# STEEL STRUCTURES OF ARENA "SOFIA"

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## 1. ABSTRACT

The design, fabrication and erection of the main steel structure for Multi Functional Sports Hall (Arena Sofia) are presented. Special attention is paid to the design procedure, design management and controlling of the production processes and technology for the assembly works.

*Fig. 1 General architectural view*

## 2. INTRODUCTION TO THE CONCEPTUAL DESIGN

The project was developed based on the Government tender for design and building announced on 23.04.2009. Glavbolgarstroy (JSC) as a general contractor, Ircon ltd. and "Tilev Architects" Ltd. as a design team has been selected from the tender body as a winner. The contract was signed in the end of July 2009 with fixed price and fixed terms: opening ceremony on 01.08.2011 (only 2 years design&build). The Hall was designed to meet the International requirements for 8 types of sports activities and later was extended to 17 kinds of sports. It consists:

- 12 300 seats (permanent and telescopes) for sports events;
- apr. 17 200 for concert activities

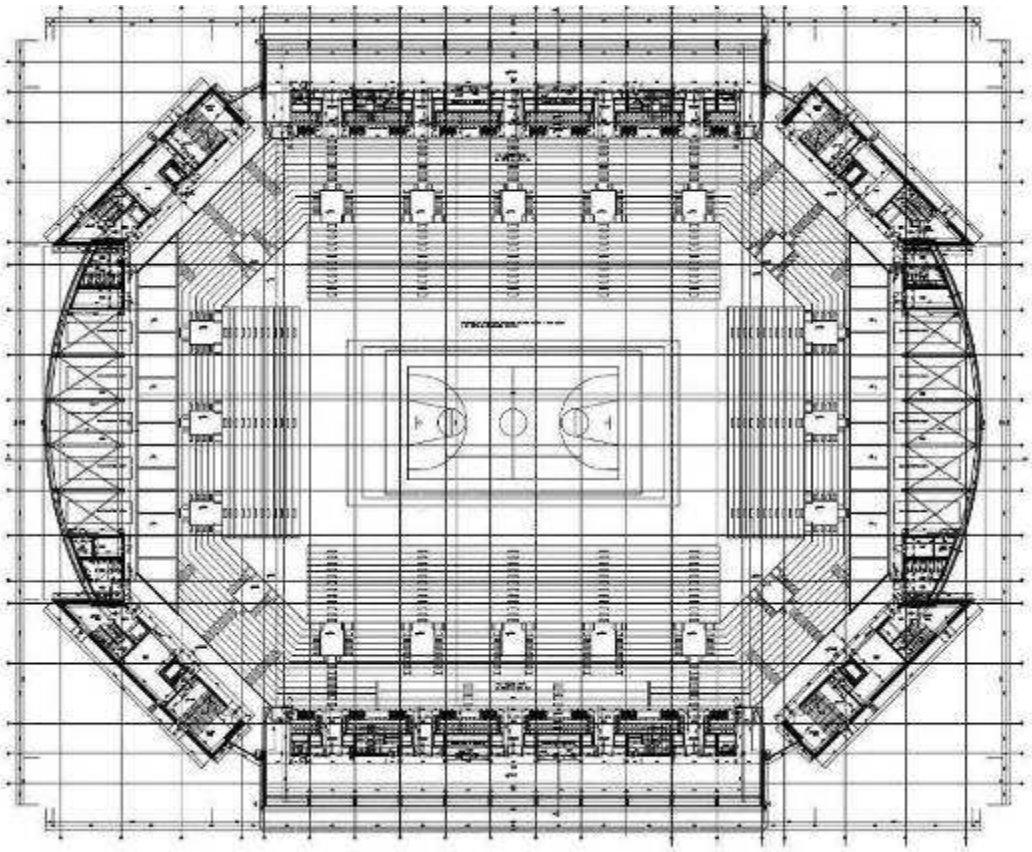


*Fig. 2 Plan view*

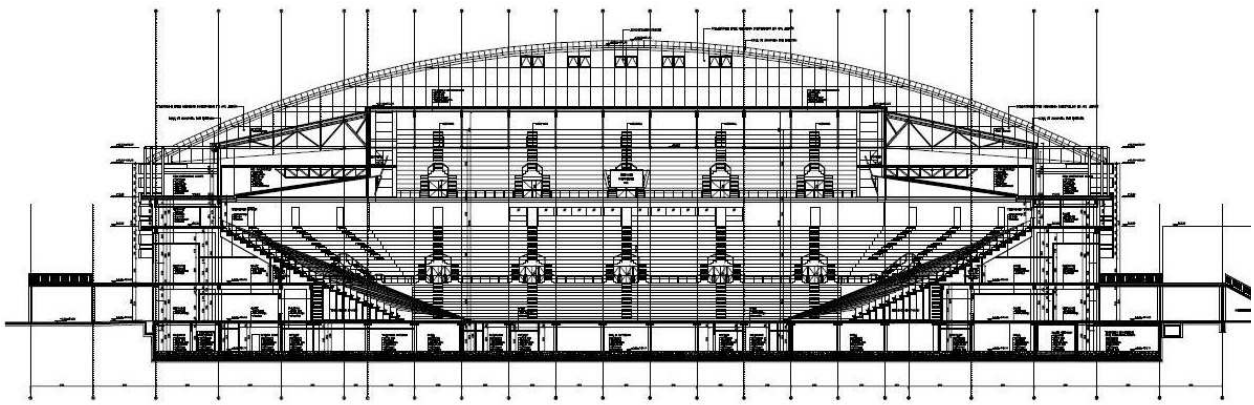


*Fig. 3 Longitudinal section*

*Fig. 4 Inside view*

## 3. STRUCTURAL SYSTEM

The structure is divided into two parts:

- Reinforced concrete structures (RC) for basement, tribunes and arena;
- Steel structure for the roof.

