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ТРАНСПОРТНЕ БУДІВНИЦТВО

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G. M. GASII[1*]

[1*]Dep. «Structures from Metal, Wood and Plastics», Poltava National Technical Yuri Kondratyuk University, Pershotravnevyi Av., 24, Poltava, Ukraine, 36011, e-mail grigoriigm@gmail.com, ORCID 0000-0002-1492-0460

TYPES OF STEEL AND CONCRETE COMPOSITE CABLE SPACE FRAMES

Purpose. Modern terms of the construction generate the need to find new structures, including roof systems that would meet modern requirements. An important aspect in finding constructive solutions for new structures is the use of reliable and advanced materials. Considering this, the decision to develop the new space structures to a wide implementation in practice of domestic and foreign construction are relevant and perspective direction of building structures development. **Methodology.** Given the results of previously conducted theoretical research of existing types of space roof structures find promising areas of improvement or creation of new structures that should be devoid of weaknesses and imperfections of analogs and they should have an economic effect through rational use of materials. **Findings.** Types of steel and concrete composite cable space frames and structural features of its elements are developed and considered. The steel and concrete composite cable space frame is a completely new kind of space structure system that has the original structural concept and it was designed to cover large-span industrial and public buildings. The basic elements of that structure system are modular element of the bottom chord and space steel and concrete composite module that consists of tubular rods and reinforced concrete slab. All modular elements are made in the factory. With bottom chord modular elements and space steel and concrete composite modules can be assembled three types of longitudinal elements. It is the beam element, arched element and hanging element. Also with the modules can be assembled various structure system and their combinations. Number of space steel and concrete composite modules and bottom chord modular elements, which is needed to collect steel and concrete composite cable space frames, is determined by calculation and optimal designing. Recommended dimensions of the modular elements of the steel and concrete composite cable space frames are presented. **Originality.** The new efficient construction roofs that appointment for covering large-span buildings were developed by the author. **Practical value.** Developed steel and concrete composite grid-gable roofs are designed for industrial and civil construction. Applications of developed designs for the construction of large-span covering objects provides a significant economic benefit through the efficient use of materials.

Keywords: plate; tube; bar; bolt; module; top chord; bottom chord

Introduction

There is a problem often in building sector, which lies in the complexity of work and material overruns due to no effective use. This situation in the construction has developed due non-compliance existing industry design solutions to modern requirements that over time morally and physically obsolete. These factors directly affect the overall cost and duration of the construction project, so there is a requirement to improve and finding the new structures systems, including space structures that would permit largely achieve savings of materials and reduce complexity of technological processes.

This was the cause of the idea of developing the new concept of the space steel and concrete composite systems that not only will combine in

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themselves the results of previous studies [5, 6, 10] and will have positive properties of existing spatial structures, but will have own unique properties are specific to them.

Analysis of recent sources of research and publications has shown that steel and concrete composite is a material that were used very widely in various fields of construction [3, 8, 9, 11, 14, 15]. Currently the main directions of research the steel and concrete space structures are related with the improvement of methods of calculation and constructive solutions as well as study influence of different types of load on the stress-strained state and so on [4, 7, 12, 13].

The analysis of previous studies has shown that most of the steel and concrete space structures are monolithic. However, prefabricated structures, which would allow building curved surface, have not developed yet.

Purpose

To develop and present main types of steel and concrete composite cable space frames that will allow building large-span roof system applied to transport infrastructure.

Methodology and Findings

There is an opportunity to build cover buildings various sizes and shapes, including various membrane curvature, domes, and others due to that steel and concrete composite cable space frames is modular. Considering the novelty of the structure concept of the steel and concrete composite cable space frames a priority task is to define the field of application these structures and to develop several types of forms and structural elements. Concurrently all samples that were developed were patented. The basic elements of that structure system are modular elements of the bottom chord (Fig. 1) and the steel and concrete composite space modules that consists of tubular diagonal and reinforced concrete slab (Fig. 2) [2].

