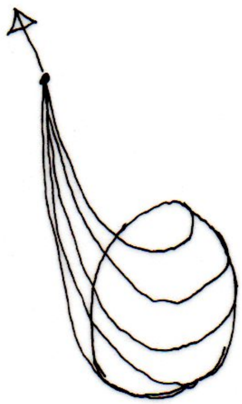


*fig15 - A anti-clastically bended tensile structure.*

Certain nets of ropes and rafters can provide various shapes: if some rafters are fixed between two hanging ropes, (see fig16) they appear compressed as the model used by Schwanzer in 1958 for the European Pavilion: both surfaces can be obtained: synclastic (see fig17) and anti-clastic (see fig18).

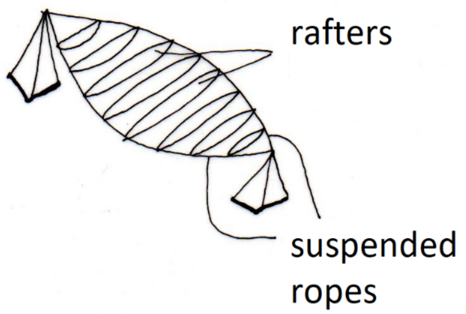


*fig16 - Rafters fixed between two hanging ropes.*

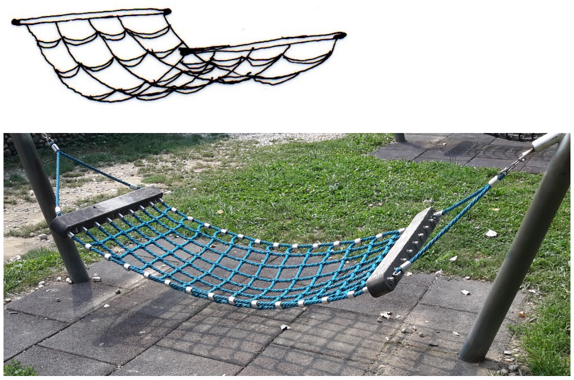


*fig17- Synclastic rope net.*

Some more shapes can be produced combining chains and rigid pylons: the first example is when there is a simple curvature, the ropes are free as Catenary, and the pylons are fixed only to the ropes (see fig19).

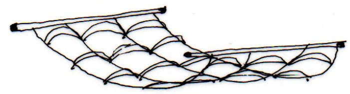


*fig18 - Anti-clastic rope net.*

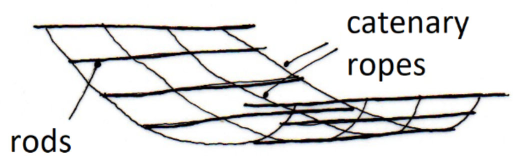


*fig19 - Simple curved net of ropes combined with rigid pylons.*

When instead the suspension points of the ropes – which have the same length – do not shape parallel lines, then the out-coming surface is anti-clastic (see fig20).

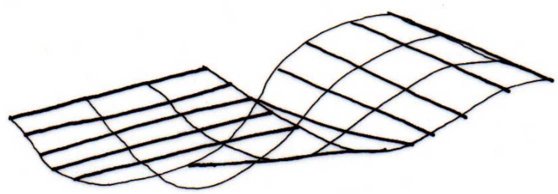


*fig20 - Anticlastic net of ropes and rods.*

When the nets are anchored to the border in various ways then we can have freely hanging membranes; they can be made up with single cables or with ropes' nets, suspended by a frame and so shaping either synclastic or anti-clastic surfaces (see fig21).
Concluding the pre-stressed systems are the followings: rope, any linear element which is flexible and can be stressed by traction; non-pre-stressed rope which gets shape only if

subjected to load (even only its deadweight); pre-stressed rope with already a straight line (even without load).

