Bearing capacity of the facade system under temperature effect

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Abstract. Hinged facade systems are the external enclosing structures of buildings. These systems are subject to a range of loads, including temperature effects. Temperature effects significantly affect the structural bearing capacity. This article presents the results of experimental and theoretical studies of the bearing capacity of a hinged facade system, taking into account the influence of temperature load on the example of a design with gear assemblies of flexible fastening of facing panels. An assessment of the stress-strain state of nodal structural elements is given. A comparative analysis of the strength and deformability of suspended facade systems with flexible and rigid joints of structural elements is given. On the basis of experimental studies, it was found that to ensure free movement during temperature influences in riveted joints, it is necessary to place the rivet “head” in the oval hole and press the rod into the round hole. Assessment of the stress-strain state of the connecting elements in flexible nodes showed that stresses from the temperature load arising in the supporting brackets are very small and amount to ~ 1.5% of the maximum allowable stresses. This allows us to conclude that these stresses can be ignored.

1. Introduction

Hinged facade systems (hereinafter referred to as the HFS) are widely used in the construction and reconstruction of buildings today. Being external enclosing structures, HFS are subjected to a complex of force and non-force influences affecting their bearing capacity. Temperature load is one of them. The influence of temperature stresses arising in the structural elements of the HFS, due to large temperature differences on the internal and external surfaces of the structure, negatively affects its bearing capacity and operational reliability.

To exclude internal stresses from the temperature load occurring in the HFS, the fastening of the facing panels should be pliable, providing freedom of thermal deformation of the frame. When strains are constrained, the temperature load can cause not only damage to the lining and rivets cut; but also the destruction of the anchor dowels of the supporting bracket and the collapse of the structure.

A number of works of Russian and foreign researchers are devoted to the study of the bearing capacity of fastening hinged facade systems. So, in [1], the results of experimental and theoretical studies of the strength of fastening of the supporting brackets to the base of sandwich panels are presented, which allowed the authors to develop recommendations for the design of fasteners for such systems. In works [2,3], based on the studies, an empirical dependence was obtained that allows one to...
determine the strength of the anchor to break out of the base of the HFS and established the ultimate bearing capacity of various types of compounds with different combinations of loads. The bearing capacity of joints of thin-walled profiles with the help of blind rivets and self-tapping screws working in tension was studied in [3–7], in which it was noted that the most likely type of failure of such joints is the screw being pulled out of the base and the sheet torn through the washer. The results of experimental studies of the bearing capacity of fastenings of metal elements on rivets. cited in [8], showed that the strength of the joints on blind rivets depends not only on the material and diameter of the rivets, but also on local deformations of the element in the rivet region. In [8–10], it was noted that the bearing capacity of fasteners on exhaust rivets is determined mainly by the work of thin-walled connected elements in place of the hole when interacting with the rivet.

2. Materials and methods

In order to identify the influence of temperature forces on the strength and deformability of the HFS, experimental and theoretical studies of the design with flexible mounting of cassettes made of composite material were carried out (figure 1). The fastening of the facing panels to the supporting structure of such a system is made as gear joints, providing free movement of the connected elements in the nodes arising from thermal deformations [11–14]. The constructive solution of the compliant nodes provides for the mirror arrangement of the L-shaped glues, which makes it possible to perceive vertical shocks perpendicular to the plane of the earth that occur during an earthquake [15].

![Figure 1. Design with flexible mounting of cassettes: 1 - 2 - toothed spike; 2 - gear bracket of the carriage; 3 - carriage; 4 - drainage profile made of aluminum alloy; 5 - the reverse part of the extension cord; 6 - extension cord; 7 - bracket; 8 - composite panel; 9 - insulation; 10 - anchor dowel; 11 - dish-shaped dowel; 12 - paronite gasket; 13 - blind rivet](image-url)

The compliance with thermal deformations of the rivet fastening of the drainage profile in the structure under consideration was studied on the basis of the experiment.

