PAPER • OPEN ACCESS

# About need of calculations for the steel framework building in temperature influences conditions

To cite this article: Y Otrosh *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **708** 012065

IOP Conf. Series: Materials Science and Engineering **708** (2019) 012065 doi:10.1088/1757-899X/708/1/012065

# About need of calculations for the steel framework building in temperature influences conditions

**Y Otrosh[1,3], O Semkiv[1], E Rybka[1] and A Kovalov[2]**

[1] Department of prevention activities and monitoring, National University of Civil Defence of Ukraine, 94 Chernyshevska St., 61023 Kharkiv, Ukraine
[2] Research laboratory of innovations in the field of civil safety, Cherkasy Institute of Fire Safety named after Chornobyl Heroes of National University of Civil Defence of Ukraine, 8 Onoprienko St., 18034 Cherkassy, Ukraine

E-mail: [3] yuriyotrosh@gmail.com

**Abstract.** In the article a technique of studying technical condition for steel structures that were damaged by high temperature impact, as well as a climatic effects on building structures due to the difference in ambient temperatures is described. Based on obtained data, there was made a conclusion about technical condition of the structures and possibility or inability to restore their serviceability by repair, reinforcement or replacement. There were conducted a comparative analysis of the results of experimental studies and numerical analysis. The mathematical model makes possible operative prediction for the controlled parameters values of building structures. In the article, examples about practical application of the techniques are described that allow doing technical examination of objects, damaged by temperature influence. The aim of this study is to substantiate the need to make calculations about temperature impacts for buildings with a steel frames and to develop measures to ensure the serviceability of steel structures of buildings and structures in conditions of temperature impact.

## 1. Introduction

A number of documents have been adopted in Ukraine that set out mandatory safety requirements, including fire, in construction (for buildings with steel frame) [1].

The increased risk of man-made emergencies in Ukraine is due to the fact that in the most important areas, high-risk and potentially hazardous facilities have achieved its project life resource at 50–70%, sometimes reaching pre-accident levels [2].

For further safe operation of buildings and structures, including steel frames, it is necessary to make constant diagnostics of the structures, to determine its controlled parameters (material strength characteristics and deformability, deflections and displacements of structures), as well as develop methods of structure protection from temperature influences in accordance with the current regulatory requirements [3].

There was a simulation of the study [4] of thermal properties of reinforced concrete structural elements provided. Thermal analysis was carried out numerically using the ABAQUS package. Results comparison of various research studies taking into consideration the influence of boundary conditions, like temperature, convection, and radiation. The assignment of convective and radiation boundary conditions made it possible to obtain more accurate results. A decrease in the difference between simulated and experimental results was observed with the use of thermal characteristics according to Eurocode2, which took into account the moisture content.

In the article [5] there were analyzed the results of the engineering assessment of fire damage of prefabricated preliminary tense ferroconcrete elements. The study consisted of two phases: a phase of engineering processing of materials, including laboratory tests of concrete samples, and verification of the capacity of fire-damaged elements. For a theoretical calculation there was used an analytical model that takes into account the loss of rigidity. The analytical model served as a test of the results and increased the level of confidence in the technical recommendations.

In article [6] there are described the characteristics of steel structures that were restored after the crash. Assessment and reconstruction processes are analyzed in details. Emergencies occurring during the operation of the buildings were the result of many mistakes: incorrect intervals between inspections, errors during periodic inspections, incorrect recommendations for repair works. Recommendations about post-reconstruction monitoring facilities have been formulated. The methodology of specialized research, such as geodetic, optical, geological, chemical, strength tests, both destructive and non-destructive methods, has been determined.

The necessity of defining the limits of deformations, deflections, damages or other faults of structural elements and all reconstructed structures was specified, as well as defining the conditions for decommissioning of objects in the following exceptional situations.

During structures design development, the serviceability and safety must be ensured throughout the service life [7]. In addition, the design of structures must be compliant with the environmental protection requirements, as well as other special conditions [8, 9].

## 2. Unresolved issues

Despite the existence of requirements about temperature effects, they are often neglected in practice, leading to significant economic losses.

The aim of this paper is to substantiate the purpose of calculations about temperature impacts on buildings with a steel frames and to develop measures that allow to ensure the serviceability of steel structures in buildings in temperature influence conditions.

## 3. Main part

The construction of buildings that were built before 2000 year were designed for different types of loads, including climatic ones. The requirements for loads amount, before 2000 year was almost 1.5 times smaller than the current one. Neglecting those circumstances leads to structure destructions and economic losses.

