IOP Conference Series: Materials Science and Engineering

PAPER • OPEN ACCESS

Experimental study of the work of a temporary structure of a dismountable bar system

To cite this article: G N Shmelev *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **570** 012096

IOP Conf. Series: Materials Science and Engineering **570** (2019) 012096 doi:10.1088/1757-899X/570/1/012096

Experimental study of the work of a temporary structure of a dismountable bar system

G N Shmelev[1], L I Khaidarov[1], L S Sabitov[2,3], L R Gimranov[1], N F Kashapov[2]

[1]Kazan State University of Architecture and Engineering, 1 Zelenaya street, Kazan, 420043, Russian Federation

[2]Kazan (Volga region) Federal University, 18 Kremlevskaya street, Kazan, 420008, Russian Federation

[3]Kazan State Power Engineering University, 51 Krasnoselskaya street, Kazan, 420066, Russian Federation

l.sabitov@bk.ru

Abstract. Mobile spatial bar designs are widely used in the construction of temporary buildings and structures, such as scenes, stands, awnings, pavilions, etc. Such structures are statically indefinable and have gaps in the nodes of the connection. To study the actual work of such systems, an experimental study of the construction of the stage was carried out and a comparative analysis of the results of testing and calculation was performed.

Introduction

When conducting private and public events, buildings from collapsible bar systems are in demand. The advantage of these systems is the ability to assemble structures of various shapes, quick installation and disassembly due to special node connections and ease of elements. It is necessary to note the features of such structures compared to capital ones:

- lack of foundation and installation on an unprepared base;
- significant compliance of node compounds;
- short period of operation.

Collapsible buildings were used during the FIFA 2018 World Cup, including erection of the stage in Kazan (figure 1). In connection with the installation of the structure on an unprepared base, during the period of operation, the technical condition was monitored with control of efforts and movements in the most stressed areas. After the event, a series of building tests were performed by loading the poles below with jacks to study its actual work.

Figure 1. General view of the construction of the stage

1. The construction of the stage

The construction of the stage on which the test was performed was located on the bank of the Kazanka river and served as a stage for performances of creative teams and installation of the screen and sound equipment for broadcasting matches.

The main volume of the structure is assembled from the modular bar system Layher Allround. For the installation of the screen and the canopy device, additional collapsible metal trusses were used. The whole construction along the contour was sheathed with mesh-banner material. The plan and section of the construction are shown in figures 2, 3.

