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THE METHODOLOGY AND RESULTS OF EXPERIMENTAL INVESTIGATIONS OF STEEL AND CONCRETE COMPOSITE CABLE SPACE FRAME ON EFFECT SHORT-TERM LOADING

The article presents methodology and results of experimental investigation of full-scale steel and concrete composite cable space frame 5.3 m on effect short-term loading. The experimental sample consisted of flexible elements of the lower belt and steel and concrete composite space modules. Elements of the lower belt were made of pieces of rolled steel with a circular cross section of 16 mm in diameter. The steel and concrete composite space module was in the form of a regular rectangular pyramid of 0.5 m high and length of a side of 0.8 m, and consisted of a reinforced concrete slab of 50 mm thick and grids of steel tubular rods with an outer diameter of 42 mm and a wall thickness of 3 mm. The experimental research technique provided for measuring the structural deformations at a load that was 70 % of the destructive load. As a result of the experimental test, data were obtained, on the basis of the data analysis the dependencies between deformation and loading were obtained. It was found that the studied structure during the test demonstrated the collaboration of all its components.

Key words: steel and concrete composite, cable, module, bolted connection, deformation.

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МЕТОДИКА ТА РЕЗУЛЬТАТИ ЕКСПЕРИМЕНТАЛЬНИХ ДОСЛІДЖЕНЬ ЗБІРНОЇ СТРУКТУРНО-ВАНТОВОЇ СТАЛЕЗАЛІЗОБЕТОННОЇ КОНСТРУКЦІЇ НА ДІЮ КОРОТКОТРИВАЛОГО НАВАНТАЖЕННЯ

У статті наведено методику та результати експериментального дослідження напруженого стану повнорозмірної збірної структурно-вантової сталезалізобетонної конструкції прольотом 5,3 м на дію короткотривалого навантаження. Експериментальний зразок складався з гнучких елементів нижнього пояса та просторових сталезалізобетонних модулів. Елементи нижнього пояса були виготовлені з відрізків сталевого прокату круглого перерізу діаметром 16 мм. Просторові сталезалізобетонні модулі мали форму правильної чотирикутної піраміди висотою 0,5 м зі стороною 0,8 м і складалися з залізобетонної плити товщиною 50 мм і решітки зі сталевих трубчастих стрижнів із зовнішнім діаметром 42 мм та товщиною стінки 3 мм. Методика експериментальних досліджень передбачала вимірювання деформацій елементів конструкції при навантаженні, яке дорівнювало 70 % від руйнівного. Встановлено, що досліджувана конструкція впродовж усього випробовування продемонструвала сумісну роботу усіх її складових.

Ключові слова: сталезалізобетон, ванта, модуль, болтове з’єднання, деформації.

Introduction. Steel and concrete composite cable space frame is a new type of a composite roof structure, which is assembled from three-dimensional steel-concrete composite modules and a flexible lower belt [1]. The essence of the steel and concrete composite cable space frame consists in a new way of combining the structural elements, which results in the combination of the bearing and protecting abilities, shortening the construction period, and rigidity. The steel and concrete composite cable space frame has a simpler way of providing the joint operation of the elements than conventional steel-concrete structures. That provides decreasing complexity both building construction and junctions production than the space grid structures, and lesser deformability than the cable structures. In addition, the steel and concrete composite cable space frame is architecturally expressive, also resource-saving than other types of structures with similar dimensions and bearing capacity [2]. Applying the steel and concrete composite cable space frame it is possible to build roof structures of various sizes and shapes [3].

Analysis of recent studies have shown that among the existing composite structures most often there are steel-concrete structures, the feature of which consists in the combination of reinforced concrete slabs with steel rod elements [4]. Therefore, the study of steel and concrete composite cable space frame is a promising direction of development of building structures [5]. Today the proposed designs have been widely researched. The small-scale samples of steel and concrete composite cable space frame both experimentally and theoretically have been investigated, and the stress-strain state of individual elements has been investigated too, and optimal geometric dimensions of the structures were identified [6].

Highlight unsolved parts of the general problem. The analysis of previous works has showed that behavior peculiarities of the proposed structure on large-scale sample under short-term loading have not been conveniently studied yet.

Formulation of the problem. Task consists in designing of a methodology experimental researching of stress-strain state of steel and concrete composite cable space frames.

