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EXPERIMENTAL RESEARCH METHODOLOGY OF FULL-SCALE STEEL AND CONCRETE COMPOSITE CABLE SPACE FRAME PROTOTYPE

The article describes the main features of experimental studies methodology of new space systems constructive solutions effectiveness. Research methodology is developed by the example of full-scale prototype of the steel and concrete composite cable space frame, which consists of space steel and concrete composite modules and flexible bottom chord. Methodology for study stress-strain state of the prototype by testing in the uniform load applied to nodes is developed. It also provides the nodes displacement definition of the prototype. According to the developed technique, stressed state of full-scale prototype of the steel and concrete composite cable space frame was studied with tensionmetric and photogrammetric methods. Equipment and devices arrangement schemes for measuring deformations and displacements of the full-scale steel and concrete composite cable space frames prototype are presented.

***Keywords:** steel-concrete composite material, plate, modulus of elasticity, stress-strained state.*

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МЕТОДИКА ЕКСПЕРИМЕНТАЛЬНОГО ДОСЛІДЖЕННЯ ВЕЛИКОГАБАРИТНОГО ЗРАЗКА ПРОСТОРОВОЇ СТРУКТУРНО-ВАНТОВОЇ СТАЛЕЗАЛІЗОБЕТОННОЇ КОНСТРУКЦІЇ

Наведено головні особливості методики експериментального дослідження ефективності конструктивного рішення нових просторових систем. Сформульовано методику дослідження деформативності великогабаритного зразка просторової структурно-вантової сталезалізобетонної конструкції, яка складається з просторових сталезалізобетонних модулів та гнучкого нижнього пояса. Розроблено методику дослідження напружено-деформованого стану великогабаритного експериментального зразка просторової структурно-вантової сталезалізобетонної конструкції шляхом випробування його на дію рівномірного навантаження, прикладеного у вузлах з'єднання, а також методику визначення прогинів у вузлах дослідної просторової структурно-вантової сталезалізобетонної конструкції. Для дослідження напруженого стану просторової структурно-вантової сталезалізобетонної конструкції застосовано тензометричний і фотограмметричний методи. Наведено схеми розміщення обладнання та пристосувань для вимірювання деформацій і переміщень.

***Ключові слова:** сталезалізобетон, плита, модуль пружності, напружено-деформований стан.*

Introduction. The development of construction industry needs to change and implement the latest designs. The obligatory condition for successful implementation of design concepts into real construction sector is their researching and compliance with today's requirements. The structure that completely satisfies these requirements is the steel and concrete composite cable space frame. The originality of this concept lies in combining various elements, which effectiveness is determined by the terms of their location in structure.

Analysis of recent sources of research and publications analysis showed that among composite structures often steel and concrete composite shells are highlighted, which specific is a combination of concrete slabs with steel rod elements for partial discharge slab. In such constructions, plates could be unloaded by means of steel rods. In [1] it is investigated the strength and deformability steel and concrete composite structure. The top chord of the structure is made of steel T-section beams, which are combined to monolithic concrete slab with anchors.

In [2] it is proposed improved design, consisting of modular steel elements, top and bottom chords and reinforced concrete slab. This design differs from the previous ones by way of ensuring collaboration steel component and reinforced concrete slab.

Considering the idea to combine the plates and rods with collaboration in the structure by the new way is the original and distinguishes the proposed structure among existing as a new type of roof and allows deny drawbacks inherent counterparts. The concept of the proposed solution is a synthesis of experience and new developments in which the modular elements, complexity and difficulty of manufacturing technology are used, which assembly and installation is less than that of counterparts [3].

Efficiency constructive solution space structures and their elements were investigated and confirmed earlier [4–7].

Highlighting of the general problems parts unsolved earlier. The analysis of previous works has showed that there are no studies of the proposed structure peculiarities on large-scale prototype.

The problem formulation. The task is to develop steel and concrete composite cable space frames experimental research methodology.

The main material and results. The experimental research methodology includes testing of steel and concrete composite cable space frame prototype that has span of 5.3 m under temporary load (Fig. 1).

