THE FLAT DOUBLE-LAYER GRID-CABLE STEEL-CONCRETE COMPOSITE STRUCTURE

G.M. Gasii
Ph.D., Associate Professor

Poltava National Technical Yuri Kondratyuk University, Poltava, Ukraine
Faculty of Civil Engineering
Department of Structures from a Metal, Wood and Plastics

ABSTRACT

The paper studies constructive concept of the flat double-layer grid-cable steel-concrete composite structure. The flat double-layer grid-cable steel-concrete composite structure is the new kind of roof system for long-span buildings. The composite structure has been developed in Poltava National Technical Yuri Kondratyuk University on department of structures from a metal, wood and plastics.

The feature of the constructive concept is in the bottom chord that consists of flexible rods and top chord that is made from a concrete slab. The flexible rods are made from segments of steel cables that have special details at the ends through which the segments are jointing to each other.

The bottom chord is not complex and its manufacturing and assembly takes not much time. Due to the use of steel cables the total weight of the structure decreases, besides we can save materials and as the result the total cost of construction also decreases.

Describes the results of the numerical investigation of load bearing capacity of the modular steel-concrete composite spatial unit.

INTRODUCTION AND PROBLEM STATEMENT

In the current development of scientific and technological achievements and increasing social needs of the population, there is a need to find more effective structure systems, including roof system. The main requirements that apply to the structure systems of buildings, in addition to reliability and load capacity, is an architectural expression, aesthetics, ergonomics and good indicators of energy efficiency. The important aspect of designing and finding constructive concept for new designs is the use of reliable and advanced materials. Steel and concrete with various modern fillings belong to the materials that satisfy that requirements.

The effectiveness of the developed designs also depend on how materials are used and behavior of constructions it means that materials should be under the forces, which they are resisting well for example steel rational are used as stretched or compressed elements but concrete as compressed elements. Considering this fact has been decided to combine steel rods and concrete slabs in a unified spatial design and further its research to a broad

implementation in practice of construction. This decision is a promising direction of development of building structures.

ANALYSIS OF RECENT SOURCES OF RESEARCH AND PUBLICATIONS

The analysis has showed that traditionally the most known large-span spatial designs are made entirely of steel members, including flat double-layer grid [1]. However, there are examples of steel combined systems [2]. In addition, steel-concrete composite constructions are used widely in a variety of designs [3, 4]. These constructions are used in many sectors of industrial and civil construction [5]. Steel-concrete composite constructions are used as roof systems, slab system, columns, different plate structures and bearing elements of buildings and structures [6].

HIGHLIGHT UNSOLVED PARTS OF THE GENERAL PROBLEM

Based on the analysis of previous studies and taking into account the advantages steel-concrete composite constructions the issue of development of the structural concept of the new spatial structure systems with its use has not fully investigated.

PROBLEM FORMULATION

The aim of the study is to identify the most promising and effective designs using the theoretical studies of the current state of construction and spatial steel and concrete composite structures. Given the physical and mechanical properties of materials and properties of structural elements is to offer and develop the new type of space structure systems.

THE MAIN MATERIAL AND RESULTS

The development of the construction industry is accompanied by the introduction of effective materials. The use these materials allows to get structure systems with the necessary strength characteristics and technical-economic indicators, but together with their development there is a need in the development of new geometric shapes and structural concept.

Now, the grid systems are the best known among long span and spatial structures. These systems have a great ability and flexibility to the form finding that evidenced by lots of original shapes in the world [7].

Flat double-layer grids are allocated more frequently from the general class of the grid systems than other. That is why, for the development of the new type of space structure systems has been taken the flat double-layer grids as a basis. The original concept of structural system has been developed using world experience of shaping large-span constructions. This is about the flat double-layer grid-cable steel-concrete composite structure (Figure 1).

This is the new kind of a spatial construction, the essence of which lies in reasonable uses of materials and their properties [8].

Figure 1. Segment of The flat double-layer grid-cable steel-concrete composite structure:
1 – a top chord; 2 – a diagonal; 3 – a bottom chord; 4 – a nodal bolted connections

The flat double-layer grid-cable steel-concrete composite structure consists of modular steel-concrete composite spatial units that are connected to each other through the nodal bolted connections (Figure 2) in an entire design.

Elements of construction are made with automated processes, especially this applies to the production of nodal parts and processing the ropes.

The modular steel-concrete composite spatial unit is made from segments of steel tubes and reinforced concrete slab.