In general, the basis of the steel and concrete composite space module is reinforced concrete or steel-concrete square slab. It plays the role of the top chord of the steel and concrete composite cable space frames. In general, dimensions of the reinforced concrete slab can be different and are calculated, but the recommended dimensions of the slab in the plan are 1.5×1.5 m or 3×3 m. The diagonals are made of circular cross section, preferably with a tube, which plays the role of the lattice of the structure. The angle between tubular diagonal and their horizontal projections α can be for as conventional space grid structures, but recommended 45°. The steel and concrete composite space modules are combined to each other by means of the nodal connections in a plane of the top chord (Node 2, see. Fig. 3) in the plane of the bottom chord (Node 1 see. Fig. 4), construction of which can be different design depending on the type of steel and concrete composite cable space frames [1].

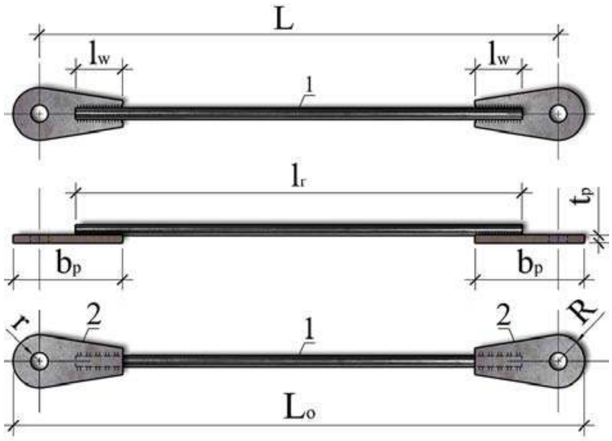

Fig. 1. Modular elements of the bottom chord of steel and concrete composite cable space frames:
1 – steel rode; *2* – steel plate with hole

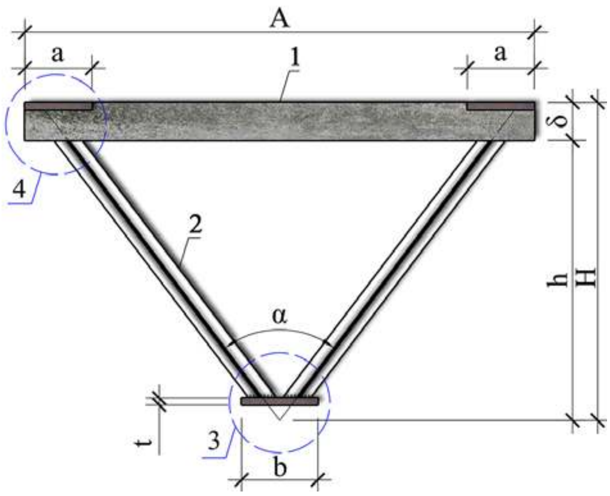

Fig. 2. Steel and concrete composite space module:
1 – reinforced concrete slab;
2 – tubular diagonal
3 – node on top chord (node 1);
4 – node on bottom chord (node 2)

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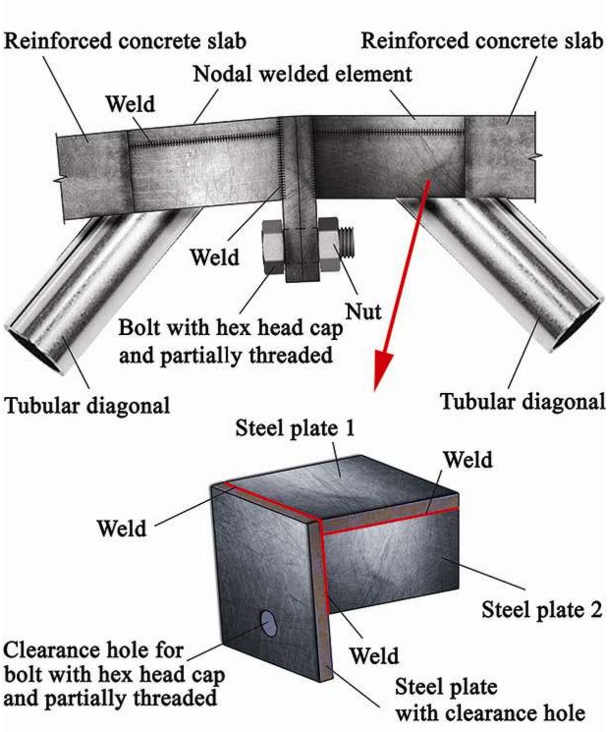

