LIGHTWEIGHT STRUCTURES in CIVIL ENGINEERING
INTERNATIONAL IASS SYMPOSIUM
Organized by Polish Chapter of
International Association for Shell and Spatial Structures
Warsaw, 24-28 June, 2002

ARCHITECTURAL VALUES OF SUPPORTS IN TENSION MEMBRANE STRUCTURES

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ABSTRACT: The article presents the search for architectural values occurring in the supporting elements. The study has been restricted to the objects with structures of fabric appropriately shaped and tensioned, due to the fact that supports in such structures are clearly exposed and decide upon the expression of the entire object.

Key words: tensile structures, membrane structures, fabric roofs

1. INTRODUCTION

We have been able to observe the permanent growth of the number of structures using fabric as a load carrying element for several dozen of years now. Such structures are often called tent structures or in short - tents. The use of the term „tent", however, induces a pejorative association with their temporary nature and low durability, while the fabric structures made now have over 25 years durability and are not put up in the summer only and dismantled for the winter season to be protected against bad weather conditions. Furthermore, the light weight of fabric structures allows to use them in objects of immense span.

Special type of fabric is the basic load carrying element. Fabric and the tie rods are flabby materials able to convey tensile stresses only, therefore they require strictly defined fitting methods. For appropriate spatial rigidity, even with unfavourable gusts of wind, they need appropriate shape. Flat surfaces of fabric may function as a covering of a structure sufficiently rigid, however, are not wind resistant. They start to vibrate under wind and make arduous noises in short called flutter.

The use of fabric as a load carrying element is possible thanks to its proper formation. The introduction of initial stress allows to stiffen the fabric, but within certain limit only. Even slight gusts of wind affecting the large surface of the fabric cause its deformation and the increased initial stress exceeds the fabric strength. In order to prevent it, the fabric surface should be formed to have negative Gauss curvature [1] i.e. to have an opposite bend in each point. In experiments such surfaces can be obtained from soap membrane and the surfaces obtained that way are called minimum surfaces. Such surfaces, to use a highly simplified terminology, are most frequently called saddle or conic surfaces.

Obtaining the proper shape of the tensioned fabric is possible thanks to the use of appropriate arrangement of the supports. Kolendowicz [5] presents the precise definition of an element that immobilizes another structural element by eliminating its degrees of freedom. A support as a part of an engineering structure first of all performs the structural function and in tensioned fabric structures, the support being particularly exposed, participates in creating the object's form. Therefore, the selection of appropriate shape harmonizing with the whole is so essential. Comparing the visual size of the fabric surface and the support elements, the supports may be treated almost as the architectural details. Colloquially, details are what we call the fragments of the architectural finish of a structure, e.g. framing of an opening or the architectural development of a structure substantion [4].

