PRODUCTION OF FULL-SCALE EXPERIMENTAL MODULAR SPECIMENS OF THE STEEL AND CONCRETE COMPOSITE CABLE SPACE FRAME

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***Artykuł recenzowany**

Abstract

The steel and concrete composite cable space frame is a new type of space roof structure that was designed in Poltava National Technical Yuri Kondratyuk University and fully patented. The article presents procedure preparation of prototype of steel and concrete composite cable space frame in full scale. The main focus is on the specifics of the technological operations of preparation and production of steel and concrete elements of the structure. There is technological sequence of operations in the article also.

The full-scale experimental structure consists of the space steel and concrete composite modules and flexible modular steel elements, which are combined with each other via single-bolt connections.

The space steel and concrete composite module consists of monolithic reinforced concrete slab and a structural lattice that is made from steel tubes.

Production of steel parts of structure were carried out at the factory of building structures and concrete performed under conditions close to those of the construction site.

Keywords: module, tube, plate, hole, welding, bolt.

1. Introduction

The necessary condition for the development of a production industry is continuous improvement existing solutions or development of new solutions. The construction industry is not exception, moreover considering the current economic conditions there is the dire need of implementation the new effective structures. The structure that completely satisfies these requirements is the steel and concrete composite cable space frame. The originality of this concept lies in combination of various elements, such as slabs and rods. The effectiveness of the concept is determined by the terms of location of these elements in the structure. The structure consists of steel and concrete composite space modules and flexible modular steel elements, which are combined with each other via single-bolt connections. The space steel and concrete composite module consists from a monolithic reinforced concrete slab and a structural lattice that is made from steel tubes.

2. Analysis of recent sources of research and publications

The analysis has shown that one of the main directions in the development of building structures is the study of composite systems, especially steel and concrete composite structures. This is primarily due to their good strength characteristics [1–5]; secondly, steel and concrete composite structures are versatile and have a wide scope [6–9]. They can be successfully used in mechanical engineering, bridge construction, mining and construction of various buildings [10–14] etc.

The analysis found that the most of works devoted to the study of stress-strain state of new or improved designs, and almost not solved issues of technological, manufacture or production nature.

The purpose of study is to present the main aspects of the modular elements production and preparation of steel and concrete composite cable space structure.

3. The main material and results

The steel and concrete composite cable space structure is the new type of modular space systems [15–17]. It should be noted that this system and all components were patented. The proposed systems have a number of significant structural the differences and more advantages compared with analogues, namely: lower costs of steel, there is no need to assembly welding, simple connection nodes and therefore less complexity and cost of whole project. The structure includes a top reinforced concrete chord and bottom steel chord, but depending on of some parameters, including the form and load, it can have different designs in particular nodal connections [18, 19]. In this case, for assembly of the experimental structure were used modules with single-bolt connections [20, 21]. The structure was calculated by a numerical method. In result were obtained the optimal geometric dimensions, profiles and dimensions of cross sections of structural elements and designed drawings [22–24].

Production of modular elements was made completely in the factory without of unique equipment. Technological of operations that were needed for modules production are common for plant-manufacturers of steel building

structures. By the way, thanks to the peculiarities of constructive concept of modules [25] production processes are not required a large number of types and sizes of metal rolling. It is has a positive effect for reducing both complexity production and assembly operations.

The steel and concrete composite space modules consist of two parts: reinforced concrete slab (top chord) and a steel frame, and depending on the position in the structure it can be span and support. The support module differs from the span module by presence of support nodes that are designed to connect the structure with vertical bearing elements and transfer a load on it. The steel frame was made of steel sheet and seamless tubes and was consisted of a flat closed steel skeleton (Fig. 3.1) and the spatial lattice (Fig. 3.2). The design specific of the frame allowed manufacturing them without complex and precise measuring instruments, unlike counterparts. It should also be noted that due to the modularity of the structure and the small number of types of metal profiles there was no need to frequently adjust equipment for cutting.

Manufacturing technology of the frame of space modules involves several processes with using electric welding and several stages. In the first assembling stage of the frame of space modules was carried out prior connection all steel parts with spot welding. After that, geometric dimensions were checked to identify deviations; because all factual dimensions corresponded to the project then all joints were welded completely.