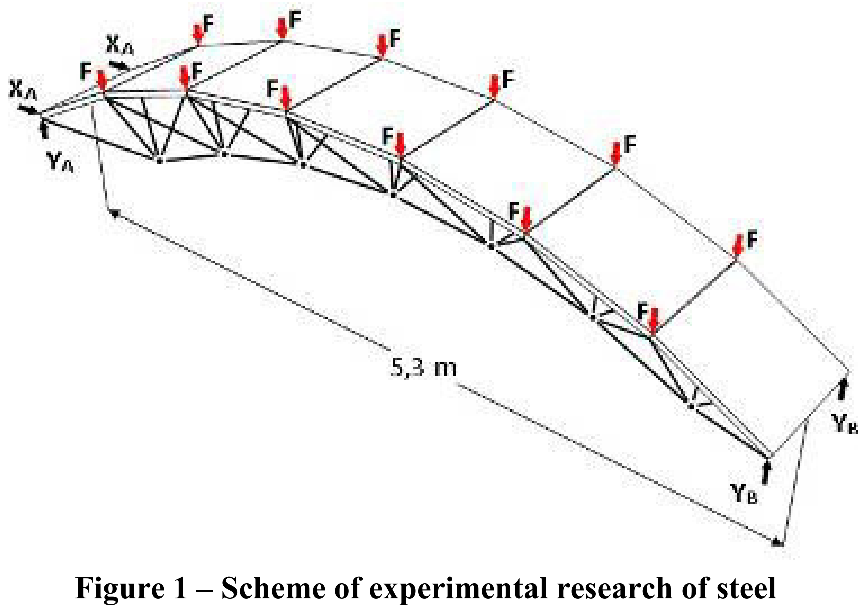


Figure 1 – Scheme of experimental research of steel and concrete composite cable space frame prototype

Steel and concrete composite cable space frame prototype testing was conducted in academic laboratories of Poltava National Technical Yuri Kondratyuk University. It was done only after it was finally installed and 28 days after concreting. Because of the large prototype size, the use of standard laboratory power equipment, including presses for the creation and application of temporary nodal load on the prototype was impossible. Therefore, prototype loading was performed using steel cargoes. Each of these cargoes had the form of a solid short cylinder and weight 42 kg. For applying force on the prototype, traverses were used, consisted of a crossbar and two rods, having cargoes on them (Fig. 2).

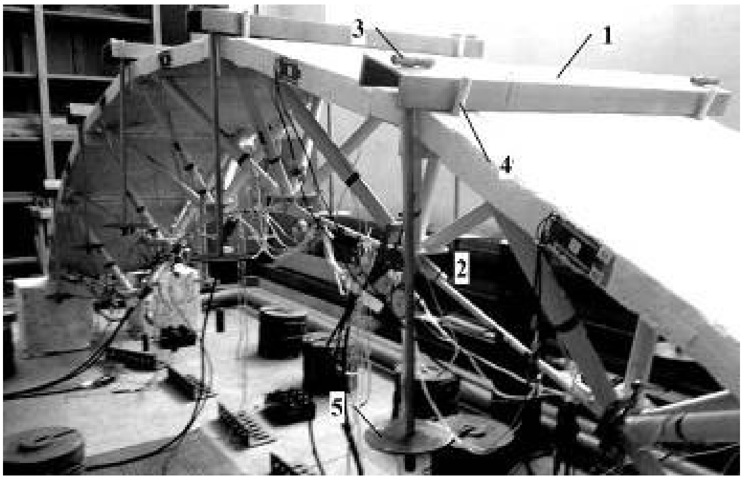


Figure 2 – The traverse to loading the prototype:
1 – crossbar; 2 – rod; 3 – hinge; 4 – fuse; 5 – plate

The traverses were set on top chord of the prototype at nodes. To prevent traverses displacement or movement, fuses in nodes were arranged (Fig. 3).

