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Cable Mesh Structures

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Abstract: This paper presents the spectacular beauty of mesh of cables structures. There are presented here some representative examples of buildings that use cable meshes, curved in two directions.
Keywords: mesh, cable, curved, structures

1. INTRODUCTION

A construction is defined as being a tridimensional structure.

To create a construction, the architecture needs technique. With the help of technology, it takes shape and becomes an expression for its era. The technique always influenced the architectural shapes.

Nowadays, the architecture is characterized by an exaggeration of the technical side, hence neglecting the artistic nature of the constructions.

There is a simple question that needs answered: can the useful be also beautiful? The structural shapes do not result from calculus, instead they are of a configurative nature. The relationship between construction and shape are more complicated than what a calculus result would suggest. It is, nevertheless, an artistically creation and this justifies its name: "structural shape". We must understand it as an artistically and constructive expression, which was inserted in an architectural concept and considering, in the same time, the laws of nature. This combination makes the construction have a valid expressive force.

Architecture always presented structural shapes. These shapes persist in time, and are more durable than the styles of the eras. Each material and each construction method leads, in each civilization, to another option. But, as long as the laws of the structure are obeyed, the shape principle remains the same in all cases.

Even if a skeleton based structure is in fact tridimensional, the engineer designs it as being planar, the spatial connectivity between the inner elements being ignored. This fact simplifies the calculus, but the construction surely holds bearing capacity reserves.

The modern construction with a framing structure is a result of using steel and concrete. Among its characteristics, we can mention the cross-section reduction of all bearing elements, based on a minimal static dimensioning and on a clear separation of the bearing structure from the non-bearing elements.

The framing construction has, at its basic concept, beams and column, connected to create a rigid system. This system lowers the self-weight of the construction and is economical, from the costs point of view.

From the wide variety of spatial load bearing capacity structures, the authors of this paper will talk about cable and net structures. The idea of the cable structure was used in the roof design and construction.

This paper refers to pioneering construction projects, the problems encountered in their execution and how to solve the difficulties that appear during their life time. In order to get to the actual stage of the construction elements, of their slenderness and resistance they had to go a long way. This path was taken by design engineers who were bold enough to find solutions to all encountered problems.

2. EXAMPLES OF CABLE STRUCTURES

One of the most known piece of construction based on curved cables on two directions is the Exposition Hall Rio Grande do Sul. The longitudinal sustaining cables are passed through two semicircular compression arches, anchored then into the ground. Between the two arches the cables are not parallel, being brought together concentric through transversal cables in the middle of the construction. All the transversal cables are in the shape of circle arches. It results, in the end, a part of a rotation shape, the longitudinal cables being the chains as the transversal ones forming the circles, as shown in Fig.1. Besides the two compression arches from the frontal sides of the structure, the rest of the cables are subjected to tension. In order to prevent slipping of the cables, a special device was used which maintained the initial geometrical shape of the structure, [1].

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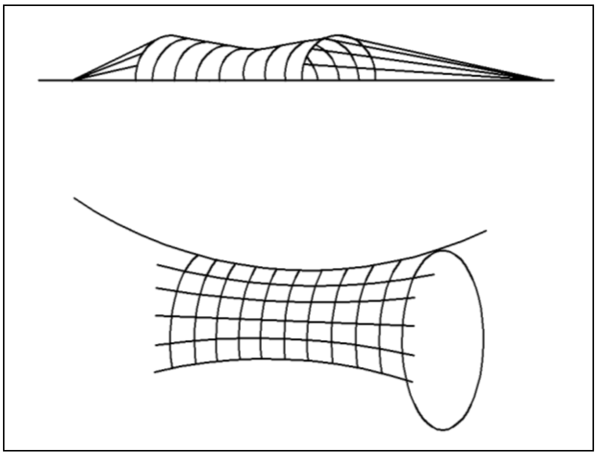

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b

Fig.1 Rotational shape structures, [6]

Another construction using cables curved on two directions is the Raleigh Arena, as shown in Fig.2, [3].