Fig. 3. Example of the nodal connections on a plane of the top chord (Node 2)

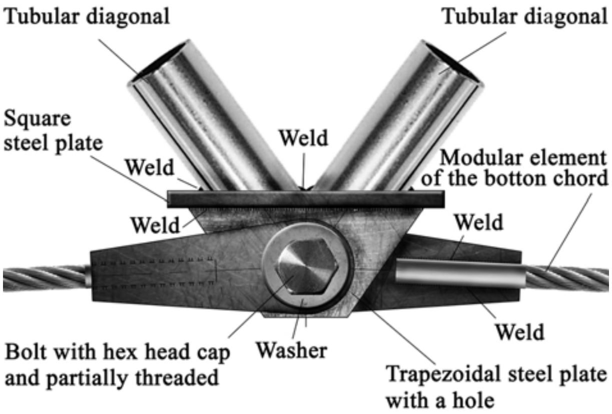

Fig. 4. Example of the nodal connections on a plane of the bottom chord (Node 1)

The node on plane of the top chord includes the nodal welded element, which consist of three steel parts: rectangular steel plate 1, rectangle trapezoid steel plate 2 and rectangular steel plate with clearance hole. These steel plates are connected with electric arc welding. Two nodal welded elements that are part of steel and concrete composite space modules are connected with partially threaded bolt with hex head cap through the clearance hole.

The node on plane of the bottom chord includes the nodal welded element, which consists of two steel parts: square steel plate and trapezoid steel plate with clearance hole. These steel plates are connected with electric arc welding.

To reduce the weight of the steel and concrete composite space module was offered improved design solution, the essence of which was to use the plate as the top chord, which is made from lightweight concrete or ferrocement, as well as tubular rods were used, which are made from high-strength steel. As a result, the lightweight element of structure was patented. Lightweight element of structure is part of the steel and concrete composite cable space frames and can be used in the construction of large-span public and industrial buildings. The effectiveness of lightweight elements consists in low weight, ease of installation, low complexity manufacturing, short period of the construction. It should be noted that lightweight elements are made entirely in the factory.

With bottom chord modular elements (see Fig. 1) and space steel and concrete composite modules (see Fig. 2) can be assembled three types of longitudinal elements. It is the beam element, arched element and hanging element (Fig. 5).

Longitudinal elements can be used equally effectively as cover for large and small spans (Fig. 5) and be an alternative to precast concrete system, which consist of hollow or ribbed panels that are mounted on truss or beams, also composite steel deck concrete roof system.

Longitudinal elements, which do not exceed the length of the dimensions of transportation are completely manufactured and assembled in the factory. In this case, longitudinal elements are delivered to the building site as a complete construction. This will greatly reduce the complexity of assembly and installation and reduce the total duration of the construction steel and concrete composite cable space frames. The effectiveness of complete factory manufacturing of the modular or longitudinal elements is especially evident in the case when elements have constructive improvements that are designed to simplify and reduced the length of works. For example, Fig. 6 shows the steel and concrete composite space module with a steel frame, the effectiveness of this solution lies in the frame that serves as not only a means to strengthen the slab, but also to connect the mod-

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ules to each other in the case of welding. In addition, steel frame also serves as a permanent form during concreting of module. Fig. 7 shows another example. It is the steel and concrete composite space module, which besides steel frame has additional elements – steel shelves, which serve as an aid in the installation the construction.