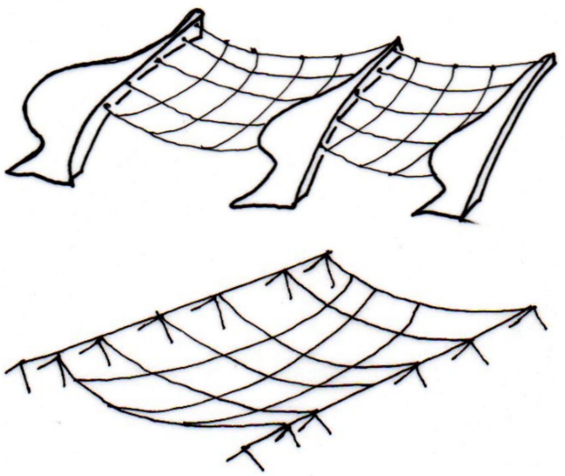


*fig21 - Ropes' net anchored to the borders.*

The length of pre-stressed rope with no stress applied is less than the minimum distance between the two contact points: when the temperature increases the reacting strength of the rope decreases for the material expands, and vice versa.
Supporting points never move even when there is temperature difference: geometrical positions of supporting points and of shaping points are always the same.
The anchorage system can also be modified; they can be full anchorages, anchorages only for compression or for flexion and traction.
Two ropes intersecting always form flat surfaces and volumes, either synclastic or anticlastic (see fig22 and fig23).

More complex structures can be made up of ropes: starting from simple objects such as a piano, a guitar, which have stretched surfaces formed by parallel ropes; but we can also find parallel ropes in the realization of a traction system, such as the antennas and the sailing masts.

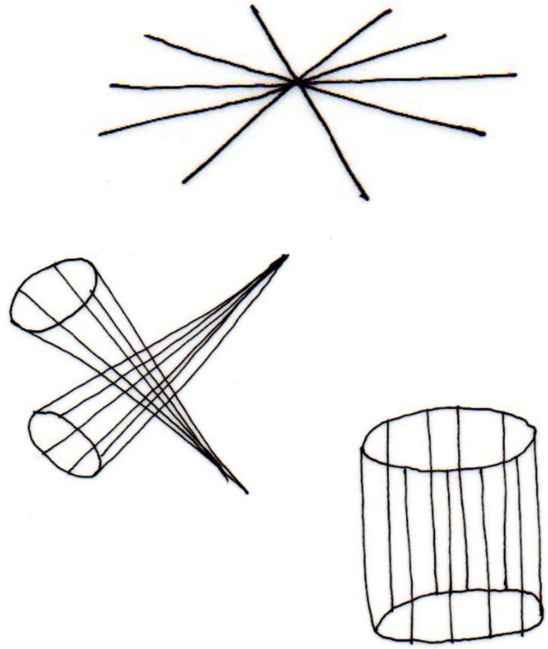


*fig22 - Intersecting ropes shaping flat surfaces or spatial volumes (Synclastic).*

Finally, other systems can be realized in a composite way such as: tri-dimensional portable systems with ropes and membranes; they need to be supported by pylons and tripod; the latest ones resist to compression so avoiding the collapse of the structure.

It is preferable to get four pylons instead of three, so two of them resist to compression and two to traction, or one to compression and three to traction. In order to ensure the stability, the ropes' knots should be fixed in the space according to at least four dimensions (see fig24).
It is also possible to arrange an anchorage with tripods anchored in three different directions, so shaping various structures (see fig25).

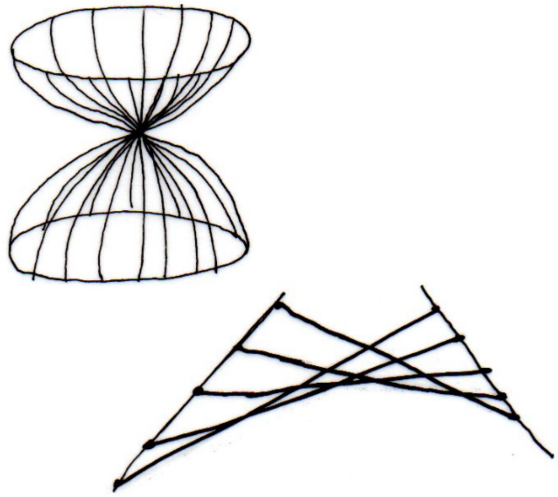


*fig23 - Intersecting ropes shaping flat surfaces or spatial volumes (Anticlastic).*