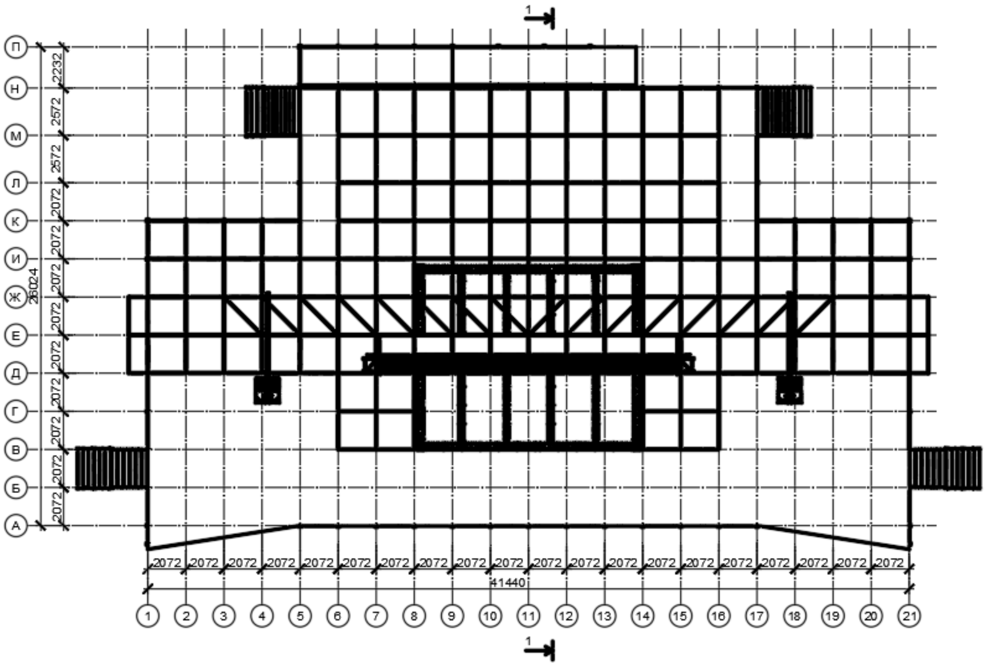

Figure 2. Stage construction plan

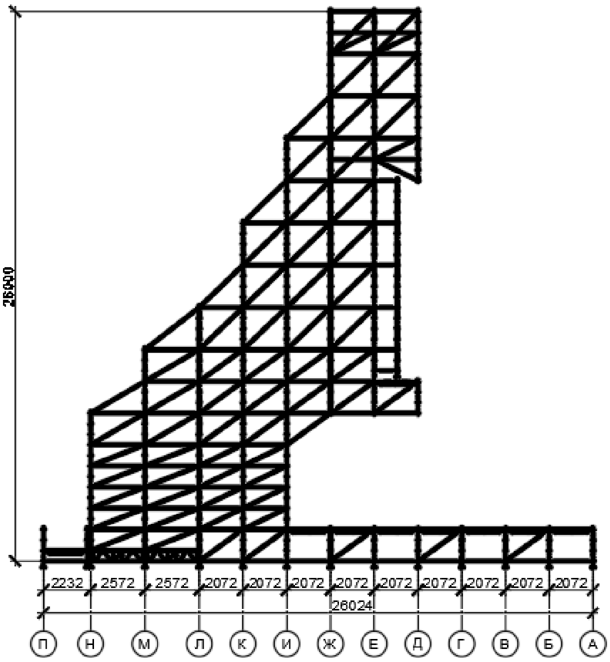

Figure 3. Cross-section of the construction of the stage

2. System Layher Allround

Layher Allround is a modular system of scaffolding assembled from core elements into a three-dimensional structure with a wedge-node connection (figure 3). The main elements of the system are standard, cross-beam, brace and screw support jack. The system is assembled in mutually perpendicular directions, but it is possible to connect not at right angles by using additional building clamps.

Standard, cross-beam and brace are made from pipes with a diameter of 48.3 mm and a wall thickness of 3.2 mm of steel grade C235. Standard s are made 0.5… 3.0 m long with a gradient of 0.5 m, to which, in increments of 0.5, round flanges are welded with eight holes for fastening cross-beams and braces. Assembly of the standards in height is performed by the sleeve connection. Cross-beam and brace have special heads with a fixed wedge at the ends. Head connection with bar of cross-beam is welded, of brace - riveted, allowing rotation of the element in a vertical plane.

The manufacturer applies to the output of the documents on the calculation of the elements and the carrying capacity of the elements and node connections.

3. Numerical simulation of the support lift

To determine the forces and movements when lifting the standard, a calculation was made using the finite element method in the Lira-SAPR PC. The volumetric model is presented in figure 4.
The calculation took into account the following loadings:
- own weight of the bearing elements;
- the weight of the screen and sound equipment;
- the weight of the ballast installed to prevent tilting of the structure;
- load on the support from the jack.