The experimental model of the rivet joint consisted of two plates with a size of 120x50x2 mm, made of aluminum alloy AMg6, connected using a blind rivet with countersunk shoulder 5x12 A1 / A2 and fasteners in the grips of the test setup.

Two types of joints were tested: A and B. In the A-type joint, the rivet core was pressed in oval, and the “head” in the round hole of the connected elements. In the B-type joint, on the contrary, the
“head” of the rivet was pressed into an oval, and the rod into a round hole. For testing, 5 samples of compounds of each type were made (figure 2).

Figure 2. Experimental samples before testing: a – type A; a – type B

Experimental studies of the strength and deformability of riveted joints were carried out in the laboratory of Moscow Scientific Research Center "Construction". Tests were conducted using the Hydrajaws Mounting Tester, designed to measure force and linear strain (figure 3).

Figure 3. Experimental equipment with a sample

Compounds were tensile tested. The deformed state of the rivet joint of the elements in the assembly from the action of temperature influences was simulated. It was assumed that the riveted connection with an oval hole in one of the elements does not provide free movement from temperature deformations of the drainage profile and transfers part of the load to the system mounting brackets. The test design is shown in figure 4.
Figure 4. Test design: 1 - test sample; 2 - a fixing bolt in captures; 3 - motionless captures; 4 - metal prisms; 5 - fixed captures of the tester; 6 - pyramidal support; 7 - a hydraulic jack; 8 - lever application of force; 9 - measuring device (load registration); 10 - measuring device

A tensile mechanical load of up to 25 kN was applied to the testing rivet joint, and hydraulics were used to record the load using an accurate analog measuring device, which ensures reliable measurements. Load distribution bridges, a pyramid support, and metal prisms kept the load away from the test compound. The measurement error of the load did not exceed 2% of the actual measurement result.

The load was applied by steps, manually adjusted. Each loading step was no more than 0.05 kN. The tests were carried out until the maximum load was fixed, at which a rivet was shifted to the edge of the oval hole. To ensure the accuracy of strain measurements, the rivet joint was centered along the axis of application of the load.

During the test, at each step of sample loading (0.05 kN), absolute deformations Δ (mm) of the riveted test compound were recorded. Upon reaching the maximum load, the maximum possible movement of the rivet in the oval hole was 8 mm (figure 5).

Figure 5. Experimental samples after testing: a – type A; a – type B
3. Results and Discussion
The stress – strain diagrams (figure 6) shown the asymptotic approximation of the curve to the line parallel to the X-axis after reaching the maximum loads at which free rivets were observed in the oval hole of the joint.

Figure 6. The «load-deflection» graph

The test results showed that the ultimate load when the rivet was shifted in the oval hole for the A-type samples was 88 N, and for the B-type samples – 912 N (Fig. 6). Such a significant difference in the ultimate loads for the tested types of samples is explained by the effect of the crushing of the metal that occurs in the region of the hole when the rivet is pressed. In B-type samples, the crushing of the metal creates a tight contact of the rivet with the connecting element, which increases the bearing capacity of such a connection.

Experimentally obtained that the joints on the blind rivets with the placement of the “head” of the rivet in the oval hole (B-type) are pliable to temperature influences, providing free movement of elements experiencing thermal deformations in the assembly.

Assessment of the bearing capacity of the HFS with nodes of different compliance with thermal effects was carried out according to the standard methodology. Two hinged facade systems were considered: with compliant (figure 7, a) and rigid (figure 7, b) compounds of nodal elements. The temperature load in the calculation was set, as an example, for the climatic conditions of Moscow.
Figure 7. Design schemes with compliant (a) and rigid (b) joints

The magnitude of the linear deformations of the drainage profile in a system with compliant joints of elements was 2.3 mm. This elongation with is compensated by a gap of 130 mm made in the design. So, experimentally confirmed, that forces which may arise because of temperature changes are excluded in this case.