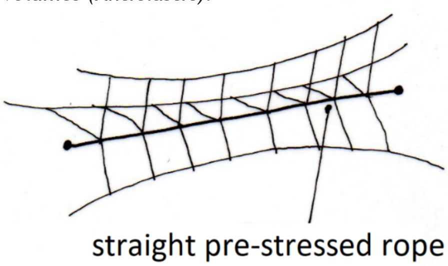



*fig24 – Anchorages.*

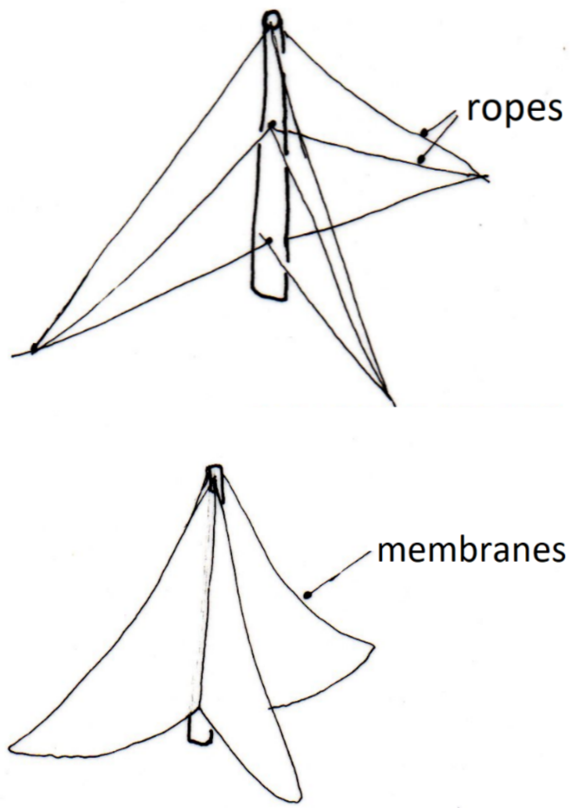



*fig25 - Anchorage with tripods.*

In the case of systems at pre-stressed ropes the parts stressed by compression should have a larger thickness, while the parts stressed with tension are to be very thin. Recapitulating we can design: structures hanging as a shell, pure suspended structures, prestressed structures, i.e. tensile ones (both systems and rope nets)[4].

**Examples of Tensile Membrane Structures in the history**

The most famous technological experimentation of tensile structures was "[…] inevitably tied up with the progress in Western society": this consideration written by Maria Bottero in the '70s can actually introduce one of the most well-known genial systems made out of these tensile structures: the Munich's Olympic games project, made up by Frei Otto for the Games run from August the 26th to September the 11th, 1972[5] (see fig26, fig27, fig28, fig29).

The peculiar shape and grandiosity actually provided to the spectators very strong sensations: "[…] certainly, the attentive observer will notice the gigantic size of the columns, which like masts on a sailing ship, hold up the roofing *'sails'* by means of cables. He will notice that from some angles the stadium looks positively like a full-rigged ship that for some unknown reasons has been left stranded on land, instead of sailing across the ocean as it would see more appropriate and sensible. […] in the work of Le Ricolais and Frei Otto, for example the figuration and calculation of new possible structures start out from a careful study of the natural phenomena, such as the surface tension of the soap solution films, or the structural configuration of certain marine organisation (Radiolaria). These possible new structures are generally not limited by use determination, which does not mean that these structures cannot be used.

*fig26 - Frei Otto's Olympic Games project in Munich 1972: The tensile structures (Source: AAVV (1972), Tensile, Space, Pneumatic structures, a review of contemporary architecture, in Zodiac n. 21 September, Edizioni Comunità, Milano).*

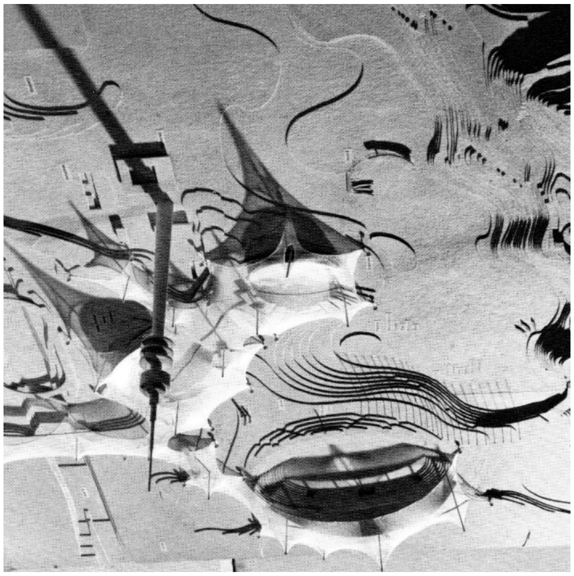


*fig27- Frei Otto's Olympic Games project in Munich 1972: Global view (Source: AAVV (1972), Tensile, Space, Pneumatic structures, a review of contemporary architecture, in: Zodiac n. 21 September, EdizioniComunità, Milano).*