IOP Conf. Series: Materials Science and Engineering **570** (2019) 012096 doi:10.1088/1757-899X/570/1/012096

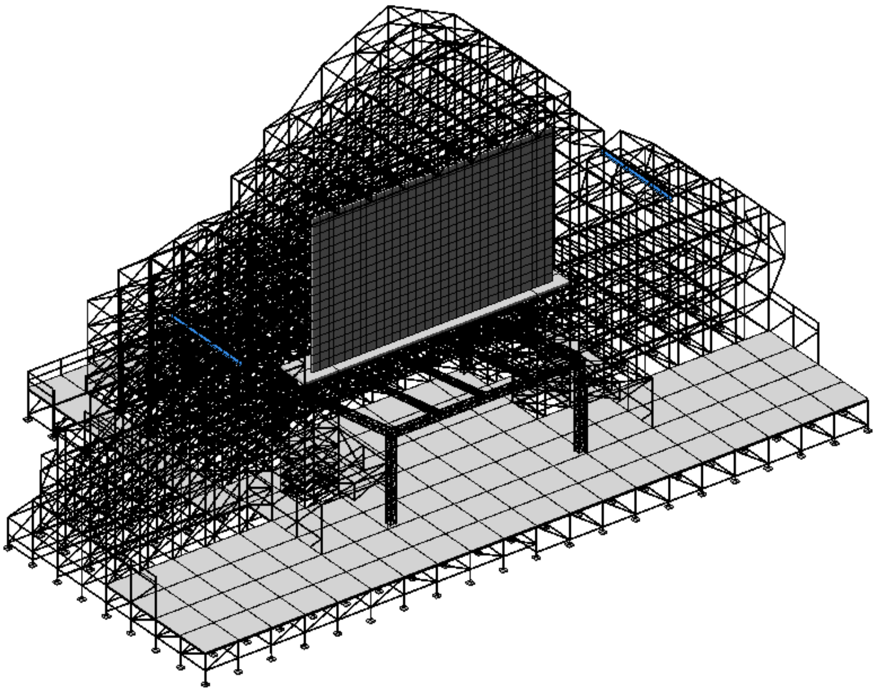

Figure 4. Spatial view of the calculated model of the construction of the scene

Under the distribution boards under the supports, the base soil is modeled in the form of silty sand with a strain module of 18 MPa.

Vertical cross-beams are modeled as bars with absolute hinges at the ends and with eccentricities in accordance with the node design. The cross-beam element model is made with elastic hinges at the ends in the vertical and horizontal planes. In fact, when rotated in the vertical plane, the node cross-beam- standard works in a non-linear fashion. In the calculation, a linear work schedule was adopted due to the fact that only minor moments occur in the cross-beams with the considered loads, and the initial part of the work schedule curve differs little from a straight line.

Stiffness elements were assigned in accordance with the material and the geometric dimensions of the cross section, with the exception of vertical cross-beams, for which the manufacturer has established linear stiffness, taking into account the gaps, turning in the joints and bar bending due to the transfer of force with eccentricity.

According to the results of the calculation, changes in the forces in the elements, movement in the loaded and neighboring standards were calculated.

4. Test

The purpose of the test was to determine the stress-strain state of the elements of the structure during loading and unloading of one and two adjacent supports. The experiment examined the raising and lowering of standard in the K / 13 axes.

4.1. Test method. The rise of the standard was carried out with a manual hydraulic pump with two jacks through the bottom row of cross-beams (figure 3). At the same time, the maximum load on the standard was 3.6 tons. After the lifting by turning the screw, the lifting height of the standard of the standard decreased, the hydraulic jacks were unloaded and the standard lowered to the hanging position.