The main peculiarity of the reinforced concrete slab is the structural concept. Slab is made from cement-sand mortar and steel woven nets. The slab have size 1500×1500 mm in plan and height of cross section 60 mm. The slab is reinforced with woven steel nets and steel bars (Figure 3).

The nets for reinforcing are made from thin steel wire that had a diameter of 1.2 mm. The steel nets have size of cell 20×20 mm. It is distance between the woven steel nets 5 mm. This distance is provided with steel disc-gaskets that were placed between nets. Steel disc-gaskets sre placed in every 200 mm.

Steel nets and steel disc-gaskets are connected together with a cement-sand mortar in a single structure. This way of reinforcement of the slab allows

reducing a weight and cost of materials in comparison with conventional reinforced concrete structures with the same bearing capacity [8].

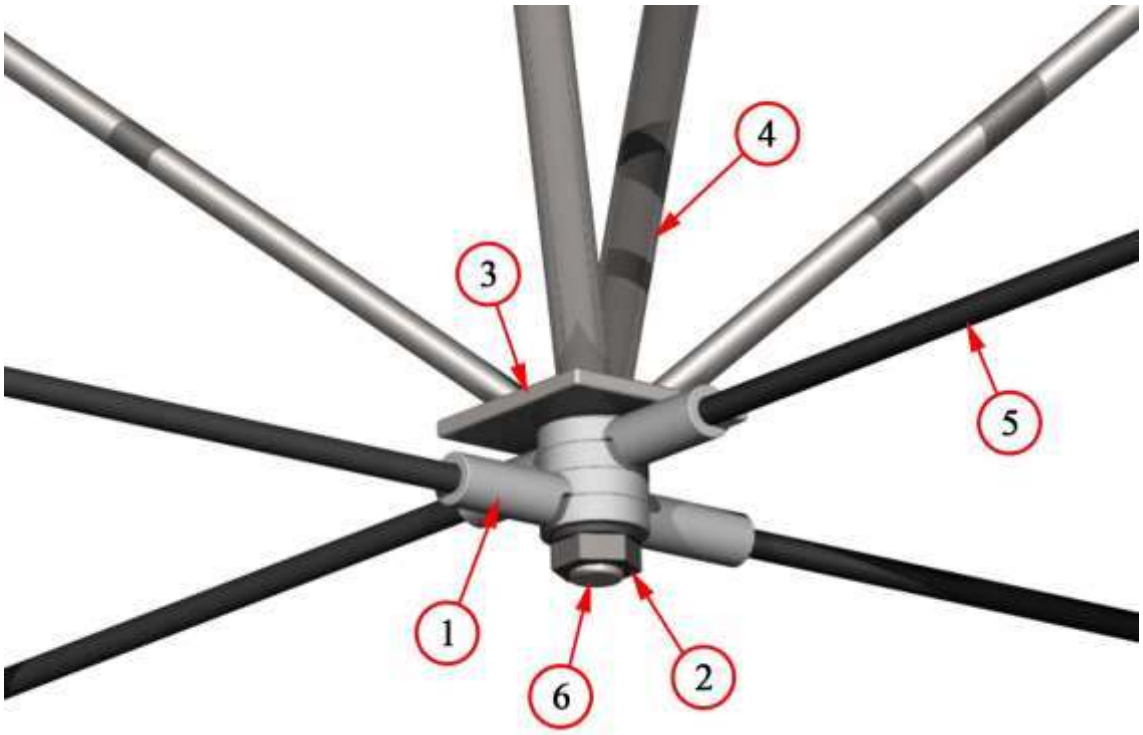


Figure 2. The nodal bolted connection:
1 – a connecting detail; 2 – a nut; 3 – a connecting plate; 4 – a diagonal; 5 – a bottom chord; 6 – a bolt