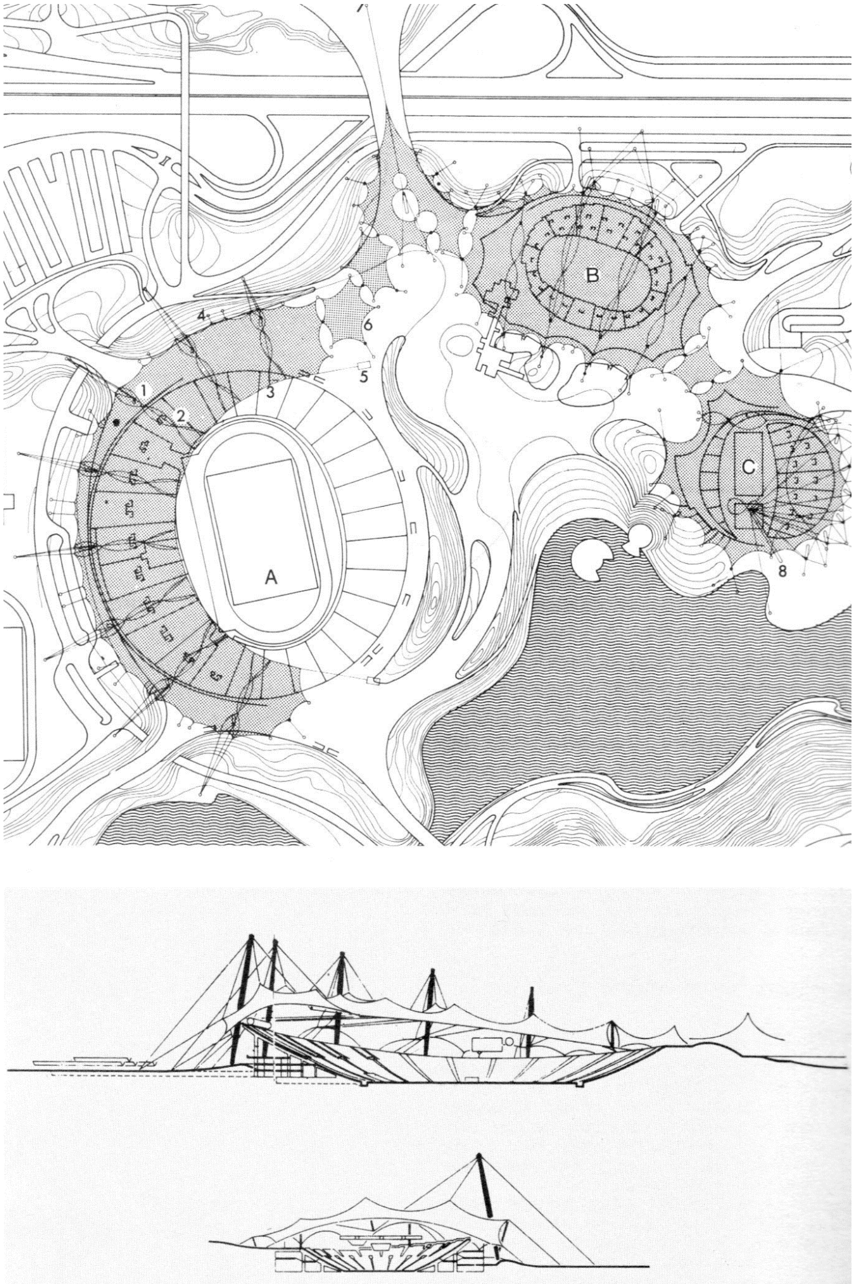



*fig28 - Frei Otto's Olympic Games project in Munich 1972: plan and section (Source: AAVV (1972), Tensile, Space, Pneumatic structures, a review of contemporary architecture, in: Zodiac n. 21 September, Edizioni Comunità, Milano).*

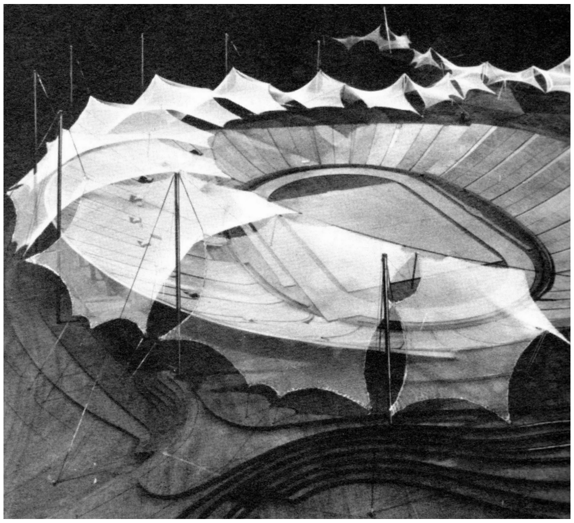


*fig29 - Frei Otto's Olympic Games project in Munich 1972: The stadium (Source: AAVV (1972), Tensile, Space, Pneumatic structures, a review of contemporary architecture, in: Zodiac n. 21 September, Edizioni Comunità, Milano).*