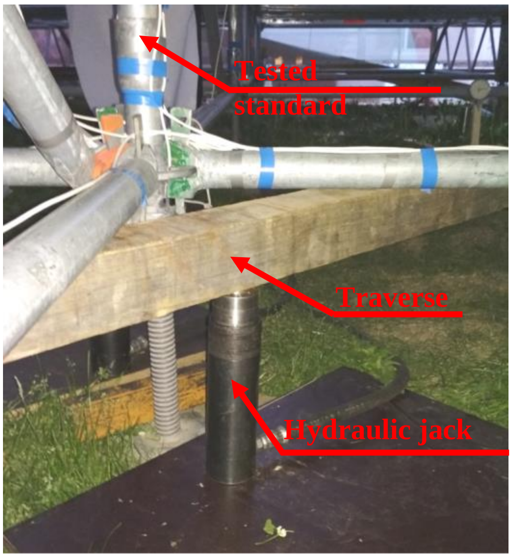

Figure 5. Scheme of the standard's rise by jacks

To measure the voltages in the elements, strain gauges and National Instruments equipment were used: the NI SCXI-1000 chassis with the NI SCXI-1521 and NI SCXI-1317 modules. The stresses in the elements were saved in a spreadsheet for further processing and determination of the effort. In each element under consideration, two strain gauges, symmetrically arranged in one section, were installed. The layout of the strain gauges is presented in figure 6.

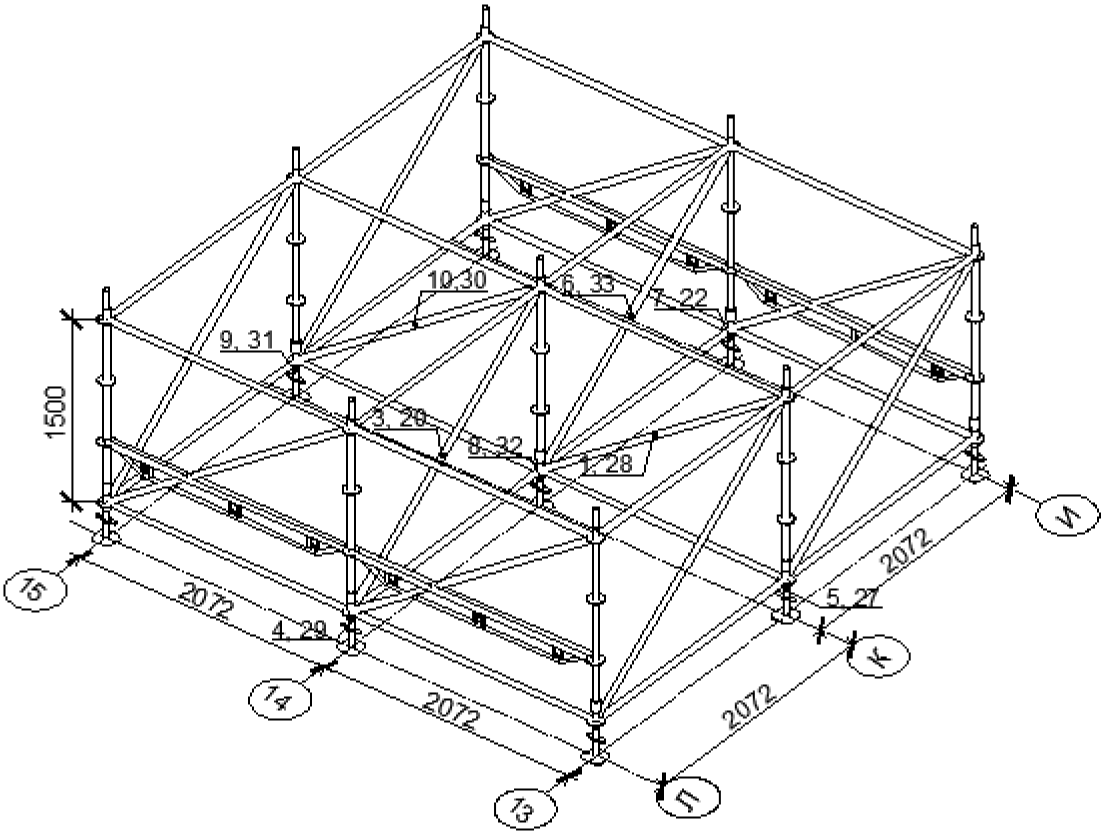

Figure 6. Layout of strain gauges

Vertical displacements or movements were measured in standards in the "K / 13", "K / 14" and "K /15" axes at the level of the lower tier of cross-beams. The measurement was performed by mechanical deflection of 6-PAO. Instrument readings were recorded in the journal at each stage of loading.

