STEEL AND CONCRETE COMPOSITE CABLE SPACE FRAMES

Leonid Storozhenko, Grygorii Gasii

The paper shows creation of contemporary constructive solution for construction of buildings. It are steel and concrete composite cable space frames. The techniques of eliminating the weakness of the current structural solution of the long span roof structures of buildings and structures by adjustment and enhancement are presented. The concept of the steel and concrete composite cable space frames and all constructive solution were patented internationally.

Keywords: slab, node, bolt, grid, belt, rigid rod.

Introduction. The steel-concrete composite cable space frames are a novel kind of space bearing systems that have the pioneer concept. The steel-concrete composite cable space frames are used for covering different buildings and structures, including large-scale hangars of airports, machine galleries and depots, docks, structures of the mining and metallurgical industry, sports arenas, stadiums and others.

Analysis of recent sources of research and publications analysis has shown encompassed by efficient structures generally are emphasized composite roof structures, the uniqueness of which is a combined together concrete plates and steel bars. In consideration of the above, the intention to combine the plates and bars to collaboration in a novel structure by the unusual technique is unusual. The notion of the suggested solution lies in a combination both a practice and modern developments.

The task of paper is to think up an unusual conception of the pioneer and efficient space structures and their bearing elements and solve the issue of their production.

The main material and results. In the first place, it was getting review data about the specifics, both wealth, and weakness of actual structures. Structures that have attracted attention were the steel-concrete composite structures and space systems. In consideration of the requirements for modern structures, the up-and-coming solution are the steel-concrete composite plates, and cable systems, and grid structures (Fig. 1). Next analyzing the practice of application, and the results of both experimental and theoretical investigations, and behavior under a load of these kinds of structures. It was assumed that it is effective to develop them to invent advanced efficient compound of structural elements [1–5].

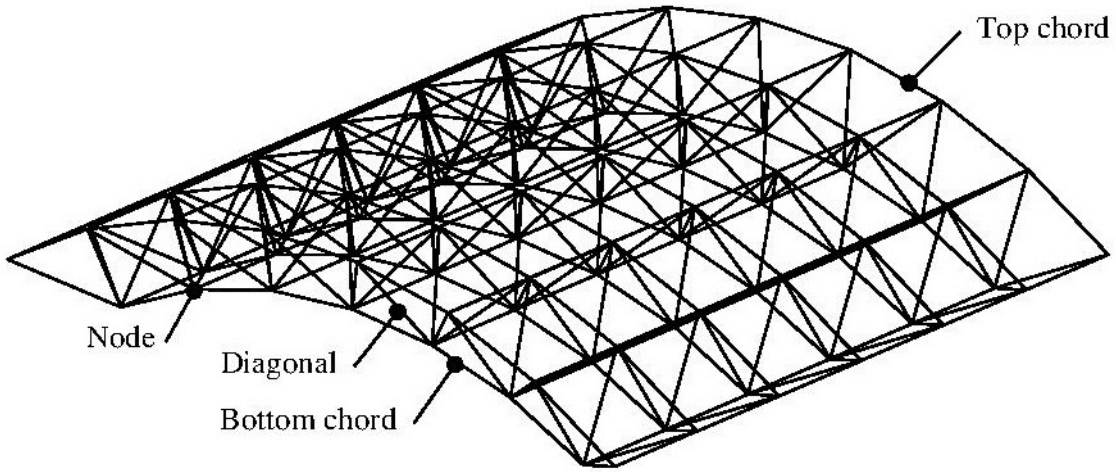

Figure 1. Ordinary double-layer grid structures

The procedure of finding novel techniques of connecting bearing elements and bettering current structural solution has formed the second step of the development of the steel-concrete composite cable space frames. On this step, besides straight endeavor to produce a novel technique of connecting structural elements and their position in the structure, furthermore, the attention was paid to the analysis the weakness of the considered structures and the means of their solving.

The main purpose of creating a novel design by bettering current ones was solution the issue that consists of the enormous involvement of nodal joins. The necessity of the solution of this issue certain by the fact that the bearing capacity and reliability of the nodes determine the bearing capacity and reliability of the structure as a whole. For the steel-concrete composite structures, this issue lies in the need to use diversity anchors in the cross sections to contribute joint the steel-concrete parts. This is in