*Fig. 5 Model of the structural system*

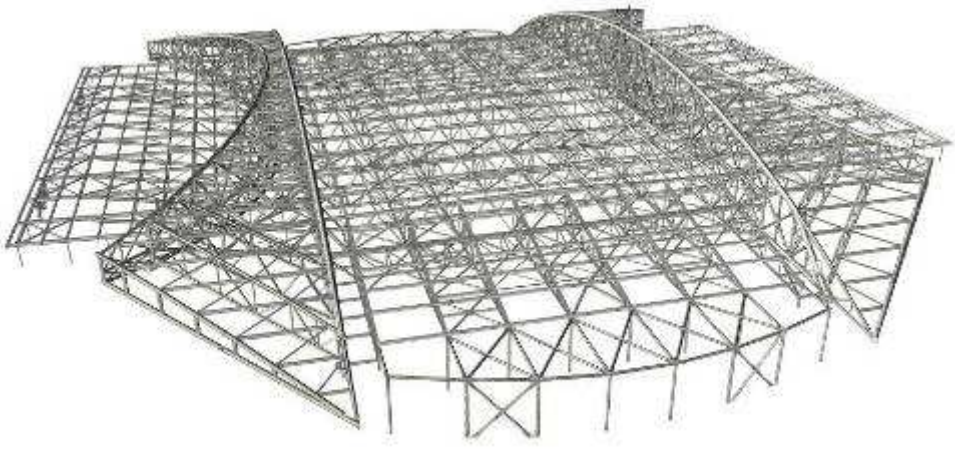


*Fig. 6 Roof steel structure (General view)*

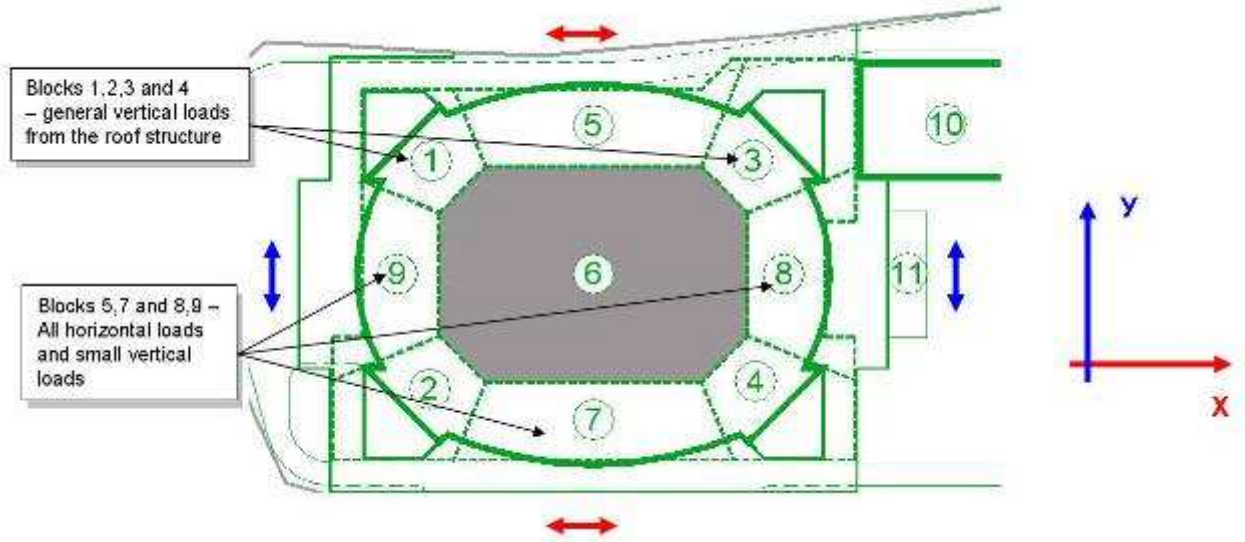



*Fig. 7 Loads directions*

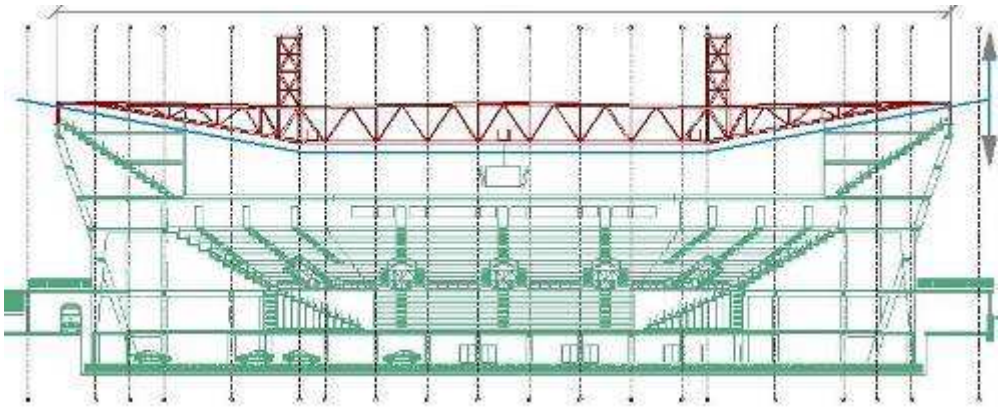


*Fig. 8 Section (L=96m)*

The design conception was based generally on the following idea:

- Separation of the vertical and horizontal loads. The structural system was designed in the manner all vertical loads from the roof to be transmitted by 2 space trusses to RC block numbered 1, 2, 3 and 4 and relatively very small vertical components appeared within the pending columns at block 5, 7, 8 and 9.
- All horizontal loads from the roof structures (wind, seismic, temperature) are transmitted to the sub RC structures by means of horizontal and vertical bracing system connected at block 5, 7, 8 and 9. The bracing system was designed to be very closed to the "temperature center", giving the possibilities to reduce the value of the forces due to temperature difference.

