Analysis of defects of overhead facade systems and other light thin-walled structures

L.ENDZHIEVSKIY[1,a], A.FROLOVSKAIA[1,b], Y.PETROVA [1,c]

[1]School of Engineering and Construction, Siberian Federal University, 82 Svobodny, Krasnoyarsk, 660041 Russia

E-mail: [a]end-lev@yandex.ru, [b]tereshkova81@mail.ru, [c]yevtifeva@mail.ru

Abstract. This paper analyzes the defects and the causes of contemporary design solutions with an example of overhead facade systems with ventilated air gaps and light steel thin-walled structures on the basis of field experiments. The analysis is performed at all stages of work: design, manufacture, including quality, construction, and operation. Practical examples are given. The main causes of accidents and the accident rate prediction are looked upon and discussed.

1. Introduction

Currently, the building market at all levels is overfilled with materials, technologies and design solutions. The flow of research and developments in various areas is so huge that it is not always easy even for a specialist to understand what is better to use for the object construction in this or that case.

Modern materials and design solutions must meet requirements of a customer such as longevity, durability and strength, high thermal performance, environmental friendliness and cost effectiveness, simplicity and speed of assembly, flexibility of structures, etc. All progressive methods and technologies practically satisfy these indicators. But in fact it turns out that some structures ask for more detailed, qualitative study and approach [1].

The authors of the monograph [2] have shown that accidents of buildings and structures occur due to either human activities (violation of production technology, lack of discipline, inattention, etc.) or natural hazards (earthquakes, hurricanes, floods, etc.). At that statistics shows that the accident is the result of a number of complex reasons: poor funding of measures to ensure safe operation and timely repairs, insufficient study of the causes of the occurred tragedies that often lead to repetitive errors during design, construction and installation.

A study of the causes of accidents and disasters will enable us to better understand the patterns in the structures, buildings and installations, as well as to attract the attention of scientists, planners and builders to disadvantages, shortages, and drawbacks of materials, technologies and design solutions.

In this paper, the authors analyze two types of modern design solutions, which are used in practice. Overhead facade systems (OFS) and buildings from light steel thin-walled structures (LSTS) are taken as objects of research. These constructive solutions are characterized by the fact that, according to manufacturers, they are easy and simple to be assembled. In advertising they are compared with the children's toy design kit.

IOP Conf. Series: Materials Science and Engineering **191** (2017) 012046 doi:10.1088/1757-899X/191/1/012046

2. Overhead facade systems

Facade systems of modern buildings are as popular [3,4], as complex in design, installation and operation. Any technical mistake associated with their installation or operation becomes immediately obvious, in contrast to defects of internal structures.

In the OFS design there appear the following defects, leading to their partial collapse: the lack of a unified approach and the calculation method of the bearing and fastening elements, reliable data about the real behavior of the structure, calculations of thermal effects and other factors.

In the analysis of defects, depending on the quality of materials and products one can mention: the use of substandard materials or their replacement by materials of a lower quality, uncertified without the consent of the manufacturer of facade systems.

For example, the replacement of clasps from stainless steel by low carbon steel has led to the fact that some operation years later most of the façade elements have come out of its design position (Fig. 1), which has resulted in unpresentable appearance of the building.

Figure 1. Defects of façade systems: facing walls design inconformity

Replacement of composite cladding panels by a lower quality class of flammability led to the fire of the facade of a multistory apartment building (Fig. 2) in September 2014 in Krasnoyarsk (Russia).

Figure 2. A residential building is on fire in Krasnoyarsk (Russia)

Inflammation of overhead façade systems is quite common fact.

In the researchers point of view the main causes of the façade system fires are the failure of fire prevention measures and savings in all phases of construction. Unscrupulous construction participants artificially create low cost structures design by eliminating unnecessary, from their point of view, trials, studies, calculations, installation of additional fire nicks, etc.

One of the things that contribute to the fire danger is combustible materials, the spread of flaming droplets during melting of materials and other factors [5]. One of the most flammable materials in the design of facade systems is a hydro windproof film (membrane), which performs the function of protecting the insulation layer against weathering. As a result of its burning, the fire spreads throughout the structure of the facade (Fig. 3). Noncombustible membrane application leads to an increase in the cost of the entire system.