As an example of neglecting the requirements about calculations of temperature climatic influences on steel structures, is appearance of damage in the walls of the building after the coating structures installation.

The building structures technical conditions were carried out based on frame steel structures inspection, junctions between steel structures and walls as well as brick walls in the level of coverage.

The non-residential building is a separate four-storey rectangular construction with the total dimensions of the axes 65×12 m. The height of the floors is 4.8 m. A two-span four-storey frame is adopted in diameter.

The columns have a section of 400×400 mm. The T-section crossbar with the lower expanded part (shelves from the bottom). On the shelves of crossbars rests slabs of overlapping. The connection of beams with columns is rigid. The cover is designed cold, without insulation. The temperature effects of the design were not taken into account.

The purpose for the load-bearing structures inspection arose after appearance of cracks in the places where steel structures adjoin the brick walls as well as in the brick walls in the level of coverage.

During the examinations the following information, which is needed for further detailed examination of the structures, was obtained:

– steel frames are flush-mounted in the horizontal plane with steel girders resting on top of the walls in the area of the stairwells. The connections between steel structures elements are made by welding, which led to the emergence of rigid steel structure;

– construction continued in winter (winter was "mild", but in some weeks the temperature decreased to –10°C);

– the duration of the constructions before the first cracks was approximately 2 months. Cracks were located in the walls of the stairwells in the covering level and 4 floor as well as in the walls of the elevators machine room in places of reliance on the walls above the steel runs (Figure 1);

– the design of the coating was designed with an unheated attic (cold), without insulation, which, together with the lack of flexibility in the elements joints due to welding, could have caused cracks in the brick walls when the ambient temperature was changed, since the free slip of steel beams during heating was not possible. This is considered to be the most likely to cause cracks on the beam-top wall contact and in the stairwell walls (cracks were observed when the ambient temperature exceeded the temperature at which construction were made was approximately 40°C.);

– the location of cracks – in the walls of the stairwells, which are located in the end zones of the building. In those areas the manifestation of temperature deformations was greatest (from the center to the edges).

**Figure 1.** Horizontal crack at the point where the metal beam rests on the wall.

In accordance with the requirements of applicable regulations, the technical condition of the coating bearing steel structures is evaluated as normal [10].

In accordance with the requirements, the condition of the building structures in general (except for the places of support of steel beams on walls and walls of staircases within 4 floors) is evaluated as normal, and the condition of walls within the support of steel beams and walls of stairs cells within 4 floors – as satisfactory.

The design scheme of load-bearing structures is adopted in the form of a space frame (Figure 2). The load from the wind pressure and the self-weight of the structures is applied in the form of a uniformly distributed load along the length of the sections into which the frame has been conditionally broken.

The load on the weight of the process equipment is applied in the form of concentrated forces at the places of installation of the equipment.

In addition it was performed, the calculation of the coating structures for uniform heating of the metal to a temperature of +40°C.

The maximum effort in the frame elements was used for the calculations verification. The frame calculation was performed using LIRA software (Figure 3, 4). The effort in the frame members was much smaller than the limit (table 1).

**Table 1.** Results of calculation.

| Parameter | LIRA SAPR | Experiment | Regulatory document |
|---|---|---|---|
| maximum deformation of the frame, mm | -0.0533<br>+0.0581 | –<br>– | <15<br><15 |
| cracks, mm | -2.75<br>+5.49 | <5<br><5 | –<br>– |
| maximum deformation of the frame (+40 $^{o}$C), mm | -16.5<br>+15.7 | –<br>– | <15<br><15 |