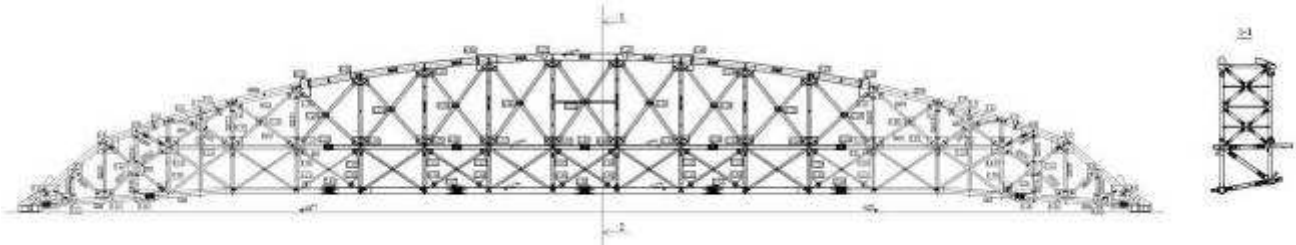


*Fig. 9 General truss (L=120m)*

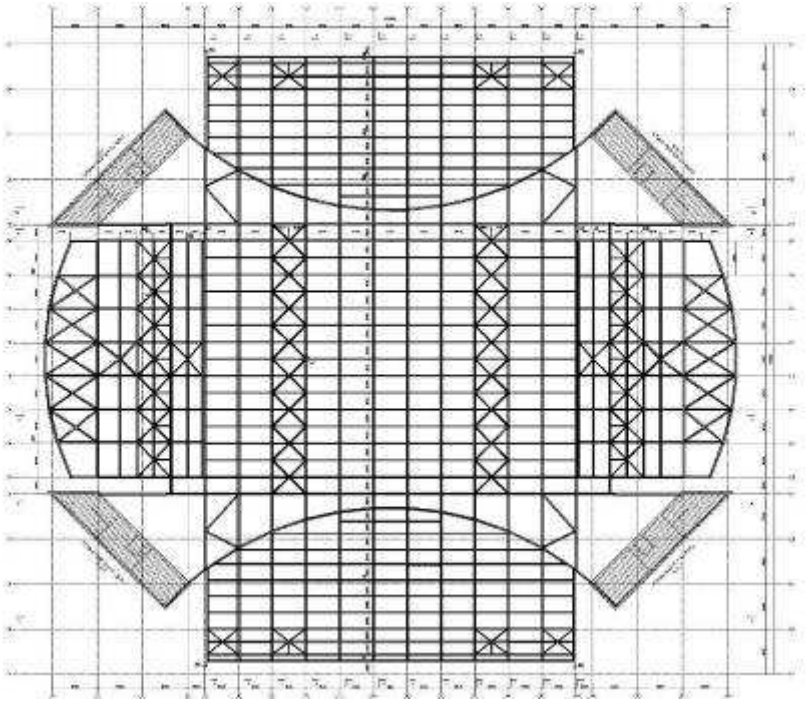


*Fig. 10 Plan on the top chords trusses*

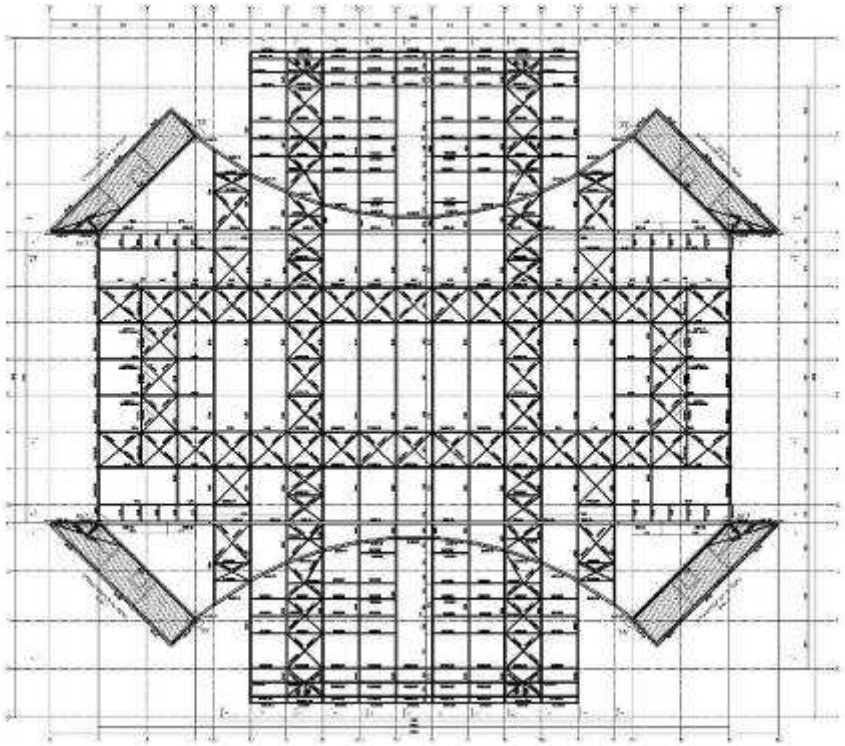


*Fig. 11 Bottom chords trusses*

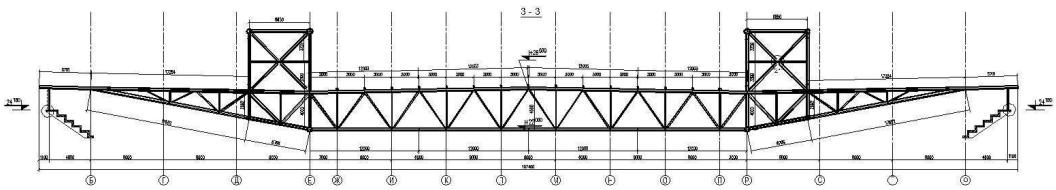



*Fig. 12 Cross-section*

## 4. DESIGN PROCEDURE - EVALUATION OF THE INTERACTION BETWEEN RC STRUCTURE AND ROOF STEEL STRUCTURE

Because of the restricted time, the design of the RC and roof structures and the analysis was done in the following stages:

*I stage:* Full preliminary model for both sub-structures. Based on the dynamic analysis and 3D FE model, the interaction between sub and upper structure was investigated in the beginning of the design process. It was needed at that early stage to predict on realistic level the amplification of the seismic roof forces due to the roof is supported by RC structure. Because the difference of the stiffness of the steel and RC structures, the amplification was not significant and the total coefficient of 1.1 was used to cover such effects

*II stage*: Separate detailed models for Roof steel structure and RC substructure.