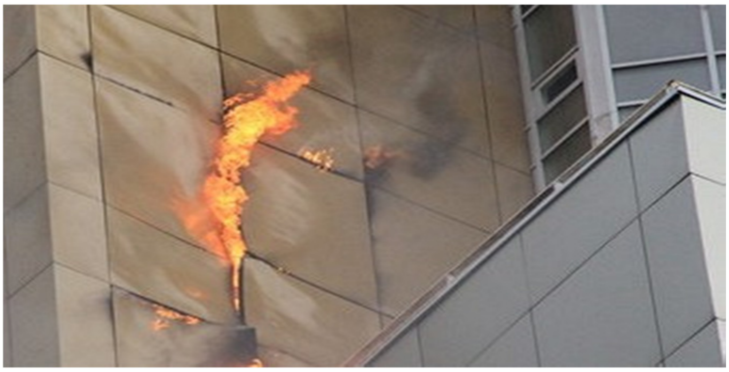

Figure 3. Membrane burning in the facade system design

To eliminate fires the builders have recently started to refuse its use. The result is that the insulation is not protected from atmospheric influences, and after a while it begins to disintegrate into fibers, and this leads to the fact that the fibers clog the air gap between the insulation and the system facing material. Therefore, there is a violation of the functioning of the whole structure of the overhead facade system with a ventilated air gap (Fig. 4). But the gap is required for effective removal of moisture and vapors migrating from the premises through the outer wall to the street [6]. Its application is clearly stipulated in the design of a façade system, and the size is calculated depending on the main characteristics of the thermal protection enclosing structures (resistance to heat transfer) [7].

Figure 4. Result of hydro windproof membrane refusal

On the basis of the above facts, we can conclude that while trying to solve one problem, we find a new one. That is like going in circles. And so it will be as long as someone from the experts does not suggest a new solution or a new material that will satisfy all the interested parties.

In construction one can mention such disadvantages as insufficient qualification of workers and engineers, low degree or absence of control, violation in the sequence of operations ("chase" for terms).

Fig. 5 shows defects in overhead wall systems, resulting from poor quality of the installation. The destruction of the cladding material occurs as a result of the fact that in the erection of the vertical profiles temperature joints have not been provided, moreover, they were concreted in the pavement around the building. As a consequence, thermal deformation of the profiles occurred, qualitative changes in the design of calculating schemes of bearing elements and the values of the loads acting on them took place.

Figure 5. Destruction of the cladding material

Fig. 6 shows the defects in the installation of overhead facade system caused by the negligence of the builders.

Figure 6. Defects in the process of overhead façade system installation

Having analyzing the defects, we come to the conclusion that the use of low-quality overhead façade l systems does not meet requirements as for energy savings and presentable appearance of the building as a whole. Overhead facade systems in the construction market have been used for more than a dozen years, but for their reliable and safe use not only monitoring to identify and study errors for their further elimination are require, but more accurate and strict control at all stages of work with them.

3. Light steel thin-walled structures

One of the main problems in the LSTS construction is that the building is destroyed almost immediately (brittle fracture) and fully, and the defective items cannot be applied again (for the second time).

When designing this constructive solution it is possible to distinguish such aspects as the lack of regulatory framework applicable on the territory of the Russian Federation, the overestimation of mechanical characteristics, etc.. Manufacturers point out fire resistance, eco-friendliness and energy saving as advantages. These indicators do not directly depend on the LSTS structures application and, according to the authors, on the contrary do not show the use of thin-walled profiles. These indicators depend on the quality of the insulating layer and the type of facing material for covering walls or ceilings and surfaces [8]. Consequently, these structures must be viewed as a single system, and manufacturers need not only to calculate load-bearing structures, but also consider other materials. For example, builders use polystyrene as an insulation material in façade systems for the sake of economy, but when it burns it emits not only harmful black smoke, but the styrene, causing respiratory organs damage in humans [7].

Fig. 7 shows the alarm status of a corrugated frameless shell of the arched building with a span of 21 m in the period of installation. The deficiency of the design was the result of its delayed grouting (fixing) in the foundation. Furthermore, experts proved overestimation of mechanical properties of the steel in the certificate after the tests [9].

