EQUILIBRIUM ASPECTS IN SHAPING OF SPACE STRUCTURES

JANUSZ RĘBIELAK

Name: Janusz Rębielak, Architect, (b. Bierutów, Poland, 1955).
Address: Janusz Rębielak – Studio Projektowe, ul. Kilinskiego 2a, Bierutów, 56-420, Poland.
E-mail: j.rebielak@wp.pl
Fields of interest: Architecture, symmetry in spatial structures, numerical methods, applications of numerical models in architectonic and engineering projects.
Awards: Golden Mark of Distinction of the Wroclaw University of Technology, 1996; Silver Order of Merit, 1998; Distinguished Leadership Award of the American Biographical Institute, U.S.A., 2001; Golden Order of Merit, 2004; American Medal of Honor awarded by American Biographical Institute, U.S.A., 2004.
Publications: Rębielak Janusz: *Numerical models of chosen types of dome structures,* Proceedings of 4th International Conference "Mathematics & Design 2004", Mar del Plata-Buenos Aires, Argentina, 7-12 June 2004, Journal of Mathematics & Design, Special Edition, Vol. 4, No 1, 2004, pp. 239-249.

Rębielak Janusz: *Tension-strut systems shaped on basis of triangular-hexagonal grid,* IASS Symposium - Shell and Spatial Structures from Models to Realization, Extended Abstracts, ed. R. Motro, Montpellier, France, September 20-24, 2004, pp. 314-315.

Rębielak Janusz: *Symmetry in shaping of various types of spatial structures,* in: Symmetry: Art and Science, The International Journal of the Interdisciplinary Study of Symmetry, eds. G. Lugosi, D. Nagy, Sixth Interdisciplinary Symmetry Congress and Exhibition, Tihany, Hungary, October 22-29, 2004, pp. 214-217.

Rębielak Janusz: *Tension-strut structures and their numerical models defined in Formian,* 5th International Conference on Computation of Shell and Spatial Structures, IASS-AACM, June 1-4, 2005, Salzburg, Austria, Book of Abstracts, p. 140.

Rębielak Janusz: *Shaping of space structures. Examples of applications of Formian in design of tension-strut systems,* Oficyna Wydawnicza Politechniki Wroclawskiej, ISBN 83-7085-865-1, Wroclaw, 2005.

Abstract: *Structural systems of various types the spatial structures are often applied in modern architecture. These rather sophisticated systems are built by means of component parts arranged in the uniformly way in the space of the designed support structure. Members of the typical forms of these systems are subjected to the tension, stress or shear forces and the suitable equilibrium between them is the key factor of their stability. Lightweight structures in shape of the tension-strut systems are intended as a special structures, which consist of components subjected only to the tension or stress forces. The design processes of the spatial structures, especially of dome covers, are complex and nowadays they need application of appropriate numerical methods.*

1 GEODESIC DOME STRUCTURES

Shape of the dome cover, among numerous types of roofs, has a special historical and structural importance. Geodesic dome is a spectacular form of the spatial structural system. In the architectonic form of it is clearly visible the mathematical rules of the regular subdivisions of a sphere surface what causes its structural advantages and attracts attentions of even the casual visitors (After Fuller, 1975). This advantageous architectonic feature is caused by the minimum differentiation between the lengths of struts creating this excellent structural system, having some counterparts in nature (After Barnes, 2000), (After Berger, 1996), (After Makowski, 1992). The most stable is the triangular grid of the articulately connected members, that is why it is the most efficient structural solutions for these purposes. The triangular grid should resemble the sphere surface as far as possible and, for technological reasons it should consist of the lowest possible number of different members whose lengths vary within the minimum range. Simultaneous compliance with both requirements mentioned is a very complicated and difficult task and is the subject of numerous research. Two main stages of the procedure of determining the numerical models of a double-layer geodesic dome are shown in Figure 1a and in Figure 1b. The same rules of the equilibrium arrangement of component parts onto the appropriate spherical surfaces refer also to the process of the design of a triple-layer geodesic dome presented in Figure 1c and built by means of the VA(TH)No2 tension-strut structure (After Rebielak, 2005). In the both cases there is applied an icosahedron as the basis for the form creation of these geodesic domes.

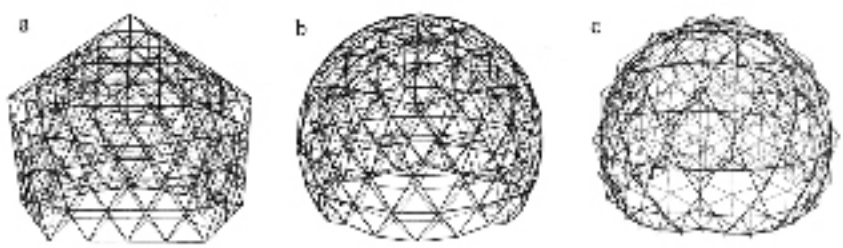

Fig. 1 Examples of creation of the complex forms of the geodesic dome structures

In some chosen cases it is advantageous to apply the more complex form of the basis for the shaping of a sophisticated geodesic structure. Another and special example of the geodesic form of the VA(TH)No2 tension-strut structure has been obtained on the basis of the icosidodecahedron. In this case suitable triangular and pentagonal areas of the structure are placed onto the appropriately chosen faces of this polyhedron, due to which the dome cover of the size of half of the sphere surface can be designed and erected.