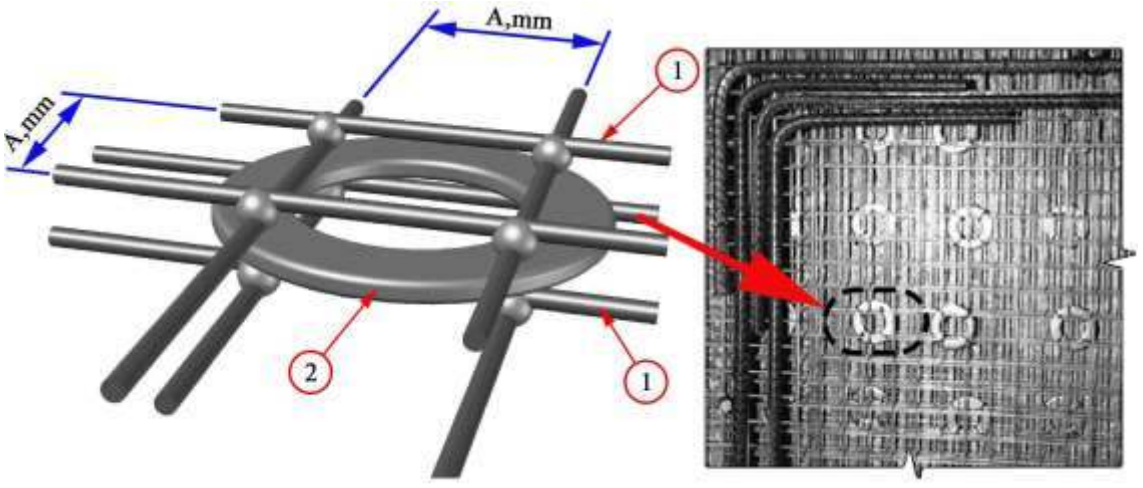
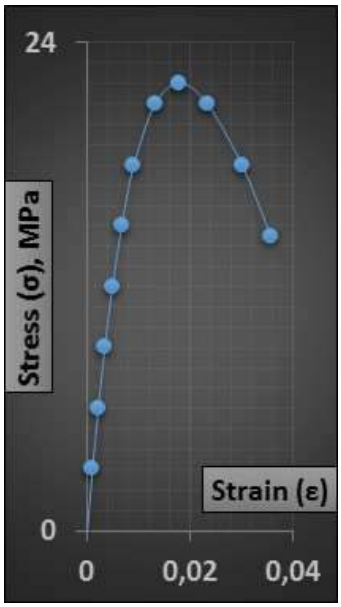


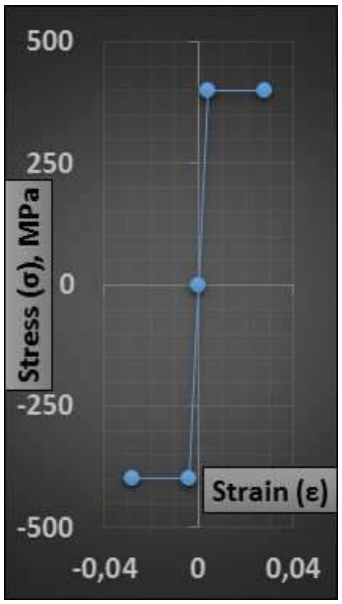
Figure 3. A Part of steel reinforcing mesh:
1 – a wire d=15 mm; 2 – a steel disc-gasket t=5 mm; A=25 mm

The average modulus of elasticity for different parts of the slab has been used for modeling its behavior.

Analysis of the stress-strain state of the construction has been investigated with the FE method. For this had been defined physical and mechanical properties of materials via experimental testing (Figure 4).



a) b)



c)

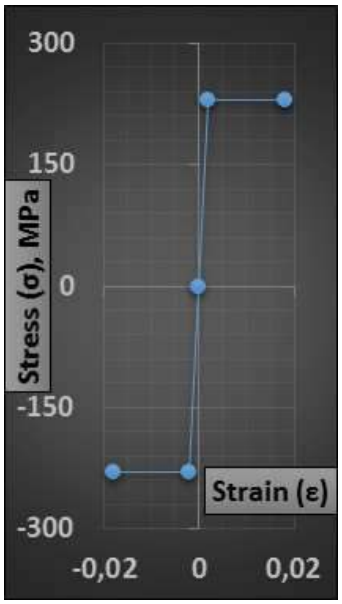


Figure 4. The stress-strain curve:
a) of concrete; b) of steel reinforcement; c) of steel

There is the boundary conditionals of modeling on Figure 5.