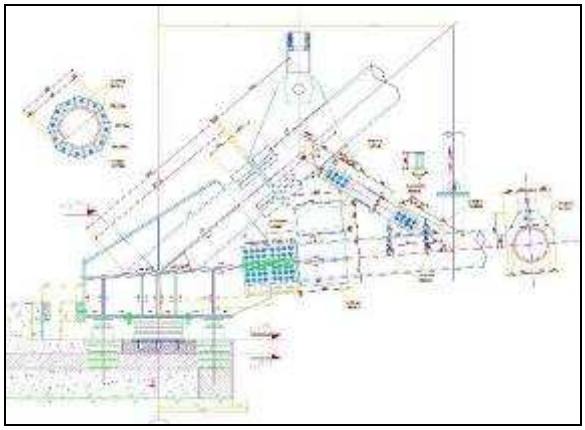
*III Stage*: Final detailed models of the whole structure. Results from the final model were used for final checks and comparison between preliminary results and final ones.

The design of the roof structure was conducted based on the Eurocodes.

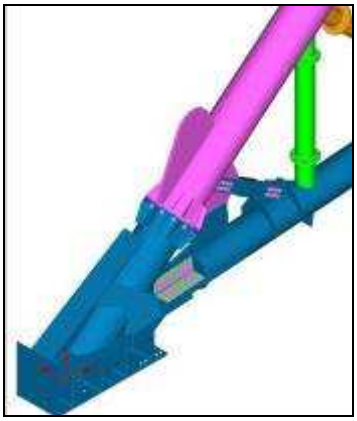
## 5. DESIGN MANAGEMENT AND CONTROLLING THE PRODUCTION PROCESS.

Fabrication of the steel structure has been organized based on EN 1090-2 “Execution of steel structures and aluminum structures – Part 2: Technical requirements for the execution of steel structures”.

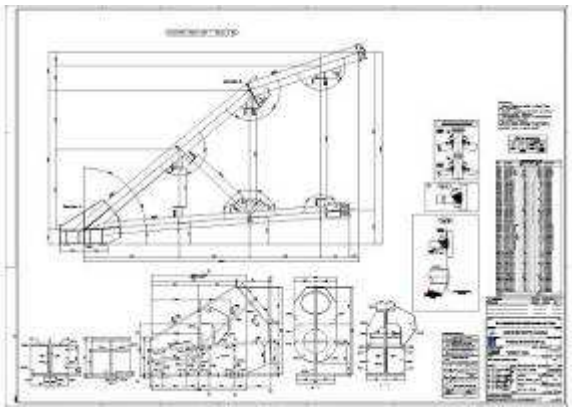
All necessary technical specifications, execution classes, permanent control of the process within the producer factory and on the site have been performed.