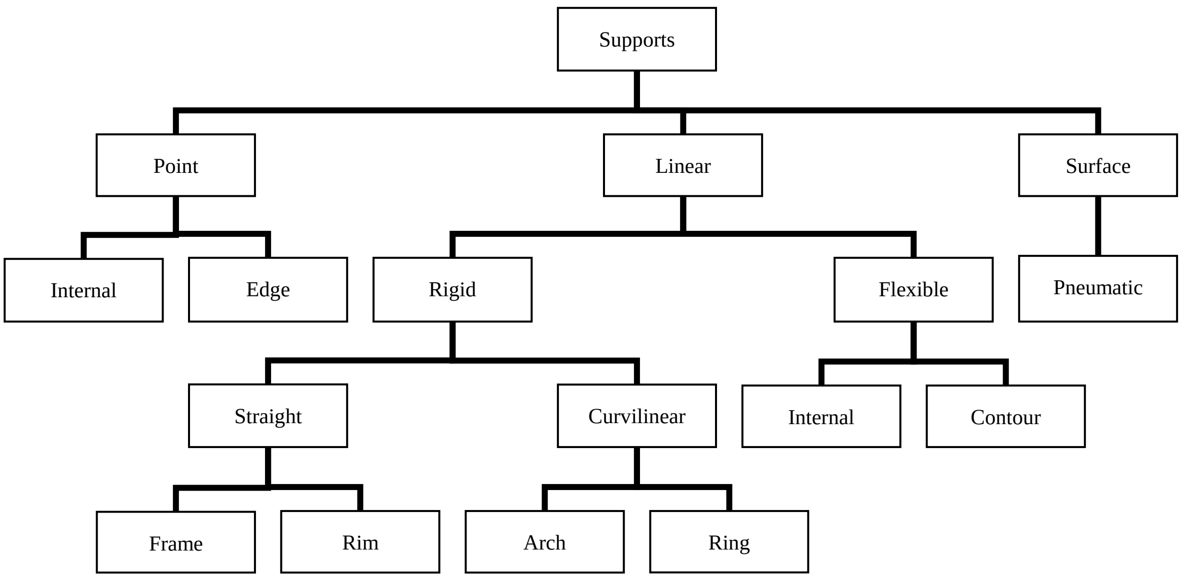

Diagram 1. Types of support elements

2. TYPES OF SUPPORTS

Types of supports applied depend on the structural system assumed, type and extent of internal forces, type and properties of construction materials used, workmanship and assembly methods and most of all of the creative invention of the designer. When proposing a particular solution, the author influences its architectural value.

The classification of supports occurring in stretched fabric structures can be made by material used, support shape, of load conveying methods. The classification suggested above has been made by the manner of fixing the coating.

The manner of terminating or fixing the fabric is technically the most difficult element of the structure, the point the low strength internal forces from the fabric are transmitted onto the multiplied strength of the support elements. The designer's task is to form this element so as to give the whole structure appropriate artistic value.

3. ANALYSIS OF EXAMPLES

A few selected examples have been analysed in order to check in how much the supports perform a structural function and in how much they could be treated as details emphasizing the object's architectural form. The examples vary by size and designation. From small open canopies to immense shields closing some internal space. In the objects analysed the application of the laws governing the architectural forms were searched for, such as: proportionality, similarity, stress, division and contrast.

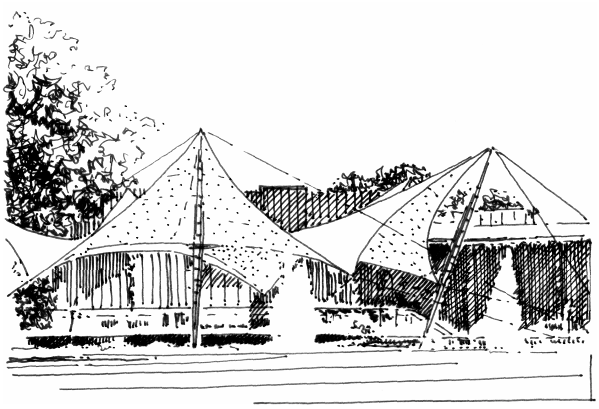

Fig. 1. Canopy roofing over a dance floor in Koeln.

The first of the examples presented is the canopy roofing over a dance floor in Koeln, Germany. The author of the canopy roofing made in 1957 is Frei Otto. Six supports have been used in this canopy roofing, each forming an inclined open-work post. The light steel posts with triangular cross-section, although 10 m long, are almost invisible against the full covering of the roofing. It is not only the contrast between the membrane material and that of the support that occurs here, but also between the curvilinear form of the membrane and the rectilinear form of the posts. In order to maintain the proportions of the particular supports, their width in the central part has been increased and the use of the open-work posts did not increase the optical weight of the whole. The covering surface, although strongly corrugated, which results in division into smaller parts, nevertheless the central symmetry joins it together creating a very strong form, while the supports constitute clear accents against its background and their repetition makes a conspicuous rhythm harmonizing with the whole.

Another example discussed is the grandstand canopy roofing at Lord's Cricket Ground, London. The authors are the designers from Michael Hopkins and Partners (1987). The canopy roofing consists of five larger and six smaller repeatable parts. The particular parts represent single surfaces supported on a quadrangle with central support ring representing the high point of the canopy and with edges fixed to the flexible connectors system. The canopy has been built on the old grandstand and constitute a connecting element between the stone wall and the white fabric. The colours, although refer to the fabric, clearly contrast with the membrane. The rhythm of ideally horizontal elements is interwoven with several vertical posts, the combination of which refers to the structure of tea-clippers and reminds of the sea power of England. The introduction of vertical supports in the points where smaller membrane elements occur represents an additional effect, which emphasizes the contrast even more and divides the whole into several repeatable parts. The size of the supports was additionally obtained by guiding them outside membrane edges and the tie rods fixing the fabric organically constitute the connecting elements.