general aggravates and complicates a structure. Sometimes, to the joint operation of the steel-concrete elements in combined the steel-concrete composite structures, there is a necessity to use steel profiles, in particular, double-T profile, to which are welded anchors. This is, contributes to weight gain too. In structures of this type, «compatible» concreting can also provide the joint operation between the steel-concrete elements. In the result of «compatible» concreting the «integrated» systems are created. This technique of providing the joint operation between the steel-concrete elements, in particular, the steel bar and the reinforced concrete slab is a promising direction for developing the novel structures. In flat grid structures, the issue of a complexity of nodal connections is an extremely acute, since it determines the overall complexity, weight, cost and construction complexity. Based on the results of the research of nodal connections of flat grid structures, it has been established that the most efficient solution for the nodal connections is the connections, which have connectors made of the steel plates. Nonetheless, there is a need to find the optimal configuration, which will allow minimizing the total length of the weld or number of bolts. The main drawback of the cable structures is their deformability and the ability to sag due to own weight at a sloping position and a long length, so the promising direction of modification of the cable structures is to find the optimal length of the elements and efficient position in a body of a structure. This can be reached by connecting cable elements and rigid elements in a single structure. An effective data for solution of this issue may also be a worldwide experience of designing architectural forms and structures that are functionally related. The best-known representative of these structures is tensegrity system. In such systems, realized ideal usage of the properties of structural elements. The systems consist flexible and rigid bars, respectively flexible bars in stretching and rigid are in compression. Obviously, the idea of tensegrity systems may be useful to design novel building structures. In general, structures that lack these deficiencies through improvement were considered as novel structural solution. Summing up all the received data of the both previous steps, the concept of the future design was clearly formed. First of all, this is a structure that consists of parts one of which should be manufactured as bars, which will in only axial forces. Depending what efforts will be in bars: compression or tension, the bars may be rigid or flexible.

The kind of the novel structure due to the location of the bars in the body structure was a double-layer tubular lattice. Nonetheless, the structure that was designed resembled current grid structures, so appeared to need a modification or an improvement, which would allow asserting about that the novel structure was developed. The first was the idea to create the grid the steel-concrete composite structure that is manufactured as a flat double-layer grid structure with a monolithic reinforced concrete slab. After analyzing the possibility of the improvement, it was concluded that such an approach allows reducing steel by replacing steel bars of the top belt on a concrete slab. The efficientness of this solution is confirmed by the fact that a two-layer grid structure has elements of the top belt that are in compressed, as it is known, the concrete resists well this kind of effort, so it is rational to use exactly concrete in that case.

Consequently, the first improvement of the kind of the novel the steel-concrete composite cable space frames was the replacement of the tubular bars of the top belt on the concrete slab (Fig. 2).

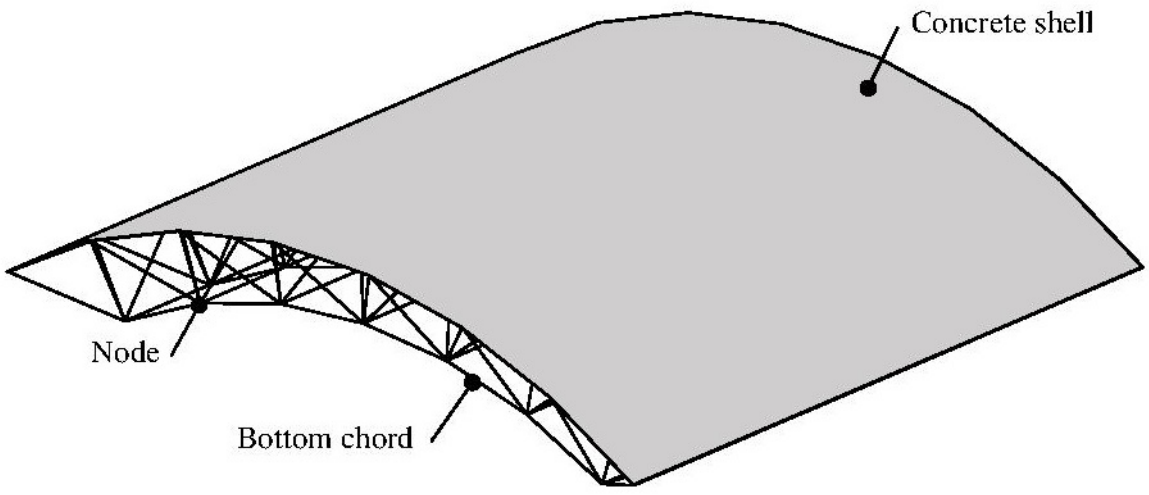

Figure 2. The steel-concrete composite space double-layer frames

Based on the idea of replacing elements, depending on the kind of internal efforts, it was decided to modify the bottom belt by replacing the rigid tubular bars by flexible ones, since the elements of the bottom belt are in tension, so it would be rational to apply flexible elements. Consequently, the plate-rod system that consists of flexible and rigid elements was developed, which fully complies the concept of the novel design. Nonetheless, this system was not flexible to shaping curve surfaces and had a complicated construction technology, therefore the next step in the development of the steel-concrete composite cable space frames was the division of the steel-concrete composite space frames into modular elements (Fig. 3) [6].

