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FORM-BUILDING UNITS OF THE STEEL AND CONCRETE COMPOSITE CABLE SPACE FRAMES

ФОРМОУТВОРЮЮЧІ ЕЛЕМЕНТИ ПРОСТОРОВОЇ СТРУКТУРНО-ВАНТОВОЇ СТАЛЕЗАЛІЗОБЕТОННОЇ КОНСТРУКЦІЇ

ФОРМООБРАЗУЮЩИЕ ЭЛЕМЕНТЫ ПРОСТРАНСТВЕННОЙ СТРУКТУРНО-ВАНТОВОЙ СТАЛЕЖЕЛЕЗОБЕТОННОЙ КОНСТРУКЦИИ

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The purpose of the study is to create a new kind of spatial composite structures from reliable and strength materials for civil and industrial construction in particular to cover stadiums, exhibition halls, hangars for aircraft and other large vehicles, garages for a large construction machinery, long-span buildings and constructions of factories and plants, etc. The analysis of structural concepts of spatial structures are made from different single and composite materials was conducted, such as steel space frames, concrete shells and domes, cable-stayed systems and tensegrity structures were studied. The most efficient structural concepts of spatial structures were found based on theoretical investigation of existing structures. There are the most known large-span spatial structures are made entirely of steel members, among them well-known structures as flat double-layer grid. The structural concepts features of interesting and original species of the cable-stayed, concrete and composite structures were also studied. Based on these studies, the new type of spatial roof structure was created, this is the spatial grid-cable steel-concrete composite structure that consists of the spatial units and flexible chord and this is unique for a few reasons. The spatial element is made from reinforce concrete slab or ferrocement slab and rigid rods, which are fabricated from segments of steel tubes. Other unique features of the new structure is the flexible chord that are able to resist only tensile stress because it is fabricated from segments of steel cable. Novelty of the new structure is the rational application of material properties and structural elements,

secondly besides the load bearing capacity the reinforced concrete or ferrocement slab also performs covering function and reliably protects the internal space of the building from weathering and aggressive external factors. The spatial grid-cable steel-concrete composite structure is assembled of the spatial units and the flexible chord with bolts and can has various shapes and contours. Curvature of the structure is attained by varying the length of the segments of the steel cable. The spatial grid-cable steel-concrete composite structures can be successfully applied in civil and industrial engineering for example to cover the long-span buildings without using intermediate supports. As a result of studies was designed the new spatial species of a roof system. This is the spatial grid-cable steel-concrete composite structure has completely new and original structural concept. The concept of the structure allows to use effectively constructive elements and saves materials.

Були розроблені нові типи вузлових з'єднань просторової сталезалізобетонної структурно-вантової конструкції. Ефективність нових типів з'єднань полягає в низькій складності виготовлення і монтажу у порівнянні з існуючими системами. З'єднання можуть застосовуватися в промисловому і цивільному будівництві для зведення покриттів малих та великих прольотів. Конструкція розроблених з'єднань дозволяє отримати економічну вигоду за рахунок ефективного використання матеріалів.

Были разработаны новые типы узловых соединений пространственной сталежелезобетонной структурно-вантовой конструкции. Эффективность новых типов соединений заключается в низкой сложности изготовления и монтажа по сравнению с существующими системами. Соединения могут применяться в промышленном и гражданском строительстве для возведения покрытий малых и больших пролетов. Конструкция разработанных соединений позволяет получить экономическую выгоду за счет эффективного использования материалов.

Key words:
Composite, cable, roof, shell, node, grid.
Сталезалізобетон, ванта, покриття, оболонка, вузол, решітка.
Сталежелезобетон, ванта, покрытия, оболочка, узел, решетка.