On the contrary, once the advantages they offer have been established (lightness, economy of materials, capacity to cover large spaces), the designer will be able to judge their most fitting use. […] the Munich tensile structures provide an opportunity for historical meditation, owing both to the reactionary that sponsored them (identification of social progress with technological development) and to a correct evaluation of the technical-scientific contribution that made their realization possible" [6]. Some examples of a structural reinforcement, to which the roof-membrane's ropes are hooked, and the reinforcement is located externally to the system itself, is the Ice Stadium within the same Olympic Games, designed by Otto (see fig30).
Also from the structural point of view the Munich's Games have been object of various studies, such as for example the Mick Hehekout's one. He in fact declared that: "[…] the supporting structure for the acrylic roof skin is a prestressed cable net construction. These cable net constructions ([…] started only in the early fifties) have been developed to be selected when the aim is to cover large spans (SFB '64 in Stuttgart) with a minimum of material input at least above ground level. […] tension stressed members […] can be as thin and as long as desired, while the material strength can be increased to the technically possible limits and at the same time completely utilized. […] in tensile structures we could for example - very globally - distinguish three categories, very severely connected with the form: suspended shell structure, pure suspended structure, prestressed cable net structure. […] (In the second system) every loading must be beared by tensile members, either parallel running over the clear span or connected with each other to form a network […] the perpendicular tensile elements are not curved in case of a linear curvature of the total roof; consequently, they do not bear hardly any load. […]
The prestressed cable net is an answer to the relative sensitiveness for deformations. The form stability in this case is reached by loading, not by weight […] The cable net structure is prestressed by pre-stressing the downward cables.

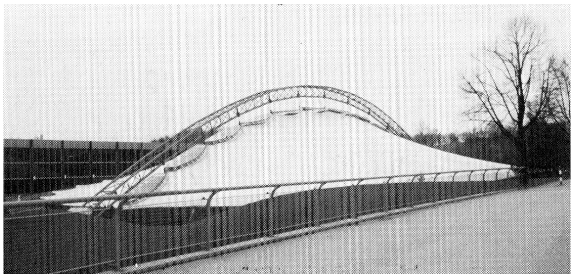


*fig30 – Frei Otto's Olympic Games project in Munich 1972: The Ice-stadium (Source: FRANCESE D. (1990), Spazio sonoro spazio architettonico, Giannini ed. Napoli).*

The surface which is represented by the intersection points in discrete points, has in every point an anticlastic curvature. When one looks for example at the model of the cable net test structure, then this facet seems (following with the eye the standing cables) to have a convex and (following the hanging perpendicular cables) a concave curvature"[7].
Apart from these well-known studies and researches carried out and designed by Frei Otto, in the past another example of tensile structure was that employed to cover the Milan Fiera in 1987 (see fig31).
This system, widely flexible, allows to create a great number of different configurations and of very high sizes, thanks to the capacity of the pre-stressed ropes to absorb very strong tensions.
Within these first experimentations actually the climatic and comfort conditions indoor were not yet considered, while later on some studies started to develop.

For example in the worldly exposition EXPO 1992 in Seville, some tensile structures were designed and built, mainly for making more welcome the outdoor spaces (see fig32 and fig33).
In fact, the Seville's weather in summer is very hot and dry, with very high levels of temperature and even some picks around 37 °C, while the relative humidity does not go beyond 11%. The site then required a double degree of control: that of quality and liveability of the internal spaces, but mainly that of the outdoor ones.
This was arranged by inventing complex and interacting each other's structures, able to modify the micro climatic conditions. There was also a very innovative information system for the automation of the appliances.

