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Design works on carcassing the circus big top in the block "A" while reconstructing Penza circus

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Abstract

The project designers describe their experiment on carcassing the big top of the main building (Block A), the largest in Europe after the reconstruction of Penza circus. Due to the difficult conditions at a construction site, it was necessary to find an acceptable method to enlarge trusses of the big top, also to determine a method and sequence of erection of completed trusses with optimal application of erection crane's weight and high-altitude characteristics. Four options were considered for pre-assembly works of parts suitable for transportation of trusses. Assembly line technique of trusses was developed based on an agreed upon with the executive version. A small area was dedicated for this purpose. Erection and dismantling method of the big top was developed. The project is accepted for production.

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Keywords: Big top; Steel polygonal trusses; Upper supporting ring; Lower supporting ring; Design work for the big top erection; Assembly options; Erection; Equipment and accessories dismantling.

1. Construction solution for the building

Penza state circus complex of buildings which is being reconstructed at the moment has been designed as a complex consisting of four different interlocked constructions referred to as Blocks A, B, C and D. Block A is a central four-floored building with a big top. Block B is joined up to its west side, and Block C is joined up to its south side. Block D (the longest building on Figure 1) is joined up to Block B.

The complex principal dimensions:

- Block A, the main building of the circus, 64.0x65.0 m, height to the big top – 30.8 m;
- Block B, 8-floored additional building, 15.6x44.7 m, height to the roof railing – 27.3 m;
- Block C, 8-floored additional building, 15.6x44.7 m, height to the roof railing – 27.3 m;

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- Block D, 2&4-floored additional building, 25.0x75.0 m.

There are service, administrative, utility, engineering and technology areas located in 8-floored buildings of Blocks B and C. There is a circus ring, animal houses and a parking area located in Block D.

In the first two floors of the additional building (Block B) there is a drive passage for large-sized transport, stage property and animal unloading, and also a parking area.

Each building has its own structural design.

Spatial rigidity and buckling resistance of multistoried buildings can be supported by monolithic stiffening cores (stairs and elevators), by the system of distributed vertical monolithic walls and connections (stiffening diaphragms) made of reinforced concrete, and by wall columns and carrying piers joined together into a stable structure by monolithic floor slabs made also of reinforced concrete.

The circus amphitheater is designed as a polygonal graded closed-loop slab of reinforced concrete supported by monolithic tilted beams made of reinforced concrete. These beams are arranged around the periphery in radial axis from the center of the circus ring.

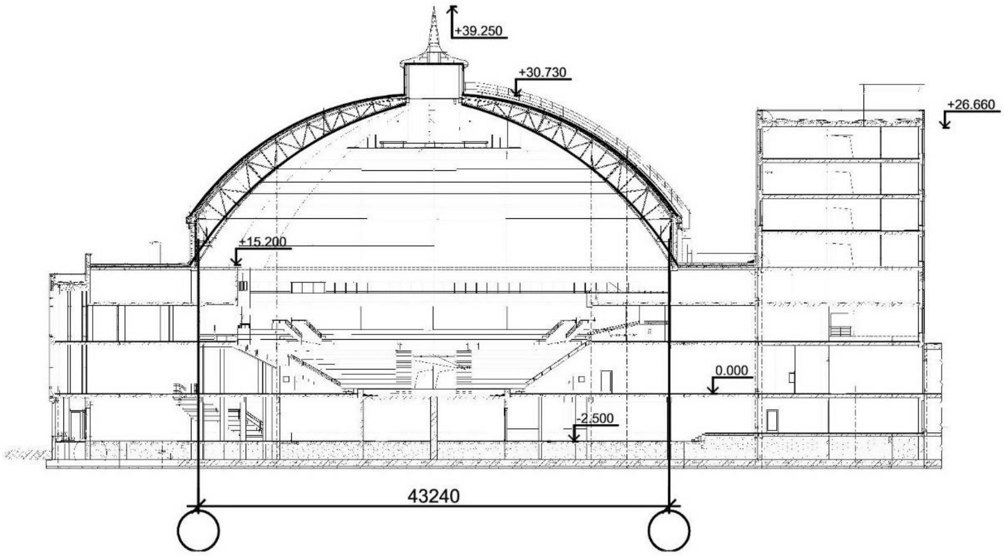

Fig. 1. Blocks A and B (with Block G joined to it) drawing in longitudinal section.

The circus amphitheater is leaned against the inner walls and carcass columns arranged in in radial axis. The amphitheater slab thickness is 160 mm, its beam depth is 500 mm.