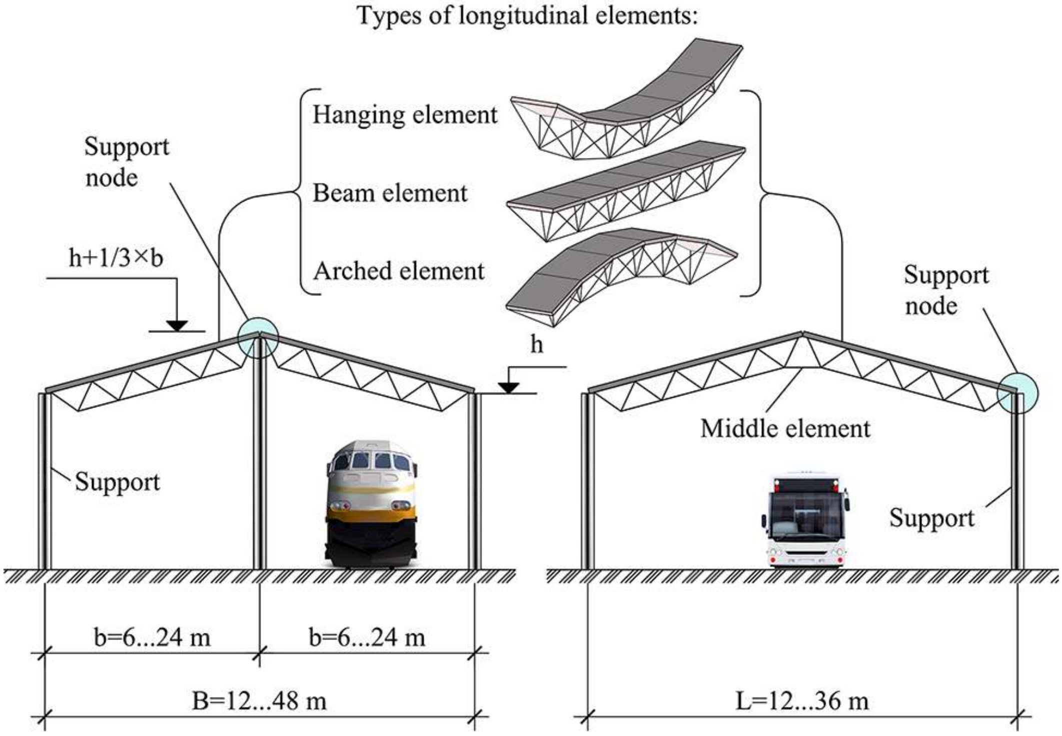

Fig. 5. Variants of roof system are made from longitudinal elements

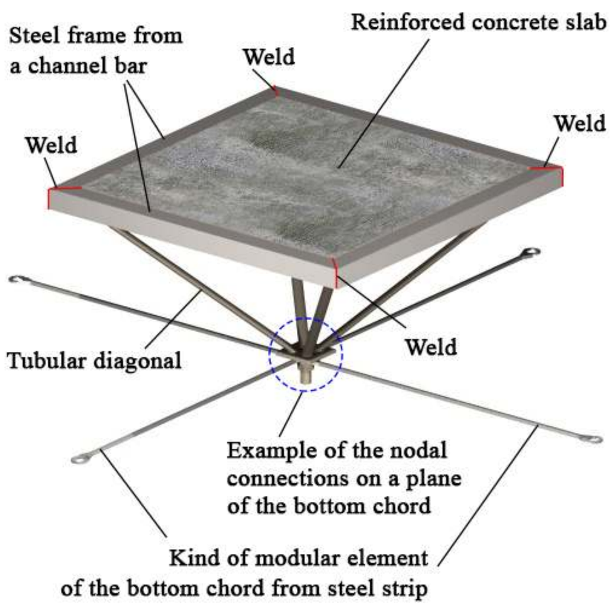

Fig. 6. Improved designs of the steel and concrete composite space module with a steel frame

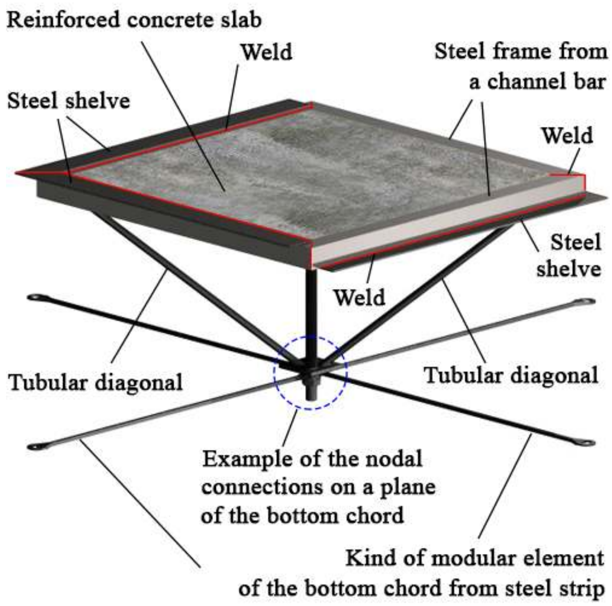

Fig. 7. Improved designs of the steel and concrete composite space module with steel shelves

