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STRUCTURAL SYSTEMS FOR MODERN ROOF COVERS

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KONSTRUKCIJSKI SISTEMI ZA MODERNE STREŠNE KRITINE
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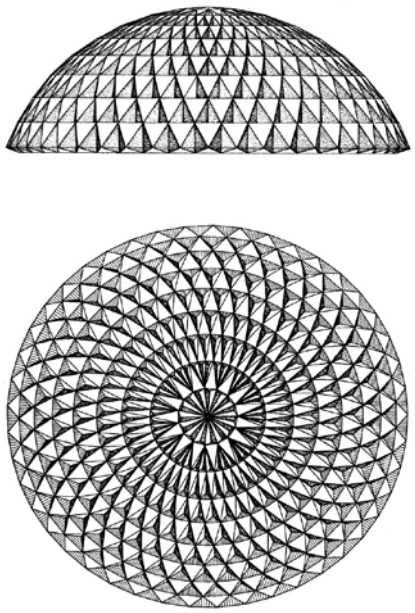
izvleček
Članek predstavlja morfološke vidike oblikovanja nekaterih konstrukcijskih sistemov, ki jih avtor predlaga za različne tipe streh. Ti sistemi so lahko gospodarne podporne konstrukcije za strehe velikih razponov in obenem omogočajo zanimive arhitektonske oblike. Prikazani so primeri konstrukcijskih oblik izdelanih za potrebe strešnih kritin za prekrivanje koncentričnih oblik tlorisne osnove ter geodetskih kupol. V postopku oblikovanja teh sistemov se uporabljajo moduli v obliki tetrahedrona, ki jih je možno na različne načine razporejati po prostoru ustvarjenega konstrukcijskega sistema.

ključne besede
konstrukcijski sistem, lahka strešna konstrukcija, arhitektonska oblika

abstract
The paper presents the morphological aspects of the shaping of some structural systems proposed by the author for various types of roofs, which can be economical support structures for large span roofs and at the same time may produce interesting architectonic forms. Examples are shown of structural forms designed for the needs of covering spaced over concentric forms of base projections and for geodesic domes. In the process of shaping these systems modules in the form of tetrahedrons are applied, which as repeatable units can be arranged in various ways in the space of the created structural system.

key words
structural system, lightweight roof structure, architectonic form

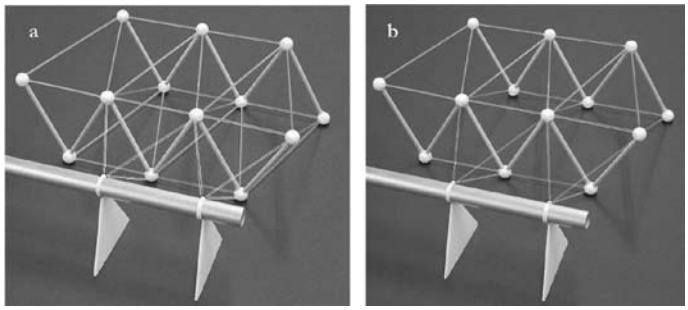
Introduction
Material form of an architectonic object is created by means of a structural system. Building technology has been permanently changed along the history of human civilization. On each stage of the development of architecture the right connection between the functional aspects, building structure and artistic form gives in result a building, which may be called a masterpiece of architecture independently of actually obligatory criterions of esthetic evaluations. In some historic ages, like in the gothic architecture, the structural system properly used according to materials common available applied in this time in building construction, played crucial role in shaping of architectonic views of buildings. Similar rules are respected in several architectonic trends have been emerged since beginning of twentieth century. Industrializations and mass production had an important influence on perception of architectonic form of numerous types of buildings. Rapid evolution of building technology and design methods, including computer aided processes of static and dynamic calculations, have opened widely possibilities of creation of amazing architectonic shaped, which were hardly to imagine or simply considered as impossible to build even a short time ago. Many types of modern structural system enable to build objects characterized by great economic, functional and structural efficiency and obtaining unique architectonic views. In the paper are presented selected examples of architectonic projects and structural systems recently worked out by the author.