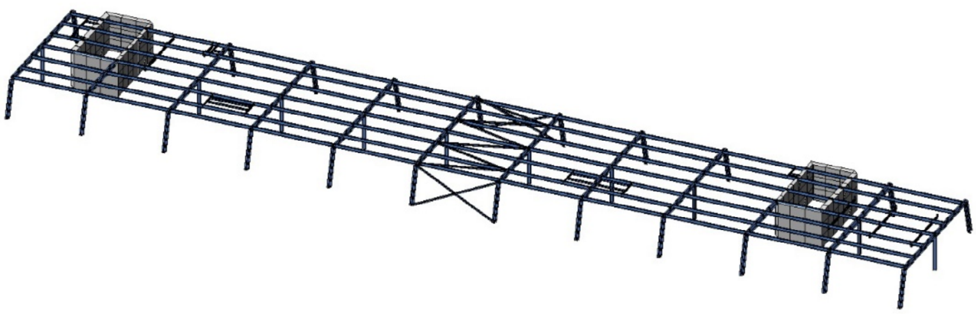

**Figure 2.** The frame design scheme (3D).

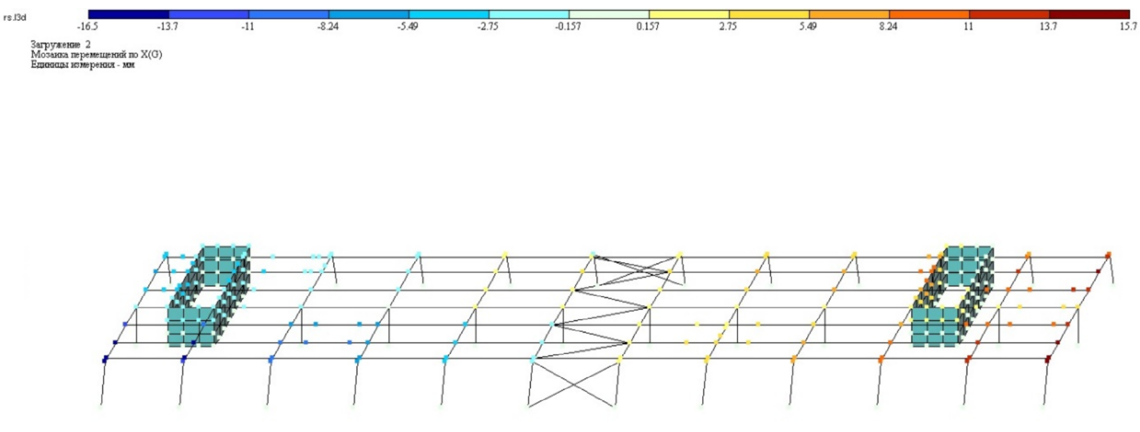


**Figure 3.** The frame movement under the own gravity of structure, technical equipment and influence of metal uniform heating.

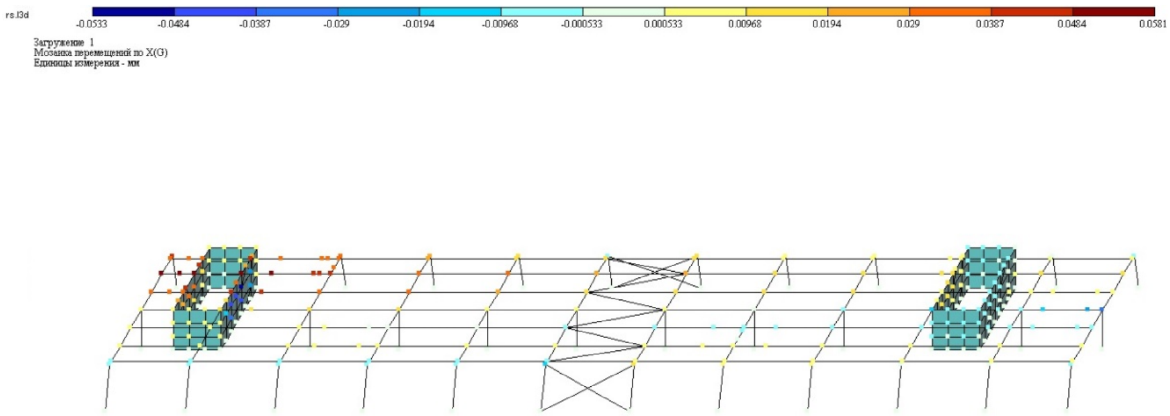


**Figure 4.** The frame movement under the own gravity of structure and equipment.

Based on the calculation results there were made the following conclusions:

– strength, durability and rigidity of the frame elements are ensured;

– maximum displacements under the influence of self-weight of structures and technological equipment are 0.0533 mm, which is much less than the limit;

– maximum displacements under the influence of structures self-weight , technological equipment and uniform heating to a temperature of +40 $^{0}$C are 16.5 mm. Because the steel beams sliding on top of walls was impossible, this fact led to inclined and horizontal cracks in the brick walls;

– further exploitation of building structures is possible in case of its project development to make reinforcement of the structures of the building cover and as a result to eliminate the effect of temperature deformations;

– based on calculations and analysis of the building construction system, a project was developed to strengthen the structures of the building covering, and was made used in practice.