Production of the modules was started from preparation of conductor (Fig. 3.1, a), which arranged stops (3) on the platform (4). The conductor was needed to provide the design dimension of module. Then steel plates (1) were placed, and were joined with rods (2) by means of spot welding (5).

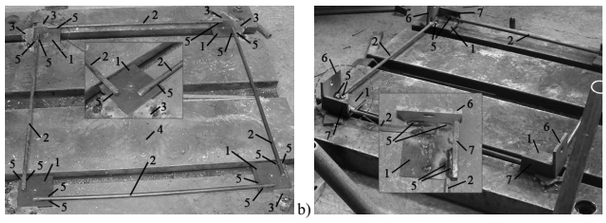


Figure 3.1 – Production of flat steel skeleton of the frame space module: a) forming a frame size; b) production nodes; 1, 6, 7 – steel plate; 2 – rod of circular cross section; 3 – conductor stops; 4 – platform conductor; 5 – spot welding

The rods (2) need to safe a form of flat steel skeleton during transportation. Requirement the rods installation was due by technological features. Production of the modules includes concreting in another place, it can be both as construction site and as plant of concrete products. So manufacturing of modules usual includes transportation. Then were formed the nodes of joints in the plane of reinforced concrete slab (Fig. 3.1, b), which consisted of steel plates (6) and (7). In the plate (6) was provided a hole for bolting.

Spatial lattice manufacture from tubular rods (2) and the steel plate (1) was the next process (Fig. 3.2, a). In the next, the spatial lattice was connected with flat steel skeleton (Fig. 3.2, b) and was joined to the plate (1) and plate (4), which had a hole for bolting.

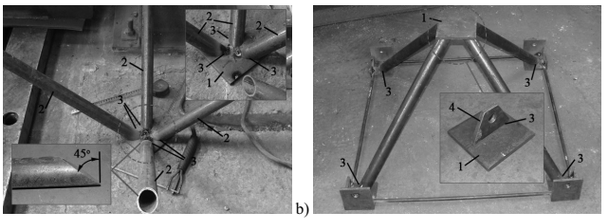


Figure 3.2 – Lattice production of steel frame of space module: a) connection tubular rods and steel plate; b) connection flat steel skeleton and steel tubes; 1, 4 – steel plate; 2 – tubular rod; 3 – spot welding

There are operations and labor hours for space modules production in Table 3.1. There are eleven simple operations for space modules production. The main and the most important operation is the cutting, but before cutting there is need marking details according to the sketch (Table 3.2) and application scratches in places of cutting. Usually for marking of details are used templates. Cutting simple steel details like polygon plates are performed with a guillotine. Cutting steel tubes performed with a ribbon-saw. Cutting curved steel details from steel sheet are performed with a gas cutting.

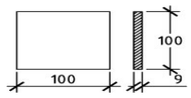
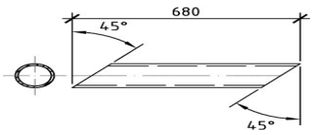
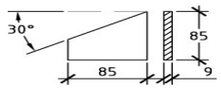
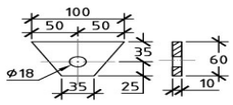
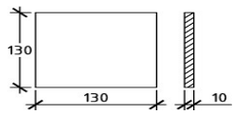
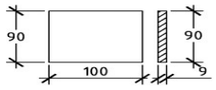
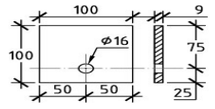
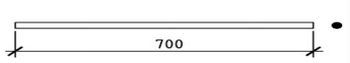
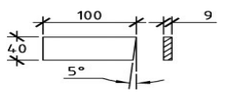
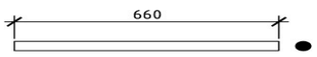
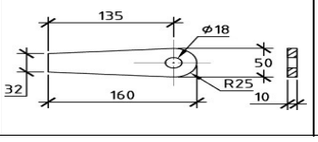
All joints were completely welded after every detail had been connected with each other. Consequently, the steel frames were obtained that in the next were covered with a special coating and then were concreted. For concrete compaction in this case can be used different methods. In this case was used rodding. It is a hand method of poking with 2 m long, 16 mm diameter rod at sharp corners and edges.