4.2. Test results. Displacements during lifting are presented in table. 1, change of efforts in elements in a graphic form - on figures 7-8.

Table 1. Vertical displacements of supports during testing

Load, kg		**Vertical displacements of standards in axes, mm**		
		К/15	**К/14**	**К/13**
Loading	0	0.00	0.20	0.02
	500	0.01	0.60	0.02
	1000	0.02	1.42	0.02
	1500	0.04	2.22	0.03
	2000	0.08	3.28	0.05
	2400	0.10	4.08	0.10
	2800	0.13	4.80	0.13
	3200	0.18	5.48	0.18
	3600	0.21	6.08	0.20
Unloading	3200	0.21	5.50	0.20
	2800	0.20	4.95	0.20
	2400	0.18	4.35	0.20
	2000	0.13	3.78	0.13
	1500	0.11	3.05	0.12
	1000	0.09	2.09	0.12
	500	0.06	0.42	0.08
	400	0.02	-0.45	0.08
	300	0.01	-1.00	0.00
	200	0.01	-1.20	0.00
	100	-0.01	-1.35	-0.02
	0	-0.01	-1.4	-0.03

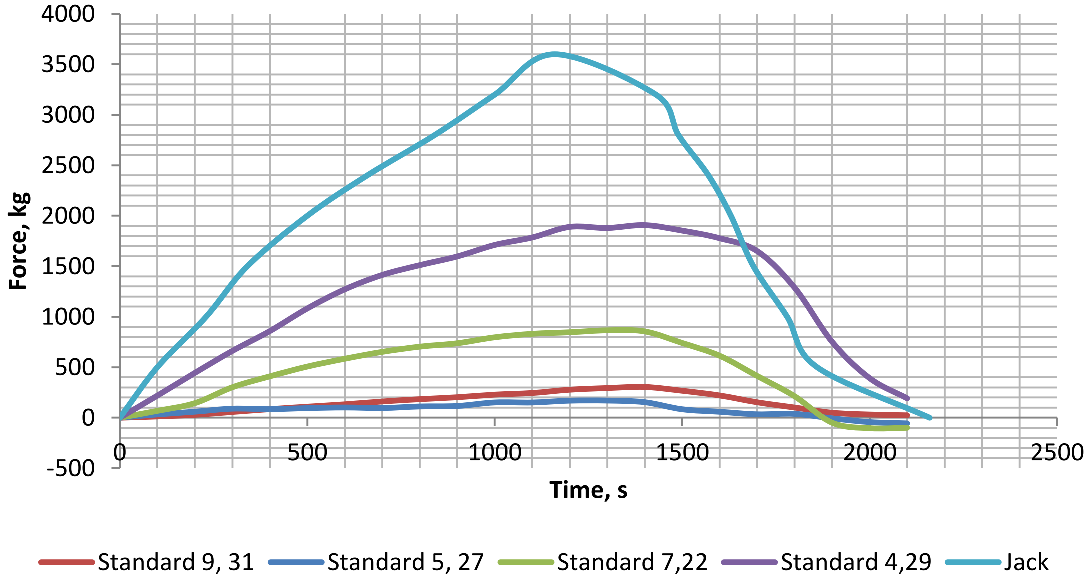

Figure 7. Change of support reactions under standards

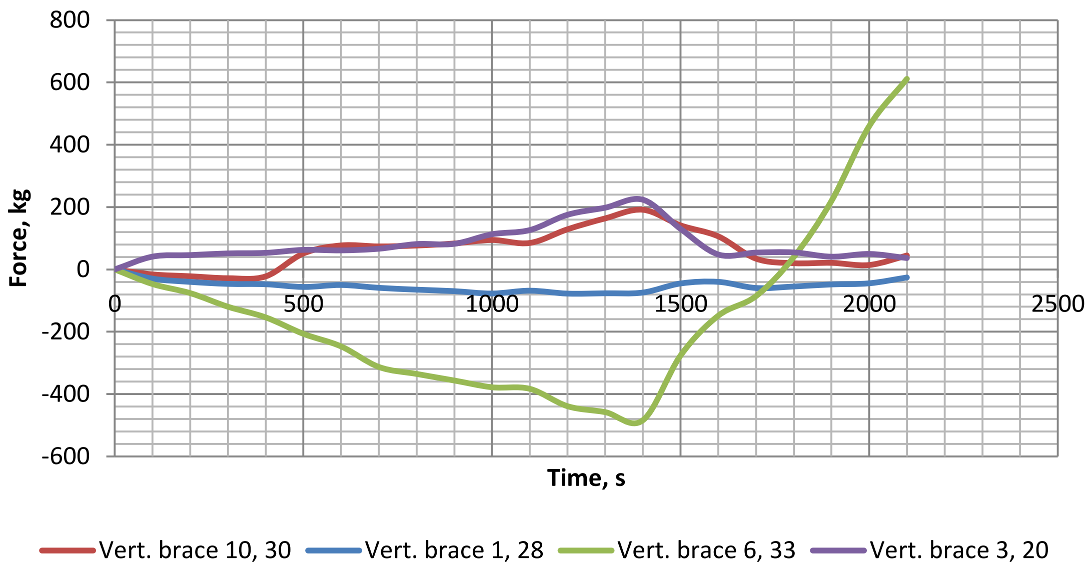

Figure 8. Effort changes in vertical braces