The main material and results. Steel and concrete composite cable space frame consists of steel-concrete composite modules and elements of lower belt (Fig. 1). The steel-concrete composite module consists of thin-walled reinforced concrete slab and tubular rods with an outer diameter of 42 mm and a wall thickness of 3 mm. The thin-walled concrete slabs form a top belt of a thickness of 50 mm.

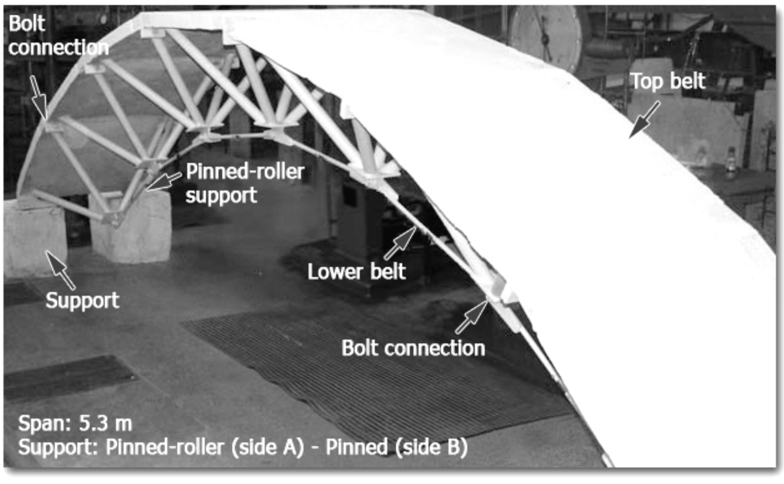

Fig. 1. Full-scale experimental sample of the steel and concrete composite cable space frame.

Jointing steel-concrete composite modules and elements of lower belt together was performed via bolted connection on both top and lower belts (Fig. 2) Bolt connections on top belt were rigid and bolt connections on lower belt were pinned.

Because the dimensions of the full-scale steel and concrete composite cable space frame were significant, the use of standard laboratory power equipment, in particular of presses for creation and application of temporary structural loads were impossible. Therefore, the loading of the full-scale steel and concrete composite cable space frame was carried out via cargos. Each of such cargo has been made of cast iron and had a solid disc shape and weight 42 kg. To application the load in the form of cast-iron discs to the experimental sample, the traverse system was applied, which consisted of a cross-arm and two steel rods with detents on which discs were hung. Such traverses were laid by a cross-arm on the top belt of the steel and concrete composite cable space frame at the joints (Fig. 3).

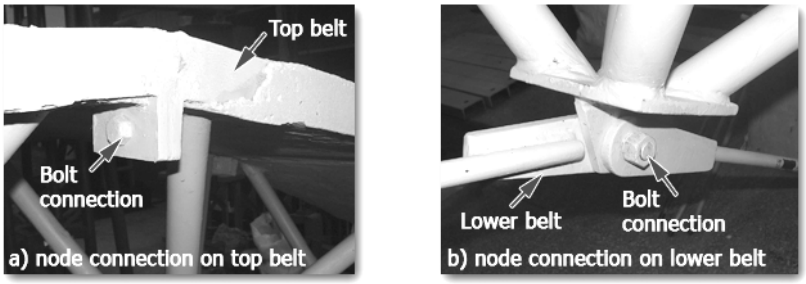

Fig. 2. Node connections of the steel and concrete composite cable space frame

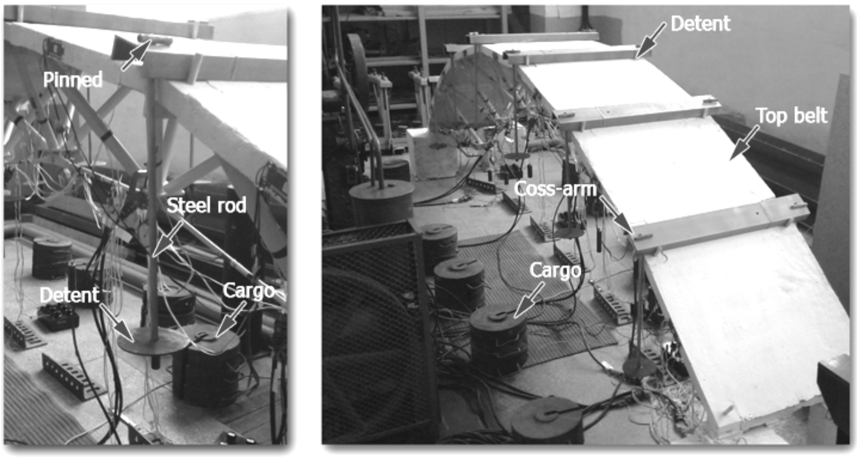

Fig. 3. Loading of the steel and concrete composite cable space frame.