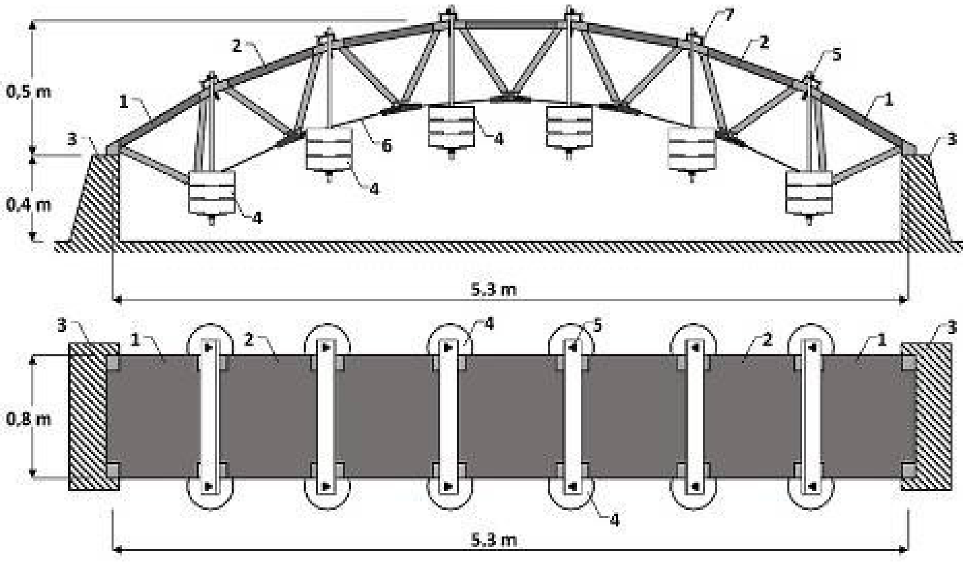
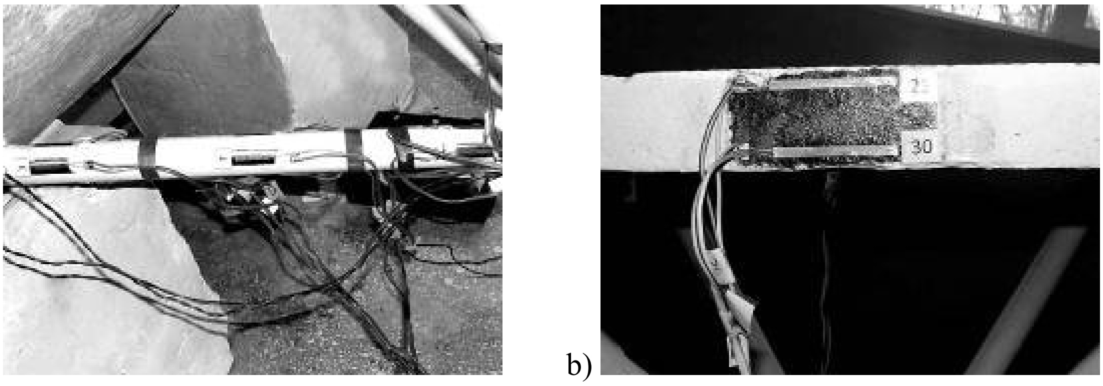


Figure 3 – The prototype test scheme:
1 – support module; 2 – span module; 3 – support; 4 – the cargo;
5 – traverse; 6 – lower chord; 7 – fuse

Full-scale prototype of the steel and concrete composite cable space frame testing was carried out in several stages. For measuring strain in the cross-sections of the prototype were used wire strain gauges resistance were used, which had the backing paper. They were made of glue BF-2. For measuring strain of steel elements of the prototype, strain gauges with a base of 30 mm (type 2PKB-30-200HB) were used, which have tensosensibility factor of 2.19 and resistance 201–201.49 Ω. For measuring strain of concrete elements of the prototype, strain gauges with a base of 50 mm (type PKB-50), which have tensosensibility factor of 2.21 and resistance 310.3 Ω ± 0.3 Ω were used. Strain gauges of each type were from the same batch that had been tested for suitability for using accordance to national code. Wire strain gauges were attached to the surface of the prototype on certain places with glue BF-2 (Fig. 4).



a) b)

Figure 4 – A general view of placing strain gauges on steel (a) and concrete elements (b)

To quality joining strain gauges to the surface of steel and concrete elements of the prototype and for their correct work during testing, these areas were cleaned to smooth state by grinding equipment and devices with varying degrees of abrasiveness, then skim alcohol solution, and coated with several thin glue layers.