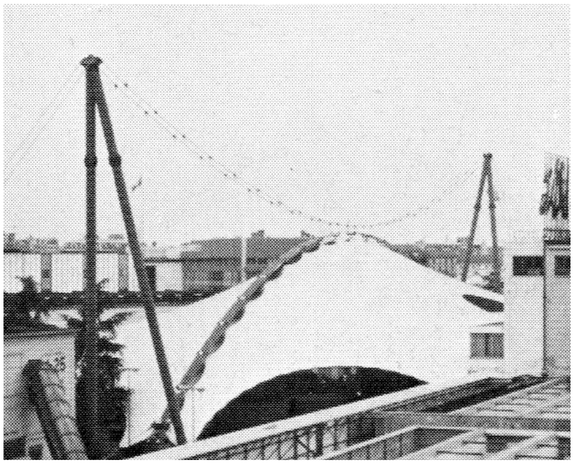


*fig31 - Milan's Fiera 1987 Picture (Source: FRANCESE D. (1990) Spazio sonoro spazio architettonico, Giannini ed. Napoli).*

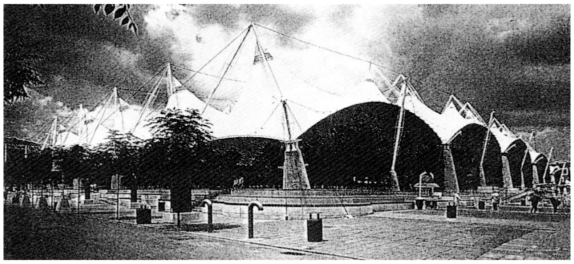


*fig32 - Seville's Expo 1992: Avenida Europa (Source: RUFFILLI M. (a cura di) (1993), Tecnologia e architettura bioclimatica all'Expo '92 di Siviglia, BIDCAA, Napoli).*

*fig33 - Seville's Expo 1992: first sight of the tensile structures (Source: https://www.architetturaeviaggi.it/photogallery.php?par=spagna_FT_10).*

The more frequented areas by audience were in fact the external open-air spaces, but it was unimaginable to leave the place completely without any protection from the aforesaid very hot and dry climate. Apart from the pedestrian paths, covered with a filter-construction which integrate green and water for cooling the paths themselves, by means of simple portals at tubular section aligned so as to shape a sort of tunnel covered by vines, the other interesting and innovative system in the Expo 92 is made up by the Rotunda, as information point (see fig34).

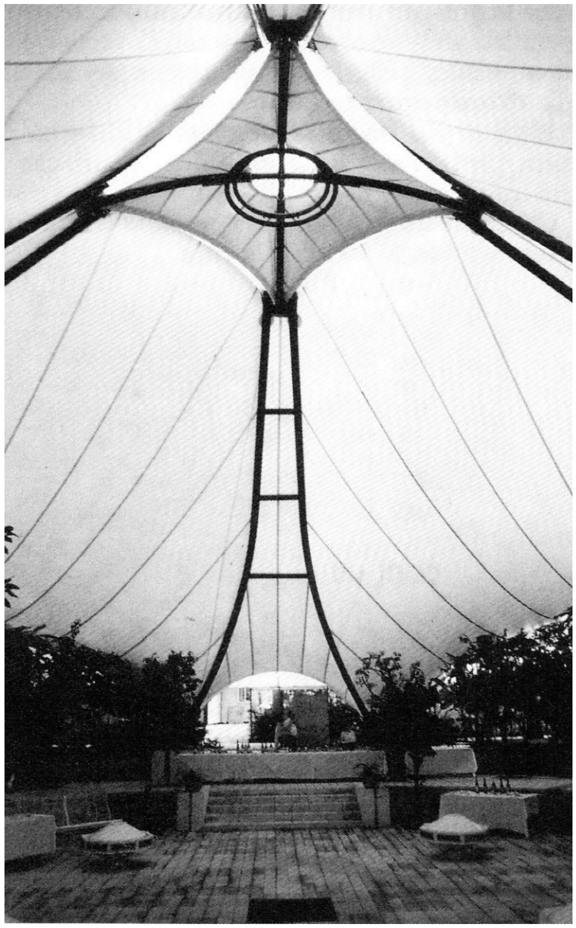


*fig34 - Seville's Expo 1992: Rotunda. (Source: Ruffilli M. (edited by) (1993) Tecnologia e architettura bioclimatica all'Expo '92 di Siviglia, BIDCAA, Napoli).*

The latest was completed by means of a cone shaped tensile structure made up of white PVC, provided by an opening at the top of the roof, suitable to allow the air entering at the base and the warm air exit from the top.

Vaporizer and irrigation systems useful for both the internal trees and for decreasing the temperature of floor and roof, contribute to make internal air fresh and humid, and, thanks to the chimney effect - due to the peculiar configuration of the tensile system – it is possible to stay in this space at optimal microclimatic conditions. In this environment the passage moment between the long promenade which from the pavilions leads to the expected resting area is underlined also symbolically by the various signs, both bioclimatic and lighting: from the dry and glaring heat which is felt outdoor one goes towards the hosting freshness of the pleasant shadow indoor (see fig35).