To fix and prevent of the displacement or movement of the traverses when loading full-scale experimental sample of the steel and concrete composite cable space frame, the detents were arranged at the traverse locations. Due to this solution, testing the experimental sample of steel and concrete composite cable space frame on the effect of a temporary load in accordance with the experimental research methodology was possible.

Strain of full-scale steel and concrete composite cable space frame were measured in accordance with the experimental research methodology (Fig. 4).

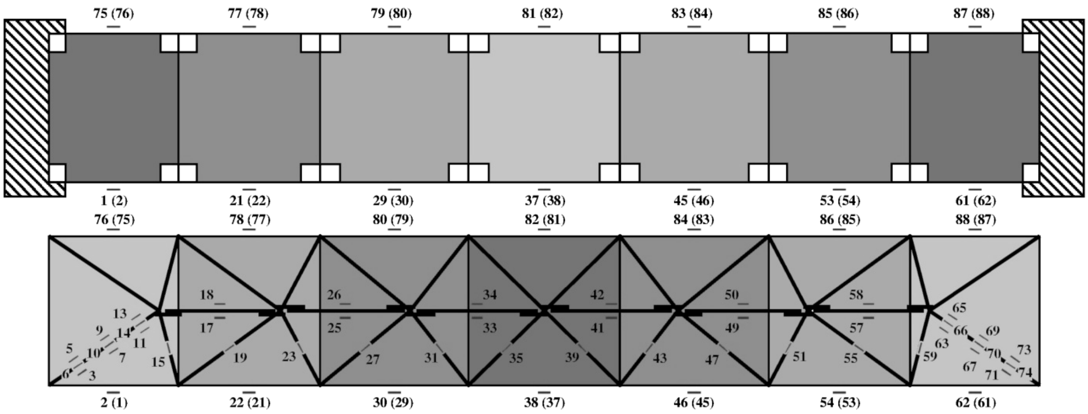

Fig. 4. Places where the strain was measured

The test was carried out in 10 stages (Fig. 5 and Fig. 6).

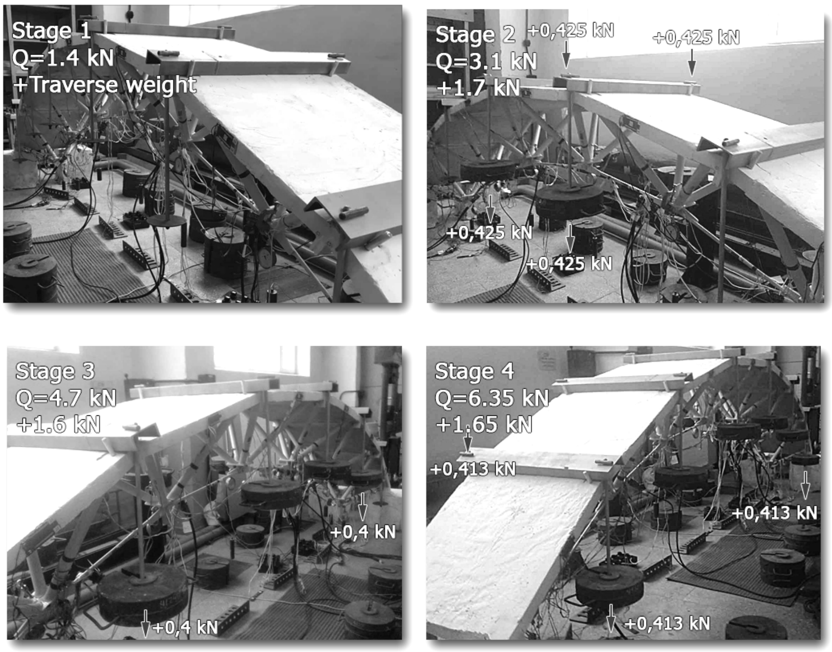

Fig. 5. The full-scale experimental sample of the steel and concrete composite cable space frame during the test