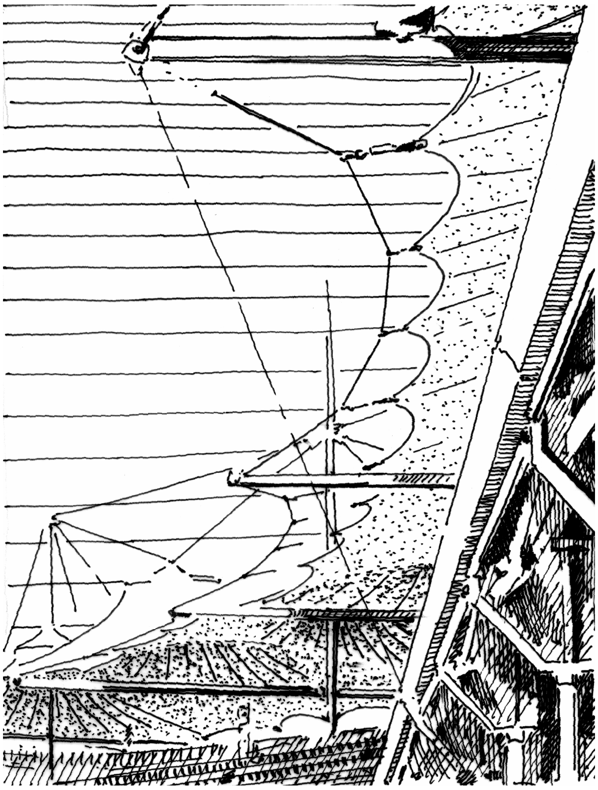

Fig. 2. Grandstand roofing at Lord's Cricket Ground, London

Another example is the sheltering of the grandstand of San Nicola stadium in Bari, Italy. The author of the structure built in 1990 is Renzo Piano Building Workgroup. In this case the canopy roofing covers the all the grandstands of the stadium. The supports for the roofing are steel bent cantilevers with a box-section, mounted on the grandstand structure. The conspicuous thickness of the load carrying elements, characteristic for the ferro-concrete structures refers to the grandstand structure and clearly contrasts with the fabric membrane.

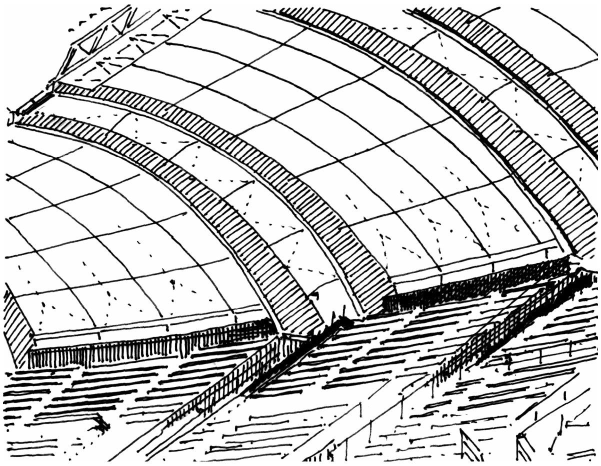

Fig. 3. The Stadium in Bari

The applied rhythm of supports causes that it is not tiring with 52 repeats, in addition being the result of the sectors' rhythm. The varying thickness of the cantilevers is emphasized by the distribution of stresses and the structure's logic, whereas the cantilevers' inclination towards the centre clearly sets the internal space ajar. The introduction of connecting elements increasing the fabric's strength, divides the particular surfaces into smaller fields, which reduces the visual perception of the membrane strong form.

An example of canopy roofing closing the total space below is the canopy roofing of Inland Revenue sports hall in Nottingham. The authors of the structure are Michael Hopkins & Partners. The major supports are four inclined posts supporting with tie rods the bent double beams. The posts and the tie rods resemble masts with cordage. They are made with steel pipes and seem to be slightly too lean with the roofing surfaces so large. With the double symmetry of the arrangement and clear convexity of the membrane, the inclination of the posts somewhat opens this compact form. Additionally, the tie rod arrangement makes the structure exceptionally light, almost hovering over the ground. The use of the fabric allows to save energy through taking advantage of daylight.