## 4. Conclusions

Thus, on the basis of the above, it can be concluded that failure to comply with the requirements of the current regulatory documents for the calculation of steel structures can lead to violations of normal operation, and in some cases – the collapse of structures [11].

The modern development of restoration technologies allows performing works on strengthening and protection against influence of high temperatures, corrosion, etc. of building structures with different degree of damage [12–15].

The development of a mathematical apparatus for determining the residual load-bearing capacity of building structures that have been subjected to high-level force or other factors of influence for a certain period of time requires the use of such a deformation model of materials (concrete and steel), which would include all stages of its operation from the beginning of loading to complete destruction [16].

Steel structures, especially considering the influence of high temperatures, should be calculated as a single spatial system, taking into account the factors that determine the stress and deformed state, taking into account the nonlinear properties of the design scheme. If necessary, the design calculations at different stages of installation or operation should be performed taking into account the influence of the factors that determine its stress-strain state at each of the stages.

## References

[1] Vasilchenko A, Otrosh Y, Adamenko N, Doronin E and Kovalov A 2018 Feature of fire resistance calculation of steel structures with intumescent coating *MATEC Web of Conf.* **230** 02036

[2] Otrosh Y, Kovaliov A, Semkiv O, Rudeshko I and Diven V 2018 Methodology remaining lifetime determination of the building structures *MATEC Web of Conf.* **230**, 02023

IOP Conf. Series: Materials Science and Engineering **708** (2019) 012065 doi:10.1088/1757-899X/708/1/012065

[3] Outinen J and Mäkeläinen P 2004 Mechanical properties of structural steel at elevated temperatures and after cooling down *Fire and Materials* **28** 237-251
[4] Lakhani Hitesh, Kamath Praveen, Bhargava Pradeep, Sharma Umesh Kumar and Reddy G Rami 2013 Thermal Analysis of Reinforced Concrete Structural Elements *Journal of Structural Fire Engineering* **4** 227-244
[5] M Reis Engin, A Mata Luis and Dilek Ufuk 2009 An analytical model for estimating load-test deflections in fire-damaged precast, prestressed concrete members *PCI Journal* **54** 129-142
[6] Janusz R. Krentowski and Piotr Knyziak Evaluation 2017 Aspects of Building Structures Reconstructed After a Failure or Catastrophe *IOP Conf. Series: Materials Science and Engineering* **245** 032099
[7] N A A Salim and N F Zahari 2011 Developing Integrated Building Indicator System (IBIS) (A Method of Formulating the Building Condition Rating) *Procedia Engineering* **20** 256-261
[8] Vasiliev M, Movchan I and Koval O 2014 Diminishing of ecological risk via optimization of fire-extinguishing system projects in timber-yards *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu* **5** 106-113
[9] Tiutiunyk V, Ivanets H, Tolkunov I and Stetsyuk E 2018 System approach for readiness assessment units of civil defense to actions at emergency situations *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu* **1** 99-105
[10] Straub A 2009 Dutch standard for condition assessment of buildings. Ad Straub (OTB Research Institute for Housing, Urban and Mobility Studies, Delft University of Technology, The Netherlands) **27** 23-35
[11] Vasilchenko A, Doronin E, Ivanov B and Konoval V 2019 Effect of Residual Deformation of a Steel Column on its Fire Resistance under Combined Exposure" Explosion-Fire" *In Materials Science Forum* **968** 288-293
[12] Kovalov A, Otrosh Y, Vedula S, Danilin O and Kovalevska T 2019 Parameters of fire-retardant coatings of steel constructions under the influence of climatic factors *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu* **3** 46-53
[13] Andronov V, Danchenko Yu, Skripinets A and Bukhman O 2014 Efficiency of utilization of vibration-absorbing polimer coating for reducing local vibration Terms and conditions Privacy policy *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu* **6** 85-91
[14] Dubinin D, Korytchenko K, Lisnyak A, Hrytsyna I and Trigub V 2018 Improving the installation for fire extinguishing with inelydispersed water *Eastern European Journal of Enterprise Technologies* **2**(10–92) 38-43
[15] Andronov V, Pospelov B and Rybka E 2016 Increase of accuracy of definition of temperature by sensors of fire alarms in real conditions of fire on objects *Eastern European Journal of Enterprise Technologies* **4**(5–82) 38-44
[16] Otrosh Y, Surianinov M, Golodnov A and Starova O 2019 Experimental and Computer Researches of Ferroconcrete Beams at High-Temperature Influences *In Materials Science Forum* **968** 355-360