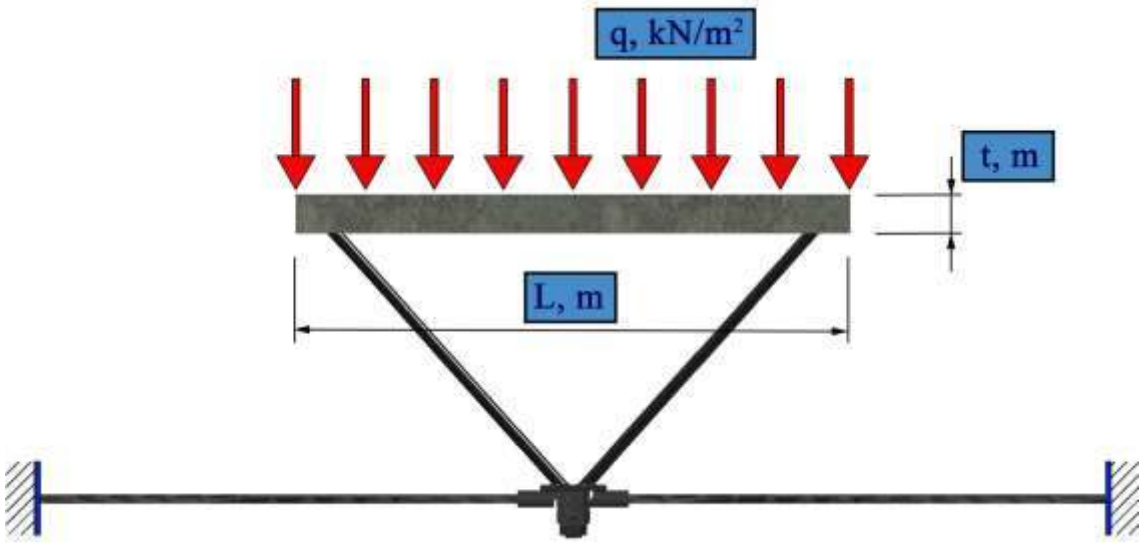


Figure 5. The boundary conditionals:
L – the length, 1.5 m; t – the thing, 0.06 m; q – the uniformly distributed load that equals snow load for Ukraine

The von Mises stress contour that shown in the Figure 6 is the result of the solving of numerical model under the estimated load.

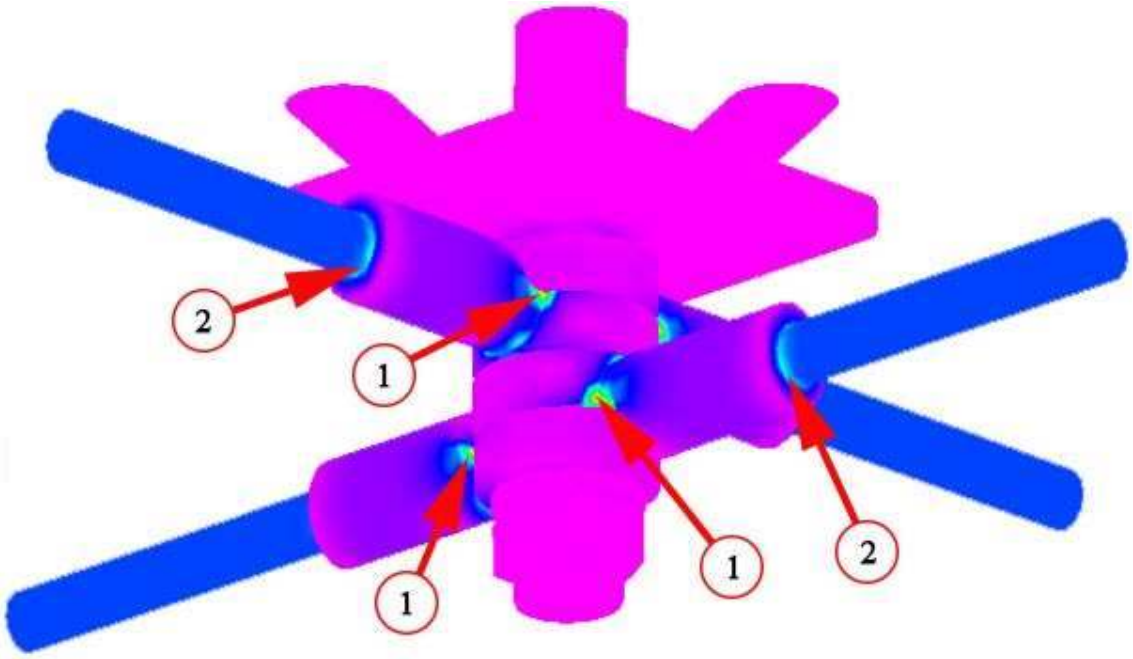


Figure 6. The von Mises stress contours:
1 – the region 1; 2 – the region 2

The figure 7 shows a destruction model of nodal connection of the developed construction.