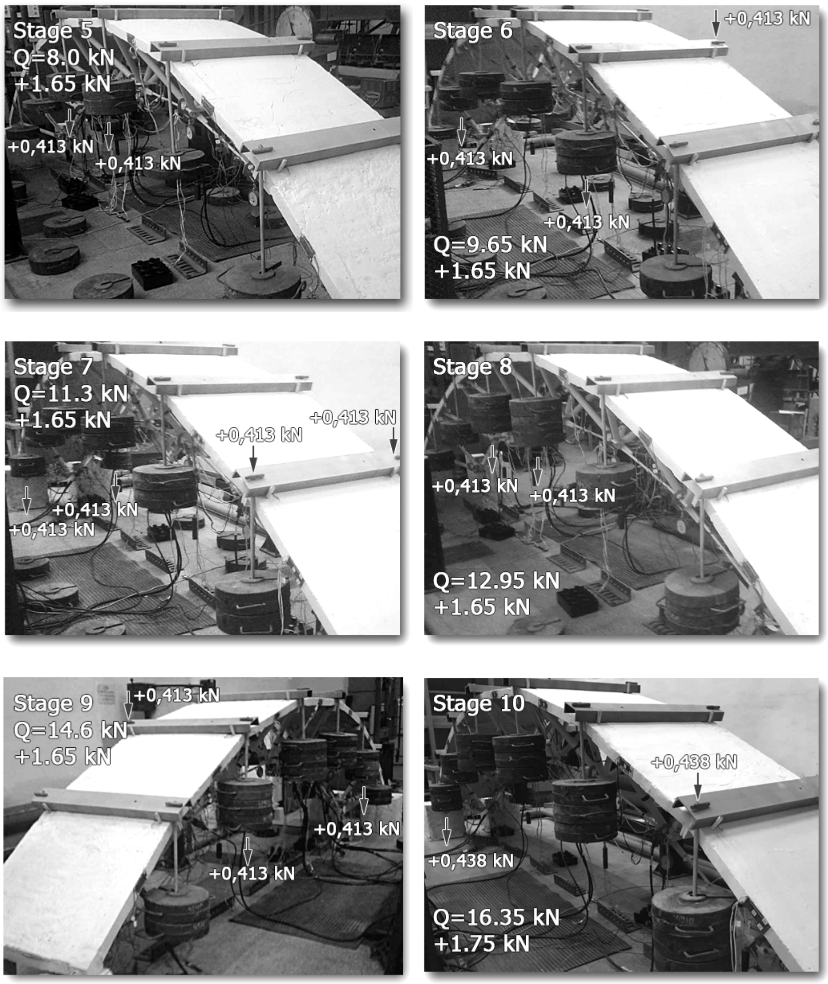

Fig. 6. The full-scale experimental sample of the steel and concrete composite cable space frame during the test

As a result of the experiment, data were obtained, the analysis of which made it possible to evaluate the behavior of the steel and concrete composite cable space frame under short-term load (Fig. 7 and Fig. 8). It should be noted that in accordance of the experimental research methodology, the steel and concrete composite cable space frame was investigated on the effect of the operational load, which was 70 % of the destructive, that is, the sample was not destroyed.

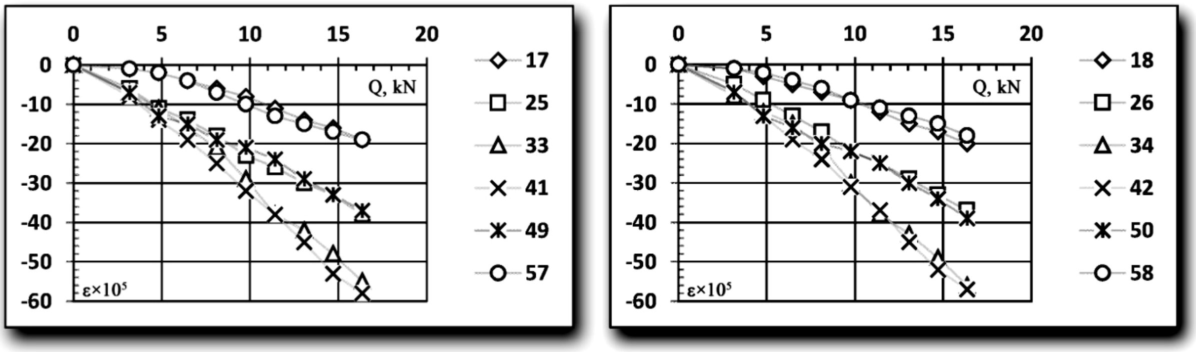

Fig. 7. The load-strain curve of lower belt.