Fig.2 Raleigh Arena, [5]

Architect Nowicki created here the prototype of cable roofing. A series of cables are suspended between two parabolic compression arches. The second series of cables are perpendicular on the first, giving the mesh the special rigidity that is needed. In the end, both series of cables sustain the roof, as it can be seen from Fig.3.

Due to the fundamental idea of double curvature surface using only tensioned cables, the weight of the roof structure is highly reduced, in comparison with other roof types. The special rigidity of the roof is directly proportional with the curvature of the roof surface.

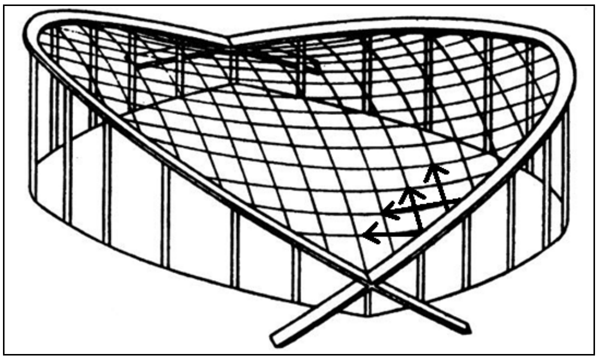
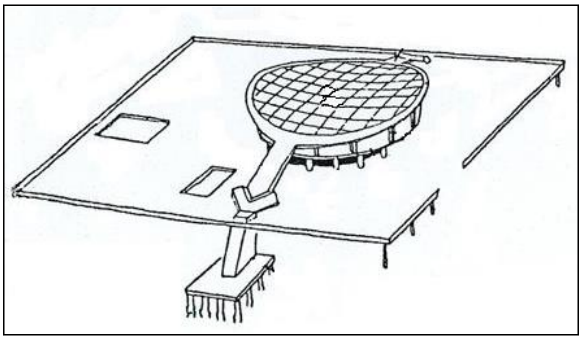


Fig.3 Raleigh Arena cables

In case of a symmetrical load, the compression arches are in equilibrium with the tensioned roof. In case of an asymmetrical load, the external walls support is needed. All the cables are in a steady equilibrium, the self load of the cables serves to both tension and compress the arches. The cable mesh together with the arches form a self sustained structure which does not need support from the exterior walls.

The Congress Hall from Berlin has a similar shape as Raleigh Arena, as it can be seen from Fig.4.



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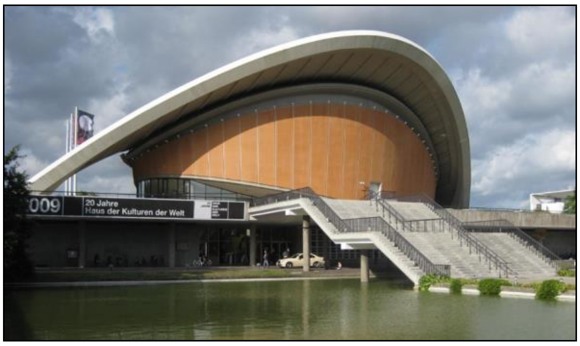

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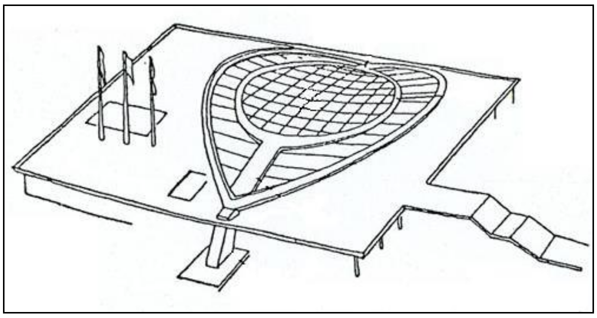
Fig. 4 a,b. The Congress Hall from Berlin (http://www.hkw.de/en/hkw/gebauede/50/1960.php)

The external wall support was replaced here by stiffening the middle of the structure. Over the hall walls is placed a very heavy ring beam, rigidly anchored in the compression arch foundation, Fig.5.

