BAR SPACE STRUCTURES - RULES OF SHAPING

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Space structures are built of prefabricated elements. This feature causes that arrangement of component parts in the space of a structure can be described by means of simple forms of symmetry which may be distinguish in 2- and 3-dimensional spaces. These structures designed as constructions of roof covers or as a construction of high-rise buildings should fulfil requirements resulting from static. The basic static lows are the lows of nature, therefore it is possible to notice some similarities between the forms found in nature and the results of engineering conception (Otto, 1985).

Bars placed in space in a uniform way and joined together by means of articulated nodes create constructions called bar space structures. Component parts of these constructions are subjected to axial forces only, resulting in the structures being more lightweight than bending constructions (Kolendowicz,1976). The modern shape of construction systems of the bar space structures were developed mainly by M. Mengeringhausen, R. Le Ricolai, S. Du Chateau and Z.S. Makowski.

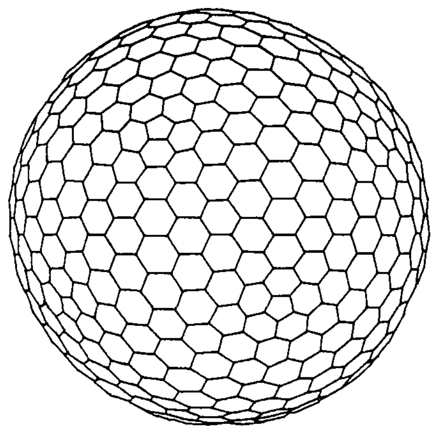
Space structures are constantly applicable to new and diversified useful purposes. They are often used as constructions of roof covers (Makowski,1993). Recently they are also proposed as structures of high-rise buildings (Rębielak, 1993, 1994).

If bars are located on a surface of single or double curvature then they can create a single-layer construction of roof cover of a span usually not greater than one hundred meters. When bars are joined in articulated nodes it is necessary to apply a triangular grid which is the most rigid form of bar grids. Such a grid, composed of bars of equal length, can be used only in flat or barrel constructions. A spherical structure has to be made of bars of different lengths. A triangular spherical grid of regular form should be made of bars of slight differentiation of their lengths, it should consist of the smallest possible number of bars of various lengths, and it should be composed of a minimum number of different triangular fields enclosed between these bars. This shape of spherical grid makes it easier to use prefabricated elements in such constructions (Rębielak, 1992). The triangular grid is the base of obtaining other forms of spherical bar grids. They are as usual determined on the basis of regular polyhedrons like the icosahedron or the dodecahedron (Fuliński, 1973).

Of all regular polyhedrons the icosahedron possesses the greatest number of the same faces in a form of equilateral triangles. One of the methods which makes possible to obtain regular triangular spherical grid is the method of secondary grid deformation. The concept of the method is to determine a triangular grid on the plane face of the polyhedron in a way which enables obtaining a spherical grid of minimum length differentiation of its segments after the grid projection from the sphere center. This method can be applied with the use of the properties of the central or orthogonal projection. In both the cases differentiation of spherical grid segment lengths is the smallest of all the possible to obtain for triangular spherical grids (Rębielak,1992).

The basic principles of geodesic dome shaping were given in the 50-s by R. B. Fuller. An example of a geodesic hexagonal bar grid is presented in Fig. 1a. A similarly regular pattern of the construction system can be distinguished in the skeleton form of a micro-structure called "radiolaria", the example form of which is shown in Fig. 1b (Tarnai, 1985).

a



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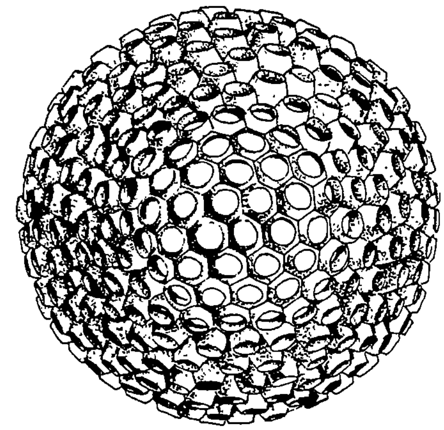

Figure 1

The pattern of this natural shape is very similar to patterns obtained by means of very regular subdivisions of spherical surface (Sanchez Alvarez, 1984).

The double-layer shape of bar structure can be created by connecting together two flat and parallel bar grids, by means of additional bars usually called as cross-braces. In this way it is possible to obtain a space structure of considerable rigidity which may be used as a construction of, for example, a roof cover of great span. In the pattern of bar arrangement in layers of these structures may by observed some similarities to the regularity noticeable in space grids of natural crystal structures. Bar space structures are multiple, statically indeterminate constructions which, among other things, means that forms of symmetry observed in patterns of force system sometimes can be completely different than forms of symmetry perceptible in bar arrangement in their spaces.

In the case of employing such structures in the construction of large span roofs it is advantageous if in areas of action of great stress forces relatively short bars are located (Rębielak, 1992, 1993), (Lalvani, Collins, 1991).