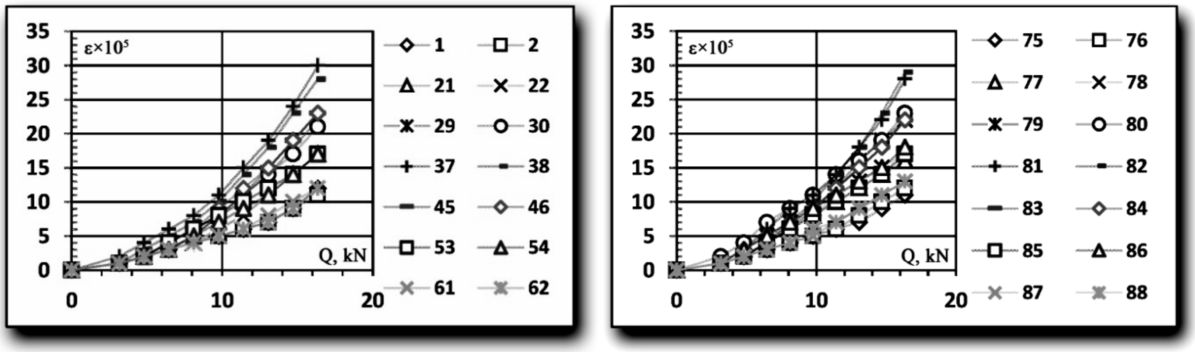

Fig. 7. The load-strain curve of top belt

Analyzing these curves, it is obvious that, in general, the strain of the experimental sample of the steel and concrete composite cable space frame were elastic. The steel and concrete composite cable space frame that was prefabricated of modular elements operated as a holistic structure, and the designed nodes of connection ensured reliable and joint operation of modular elements.

Experimental data are showing that the top belt is in compression and the lower belt is in tension. Comparison of experimental data in similar cross-sections (symmetrical) showed that the difference between them is not significant (Fig. 8).

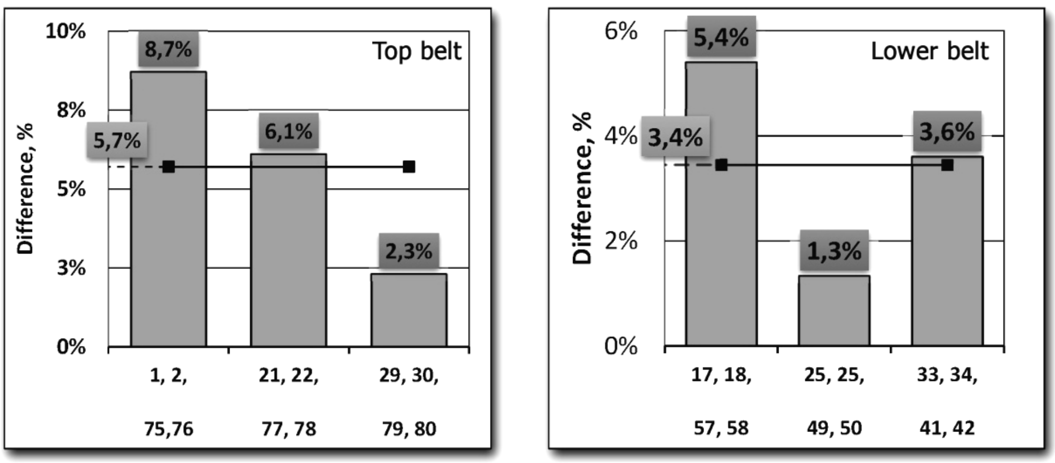

Fig. 8. The difference between strain in the similar cross-sections

No significant difference between the experimental data in symmetric cross-sections indicates that the internal forces are distributed evenly and the steel and concrete composite cable space frame has demonstrated the joint operation of all the components.

Conclusion. Observing the experimental sample during the testing it was found that its behavior and the deformed view fully correspond to the theoretical data. Also, it should be noted that when inspecting the experimental sample at each stage of loading and at the end of the testing, no damage to the nodes or structural elements was detected, in particular, no cracks were found. Experimental data are showing that the top belt is in compression and the lower belt is in tension. Comparison of experimental data in similar cross-sections (symmetrical) showed that the difference between them is not significant. The steel and concrete composite cable space frame under short-tern load operated as a holistic structure, and the designed bolted nodes of connection ensured reliable and joint operation of modular elements.

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