In the interior, over the hall, a reinforced concrete surface is placed. The arches were build and placed jointed by the ring beam, sustaining only the statically loads of the roof. The asymmetrical loads from wind and snow are absorbed by the rigid ring beam. The roof surface was separated into two halved, through the crest line. In reality, the stability of the compressed arches is maintained only with the help of the ring beam.

Both previous structures provided structural engineers a lot of challenges leading to the conclusion that the simplicity of the shape constitutes the way to building safe and beautiful.



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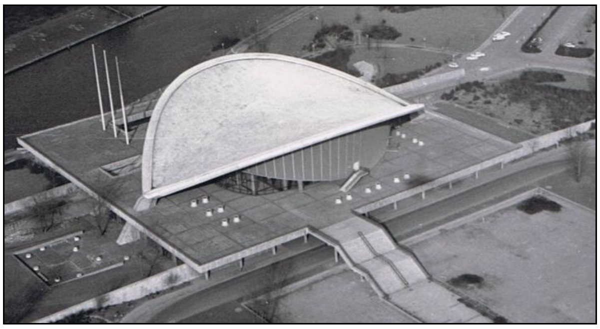

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Fig. 5 Top view, with the ring beam over the hall

Another structure of this type was built by the civil engineer Sarger, in Paris. A cable mesh with double curvature is placed between two compressed arches, over the hall, Fig. 6. It was seen that the compressed arches work better in longitudinal direction, the shape of the hall being given through cables, [4].

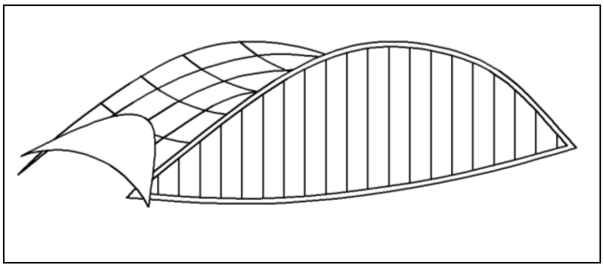

Fig. 6 Cable mesh over two compressed arches

The swimming hall from Monaco is another of Sarger’s projects, [2].

The cable mesh roof contains two transversal steel arches that sustain the suspended cables longitudinally, over which the transversal cables were mounted. The cable mesh represents, in this case, the walls, being build into the foundation. The cables were from a special kind of steel, of superior class. The weight of the compressed arches and the foundation make the structure tensed.

The surface of the roof is curved in two directions, ending in a marginal cable passing through a series of inclined columns and fixed at the base of the compressed arches. The structure has a very small weight.

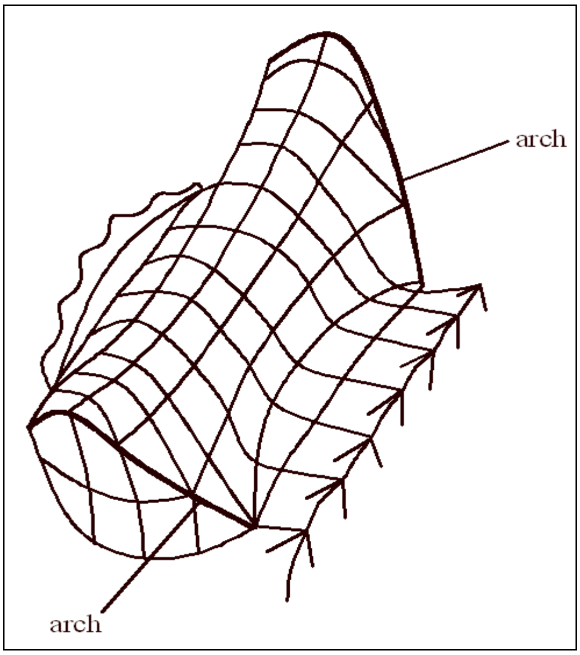

Fig. 7 Swimming pool from Monaco

From all his research, Sarger concluded that the cable mesh should be curved on two directions and contains only tensioned cables. The loads go up, through the suspended cables towards the highest points of the construction and transmit the tension through the supports. The strains are always tangential to the roof surface.