According to the results of the experiment, it was determined that when loading the standard in the K / 14 axes with a load of 3,600 kg, unloading of the neighboring standards occurs in the axes I / 14, K / 15, K / 13 and L / 14 by 3400 kg, i.e. 94% of the load is distributed to adjacent supports. When lifting the considered standard in the launch element below the loading unit after the separation from the screw jack, a tensile force of 186 kg appeared, which is equal to the support reaction under the stand before the test. In fig. 9 you can see the uneven operation of the vertical braces. One of the main reasons for this is the gaps in the nodes of the connection elements. When lowering the standard to the hanging position, the vertical displacement was 1.4 mm from the initial position.

5. Comparison of calculation end experiment results

For a visual comparison of the results of the calculation and experiment, the change in the forces and displacement during the raising and lowering of the K / 14 vertical brace is presented in figures 9-10.

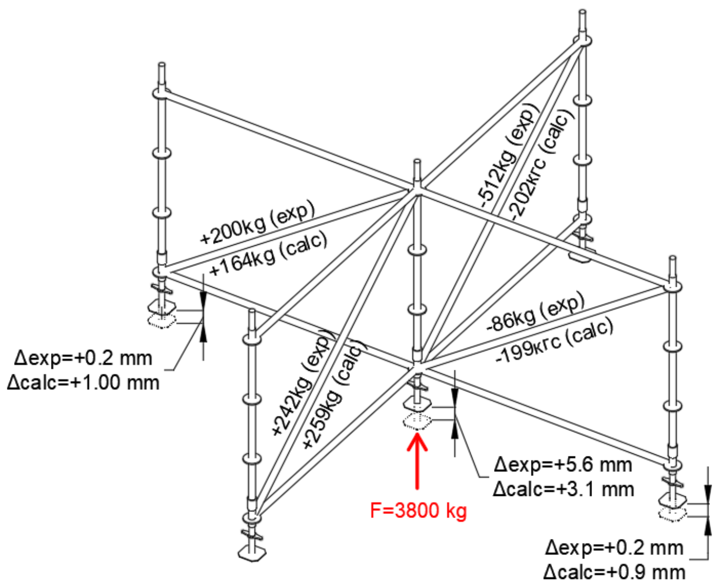

Figure 9. Changes in effort and movement when raising standard according to the results of experiment and calculation