Curvature of longitudinal elements or steel and concrete composite cable space frames is provided by reducing or increasing the length of the modular element of the bottom chord L (see Fig. 1), in consequence of which between steel and concrete composite space modules is formed mutual angle. However, it should be noted that the curvature of the arch of steel and concrete composite cable space frames is limited and depends on conditions of fixing. While designing of steel and concrete composite cable space frames need to remember that the modular element of the bottom chord are designed to work only in tension. Thus designing these systems should take the following geometric dimensions of its constituent elements and geometric parameters that will prevent the emergence of effort compression elements in the modular element of the bottom chord. Determining some optimum geometrical parameters of these structures were presented in [2]. In general, for steel and concrete composite cable space frames with recommended dimensions of the steel and concrete composite space module and angle between diagonal and its horizontal projection, the relationship between the length of the modular element of the bottom chord and angle has barely noticeable curvilinear nature.

Originality and practical value

The steel and concrete composite cable space frames are the new kind of effective space grid structures that allow saving of material resources and reducing construction laboriousness because the bottom chord of the frames are made of flexible rods. These rods in its essence and idea are not designed for compression, so for the manufacture of such rods there is no need to apply rigid and massive types of metal rolling to provide a load carrying capacity and rigidity of the frames. This specifics of the designed frames are closely associated with the utilize of high-strength steels for manufacturing elements of the bottom chord, because as we know in tension elements effectively apply high-strength steels. This fact was found after comparison between developed frames and typical design solutions of long-span roof system had been conducted. It has been found that the steel and concrete composite cable space frames can be lighter than typical roof systems about at 32–72%.

Conclusions

The steel and concrete composite cable space frames are the new kind of large-span structures, which have significant advantages, in particular, they are lighter and have lower complexity of manufacturing and assembly than analogues. The basic elements of that structure system are modular elements of the bottom chord and space steel and concrete composite modules. Modular elements of the bottom chord, steel and concrete composite space modules and three types of longitudinal elements are used for construction large-span industrial and public buildings. Thanks to its modular design the steel and concrete composite cable space frames can be varied expressive architectural outline and shape. Flat double-layer grid is the simplest type of the steel and concrete composite cable space frames. This type of structures is used efficiently for small spans like that structure that installed on individual supports or on a contour.

In general, from modular elements can be erected not only the proposed system but also many others, including steel and concrete composite cable space frames, which have complex shapes or combinations for covering hangars for aircraft, machinery or equipment, etc.

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Г. М. ГАСІЙ[1*]

[1*]Каф. «Конструкції з металу, дерева та пластмас», Полтавський національний технічний університет імені Юрія Кондратюка, пр-т Першотравневий, 24, Полтава, Україна, 36011, e-mail grigoriigm@gmail.com, ORCID 0000-0002-1492-0460

ТИПИ ПРОСТОРОВИХ СТРУКТУРНО-ВАНТОВИХ СТАЛЕЗАЛІЗОБЕТОННИХ КОНСТРУКЦІЙ

Мета. Умови існуючого будівництва породжують необхідність пошуку нових конструкцій, зокрема покриттів, які б задовольняли сучасним вимогам. Важливим моментом у пошуку конструктивних рішень нових конструкцій є використання надійних і сучасних матеріалів. Враховуючи це, рішення розробити нові просторові конструкції з метою широкого впровадження в практику вітчизняного й зарубіжного будівництва є актуальним і перспективним напрямком розвитку будівельних конструкцій. **Методика.** З урахуванням результату попередньо проведеного теоретичного дослідження існуючих типів просторових конструкцій покриттів знайдено перспективні напрямки їх удосконалення або створення нових конструкцій, які були б не лише позбавлені недоліків та недосконалостей аналогів, але й мали економічний ефект за рахунок раціонального використання матеріалів. **Результати.** Розроблено та розглянуто типи просторових структурно-вантових сталезалізобетонних конструкцій та конструктивні особливості їх елементів. Просторові структурно-вантові сталезалізобетонні конструкції – абсолютно новий вид просторових несучих систем із оригінальним конструктивним рішенням, що призначені для покриття великопролітних промислових та громадських будівель і споруд. Основними елементами таких конструкцій є модульні елементи нижнього пояса та просторові сталезалізобетонні модулі, які складаються із плит та трубчастих стрижнів. Всі модульні елементи виготовляються в заводських умовах. З просторових сталезалізобетонних модулів і модульних елементів нижнього пояса можуть збиратися три типи лінійних елементів: балковий, арковий і висячий, а також різні несучі системи та їх комбінації. Кількість просторових сталезалізобетонних модулів та модульних елементів