If the edge of a cable mesh is a polygon having a bended surface and straight edges, the tension in the cables determines bending efforts in the marginal edges. Through lowering and loading the edges the cable mesh tensions and all the loads go to the supports, as shown in Fig. 8. This idea was put into place by Sarger in Bruxelles Exposition in 1958.

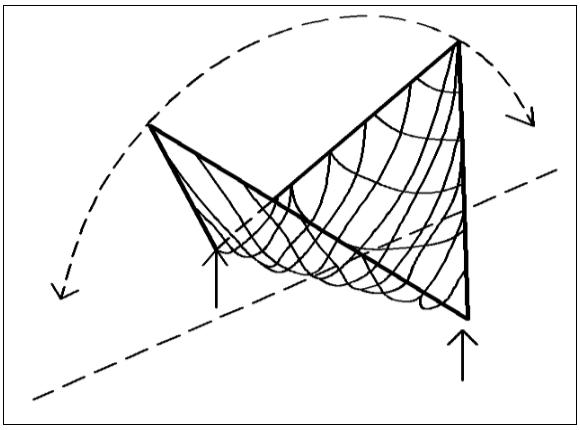

Fig. 8. Cable mesh polygonal surface

In the same year, 1958, at the same Exposition in Bruxelles, another construction was shown, this time from the architect Le Corbusier, namely the Philips Pavilion, shown in Fig. 9.

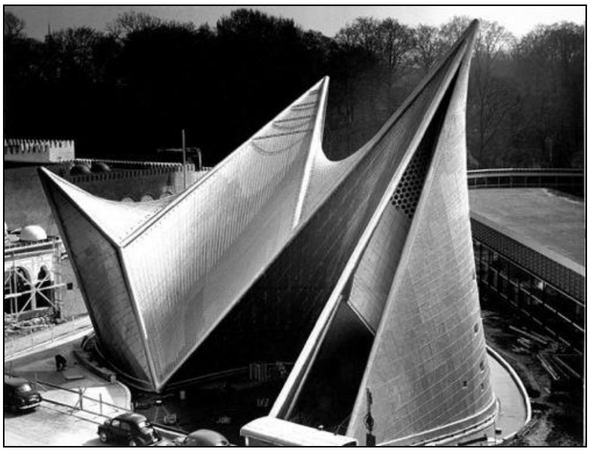

Fig. 9. Philips Pavilion, Bruxelles 1958

3. CONCLUSIONS

The main distinctive characteristic of this type of construction is obtaining the spatial rigidity through crossed cable tensioning on curved surfaces of opposite directions. In nature, the spatial cable structures resemble the wings of the bat of the feet of aquatic birds. Through these kinds of cable structures there are several types of roofs, including the curved wire mesh of opposite directions, whose stiffness is obtained by tension.

This paper refered to pioneering construction projects, the problems encountered in their execution and how to solve the difficulties that appear during their life time. In order to get to the actual stage of the construction elements, of their slenderness and resistance they had to go a long way. This path was taken by design engineers who were bold enough to find solutions to all encountered problems.

Today, the structures are of a wide variety, using a very high technology. Looking back to these structure, we are bringing a sign of respect and appreciation to all the engineers and architects that build art from another place in time.

REFERENCES

[1] *A., Meguro, J., Mitsugi, K., Ando,* A modular cable-mesh deployable structure for large-scale satellite communication antennas, Electronics and Communications in Japan (Part I: Communications), Volume 77, Issue 8, pag. 90–100, August 1994.

[2] *C., Siegel,* Structures of modern architecture, Editura Tehnica, Bucuresti, 1968.

[3] *F., Otto,* Neus Bauen in Brasilien, Bauwvelt, 1956, pag. 915

[4] *R., Sarger*, Valeur plastique des structures a l'Exposition de Bruxelles, L'Architecture d'aujourd'hui, Nr. 78, pag. 6.

[5] http://www.google.ro/imgres?q=raleigh+arena

[6] http://s3images.coroflot.com