Introduction. Sometimes there is a problem in building sector in construction of different buildings. The problem consists in the complexity of work and material overruns. Such situation in the construction has caused by contradiction existing design solutions to modern requirements, which over time morally and physically

have outdated. It directly effects of overall cost and construction duration of object. Therefore, there is a need to improve or develop the new designs, including space structures and connection system for them, which would permit to achieve savings of materials and to reduce complexity of construction processes. This caused appearance of the new concept of the composite cable space system [1], which combines both the data and results of previous studies [2 – 4] and will have both positive and unique properties. Development of airport infrastructure except machinery and equipment modernization requires modernization, changes or rebuild existing structures and construction new buildings. Structures that completely satisfy the demanding requirements for buildings of modern airports are the composite cable space frames that are a combination of steel space trusses, steel cables or bars and slabs (Fig. 1) that used for not only cover or protect from aggressive external factors, rain, snow and other atmospheric influences but also used as bearing element. The composite cable space frame was patented. The slab for these structures except concrete can be made from glass, plastic and other modern materials. Choice of material depends on building function.

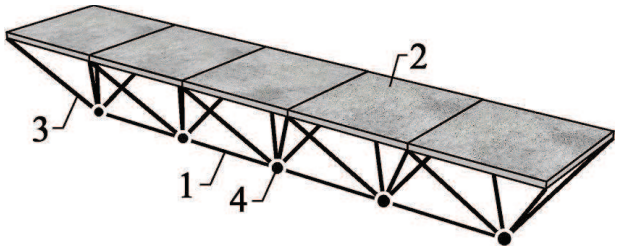

Fig. 1. Part of the steel and concrete composite cable space frame: 1 – cable or bar (bottom chord); 2 – slab (top chord); 3 – web; 4 – connection of top chords; 5 – connection of bottom chords

In designing composite cable space frames, the connecting system is one of the most crucial points, not only for the shape and geometry accommodation, but also for the local and global stability of the structure.

World experience to provide proper solutions in connection systems on the spatial structure considering structural and geometrical requirements, a lot of researchers have provided recently different types and forms [5].

Analysis of recent sources of research and publications. In [6] reported that over 250 different types of connecting systems have been suggested or used in practice, and there are around 50 commercial firms, which have tried to specialize in the manufacture of proprietary connection systems for spatial structures, each with its own types and forms that are difficult to compare. Unfortunately, many of these systems have not proved attainment of great success mainly because of the complexity of the connecting method. In [7] presented wide list of connection type with a node and its a comprehensive survey of the jointing systems all over the world. In accordance [8] all the connection techniques can be divided into three main groups: with a node, without a node, and with prefabricated units.

Concerning composite structures the analysis of recent sources of research and publications has shown that such structures is used very widely in various construction fields [9 – 15]. Currently the main direction of research composite structures is related with the improvement of methods of calculation and

constructive solutions as well as study influence of different loads on the stress-strained state [16 – 19].

Identification of general problem parts unsolved before. The analysis of previous studies has shown that most of the steel and concrete composite structures is monolithic. However, prefabricated structures, which would allow building various surface, have not completely developed yet.

Formulation of the problem. Based on overviews of existing connection systems and their advantages and disadvantages, to design and present effective and reliable connection system for composite cable space frame.

Basic material and results. The purpose of the study is to present the new kind of connection systems for composite cable space frame, which are made from modern and strength materials for civil construction in particular to cover halls, hangars for aircraft and other vehicles, garages for a large machinery, large-span buildings and structures of airports, etc. The novelty of the composite cable space frame lies in effective application properties of materials and structural concept [20]. The composite steel and concrete grid-cable construction as noted earlier consists of the three different kinds of structural elements: slabs, steel space trusses and steel cables. The steel space trusses are made from segments of steel tubes or rods. The slabs are used as the top chords, steel space trusses are used as diagonals and steel cables or bars are used as flexible bottom chords. The diagonals and slab create space module that is main element of the composite steel and concrete grid-cable construction. The space module can has different size and height (Fig. 2). The space modules are jointed together in planes both of top and bottom chords by special nodes. These nodes are made as single-bolted joints in one direction. The space modules are connected in one or two directions. It is depend on how the steel and concrete composite cable