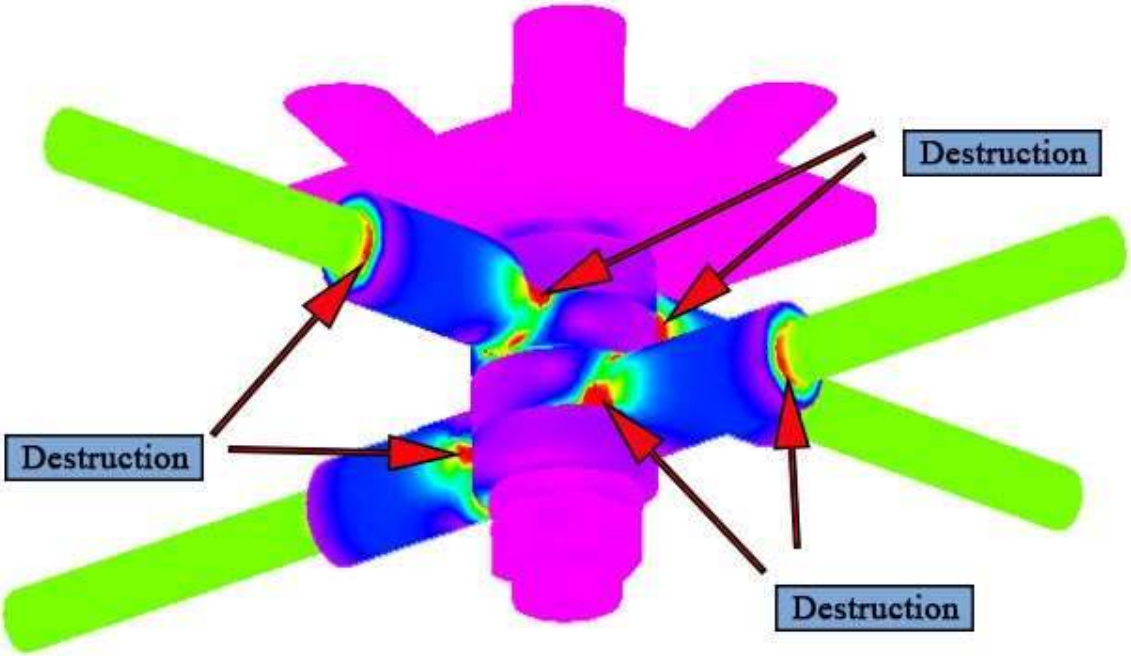


Figure 7. The von Mises stress contours at the destruction load

The contour of solid von Mises stresses (see figure 6) shows the maximum stress that has appeared is less than the limit stress of steel. The factor of safety of steel nodal details is 1.3. That makes it possible to optimize the shape of the steel details. There are the largest stresses in the regions1 and 2.

The destruction of steel details (see Figure 2) came in the regions 1 and 2 when a load had exceeded the estimated load 1.3 times.

DISCUSSION AND CONCLUSIONS

In the result of the studies is the new kind of a spatial construction that consist of modular units.

In the result of the numerical investigation found out the stress-strain state of the flexible bottom chord of the flat double-layer grid-cable steel-concrete composite structure. The von Mises stress contours have been obtained with FE method. The stress contours gave an opportunity to identify the locations of the maximum stresses and strains. The factor of safety was obtained using information about the maximum stress and strains.

Research confirms the effectiveness of structural concept of the construction.

REFERENCES

[1] Chilton J. Space grid structures. Boston: Architectural Press, 2007,180 p.

[2] Ivanyk I., Vybranets Y. and Ivanyk Y. Research of composite combined prestressed construction. Acta Scientiarum Polonorum, 2014. no. 13(2), pp. 81–88.

[3] Gasii G.M. Technological and design features of flat-rod elements with usage of composite reinforced concrete. Metallurgical and Mining Industry, 2014, no. 4, pp. 23–25.

[4] Стороженко Л.І. and Гасій Г.М. Нові композитні матеріали кріплення гірничої виробки. Науковий вісник Національного гірничого університету, 2015, no 4, pp. 28–34.

[5] Storozhenko L.I., Gasii G.M. and Gapchenko S.A. The new composite and space grid cable-stayed construction. Academic journal. Industrial Machine Building, Civil Engineering. PoltNTU. Poltava, 2014, no. 1, pp. 91–96.

[6] Nizhnik O.V Construction of steel and concrete composite girderless floor. Building construction. NIISK. Kyiv, 2013, no. 78(1), pp. 144–149.

[7] Storozhenko L.I. and Gasii G.M. Experimental research of strain-stress state of ferrocement slabs of composite reinforced concrete structure elements. Metallurgical and Mining Industry, 2014, no. 6, pp. 40–42.

[8] Стороженко Л.І., Гасій Г.М., Гапченко С.А. Просторові сталезалізобетонні структурно-вантові покриття: Монографія, Полтава: ТОВ «АСМІ», 2015, 218 с.