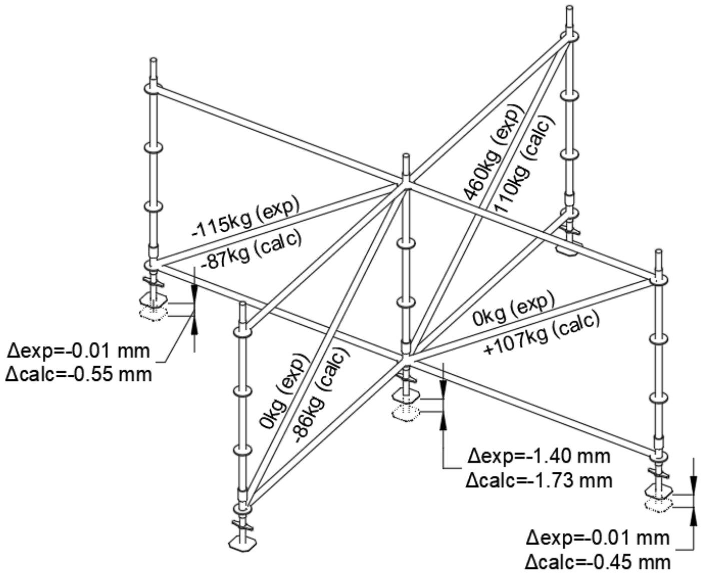

Figure 10. Changes in effort and movement when lowering standard according to the results of experiment and calculation

Conclusion. According to the results of the experiment and calculation, you can see a significant difference in the distribution of efforts in the elements of the structure. One of the important factors is the presence of gaps in the joints. In this regard, it is necessary to further study the actual operation of structures from collapsible bar systems, taking into account the gaps in the nodes of the connection for their correct modeling and determination of their stress-strain state.

References

[1] Liu C, He L, Wu Z and Yuan J 2018 Experimental and numerical study on lateral stability of temporary structures *Archives of civil and mechanical engineering 18* (Elsevier) p 1478-90
[2] Cimellaro G P and Domaneschi M 2017 Stability analysis of different types of steel scaffolds *Engineering structures* 152 (Elsevier) p 535-48
[3] Peng J -L, Ho C -M, Chan S -L and Chen W -F 2017 Stability study on structural systems assembled by system scaffolds *Journal of Constructional Steel Research* 137 (Elsevier) p 135–51
[4] Yuan X, Anumba C J and Parfitt M K 2016 Cyber-physical systems for temporary structure monitoring *Automation in Construction* 66 (Elsevier) p 1–14
[5] Zhang H and Rasmussen K J R 2013 Monitoring System-based design for steel scaffold structures used advanced analysis *Journal of Constructional Steel Research* 89 p 1-8
[6] Chandrangsu T and Rasmussen K J R J 2011 Structural modelling of support scaffold systems *Journal of Constructional Steel Research* 67 (Elsevier) p 866–75
[7] Prabhakaran U, Beale R G and Godley M H R 2011 Analysis of scaffolds with connections containing looseness *Computers and Structures* 89 (Elsevier) p 1944–55
[8] Peng J L, Yen T, Kuo C C and Chan C L 2009 Analytical and experimental bearing capacities of system scaffolds *Journal of Zhejiang University Science A* 10(1) p 82-92
[9] Crick D and Grondin G Y 2008 Monitoring and Analysis of a Temporary Grandstand *Structural Engineering Report No.275* (Edmonton: Department of Civil& Environmental Engineering of University of Alberta) p 48-98
[10] Godley M H R and Beale R G 2001 Analysis of large proprietary access scaffold structures *Structures and Buildings* 146 p 31-39
[11] Chan C L, Zhou C H, Chen W F, Peng J L and Pan A D 1995 Stability analysis of semirigid steel scaffolding E*ngineering structures* vol 17 No 8 (Elsevier) p 568-74