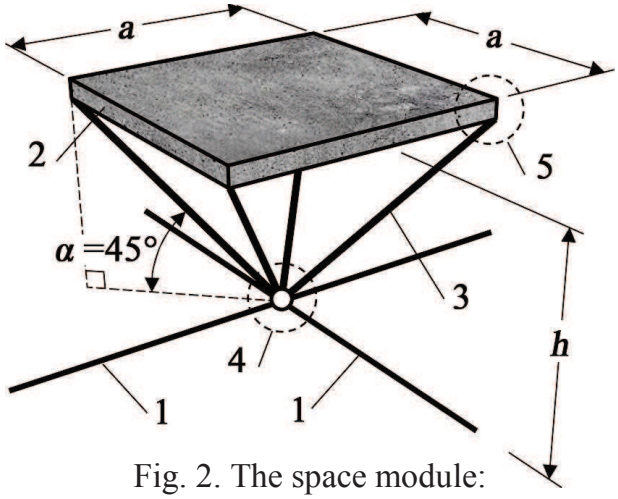

Fig. 2. The space module:
1 – cable or bar; 2 – slab; 3 – web; 4 – connection of top chords; 5 – connection of bottom chords

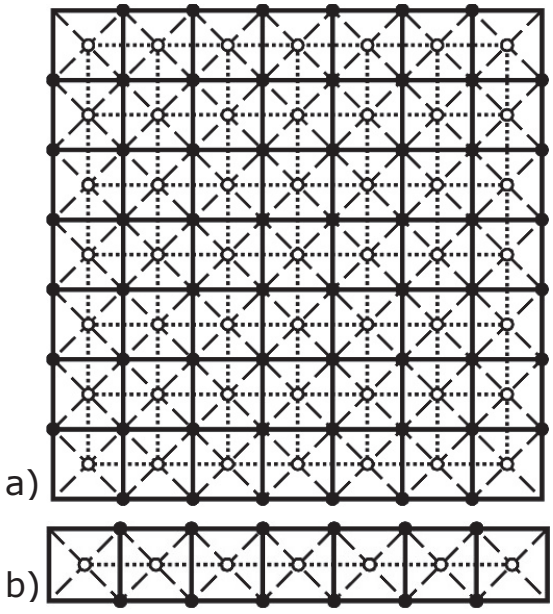

Fig. 3. The steel and concrete composite cable space frame assembled as a surface (a) and a slab (b)

space frame are going to use. If the steel and concrete composite cable space frame are assembled from the space modules as a slab (Fig. 3, a) then the space modules are jointed in one direction; if as a surface (Fig. 3, b) then the space modules are jointed in two directions.

Figure 4 shows a type of connection of space modules on top chord plane in two directions.