Slika 1: Horizontalni in vertikalni pogled na sferično obliko primerno oblikovane steklene prostorske konstrukcije.
Figure 1: Horizontal and vertical views of spherical form of suitably shaped crystal space structure.

Structural systems for concentric forms of roof covers
Domes or similar roof covers are often spaced over circular or oval form of a base projection. Special type of a spatial frame,

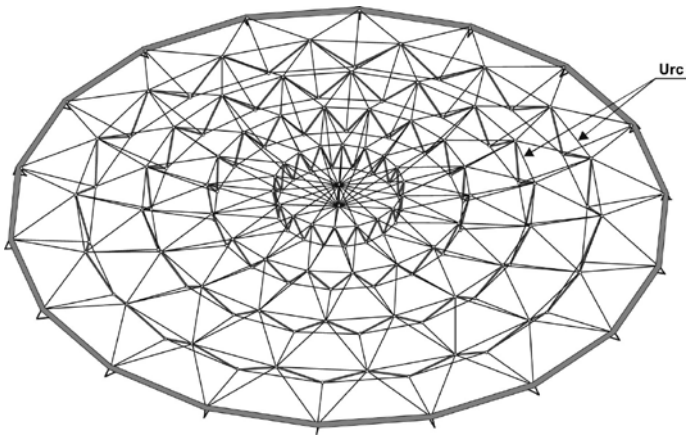
Figure 01 corresponds to Figure 1 in the text of the article, called crystal space structure, previously designed by the author [Rębielak, 1996], [Rębielak, 1999], [Rębielak, 2005], was an initial form for shaping of series of lightweight structural systems. Spherical form space structure causes, that the inner useful area could achieve advantageous conditions of diffused lighting by daylight. Specific view of the dome structure is obtained by suitable arrangement of the triangular flat panel elements placed between selected sets of cross braces of the structure. These panels are not intended as component parts of the structural system and they only create the architectural view of the dome. Half of the cladding panels in the upper layer of the spherical space structure are designed as typical roof panels. The second half is built by the window panels. This form was taken as a base for further transformations undertaken in order to obtain a lightweight bearing system for roofs of large spans.



Slika 2: a) Analitični maketi razporeditve nateznikov steklene prostorske konstrukcije, b) končna oblika po izločitvi več elementov spodnje natezne plasti.

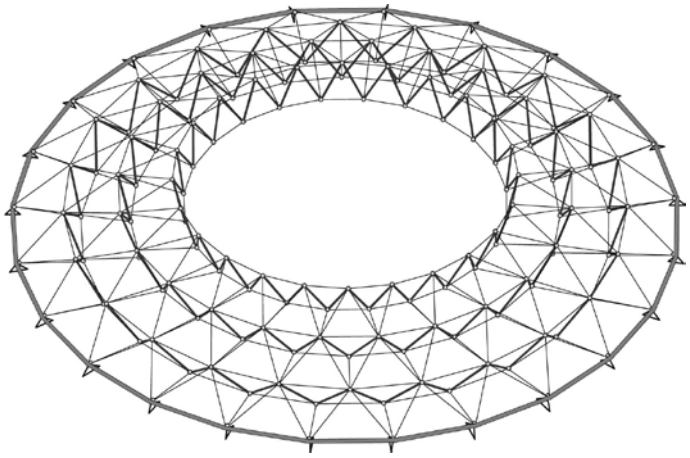
Figure 2: a) Physical analytical models of the arrangement of the tension-strut form of the crystal space structure, b) final shape after reduction of a number of the lower layer tension members.