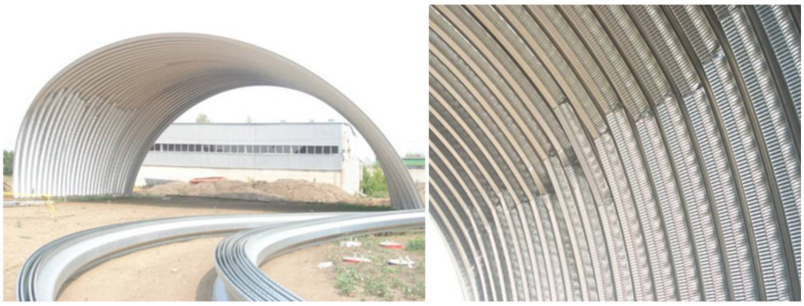

Figure 7. Loss of local stability of a corrugated shell

The factors influencing defectiveness in the manufacture of structures are: low-quality production and original manufacturing defects, failure to comply with the technology application of protective coatings.

Stage of construction of buildings is partially characterized by the violation of rules of installation and lack of proper control. For example, the collapse of LSTS structures (Fig. 8) resulted from changing the cover disk and the loss of overall stability due to the neglect of the assembly process [9].

Figure 8. LSTS destruction

Examples of accidents of LSTC buildings testify to the need for a comprehensive approach using structural measures in the development of this technology. Failure analysis of the considered structures allows to establish the main causes of accidents:

- Defects and low quality construction works,
- Project non-compliance,
- Use of the materials and structures of insufficient strength,
- Replacement of structures or parts without the approval of design organizations,
- Overload of the bearing structures in the process of operation,
- Lack of reliable means and methods of corrosion protection

Insufficient knowledge of the work of some structures under loads is also looked upon as one of the causes of failure.

Predictions of accidents:

- Tendencies of reduction of accidents of buildings and structures are not being observed.
- - Significant influence of human factor on the accident rate and the severity of the consequences of the accident are not to be excluded.
- - The severity of the consequences of accidents can be foreseen and the total number is reduced by elimination of repetition of similar errors and the causes of the accident, the "barbaric" operation and illiterate operation of maintenance work.

4. Conclusion

In conclusion we can say that each technology has its pros and cons. Having chosen "cheap, shoddy" technology we can economize, but make a huge mistake at that, which will not be corrected. It is important to have an adequate assessment of the real level of possible danger and severity of

IOP Conf. Series: Materials Science and Engineering **191** (2017) 012046 doi:10.1088/1757-899X/191/1/012046

consequences of potential accidents, and an understanding that ensuring the security of buildings and structures is an important and significant component.

References

[1] S. Ivorra, J. Garcнa-Barba, M. Mateo, C. Perez-Carramicana, A. Macia. Partial collapse of a ventilated stone facade. Diagnosis and analysis of the anchorage system. Engineering Failure Analysis: Vol. 31 (2013), pp. 290–301

[2] L.V. Endzhievskiy, A.V .Tereshkova, The history of failures and catastrophes. Krasnoyarsk: Sib. Feder. University (2013), p. 440

[3] M.A. Shameri, M.A. Alghoul, K. Sopian, M. Fauzi M. Zain, Omkalthum Elayeb. Perspectives of double skin facade systems in buildings and energy saving. Renewable and Sustainable Energy Reviews: Vol. 15 (2011), pp. 1468–1475

[4] Curtain Wall Systems: A Primer, Committee on Curtain Wall Systems. Edited by Ali M. Memari,Ph.D., P.E. M.ASCE, American Society of Civil Engineers (2013)

[5] L. Junmei, X. Xuefei, H. Cheng, L. Yanfeng, Y. Chenchen, L. Shanshan. Numerical studies on effects of cavity width on smoke spread in doubleskin facade. 2012 International Symposium on Safety Science and Technology. Procedia Engineering: Vol. 45 (2012), pp. 695 – 699

[6] Recommendations on design of overhead façade systems with a ventilated air gap for new construction and reconstruction. Administration of Perspective Design and Standards of Moscow Committee of Architecture #20 (2002)

[7] Information on http://fasadec.ru

[8] Y. Cheng, in Recent Trends in Cold-Formed Steel Construction, 1st Edition, edited by Woodhead Publishing, Denton, Texas (2016)

[9] Information on http://forum.dwg.ru