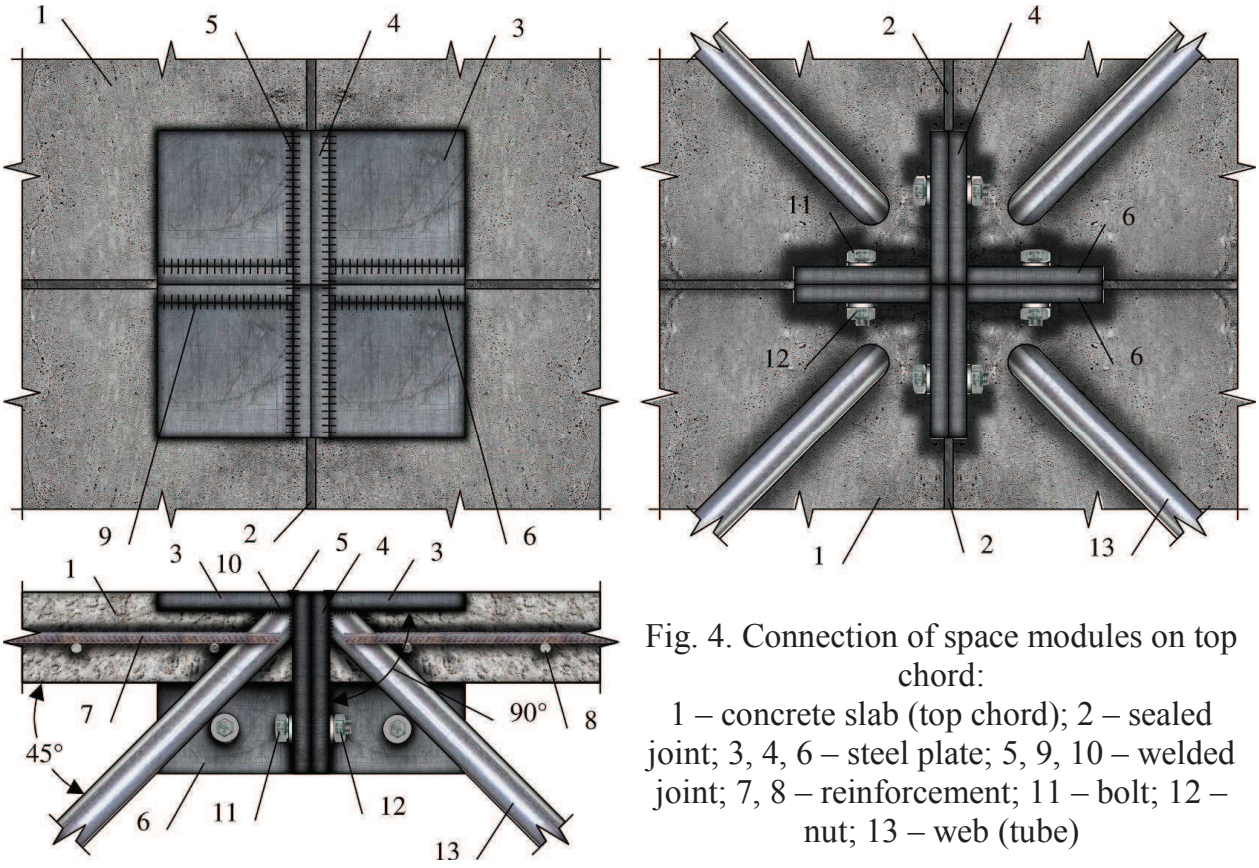

Fig. 4. Connection of space modules on top chord:
1 – concrete slab (top chord); 2 – sealed joint; 3, 4, 6 – steel plate; 5, 9, 10 – welded joint; 7, 8 – reinforcement; 11 – bolt; 12 – nut; 13 – web (tube)

The connections can be used also for curved slabs or surfaces. For this, the steel plates (1) and (2) should have angle among ourselves. The angle can be acute or obtuse (Fig. 5).

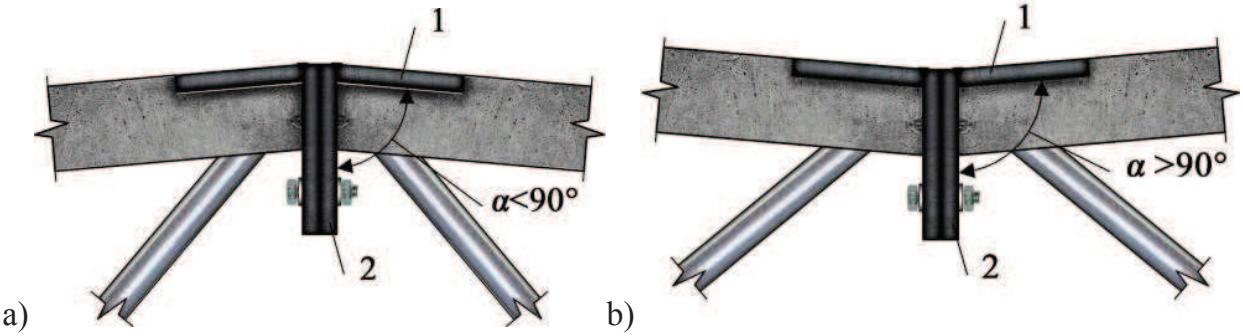

Fig. 5. Connection of space modules on top chord plane for curved structures:
a) for α<90°; b) for α<90°; 1, 2 – steel plate

There is an opportunity to assemble flat and curved covers (Fig. 6) for considerable range of areas by means presented connections.