Indications of strain gauges were taken with the equipment «AYD-4». Connection between strain gauges and the device was provided via copper multicore wires of cross-section 0,2 mm² and length up to 6 m. Considering that there were a lot of strain gauges that were used to study of stress-strain state of the prototype, in this case there was the notion «quantitative strain gauges», so for measuring of strain from all strain gauges, single pole switch was used. Except the measurement of the prototype elements strain of steel and concrete composite cable space frame, measurement of nodes displacement by mechanical and photogrammetric method was done (Fig. 5).

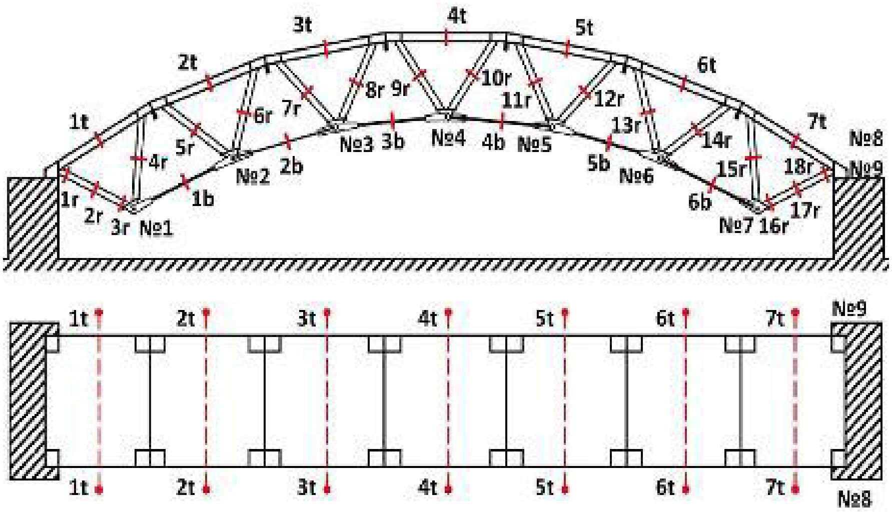


Figure 5 – Number of nodes and sections of the prototype

For measurement vertical displacements of the prototype, the equipment was set on each node of the bottom chord (Fig. 6).

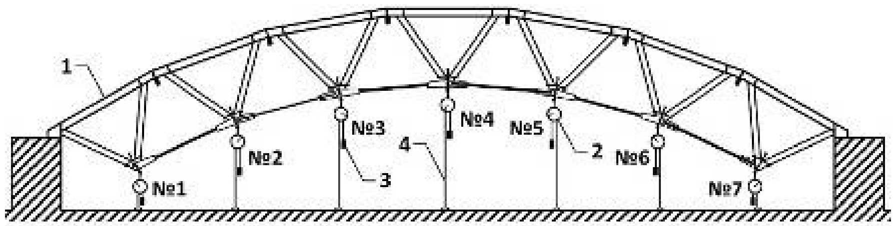


Figure 6 – Placement of instruments for measuring displacements:
№1, №2, ..., №7 – numbering devices; 1 – research design; 2 – device 6PAO;
3 – the cargo; 4 – steel wire Ø 0,25 mm

In addition, horizontal displacement was determined. In particular, horizontal displacement of nodes №8 and №9 were measured (Fig. 7).