The big top of the circus is the central and the most important part of the whole structure. The reconstruction of the circus includes the big top dismantling, its enlargement to 45.2 m in diameter and building a new grid platform 18.0 m in diameter at the height of 26.0 m. The big top height is supposed to be 30.55 m at the central drum level.

The lower parts of the big top are supported by load-bearing walls of reinforced concrete at the height of 15.0 m. The thrust presents a monolithic girt strip placed on the wall top.

The big top of the circus is planned to consist of 16 main roof trusses which are 24.75 m long each (19.45 m in plane view) and of 16 secondary short-cut roof trusses which are 17.60 m long each (12.50 m in plane view)

The main roof trusses are fixed at the top by the supporting metal ring which is 4.8 m in diameter. The secondary roof trusses are fixed at the top by the secondary supporting metal ring which is designed as secondary trusses between the main trusses assembled 17.6 m from the lower supporting structure.

Vertical and horizontal connections and cross bars are constructed on the roof trusses to provide stability of the big top geometrical shape. Roof purlins with low-combustible composite boarding are built at top-chord points of roof trusses to provide the big top roofing. Roof trusses sections are calculated according to their actual load accommodation (including the girt strip, cat walks, technical equipment, circus equipment, etc).

2. Process engineering solution for the big top construction

A construction plan for the central part of the circus complex – the circus big top – has been based on the designers' own experience in this field [1-22].

In the construction plans designed by the authors and similar to the own described [23-25, 29] it was important to choose properly the methods and the place of the pre-assembly works to make enlarged trusses parts suitable for transportation.

For assembling enlarged parts suitable for transportation of the big top trusses four different options were considered.

Option 1 consisted in assembling and bracing two main roof trusses with a secondary roof truss between them. For that work the designers required a 32 x 15 m open space for assembling a 15 m high building slipway, installing an erection crane and providing enough place for accepting shipment-sized set of details and gird assembly parts.

While using this option it is possible to assemble eight sections of the big top out of the sixteen. The other sections can be assembled as secondary roof trusses supported by secondary trusses and bracing while using the already erected enlarged parts.

Fig. 2. The open space for assembling the big top roof trusses
(shuttering constructions and other materials storage can been seen in the erection crane shadow).

The assembly workshop can be located only 33 m at closest to the center of the big top. The QTZ – 125 tower crane installed at the building sight can handle loads of 3 tons at 33 m its loaded radius. The weight of the enlarged section consisting of two main roof trusses with a secondary roof truss between them is 6.5 tons.

Option 2 differs from Option 1 while making it possible to arrange an enlarged section assembly works within 18 m of the crane loaded radius. The QTZ – 125 tower crane can handle loads of 6.5 tons here.

Option 3 suggests assembling the main roof trusses vertically with their lower and upper end resting on the considerably low trestlework (up to the 4 m from the earth level). The assembly workshop can be located only 33 m at closest to the center of the big top. The QTZ – 125 tower crane can handle loads of 3 tons here.

Option 3 suggests assembling the main roof trusses horizontally within the reach of the erection crane.

The four options were discussed with the contractor with the fourth option chosen. It was decided to assemble the main roof trusses horizontally (flat) within the reach of the erection crane [26-28]. It was not easy to find a proper open space due to the complicated conditions at Block A circus construction site [30, 31]. A small area of 32x12 m was allocated for this purpose (see Fig. 2). This open space was previously used for shuttering constructions and other materials storage. The designers had to analyze the possibilities of using this space for the enlarged constructions assembling.

Six options of assembling the roof trusses on this allocated area were analyzed, starting from assembling one separate roof truss to multiple adjustments (see Fig. 4). The designers tried to find out the most rational way of arranging the roof trusses, the erection crane, storage warehouses, access ways and the use of the QTZ – 125 tower crane.

The detailed analysis presented below cover Options 5 and 6 (see Fig. 4). Option 6 differs from Option 5 by the place of the assembling point location. Option 6 allows to use the QTZ – 125 tower crane with no limit to its handle loads.

It was necessary to allocate certain assembly points for enlarged roof trusses assembling. The height of these assembly points had to be 0.8-1.2 m. The assembling supporting structures could be made of any material (concrete, timber, bricks or steel). The demands for these structures were as follows: they should not be located under the assembly units, they should not be the same as the roof trusses in their form, and they should be allocated on one the same level. It was required to allocate at least three assembling supporting structures under each enlarged shipment-sized set of trusses (see Fig. 4). It was possible to establish the assembling supporting structures properly either with the help of a specially trained survey or after assembling the first enlarged roof truss. The enlarged shipment-sized set of trusses had to be stored in vertical elevators according to their types. Trusses themselves also had to be stored on special shell stands according to their types.