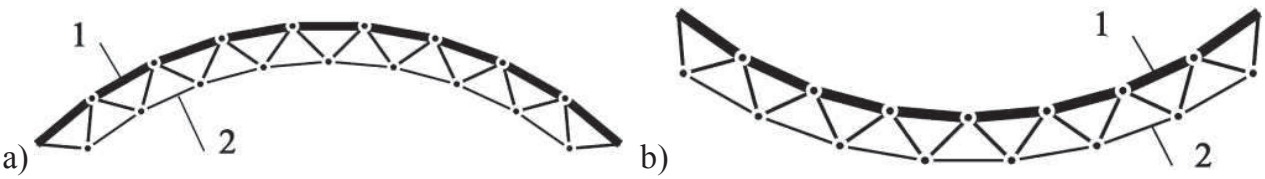

Fig. 6. The steel and concrete composite cable space frame made as curved covers by means presented connections:
1 – the top chord, 2 – the bottom chord

To connection of the space modules among ourselves on bottom chord also used single-bolted joints. For this in top point of tubes connection is need to weld a bolt (Fig. 7) through which the modular elements of bottom chord are jointed. However, for this there is needs to installation at the ends of the bottom chords special details.

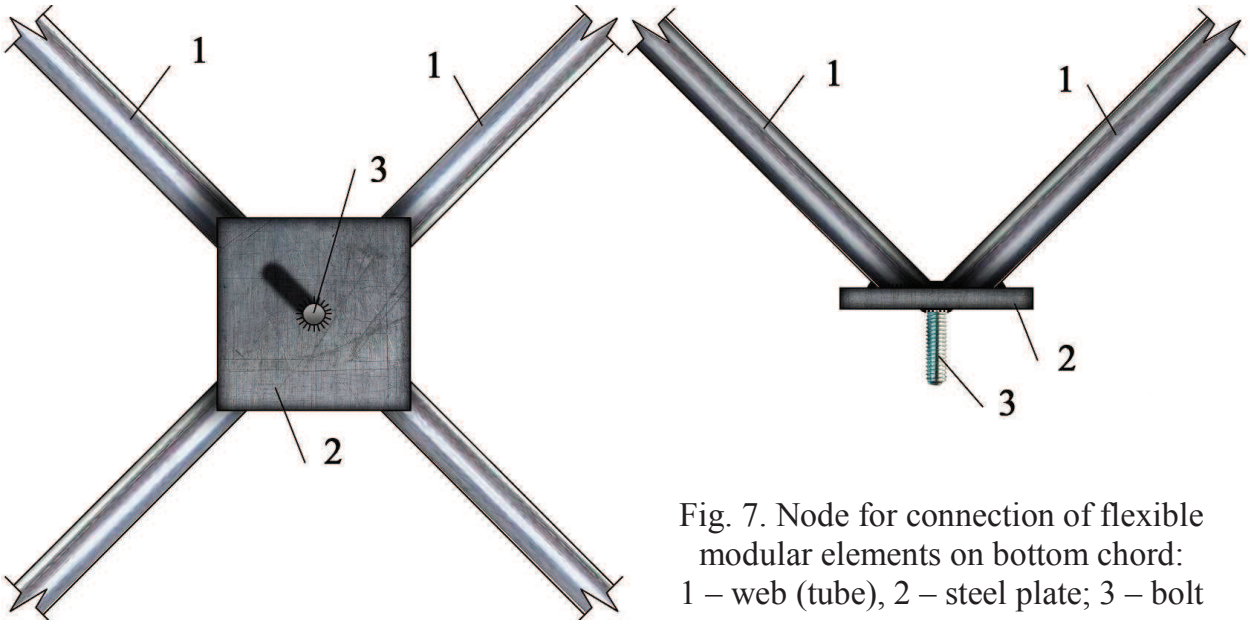

Fig. 7. Node for connection of flexible modular elements on bottom chord:
1 – web (tube), 2 – steel plate; 3 – bolt

Conclusions. The connectors for these structures are simpler than node systems for ordinary space grid structures because its members are connected with single bolted joints, which cause decrease of complexities in the mechanism of force transfer and reduce installation complexities.

The efficient of new types of the connections lies in low complexity of manufacturing and installation compared to existing systems. In addition, the main specifics the connection systems is using single-bolt joints. The connections can be applied in industrial and civil construction for construction both small and large span covering of different objects from composite cable space frames. The connections provides a significant economic benefit through the efficient usage of materials.

On top of that, assembling specifics and structural concept allow not only to save cost and time of construction but also to adjust the building site as effectively as possible.

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