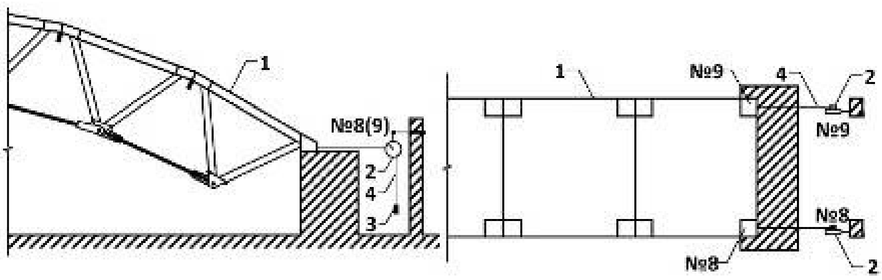


Figure 7 – Placement of instruments for measuring displacement of support nodes:
№1, №2 – numbers of devices; 1 – the prototype; 2 - device 6PAO;
3 – the cargo; 4 – steel wire Ø 0.25 mm

In addition, displacement of nodes №1 and №7 were measured with the devices 6PAO. For this at node №1 on the cap of bolt was set hinging to which, steel wire was attached, and at node №7 block via it wire was moved and attached to device. For a more detailed study of the prototype strain state, optical recording method of movement was used as photogrammetric method (Fig. 8) [8].

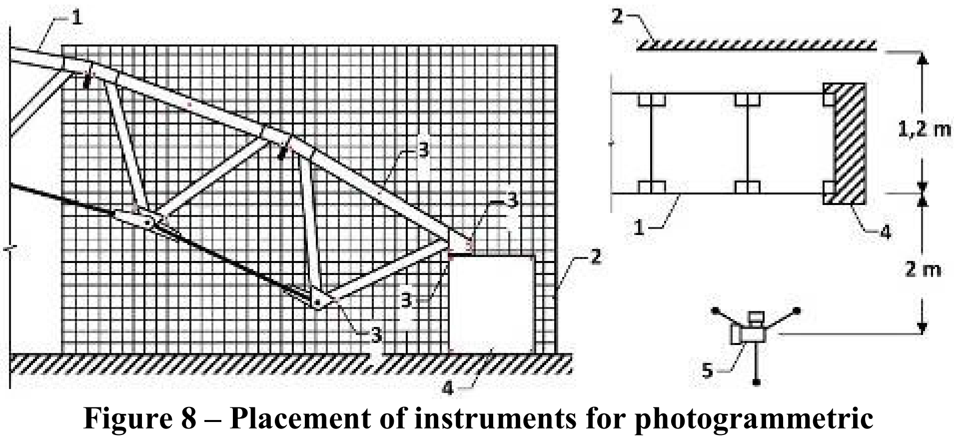
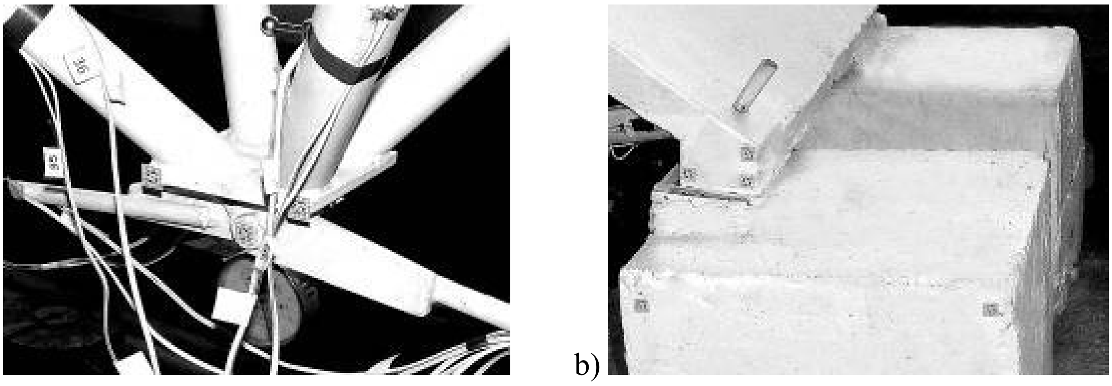