The numerical model of this geodesic structure, like all structures presented in the paper, is prepared in the programming language Formian (After Nooshin, 1993). Visualizations of the two main intermediate stages of the entire shaping procedure are presented in Figure 2a and in Figure 2b. The final shape of the designed dome structure is shown in Figure 2c.

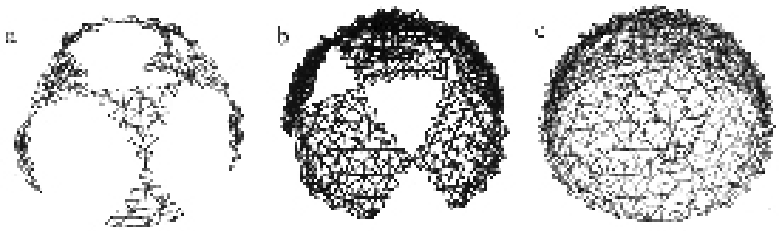

Fig. 2 Geodesic dome designed by means of the VA(TH)No2 structure on the basis of the icosidodecahedron

2 EXAMPLES OF OTHER FORMS OF STRUCTURES

The uniform way of displacement of components in space of a structure of large dimensions, which could be subjected to the load acting from the optional directions, has the curtail importance on its static stability and the equilibrium behave. One could notice it very clearly on examples of the cooling towers of the power stations, designed in shape of the hyperboloid of one sheet, see Figure 3. Space frames and tension-strut systems also can be applied for these purposes.

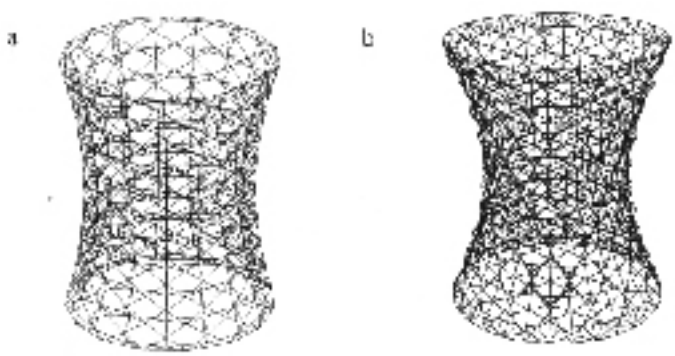

Fig. 3 Two examples of spatial structures of hyperbolical shapes

The first one, see Figure 3a, is designed by means of the double-layer space frame of the type DO (After Rebielak, 2005)and the second one, see Figure 3b, is planned to built by means of the triple-layer tension-strut structure VA(TH)No2. Many advantageous features of space structures motivate endeavors to apply them as the main support structures in objects of large scale. Space structures can be particularly promising in the design of very efficient structural systems of large scale where the balance of forces acting within them and the equilibrium of the entire system is warranted by the appropriate arrangement of component parts.

3 CLOSING REMARKS

The exceptional rigidity together with great possibilities in shaping and the relative

lightness drew the attention of architects and engineers to the space structures. The inner equilibrium of the force transmission is visible in the architectonic view of the building. Because almost everyone understands the flow of forces in the shell systems so the unity of the architectonic and the structural form is considered as perfect. The spatial systems are very efficient structural solutions having simultaneously unique and interesting architectonic form. These structural forms are very useful particularly in case of large scale objects. Many architects and engineers have designed a large number of these elegant objects sometimes of extraordinary beauty and unique aesthetic value.

Reference

Barnes, M., Dickson, M., eds., (2000) *Widespan roof structures,* Thomas Telford, London.

Berger, H., (1996) *Light structures – structures of light: the art and engineering of tensile architecture,* Birkhäuser Verlag, Basel, Switzerland.

Fuller, R. B., (1975) *Synergetics: Explorations in the geometry in thinking,* McMillan, New York.

Makowski, Z.S., (1992) *Space Frames and Trusses, in: Steel Design. An International Guide,* eds. Dowling, P.J.

Harding, J.E., Bjorhovde, R., *Elsevier Applied Science Publishers*, London-New York, pp. 791-843.

Nooshin H., Disney P., Yamamoto, C., (1993) *Formian, Multi-Science Publishing Co. Ltd.,* Brentwood,UK.

Rebielak, J., (2005) *Shaping of space structures. Examples of applications of Formian in design of tension-strut systems,* Oficyna Wydawnicza Politechniki Wroclawskiej, ISBN 83-7085-865-1, Wroclaw.