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нижнього пояса, що необхідні для збирання просторових конструкцій, визначається розрахунком та варіантним проектуванням. Наведено рекомендовані розміри модульних елементів структурно-вантової сталезалізобетонної конструкції. **Наукова новизна.** Автором розроблені нові ефективні конструкції покриттів, які призначені для перекриття великопролітних будівель та споруд. **Практична значимість.** Розроблені сталезалізобетонні структурно-вантові покриття призначені для промислового та цивільного будівництва. Застосування розроблених конструкцій для зведення покриття великопролітних будівель та споруд дозволяє отримати значний економічний ефект за рахунок раціонально використаних матеріалів.

Ключові слова: пластина; труба; стрижень; болт; модуль; верхній пояс; нижній пояс

Г. М. ГАСИЙ[1*]

[1*]Каф. «Конструкции из металла, дерева и пластмасс», Полтавский национальный технический университет имени Юрия Кондратюка, пр-т Первомайский, 24, Полтава, Украина, 36011, e-mail grigoriigm@gmail.com, ORCID 0000-0002-1492-0460.

ТИПЫ ПРОСТРАНСТВЕННЫХ СТРУКТУРНО-ВАНТОВЫХ СТАЛЕЖЕЛЕЗОБЕТОННЫХ КОНСТРУКЦИЙ

Цель. Условия существующего строительства порождают необходимость поиска новых конструкций, в частности покрытий, которые бы удовлетворяли современным требованиям. Важным моментом в поиске конструктивных решений новых конструкций является использование надежных и современных материалов. Учитывая это, решение разработать новые пространственные конструкции с целью широкого внедрения в практику отечественного и зарубежного строительства является актуальным и перспективным направлением развития строительных конструкций. **Методика.** С учетом результата предварительно проведенного теоретического исследования существующих типов пространственных конструкций покрытий найдены перспективные направления их усовершенствования или создания новых конструкций, которые были бы не только лишены недостатков и несовершенств аналогов, но и имели бы экономический эффект за счет рационального использования материалов. **Результаты.** Разработаны и рассмотрены типы пространственных структурно-вантовых сталежелезобетонных конструкций и конструктивные особенности их элементов. Пространственные структурно-вантовые сталежелезобетонные конструкции – абсолютно новый вид пространственных несущих систем с оригинальным конструктивным решением, предназначены для покрытия большепролетных промышленных и общественных зданий и сооружений. Основными элементами таких конструкций являются модульные элементы нижнего пояса и пространственные сталежелезобетонные модули, состоящие из плит и трубчатых стержней. Все модульные элементы изготавливаются в заводских условиях. С пространственных сталежелезобетонных модулей и модульных элементов нижнего пояса могут собираться три типа линейных элементов: балочный, арочный и висячий, а также различные несущие системы и их комбинации. Количество пространственных сталежелезобетонных модулей и модульных элементов нижнего пояса, необходимое для сбора пространственных конструкций, определяется расчетом и вариантным проектированием. Приведены рекомендуемые размеры модульных элементов структурно-вантовой сталежелезобетонной конструкции. **Научная новизна.** Автором разработаны новые эффективные конструкции покрытий, которые предназначены для перекрытия большепролетных зданий и сооружений. **Практическая значимость.** Разработанные сталежелезобетонные структурно-вантовые покрытия предназначены для промышленного и гражданского строительства. Применение разработанных конструкций для возведения покрытий большепролетных зданий и сооружений позволяет получить значительный экономический эффект за счет рационально использованных материалов.

Ключевые слова: пластина; труба; стержень; болт; модуль; верхний пояс; нижний пояс

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Prof. L. I. Storozhenko, D. Sc. (Tech.) (Ukraine); Prof. D. O. Bannikov, D. Sc. (Tech.) (Ukraine) recommended this article to be published

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