In the first stage of the transformation has been changed statuses of selected members and then number of chosen components was reduced, Figure 02 corresponds to Figure 2 in the text of the article. Structure designed in this way is composed of small number of struts, which in successive concentric hoops are cross braces, while upper and lower chords are built by means tension members. This form of structural system is called tension-strut crystal. Membrane panels will be placed between appropriate members of the upper layer and they can fulfill at the same time role as components of cladding system and integral part of the structure. System obtained in this way, exemplary shape of which shows next illustration , Figure 03 corresponds to Figure 3 in the text of the article, is very rigid, lightweight, it can be assembled in relatively simple process therefore its entire structural efficiency can be estimated higher than efficiency of the similar Geiger's cable dome system [Geiger, 1986]. For instance numerous tension members running in the upper layer of successive concentric hoops marked by symbol Urc, can be removed after assembly process of the whole structure, which in this case still remains very stiff. Moreover the basic form of this system can be applied as structure of a roof cover with huge central opening, Figure 04 corresponds to Figure 4 in the text of the article, what other similar systems do not make possible.



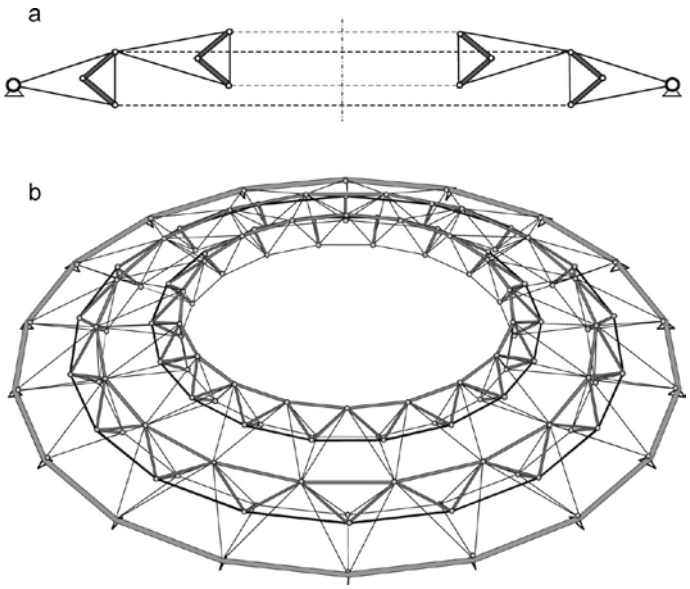
Slika 3: Splošni pogled na osnovno obliko konstrukcije nateznikov.

Figure 3: General view of the basic form of the crystal tension-strut structure.



Slika 4: Oblika konstrukcije nateznikov s središčno odprtino.

Figure 4: Shape of the tension-strut crystal structure with central opening.

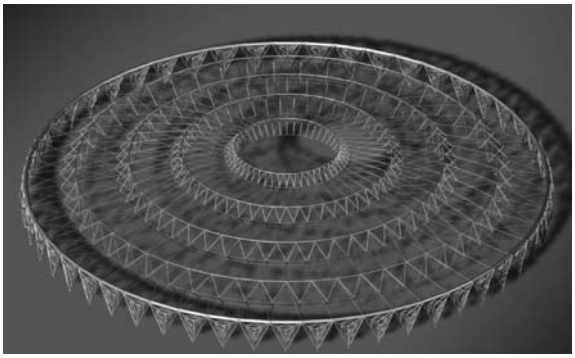


Slika 5: Primer oblike konstrukcije nateznikov tipa VU-TensO. a) shema glavnega vertikalnega prereza, b) pogled na celotno konstrukcijo kupole.

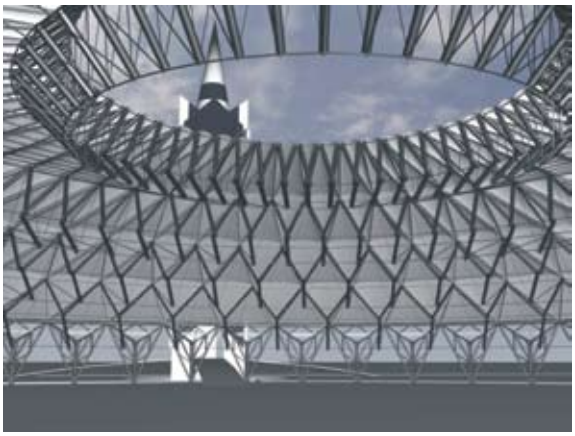
Figure 5: Example shape of the tension-strut structure VU-TensO. a) scheme of the main vertical cross-section, b) overall view of the dome structure.