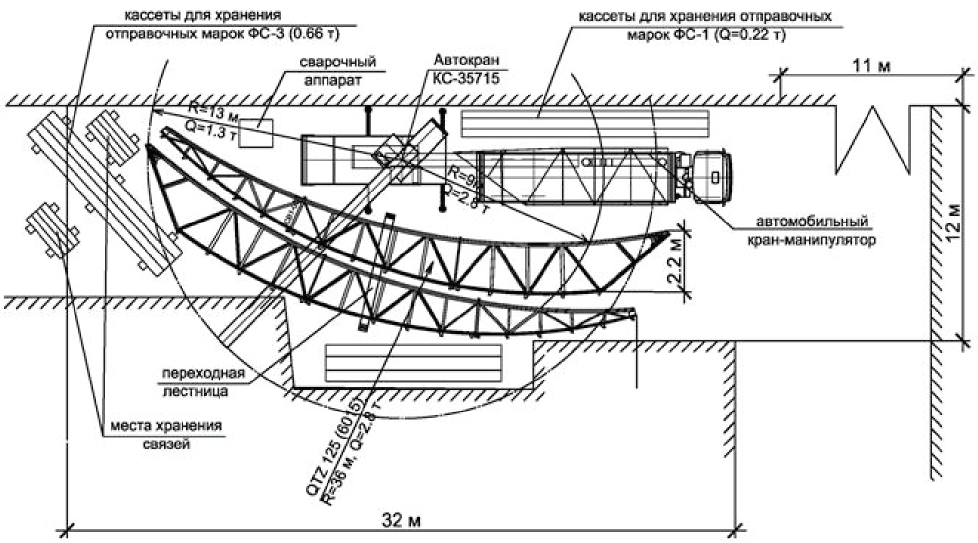

Fig. 3. The scheme for roof trusses multiple adjustments.

After the main enlarged roof trusses are assembled there would be more free space on the allocated sight to store connecting parts. They should be stored in elevators and in stock piles according to their types [31].

To assemble the upper supporting ring the designers suggested building a temporary vertical structure shaped as a four-panel tower 33 m tall (see Fig. 5). Its size (gridlines of the structure considered) is 3390 x 3390 mm. The tower had to be assembled level by level (10 levels) from two 3390 x 3390 mm panels joint together by braces and belts on each level. The panels should be connected by flange joints.

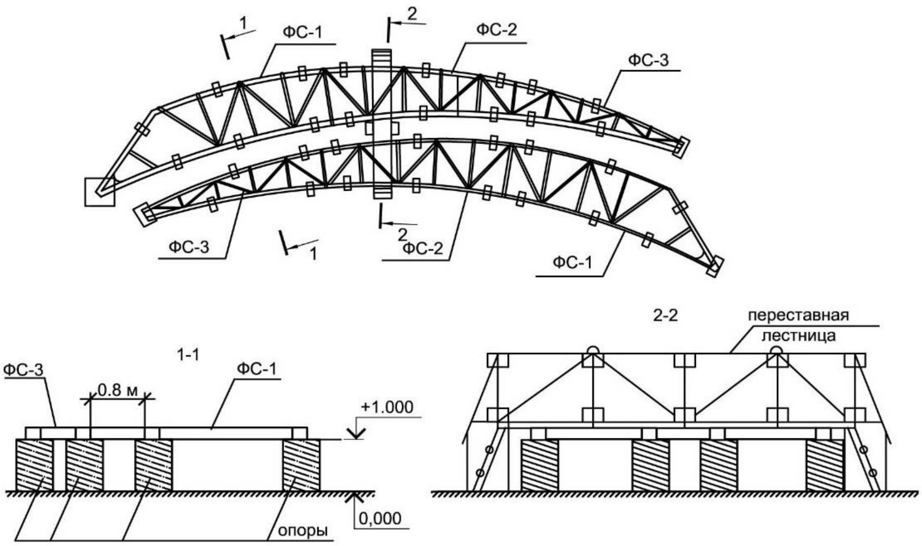

Fig. 4. The scheme of roof trusses assemble point.

One of the tower sides should contain a stepladder leading to a resting platform (being approximately 20 m above the ground level). An erection site should be built across the tower top.

For providing safety while assembling the roof trusses and while bracing the trusses of the circus big top the designers suggested two options of building up an assembling working platform.