When fastening the drainage profile according to the scheme of rigid connection of elements in the nodes (figure 7, b), the temperature load can cause not only deformation of the lining and cut rivets, but also the pulling out of anchor dowels of the supporting bracket and the collapse of the system.

Assessment of the stress-strain state of the nodal elements of the system showed that stresses from temperature influences arising in the bracket during rigid fastening of the drainage profile exceed the maximum allowable 2.7 times. That is why it should be concluded that rigid fastening of the drainage profile to the supporting bracket is unacceptable.

Stress-strain state picture of the ductile joints, as shown by studies, vary significantly depending on the type of rivet fastening of the drainage profile.

According to the calculation results, it was found that in flexible nodes with riveted joints of B-type, the additional stresses in the bearing brackets from the temperature load are ~ 1.5 % of the maximum allowable, which allows them to be neglected. In nodes with A-type joints, as shown by tests, the maximum possible force arising in the drainage profile causes additional stresses in the bracket, amounting to ~ 15.6 % of the maximum allowable, which should be taken into account in assessing the bearing capacity of the HFS.

4. Conclusions

According to the results of experimental studies of hinged facade systems with nodular toothed fastening of the cladding, it was revealed that in order to ensure free movement from temperature effects in rivets, the “head” of the rivet should be placed in an oval hole, and the press-in of the rod in a round one. An assessment of the stress-strain state of the HFS component elements with flexible fastening of the cladding panels showed that the additional stresses arising in the bearing brackets
from the temperature load, due to their small size (~ 1.5 % of the maximum allowable), can be neglected in the calculation.

In conclusion, it should be noted that the results of experimental studies of the behavior of joints on blind rivets are applicable not only to the considered structures with nodal gear fastening of the cladding, but also to all hinged facade systems with riveted joints of structural elements.

References

[1] Galyamichev A V, Kirikova V A, Gerasimova E A and Sprintse A 2018 J. Magazine of Civil Engineering 2(78) 30–46
[2] Kiselev D A 2010 Strength and deformability of anchor fasteners under the action of static and dynamic loads. PhD Thesis 29 p
[3] Katranov I G 2011 Bearing capacity of screw and rivet joints of steel thin-walled structures PhD Thesis 22 p
[4] Tusnina O A 2013 J. Industrial and civil construction 3 14–16
[5] Katranov I G 2010 J. Proceedings of Moscow State University of Civil Engineering 2 89–93
[6] Katranov I G and Kunin Yu S 2010 J. Industrial and civil construction 3 48–50
[7] Kunin Yu S and Katranov I G 2010 J. Building materials, equipment, technologies of the 21st century 7 35–37
[8] V V Mysak, O A Tusnina, A I Danilov and A R Tusnin 2014 J. Proceedings of Moscow State University of Civil Engineering 3 82–91
[9] Moss S, Mahendran M 2002 Structural Behaviour of Self-Piercing Riveted Connections in Steel Framed Housing. Sixteenth International Specialty Conference on Cold-Formed Steel Structures, Orlando, Florida USA, October 17-18 748-762
[10] Holmstrom P H, Sonstabo J K 2013 Behaviour and Modelling of Self-Piercing Screw and Self-Piercing Rivet Connections. Master thesis. Norwegian University of Science and Technology 158 p
[11] Emelyanov D A 2012 J. Industrial and civil construction 12 28–30
[12] Tusnina V M and Emelyanov D A 2013 J. Industrial and civil construction 9 11–13
[13] Tusnina V M and Emelyanov D A 2015 J. Industrial and civil construction 3 46–49
[14] Design recommendations for curtain wall systems with a ventilated air gap for new construction and reconstruction of buildings (Moscow: Moscomarchitectura 2002) p 98
[15] Tusnina V M and Emelyanov D A 2014 J. Industrial and civil construction 7 66–68