The general composition of concentric hoops in space of the tension-strut crystal structure was taken as the next base for transformations undertaken on purpose to shape numerous group of similar systems [Rębielak, 2005]. During various processes of shaping it was applied a tetrahedron modules, which were spaced over chosen triangular fields of these concentric hoops. One of the technical solutions is the VU-TensO tension-strut structure, general schemes of which shows next illustration, Figure 05 corresponds to Figure 5 in the text of the article. In this case tetrahedron modules are directed towards the perimeter of the roof, they are spaced over upper triangular fields and vertices nodes of tetrahedron modules are connected together by means of tension members creating another type of concentric hoops. This last spoken system was applied in project of a large span dome cover called the Hall 2010 [Bać, 2004], [Rębielak, 2005]. It was the author's design proposition for the World Exhibition, intended in Wroclaw, in Poland, in 2010 but finally Shanghai in China was elected as organizer of the World Expo in 2010.

Visualization of numerical model, previously defined in programming language Formian [Nooshin, 1993], of structural this system is presented two next illustrations , Figure 06 corresponds to Figure 6 in the text of the article, Figure 07 corresponds to Figure 7 in the text of the article. Some ecological reasons were a background for the concept of this building. The Hall 2010 is designed as a multi-purpose object, it has the dome form of a relatively small rise and its clear span equals 365.25 meters, which is equivalent to the length of the year measured in the number of days and has other environmental meanings. The roof is supported in 52 supports, what corresponds to number of weeks in the year, designed as special forms of spatial frames. Dome structure is composed of four hoops, what is related to four seasons of the year. It has also a central opening, what is similar to oculus in the ancient Rome's Pantheon.



Slika 6: Pogled na celotno konstrukcijo objekta Hall 2010.
Figure 6: Overall view of the structure Hall 2010.

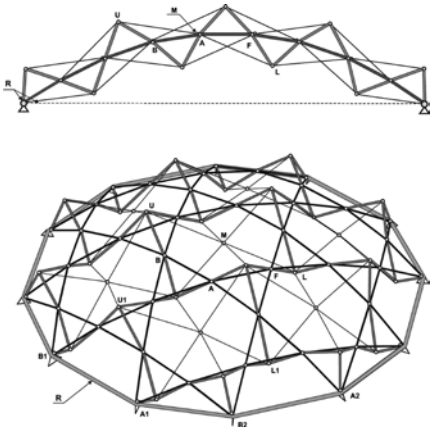


Slika 7: Pogled na notranjost objekta Hall 2010.
Figure 7: View of the interior of the Hall 2010.

Geodesic structures in architectonic projects

Patterns of some modern structural systems have their counterparts in samples of inner build of certain creature in the nature. It is happen in the comparison of geodesic domes and radiolaria, a component of plankton in ocean's water [Tarnai, 1996]. Geodesic structural forms has been widely promoted in modern architecture and engineering by a great American architect Richard B. Fuller [Fuller, 1975]. This form of the building bearing system is structurally very efficient and gives to the object inherent architectonic beauty following from pure mathematical subdivisions of a spherical surface. One of the structural tension-strut system, called VA(TH) No2 structure, is proposed also as structural system for several examples of geodesic domes [Rębielak, 2003], [Rębielak, 2005]. It was developed for reasons to be structural system for different types of roof covers, spaced over each form of the base projection and able to take any shape, even optional form, as a kind of the tension-strut structure.