The formula of bar arrangement in multi-layer space structures can be adopted to designing of high-rise building constructions. Figure 2a shows the scheme of a structural system of a very tall building. The basic function of the construction system of a high-rise building is to transfer forces caused mainly by vertical, lateral and thermal loading to the foundation.

The most essential part of this construction (Fig. 2a) is the vertically positioned bar space structure situated on the perimeter of the building. The particular segments of circumferential

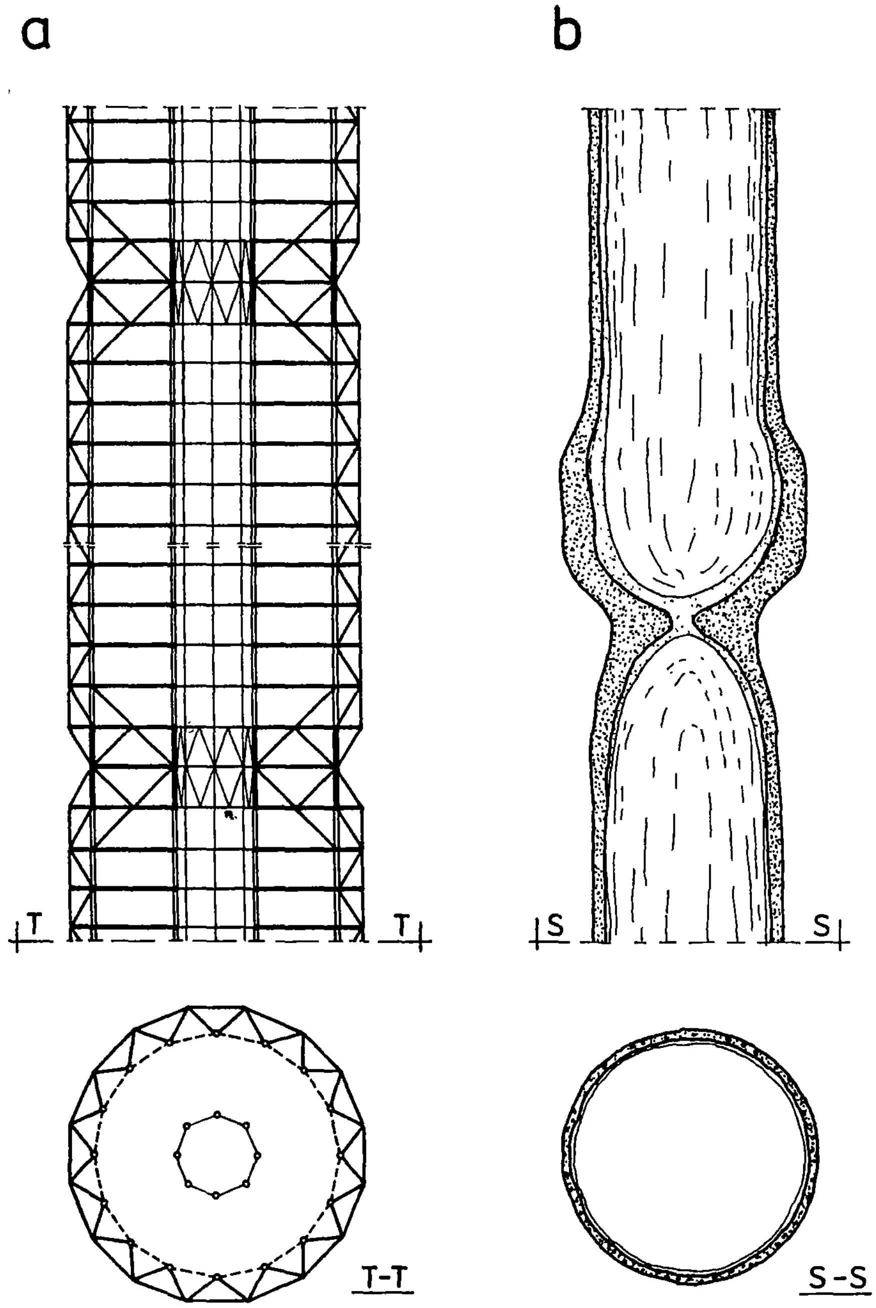

Figure 2.

bar space structure are connected by means of rigid horizontal discs shaped in the form of multi-layer bar space structures. It is proposed to use the spaces of these discs as spaces of the service storeys of high-rise buildings (Rębielak, 1993,1994).

In the scheme of this construction system some features common with biological forms may be seen. Figure 2b presents schemes of a vertical cross-section of a corn stalk.

Space structures can be applied also as constructions of roof covers and horizontal or vertical habitable megastructures. Features of this type of bar construction cause that its application as the structure of various buildings located in earthquake areas can be an economic engineering proposition in the near future.

Conditions of static as well as many other functional factors result in the finding of similar solutions of structures in nature and in engineering constructions. The regularity of these solutions entitles to stating that aspiration to symmetry is the structural necessity of nature formations as well as of results of engineering creativity.

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