Option 1 involves scaffolding erecting.

Option 2 involves building up an assembling working platform at the height of 15000 m and moving erection towers and graded scissor lifts on this platform.

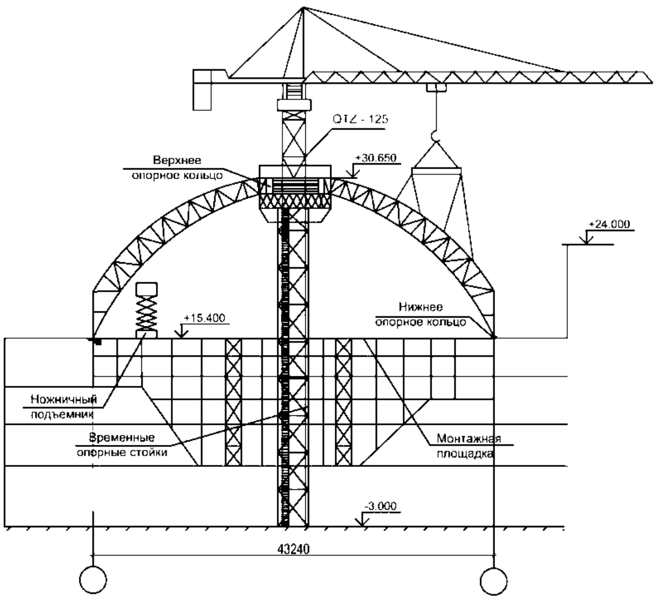

Fig. 5. The scheme of the big top erection.

Option one involves 20000 m^2 of scaffolding leasing (spaced at 2 x 1 m). Different firms suggest different terms of a lease. The lease includes wood deck (200 wood decks for every 1000 m^2). Table 1 shows the terms of a lease put forward by “Dirs” (a firm from the town of Podolsk) as an example:

Table 1. The terms of a scaffolding lease put forward by a firm from the town of Podolsk.

Quantity	1 month	2 month	3 month	4 month	5 month	6-7 month
Up to 100 m^2	200 roubles	190 roubles	180 roubles	170 roubles	160 roubles	150 roubles
Up to 200 m^2	190	180	170	160	150	140
From 200 m^2 to 500 m^2	150	140	130	120	110	100
500 m^2	90	80	70	60	55	50
From 1000 m^2 to 2000 m^2	80	70	60	50	45	40
From 2000 m^2 to 5000	75	65	55	50	45	35
Deck leasing	50	45	40	35	30	25

The terms of a lease depend on the time of scaffolding commission (as shown on Fig. 6).

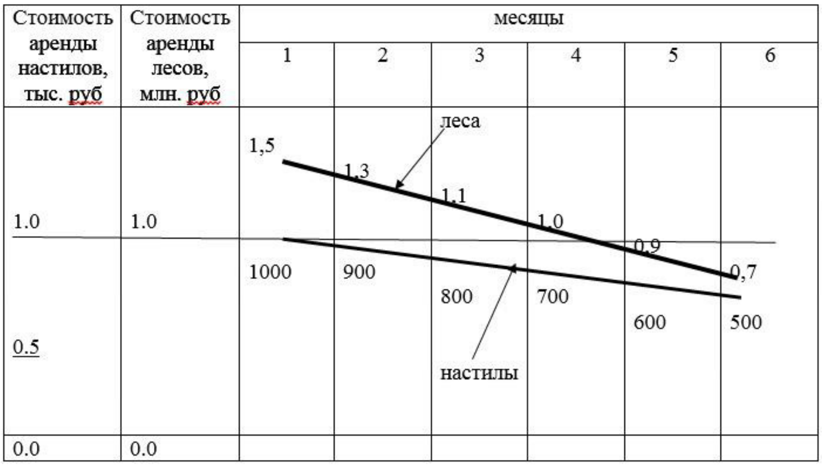

Fig. 6. The relation between terms of a lease and the time of scaffolding commission

1 m^2 of scaffolding lease price is taken as a basis.

Table 2. The amount of the materials required for building up an assembling working platform*.