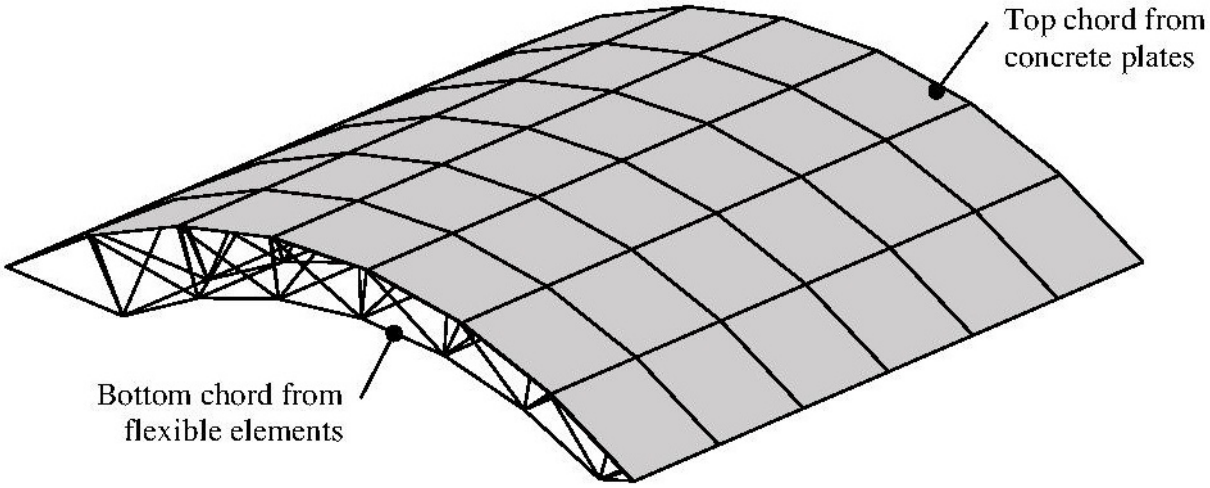

Figure 3. The novel the steel-concrete composite cable space frames

Consequently, a novel kind of structure was developed, it is the steel-concrete composite cable space frames. The final step of creating the structure was the development of joints.

Consequently, the structure that was created is a prefabricated double-layer system, which consists of space the steel-concrete composite modules and flexible elements of a bottom belt. The top belt is made of plates, which, depending on the reinforcement, can be reinforced concrete, ferrocement or the steel-concrete composite [7]. The bottom belt is made in the form of a flexible bar designed to only tensile forces.

The peculiarity of the steel-concrete composite cable space frames is connecting the advantages of the steel-concrete composite structures, space grid structures and cable structures. As well as, there is no need to arrange the roof during construction of the steel-concrete composite cable space frames because the top belt simultaneously performs two functions: bearing and protection against atmospheric influences internal space of buildings, so there is no need to apply costly roofing materials.

The space the steel-concrete composite modules may have different both forms (fig. 4).

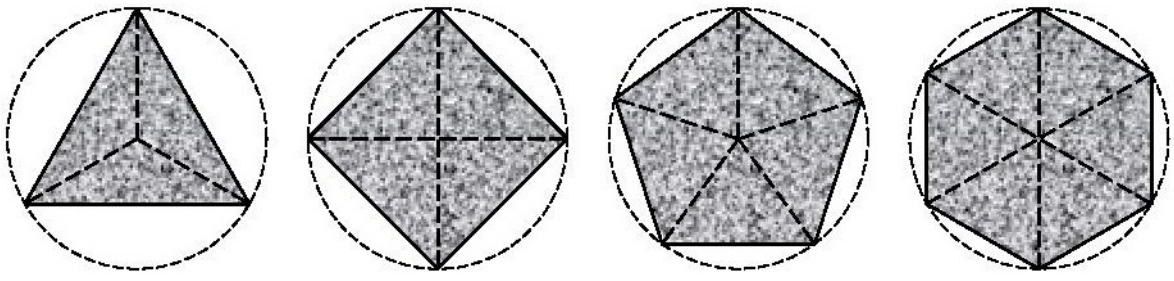

Figure 4. The shape kind of the space the steel-concrete composite modules

From the space the steel-concrete composite modules may construction different systems [8]. The novel the steel-concrete composite cable space frames are efficient for covering hangars, exhibition halls, stadiums, etc [9].