*DETAIL*



*SOLID MODEL*



*SHOP DRAWING*

*Fig. 13 Design steps*

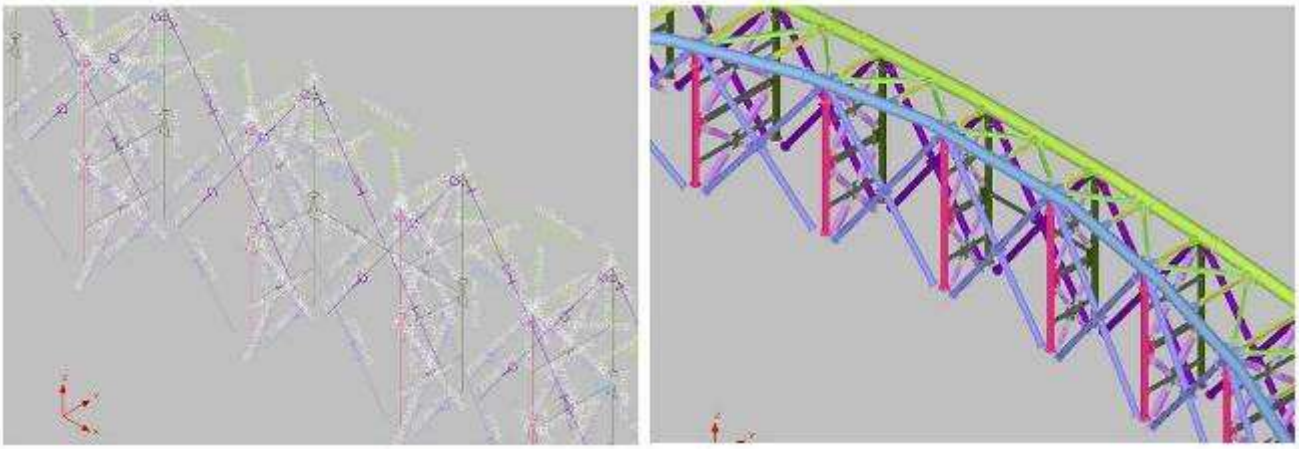


*Fig. 14 3D controlling model*

*Fig. 15 Production*

*Fig. 16 Fitting of the elements*

*Fig. 17 Butt welding preparation*

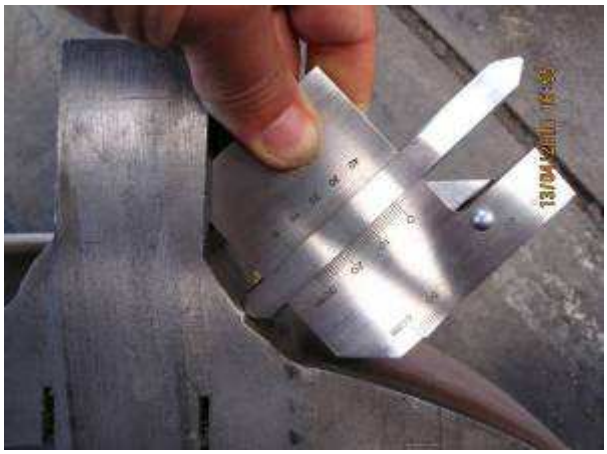


*Fig. 18 Welding shape check*

*Fig. 19 "UT" test of welding*

*Fig. 20 Penetration test*

*Fig. 21 "NDT" test of welding*

## 6. TECHNOLOGY FOR THE ERECTION

| Stages | Description | Phase |
|---|---|---|
| 1 | Erection of the assembly supports | Phase 1 |
| 2 | Site full assembly on the “mega – block” | |
| 3 | Installation of the lifting masts | |
| 4 | All details for connection | |
| 5 | Lift off | Phase 2 |
| 6 | Lifting | |
| 7 | Adjustment on the design level | |
| 8 | Fixing the supports | |
| 9 | Assembly of the “GUMBA” elastomeric bearings | |
| 10 | Assign of the elastomeric bearings | |