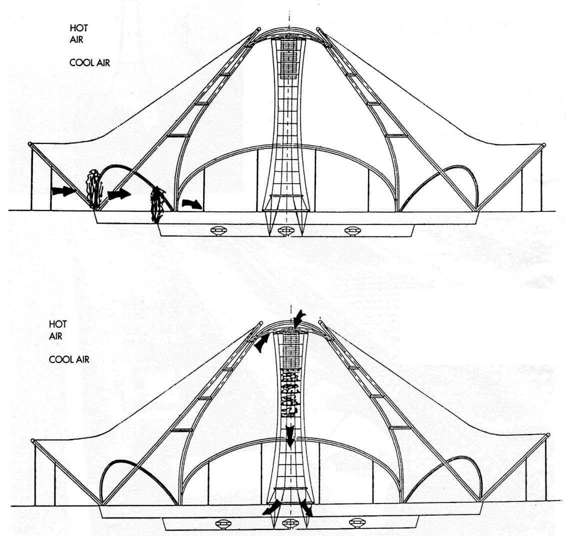



*fig35 - Seville's Expo 1992: Rotunda's working systems. (Source: Ruffilli M. (edited by) (1993), Tecnologia e architettura bioclimatica all'Expo '92 di Siviglia, BIDCAA, Napoli).*

**Bioregionalism and Sustainability in the Tensile Membrane Structures**

Lately a great deal examples of tensile structures have been designed, and the actual problems have been partly solved, both of structural and technological nature.

Here we would like to point out how the comfort condition question can be faced during the design stage, starting from a consideration: according to the arisen needs that had led to the choice of completing a tensile structure system, many other selections can be done during the design procedure and during the yard preparation: all of them can go in the direction of sustainable actions, or conversely just neglecting the environmental items and forgetting any possible negative impact. It is obvious that the first important choice to be made is that of the materials and products which will be used both for the structural support and for the structural roof, or membrane. Therefore, the cables, the membranes and the rigid pylons should at their turn be able to reduce the Ecological Footprint. If PVC or similar oil-derived prime matters are used for the membrane, which is the greater amount of substance needed for the completion of a tensile structure, it is actually useless to construct a temporary space with a flexible system, because all the advantages provided by the fact that the system do not create a great print and a permanent damage on the territory, is on the other hand nihilated by the all life-cycle's negative impacts that this PVC product can yield.

Lately the most common materials employed for tensile membrane and pneumatic structures is the PTFE/Glass Fiber, which is not so environmental negatively affecting the environment as the PVC does, but it is still difficult to recycle and to produce, in terms of life cycle. There are in fact a great number of substitutive materials with the same if not better performances of the PVC membranes, which can be adopted, but that are recyclable and have a high level of naturality: one of them is the hemp[8]. Moreover there is also the question of the bioregionalism to be faced: if the hemp, or another prime matter, is produced locally, using it for the membrane can help to promote local economy and job employment, as well as remembering people about the origin of their life, their architecture, their materials, which being regional, save the identity of the place and recall to people their origin.

*fig36 - Organic hemp canvas (Source: https://www.alibaba.com/product-detail/organic-hemp-canvas-fabric-for- waterproof_ 60716716745.html?spm= a2700.7724857.normalList. 32.3f4e7f8b5KlXnl).*

**Conclusion**

Recapitulating, temporary buildings can be considered as a sustainable system, due to their respect to the existing milieu, both natural and historic, as well as for the limited amount of material resources they need for completion: in particular as far as they are built taking account of the life cycle and reducing the ecological footprint and the environmental impact. These can both be achieved by the use of very flexible constructions, such as the tensile structures and the membrane systems, mainly when they are built with lightweight, sustainable and at great naturality products. As far as the tensile structures are concerned, it has also been briefly shown how these can actually perform in terms of loads and weights, how many typologies it is possible to realize, and which kind of care should the designers and the builders put during the decisions process so as to achieve good levels of bioclimatic and bioregionalist goals. Finally it can be possible to reassume the great number of different uses that these so flexible systems can be suitable for; they can be useful for covering archaeological sites (mainly in the Mediterranean area where they are really a great percentage of the heritage goods, and need to be safeguarded for the posterity): the aim can be supported by a very light system, both in terms of structural resistance, compared with the weight, as well as in terms of amount of material employed: the latest is actually one of the main goals of the sustainable construction.