Figure 8 – Placement of instruments for photogrammetric measurement of displacement:
1 – the prototype; 2 – sheet with marks; 3 – marks; 4 – support; 5 – digital camera

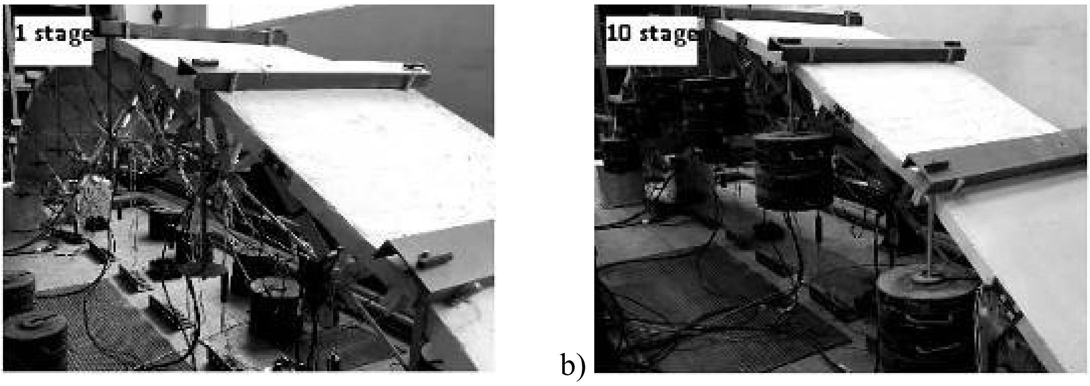
This method is based on digital pictures analysis at each stage of loading. To perform this, a special sheet that had a control grid was made. The sheet was arranged in front of the camera on the other side from the prototype. Also, on the prototype special labels were set. Special labels were set on both the top and bottom chords of the prototype (Fig. 9).



a) b)

Figure 9 – Special labels on the nodes of the bottom (a) and support (b) chord

In addition, marks were set on the support nodes; this was done to learn about their movements more widely. Also, it was enable to obtain the total value of the prototype nodes horizontal displacement and execute correct assessment of stress-strain state of the prototype. After setting up all the equipment and devices, tests were conducted in temporary load (Fig. 10).



a) b)

Figure 10 – Prototype of steel and concrete composite cable space frame prototype testing

To produce lattice and bottom chord of the prototype, seamless steel tubes, hot rolled round steel bars, rolled universal steel sheet were used. To produce the top chord, concrete mixture was used (tab. 1).

Table 1 – The composition of concrete mixture

Class for durability	Water-cement ratio	Consumption of material, kg/m³		
		Sand	Broken stone	Cement
C25/30	0,5	610	1217	383

Determination of the physical and mechanical properties of steel and concrete that were used to make the prototype, it was performed in accordance with applicable rules and regulations of national codes. Determination of the physical and mechanical properties of concrete, testing standard concrete samples of cubes and prisms with a hydraulic press PMM-250 was carried by compression.

The samples were stored in the same premises under identical conditions as the prototype. Testing standard concrete samples of cubes and prisms were performed simultaneously with the experiment. Before the samples test was conducted, visual inspection to detect external damage and defects was conducted. When the samples were viewed, damages that exceeding the permissible were not found. However, minor defects of geometry were identified, which was characterized by change in cross-sectional area to height. Overall quality of cubes and prisms standard concrete samples was satisfactory.

Conclusions. Experimental research methodology of full-scale prototype of the steel and concrete composite cable space frame was designed to obtain data that accurately describe the stress-strain state and prototype conduct under the action of symmetric load. Physical and mechanical properties of steel and concrete that were used to manufacture the prototype were standard and similar to those that commonly are used for the manufacture steel and concrete structures. Manufacturing technology of the prototype is similar to existing, but collecting and assembling methods are original in its execution. Instruments and accessories used in experimental research, allowed to obtain data that objectively describe the conduct peculiarities of the steel and concrete composite cable space frames full-scale prototype under load.

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