Materials	Measuring unit	Quantity	Weight, tons	Approximate price, mln, roubles
Tube, 159 x 6	m	2500	56.6	1.7
I №20	m	600	15.0	0.45
I №10	m	4800	48.0	1.44
Plank δ=40 mm	m^2/m^3	1450/58	-	1.16
		Total		1.75
		+20% for unaccounted materials		0.95
		Total		5.70

* cross sections of outfit structural components should be verified according calculations; materials consumption is taken relatively and should be specified when making erection drawing of temporally supporting steel constructions

Option 2 involves building up an assembling working platform at the height of 15000 m. The platform is made of steel posts (tubes 159* mm in diameter), main I-beam girders (№20*) and plank layer (40 mm in thickness). The amount of the materials required is shown in Table 2.

Only material expenses are taken into account in Tables 1 and 2. Commercial costs of assembling would depend on the salary level in a certain assembling organization. Besides, commercial costs of Option 2 would also include the price of erection towers or elevators.

3. Progress at the site: step by step description

Before the roof trusses are lifted to the assembling platform step ladders and safety lines for erectors should be attached to them. The roof trusses slinging is done with 6 meters long strongbacks with 5 tons lifting ability, with slings of different length, and with universal slings wrapped around truss top chord (as Fig. 7 shows).

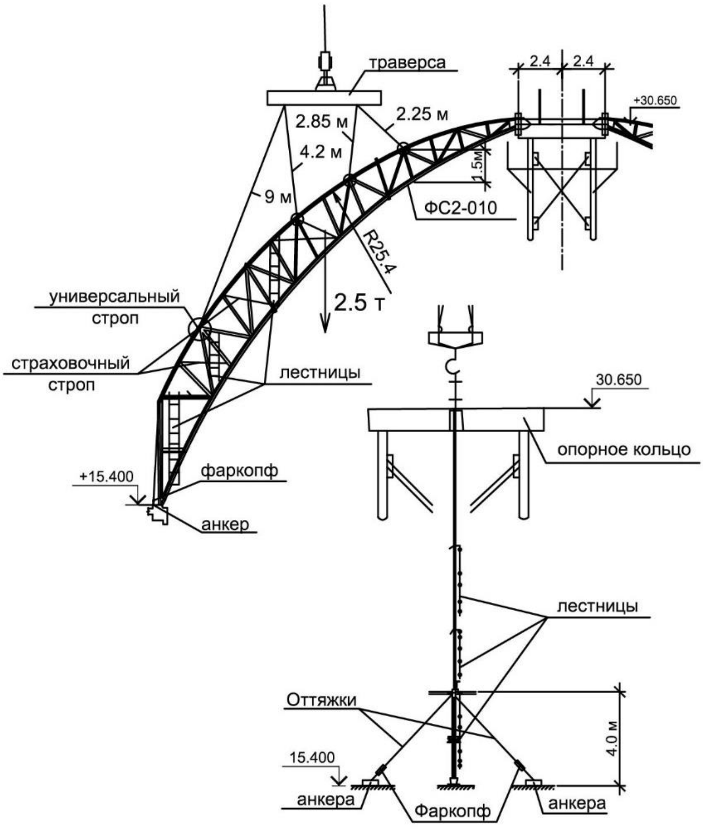

Fig. 7. The scheme of roof trusses assembling.

Hemp back-stay cable (Ø15mm, 10 m length) is attached to the bottom chord of a truss.

The length of the slings is adjusted while lifting the first roof truss. When the truss is lifted its bottom chord should be 30-50 cm above the ground level. It is kept there for 20-30 seconds and then the slings tension is checked. After that it is lifted for further 2-3 meters and kept there for 1-2 minutes more. Then the truss is checked for longitudinal strain. If there is no deflexion the truss is lifted to the assembling point. If there is some deflexion a timber strip or a steel plate should be attached to the trusses to avoid further deflexion.

Hemp back-stay cable helps the erectors (the first working at the ground level and the other working on the assembling point) grasp the truss.

Then the bottom chord of a truss is connected with the embedded part and their marks are matched. After top-dressing the truss its bottom chord is temporally fixed the same set of operations are applied to the supporting ring. The vertical position of the truss bottom chord is tested, then the truss is fixed by the back-stay cables and finally fixed at its top and bottom chords.

The slings tension is slacked by the tower crane. The slingsman goes up the step ladder attached to the truss. He unslings the truss going up and down the truss while using safety lines.

After assembling the first truss the second truss is assembled in diametric opposition to it. Then mutual perpendicular trusses connecting the first two are assembled. After these four main roof trusses have been assembled secondary intermediate trusses are attached to them.

After the big top main load carrying structures have been erected the tower crane can be dismantled and the vertical post of the supporting ring can be disassembled.

Roofworking, furnace-bar assembling and other external work is done while using a tower crane. Internal work is done while using stationary or mobile scaffolding.

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