Tensile structures can ensure protection to these ruins, while at the same time avoid touching or interact with them in a very heavy way, so respecting their identity and integrity as well as guaranteeing people a hosting and protected place, still being at the open air. They can be built with natural products, such as for example the hemp, and can ensure a high level of recyclability at their end of life, which is usually very shortcoming, being in fact these system - as said - temporary.
Another use can be considered that of the roof for temporary events, such as musical shows, theatre representations, artistic or architectural exhibitions, sport competitions, little markets, all events that could also be hosted within a closed and heavyweight building constructed with a lot of material, instead of within a temporary space: nevertheless they are often left unused for great part of the year, in between one event and the other, so being actually a great dilapidation of materials, energy and financing management: when the space for the event is instead temporary, and the system is a flexible one, the saving in terms of materials, money, energy and respect for the existing place - before and after the event occurs - are guaranteed, as well as the sustainability if the aforesaid natural materials are employed.
Finally the most important and useful employment of these tensile structures can be considered that of the weathering protection: either in winter, from rain (if the membrane is impermeable) and wind, or in summer from sun and heat, a tensile structured membrane can become a hosting roof, creating in the end, even in a public and open space, a social gathering effect: in a world in which the conviviality and the de-growth seem to strive for becoming life philosophies, staying together becomes the unique way for avoiding to damage the environment and at the same time to be happy.
And we can here recall the well-known concept of the famous economist Latouche: "[…] a policy design […] of constructing, in the North as well as in the South, convivial, autonomous and sober societies, […] the degrowth project is […] a utopia, or in other words a source of hope and dreams. Far from representing a flight into fantasy, it is an attempt to explore the objective possibility of its implementation… degrowth is a political project […] it means building convivial societies that are autonomous and economical in both the North and the South"[9], and following this logic, de-growing temporary systems, instead of making our cities to grow more and more every day becomes necessary and mandatory.

## References

AAVV (1961), *Tense structures*, in: "Architecture D'aujourd'Hui n.99" (Dicember).
AAVV (1972), *Tense structures*, in: "Architecture D'aujourd'Hui n.162" (Dicember).
AAVV (1972), *Tensile, Space, Pneumatic structures,*

*a review of contemporary architecture*, in: “Zodiac n.21 September”, Milano: Edizioni Comunità.
http://www.architetturatessile.polimi.it/.
MAJOWIECKI, M. (1985), *Tensostrutture, progetto e verifica*, Milano: CISIA.
OTTO, F. (1969), *Cable structures*, Massachussets: MIT, Cambridge.
OTTO, F. (1984), *L’architettura della natura*, Roma: Officina.
SCHLAICH, J., BERGERMAN, R., SOBEK, W. (1989), *Tensile membrane structures*, in: “IASS Congress Madrid”, September.

## Notes

1 - GONCA ZEYNEP TUNÇBILEK (2014), *Temporary Architecture*, in: “Proceedings of the 2nd ICAUD International Conference in Architecture and Urban Design”, Epoka University, Tirana, Albania, 08-10 May.

2 - AHMED EL SERAGY AND AMIRA ELNOKALY (2006), *Appro priateness’ of the Use of TensileMembrane Structures in Hot Arid Regions*”, in: “The International Conference on Urbanism and Culture”, October 28-30, Cairo, Egypt.

3 - OBERTI, I. (2009), *Requisiti energetico-ambientali delle costruzioni tessili*, in: Campioli, A., Zanelli, A., “Architettura tessile. Progettare e costruire membrane e scocche”, p. 168-176, Milano, page 168.

4 - See: PAOLINI, M. (1972), *Tensile structures with Steel cables*, in: AAVV (1972) “Tensile, Space, Pneumaticstructures, a review of contemporary architecture”, in: “Zodiac n. 21 September”, Edizioni Comunità, Milano, and MAJOWIECKI, M. (1985), “Tensostrutture, progetto e verifica”, CISIA, Milano.

5 - The more detailed description of the Frei Otto genial works ca be found in the present book by Sergio Pone.

6 - BOTTERO, M. (1972), *Munich tensile structures and progress*, in: “Zodiac n. 21 September”, Edizioni Comunità, Milano, page 2.

7 - HEHEKOUT, M., (1972), *Frei Otto and the Munich Olympic* games, in: *Ivi*, page 23.

8 - See in the present book the chapter by Michele Castaldo.

9 - LATOUCHE, S. (2009), *Farewell to growth*, Policy Press, Cambridge, pages 31-32 [LATOUCHE S. (2007) *Petit traité de la decroissance sereine*, Mille et une nuits, France].