*Fig. 22 Procedure of assembly work*

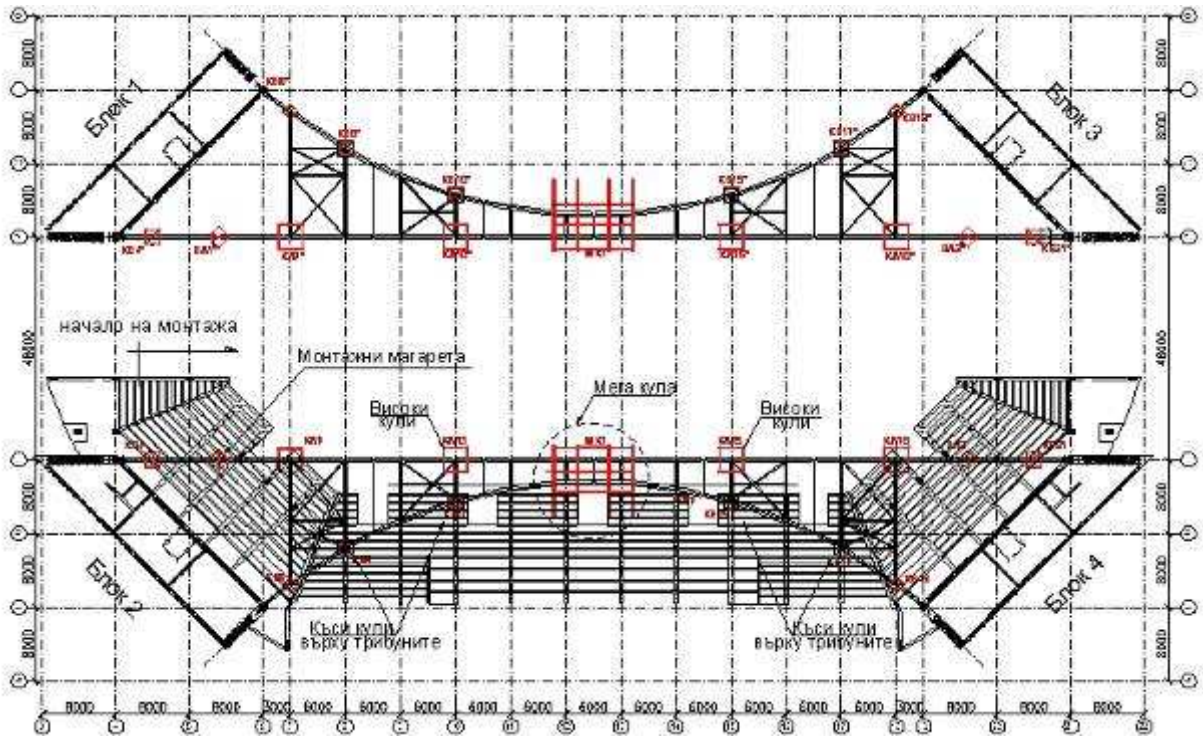



*Fig. 23 Assembly blocks*

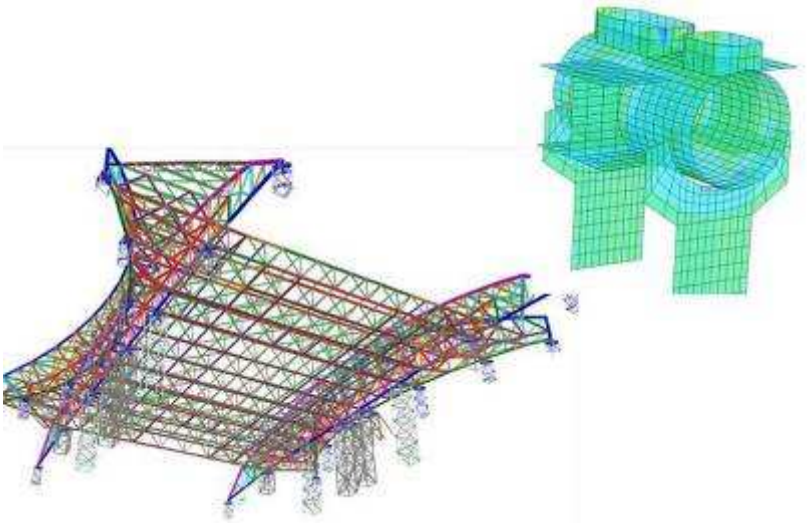


*Fig. 24 Design model of Mega block (erection stage)*

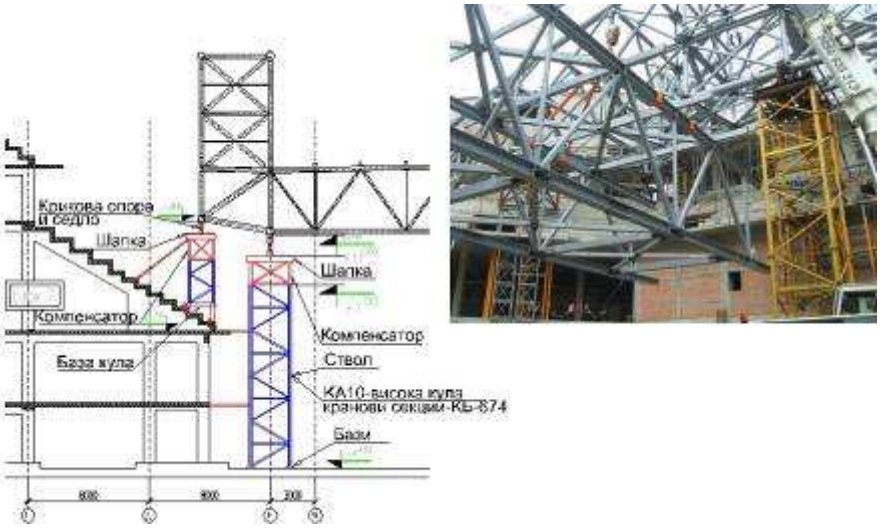



*Fig. 25 Assembly of the Mega block*

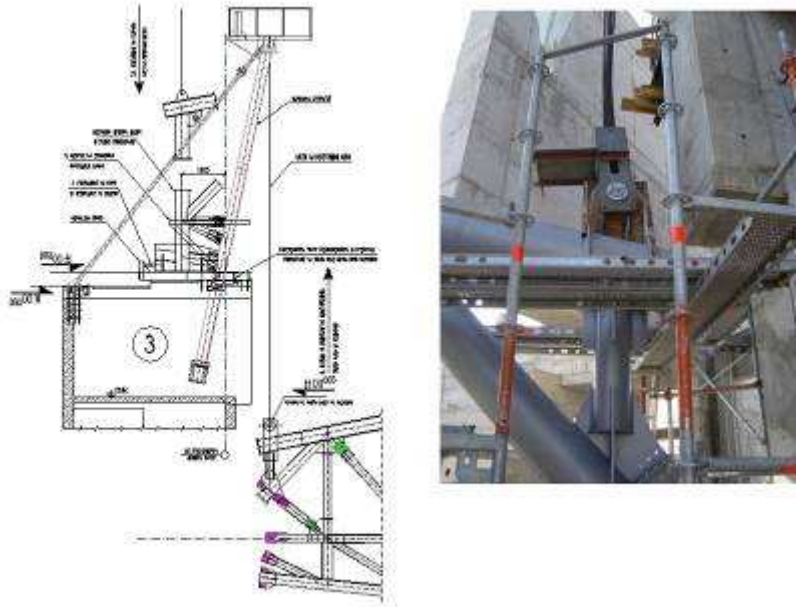


*Fig. 26 Lifting masts (8 pieces at blocks 1 ÷ 4)*

*Fig. 27 Lift off (Test)*

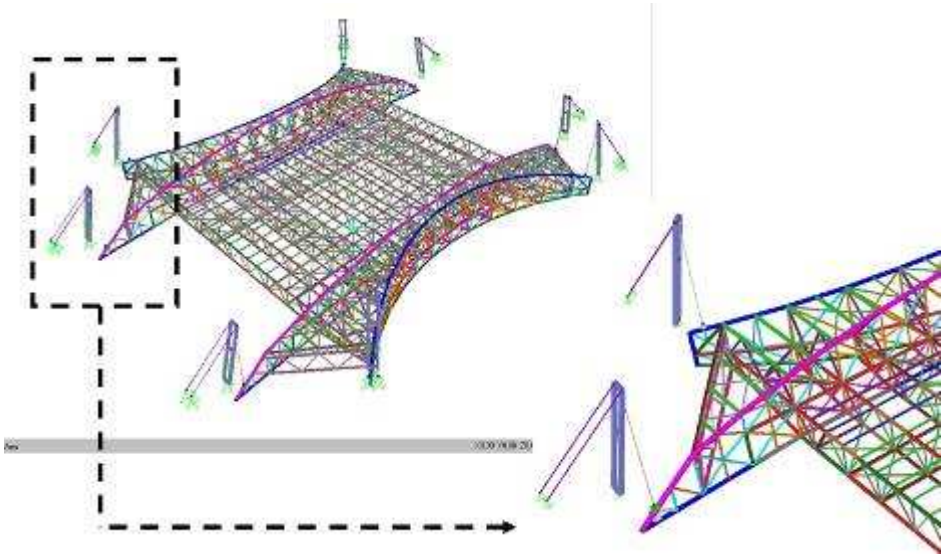