The basic concept of this system is presented in Figure 08, which corresponds to Figure 8 in the text of the article. The VA(TH)No2 structure is built around the triangular-hexagonal grid of struts placed on the same, middle surface of that system. Tetrahedron modules are suitably located over triangular fields of this grid, vertices nodes of half of them are directed up while the second half of them are directed down. Vertex nodes of these modules are connected by means of appropriate system of tension members, directions of which are focused in nodes, like node M, placed on the middle surface in centers of usually hexagonal fields. In case of this structure existence of the perimeter ring (R) is not obligatory.
The newly developed tension-strut structure VA(TH)No2 was proposed as the structural system for a special type of a geodesic dome and suggested to be placed in a central area of the intended future Centrum GEO of the Wroclaw University of Technology



Slika 8: Shema prostorske razporeditve sestavnih delov natezne konstrukcije tipa VA(TH)No2.
Figure 8: Schemes of arrangement of component parts in space of the VA(TH)No2 tension-strut structure.

[Rębielak, 2006]. The Centrum GEO shall be located on the left bank of Odra river, in front of the current main campus in the close distance to the historic center of the city of Wrocław. The geodesic structure of this object was planned as the test structure in the nature scale for the long term research intended to testify behave of the metal structure and various types of cladding system, which be successively changed during the investigation and usage of this object, Figure 09 corresponds to Figure 9 in the text of the article.

Upper part of the inner space of the dome was devoted for a multipurpose hall, lower storeys were intended as space for interdisciplinary research laboratories and in the basement was proposed to locate a wind tunnel. The diameter of the dome is rather small, because it is around 30 meters, and this magnitude follows from the urban restrictions for this down town area. General views of the central part of the Centrum GEO are shown in Figure 10, which corresponds to Figure 10 in the text of the article.

Conclusions

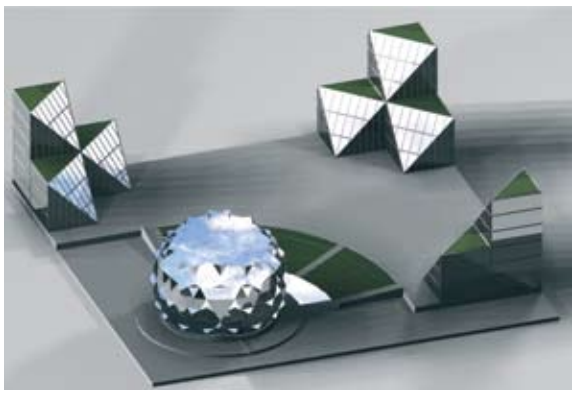
Proposed forms of structural systems can testify that the basic concept of spatial structures still has great development potential in area of shaping various types of them, which makes possible to create individual and interesting objects of unique architectonic forms. It refers to all groups of structures and objects, in particular it means to the frame, truss and tension-strut systems as support structures of roof covers. Scope of architectonic forms possible to obtain by means of presented system is extremely large, almost unlimited and is determined by the creativity of the architect necessary aided or supported by his suitable engineering knowledge.

Proposed systems can be applied as lightweight support structures of numerous types of roof covers. They can be used for needs of new designed or previously erected buildings in the modern architecture as well as for the roofs located in historic places. In the second case the architect should choose an appropriate technical solution, which gives in a result suitable architectonic view according to local tradition and other institutional requirements or restrictions.

New types of the proposed structures are lightweight, easy to assemble by means of prefabricated component parts of very simple structural shapes, due to which they can be economic and relatively not expensive bearing structures of even very large span roof covers. Erection processes of almost all of them can be made without usage of complicated assembly procedures and specific technical equipment. Application of them makes possible to design objects having very interesting and unique interior and exterior architectonic forms, which can be characterized by individual and spectacular artistic features.

Slika 9: Geodetska kupola projektirana s pomočjo konstrukcije tipa VA(TH) No2 kot stavba laboratorija za CENTRUM Geo, ki je namenjen novemu raziskovalnemu kompleksu wroclawske Univerze za tehnologijo.

Figure 9: Geodesic dome designed by means of VA(TH)No2 structure as a laboratory building for the CENTRUM Geo intended for the new research complex of Wroclaw University of Technology.



Slika 10: Pogled v perspektivi na osrednji del načrtovanega CENTRUMA Geo.

Figure 10: Perspective view of the central part of the planned CENTRUM Geo.

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