Table 3.1 – Operations and labor hours of production of steel frame for the space modules

№	Operation	References*	Unit	Amount of work	Labor hour	Total labor hour
1	Tube marking	E40-5-5; table 1; table 2 (1a)	100 element	0.28	1.1	0.308
2	Cutting tubes	E40-5-5; table 4 (4b)	100 times	0.32	6.9	2.208
3	Marking of template for rectangular shape without holes	E40-2-1; table 2 (7a)	100 element	0.03	3.8	0.114
4/1	Marking of template for elements non- rectangular shape with holes	E40-2-1; table 2 (11a)	100 element	0.02	6.4	0.128
4/2	add with 100 holes	E40-2-1; table 2 (11b)	100 holes	0.01	0.38	0.004
5	Marking of details from a steel sheet by a template	E40-2-2; table 1 (1v)	100 element	0.66	2.2	1.452
6	Cutting of steel sheet by a shearing press	E40-2-3; table 2 (1)	100 element	0.66	0.72	0.475
7	Drilling holes in the steel sheet	E40-2-6; table 2 (1a)	100 holes	0.31	1.3	0.403
8	Cutting of rods circular cross section	E2-2; table 1 (4v)	1 ton	0.004	4.4	0.018
9	Assembling modules	E40-2-19; table 2 (3g)	1 ton	0.11	6.6	0.728
10	Welding tubes with plates	E22-1-1; table 1 (1v)	10 m	1.79	3.2 × 1.2 × 1.05	7.22
11	Welding plates	E22-1-3; table 1 (1a)	10 m	1.01	5× 1.2	6.048
-	Total	-	-	-	-	19.106

*– It is series of standards that used in Ukraine to obtain labor hour of production different things.

Table 3.2 – Sketches of steel details

№	Sketch of detail	Amount	Weigh, kg	№	Sketch of detail	Amount	Weigh, kg
1		28	0.62	7		4	0.19
2		28	1.97	8		4	0.32
3		7	0.30	9		7	1.32
4		4	0.56	10		24	0.61
5		28	0.156	11		24	0.26
6		6	1.04	12		12	0.62

The manufacture of flexible modular steel element had a similar technology as in the previous case, but was much simpler because the flexible modular consisted only of three parts: steel rod of circular cross section and two drop plates with holes for bolting (Fig. 3.3). After that, the modules were covered with a special coating.

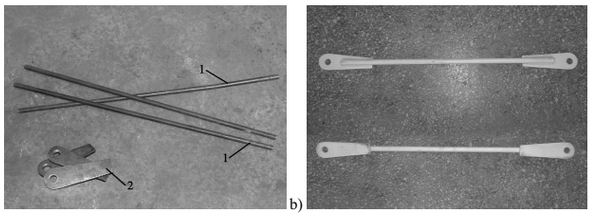


Figure 3.3 – The flexible module
a) steel parts; b) the flexible modular; 1 – the steel rod;
2 – the drop plate

4. Conclusions

The current paper presents preparation of the modular units of experimental full-scale steel and concrete composite cable space frame. The result were made five the span space steel and concrete composite modules and two the support space steel and concrete composite modules. Also were made six flexible modular steel elements. Production of all steel parts of structure was carried out in the factory of building structures and concrete performed in the construction site.

The space steel and concrete composite module consists of monolithic reinforced concrete slab and a structural lattice. The flexible modular steel element consists of steel rod and drop steel plates.

From modular elements will be going to the experimental full-scale steel and concrete composite cable space frame.

Table 3.3 – Operations and labor hours of the flexible modules production

№	Operation	References	Unit	Amount of work	Labor hour	Total labor hour
1/1	Marking of template for elements non- rectangular shape with holes	E40-2-1; table 2 (11a)	100 element	0.01	6.4	0.064
1/2	add with 100 holes	E40-2-1; table 2 (11b)	100 holes	0.01	0.38	0.004
2	Marking of details from a steel sheet by a template	E40-2-2; table 1 (1v)	100 element	0.12	2.2	0.264
3	Cutting of steel sheet by a shearing press	E22-1-34; table 2 (1)	10 m	0.467	0.52	0.243
4	Drilling holes in the steel sheet	E40-2-6; table 2 (1a)	100 holes	0.12	1.3	0.156
5	Cutting of rods circular cross section	E2-2; table 1 (4v)	1 ton	0.007	4.4	0.031
6	Welding	E22-1-3; table 1 (1a)	10 m	0.04	5× 1.2	0.24
-	Total	-	-	-	-	1

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