*Fig. 28 Lift off design model*

*Fig. 29 Lifting*

*Fig. 30 Lifting (3 hours)*

*Fig. 31 Fixing of the main supports*

*Fig. 32 Elastomeric bearings*

*Fig. 33 Fixing of the bearings*

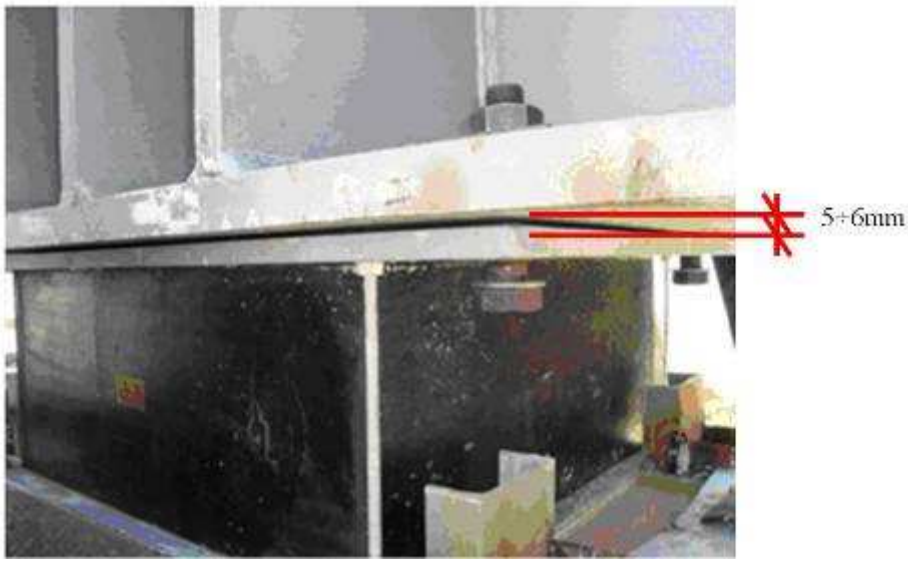



*Fig. 34 Bearings assign (one by one 8 pieces)*

*Fig. 35 Total view of the lifted structure*

*Fig. 36 Erection of the triangular trusses*

*Fig. 37 Arena view (from 31.05.2011)*

## 6. Conclusions

The project for Multi Functional Sports Hall (Arena Sofia) was realized within two years due to the professional efforts of 17 structural engineers from bureau IRCON. The steel structure was manufactured by Bulgarian producers and the erection was done with Bulgarian contractors cooperating with the Company VSL.

The authors use that opportunity to express their gait thanks for all the team of Ircon ltd and other collaborators.