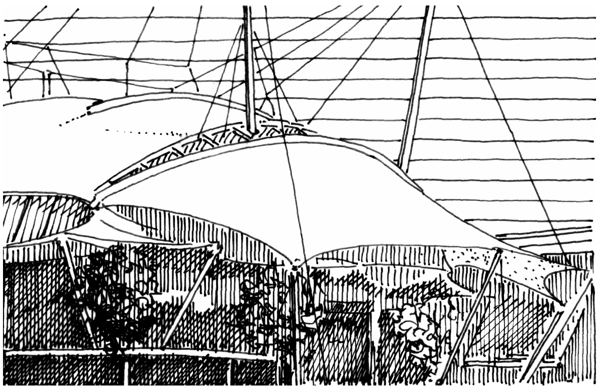

Fig. 4. Inland Revenue sports hall roofing

The last example discussed is the sheltering wall of the Burj Al Arab hotel in Dubai. The entire structure was built in 2000 by WS Atkins & Partners, its height is 321 m and the wall made of fabric, sheltering the internal atrium is the largest one in the world. The supports fixing the fabric membrane are visible inside the hotel only. From the outside the edges of the particular surface patches are visible, i.e. the points the supports are located on the other side. The edges, like the edges of flutes (horizontal here) on a Doric column shaft refract the light and introduce an interesting rhythm, essential with the wall surface so large. Inside the atrium the support elements represent a valuable supplementation to the structural elements. Against the very strong form of the ferro-concrete truss, the steel arches seem to be details made of lace. The horizontal arches supporting the fabric create a somewhat internal framework of an organism covered with a fabric membrane, whereas from the outside the membrane form refers to that of rectangular sails inflated by the wind.

4. CONCLUSIONS

The contrast occurring between the support and the fabric membrane causes that in all the cases the supports represent a conspicuous accent and attract our sight. The support elements, however do not dominate over the whole, they only constitute its valuable supplementation. The frequent repeats diminish the visual significance of a single support even more, through the introduction of the reassuring rhythm and development of perceptive experiences.

One can see the immense significance of a support in fabric membrane structures, which in addition to the load bearing function allows for a better understanding of the laws governing the structure performance, draws it closer to the observer and brings in the sense of order. The architectural details in the historical structures artificially refer to the ancient ones rested on posts and beams, representing decorative elements only, while the support in fabric membrane structures, despite their coarse technical form, may constitute a valuable supplementation of the architectural expression of the whole structure.

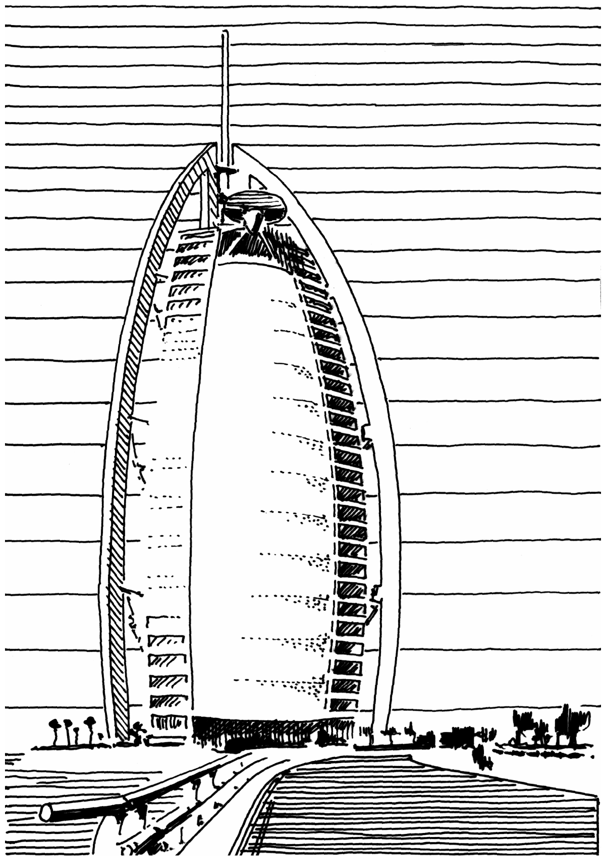

Fig. 5. The Al Arabei Hotel in Dubai

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