The main idea of the steel-concrete composite cable space frames is to obtain high strength characteristics and technical and economic benefits due to the combination of efficient structural solution, which elements in compression or only in stretching [10]. Also, in the basis of the steel-concrete composite cable space frames lies usage the principle of modularity of elements, i.e. the use of repeatedly repeated constructive elements of complete factory-made. The development purpose of the steel-concrete composite cable space frames was to obtain a novel competitive structure in the field of coating of buildings and structures, including different shells and other space forms, due to the combination of advantages and getting rid of shortcomings of the nearest analogs.

The essence of the steel-concrete composite cable space frames is the novel method of connecting the structural elements, which results in the combination of bearing and protecting functions, reduction of construction time, rational space work and rigidity, the ability to disassemble and re-assemble without destroying elements or nodes of the design. It should also be noted that the steel-concrete composite cable space frame has an easier technique providing joint work of the elements than in conventional the steel-concrete composite structures; less complex in manufacturing and arrangement of nodes connections than traditional space grid structures; less deformation than cable structures. In addition, the steel-concrete composite cable space frames are architecturally expressive, of low weight, are more resource-efficient [11] than other kinds of structures with related dimensions and bearing capacity.

Conclusions. On the basis of common information obtained from the analysis of theoretical and experimental investigation of the modern design solution, their design and construction specifics, wealth and weakness, the concept of novel efficient bearing systems was suggested in accordance with which a novel kind of structure was created. It is the steel-concrete composite cable space frames. The structural specifics of the steel-concrete composite cable space frame is that it is the modular system, which implements the principle of rational use of materials due to the pioneer combination of bearing bars and slab elements and the useful of their physical and mechanical properties. The wealth of the technological character of the steel-concrete composite cable space frames includes simple structure, construction technology, and installation of nods connection, and simple technology of manufacture of modular elements. It is significant that the manufacture of novel structures except the steel-concrete can be used completely different kinds of materials.

REFERENCES

1. Гасий Г.М. Эффективные конструктивные решения для пространственных сталежелезобетонных несущих элементов / Г.М. Гасий, О.С. Заболотский. – ҚазБСҚА ХАБАРШЫСЫ. – Алматы, 2016. – №3. – 94-103 с.
2. Стороженко Л.І. Визначення переміщень вузлів просторової структурно-вантової сталезалізобетонної конструкції експериментальним шляхом / Л.І. Стороженко, Г.М. Гасій. – Збірник наукових праць Українського державного університету залізничного транспорту, 2017. – №169. – 118-128 с.
3. Гасий Г.М. К выбору формы пространственных сталежелезобетонных структурно-вантовых конструкций / Г.М. Гасий. – Вестник Национальной инженерной академии Республики Казахстан, 2017. – №2. – 152-156 с.
4. Gasii G.M. Connections systems of the composite cable space frame / G.M. Gasii. – Сучасні технології, матеріали і конструкції в будівництві, 2017. – Т. 22. – №1. – 5-10 с.
5. Gasii G.M. Study of behavior of flexible bars as a part of the steel-concrete composite cable space frame / G.M. Gasii. – Construction, materials science, mechanical engineering. Series: Innovative lifecycle technology of housing and civil, industrial and transportation purposes. – Dnipro, 2017. – №100. – 64-69 p.
6. Gasii G.M. Kinds of the steel-concrete composite cable space frames / G.M. Gasii. – Science and Transport Progress. Bulletin of Dnipropetrovsk National University of Railtechnique Transport, 2016. – №6. – 158-165 p. doi: 10.15802/stp2016/90514.
7. Storozhenko L.I. Analysis of stress-strain state of the steel-concrete composite ribbed slab as a part of the space grid-cable suspended structure / L.I. Storozhenko, G.M. Gasii. – Academic journal. Industrial Machine Building, Civil Engineering, 2016. – №2. – 81-86 p.
8. Стороженко Л.И. Особенности конструкции и технологи монтажа новых пространственных сталежелезобетонных структурно-вантовых покрытий / Л.И. Стороженко, Г.М. Гасий, С.А. Гапченко. – Восточно-европейский журнал передовых технологий, 2014. – №1. – Т.4. – 67-72 с. doi: 10.15587/1729-4061.2014.26041.
9. Стороженко Л.І. Особливості будови та базові положення щодо проектування й виробництва просторової структурно-вантової сталезалізобетонної конструкції // Л.І. Стороженко, Г.М. Гасій. – Промислове будівництво та інженерні споруди, 2017. – №2. – 29-33 с.
10. Gasii G. Estimate of technical and economic benefits of a novel space composite structure / G. Gasii, O. Hasii, O. Zabolotskyi. – MATEC Web of Conferences, 2017. – №116. doi: 10.1051/matecconf/201711602014.
11. Gasii G.M. Comparative characteristics of the space grid-cable the steel-concrete composite slab / G.M. Gasii. – Вісник Національного університету «Львівська політехніка». Теорія і практика будівництва, 2016. – №844. – 260-265 с.