

Methods for estimating ice adhesion to surface

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Abstract. A technique for assessing adhesion of ice is described. A composition for anti-icing coatings is proposed. The composition includes silicone resin and filler – Aerosil. The results of comparative tests of adhesion of ice to a super hydrophobic and hydrophilic surface are presented. It is shown that adhesion of ice values depend on temperature and test conditions. It is established that the technique for estimating ice under lateral constraint conditions gives overestimated results of adhesion values. The presence of an anti-icing coating on the surface reduces adhesion of ice by 2-4 times. The increase in test temperature leads to a significant decrease in ice adhesion.

1. Introduction

To protect the roofs of buildings from icing, various anti-icing systems are used [1-3]. The PROL, NIVASAR-300, ULTRA GUARD STOPLED, OS - 12-03, “Slider”, “Baltek-Antice” and other compounds are presented on the domestic market of anti-icing coatings [4-6]. We have developed a composition for anti-icing coatings [7,8].

When developing the anti-icing composition, SILRES® MSE 100 silicone resin was used as a binder, and R 972 grade aerosil was used as filler. Coating adhesion to the substrate, evaluated by the lattice notch method in accordance with GOST 15140-78 “Paint and varnish materials. The method for determining adhesion after wetting was 1 point.

One of the indicators of the quality of anti-icing coatings is adhesion. It is known that the adhesive strength of ice to a coating is determined by the chemical nature of the film former and, in accordance with the thermodynamic concept of adhesion, is a function of its surface energy or surface tension. With an increase in the difference between the values σ_{wat} of water and σ_{coat} of the coating, the spreadability of water along the surface layer of the coating decreases. The decrease in surface wetting leads to a reduction in the contact area between the frozen water and the coating and, as a consequence, to a decrease in the adhesion of ice to the coating.

Currently, there are several methods for assessing ice adhesion. In [9], a method for determining the adhesion of ice to smooth cylindrical samples by shear under constraint conditions is given. The disadvantage of this method is overestimated adhesion values.

A method for measuring adhesion on shear of ice at various temperatures is described [10]. The method is carried out using a platform pivotally attached to a frame. The test sample is mounted with a plate frozen to it through a drop of water. A trolley with loads is attached to the plate. The ice-material contact is destroyed when the angle of inclination of the platform changes. The disadvantage of this technical solution is the lack of measurement accuracy.

2. Materials and methods

We propose a method for determining ice adhesion to a metal surface, which consists in the following. The metal sleeve (2) was placed on the base (1) and filled with water (Figure 1). The inner surface of the sleeve was previously treated with an anti-icing compound. To prevent water from flowing out of



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the sleeve, the lower surface of the sleeve was waterproofed and, after freezing, the waterproofing was removed before the test. Metal sleeve was placed in a freezer with a temperature of -10°C and -18°C .

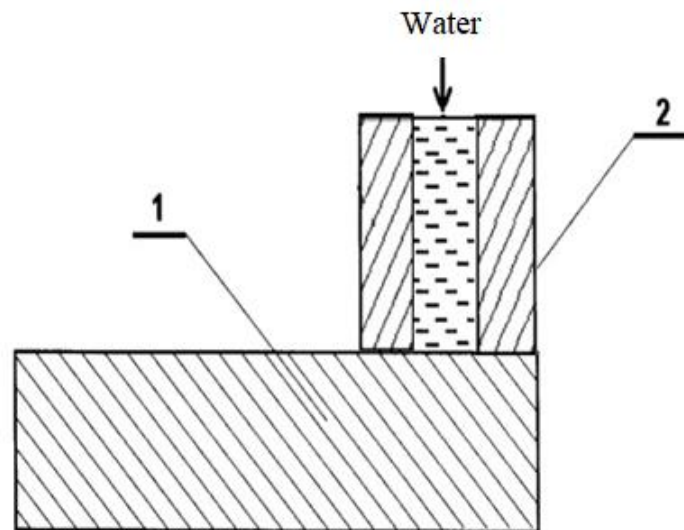


Figure 1. Scheme of freezing water in a metal sleeve

The measurement of the adhesion strength of ice to the test material was evaluated by determining the force required to shift the ice from the surface of the test material. The shear ice test was carried out using a hydraulic press in compression mode with a gripper speed of 0.5 mm/min . The adhesion of ice to the test material was calculated by the formula

$$R = \frac{P}{S} \quad (1)$$

where P is the force applied to shear the ice from the material;
 S is the area of the lateral surface of the cylinder (the area of contact of ice with the surface).

Galvanized iron, metal, concrete are used as the surface. The effect of temperature at the time of the test on ice adhesion was also investigated.

3. Research results

The analysis of the experimental data shown in Figs. 1-3 and Table 1 indicates that under conditions of constraint, the adhesion of ice to a metal surface is 0.213 MPa , and with the use of an anti-icing coating - 0.1 MPa . The adhesive nature of the destruction was observed.

When ice is frozen at a temperature of -5°C , ice adhesion decreases to 0.014 MPa , and with the use of anti-icing coatings to 0.004 MPa .

Table 1. Adhesion of ice to a metal surface

Surface type	Adhesion, (MPa)	
	Freezing temperature, ($^{\circ}\text{C}$)	
	-18	-5
a metal surface with coated on the basis of anti-icing composition	0.142	0.004
Hydrophilic metal	0.213	0.014

Under lateral constraint, curves 1 and 2 are identical in their parameters (Figure 2). The angles of inclination of the ascending branches of the curves are almost the same, a shift on the time scale is

observed. Almost identical curves 1 and 2 indicate a weaker effect of the anti-icing coating on ice adhesion under lateral constraint conditions. The maximum load value is 1150 kg.

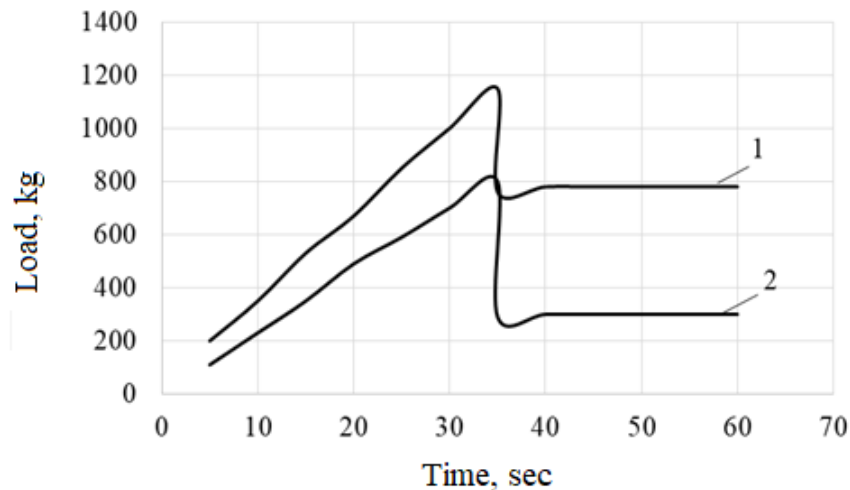


Figure 2. Deformation dependences when testing ice shear under conditions of lateral constraint: 1- metal hydrophilic surface; 2 - a metal surface with coated on the basis of anti-icing composition

Figure 3 shows the values of ice adhesion to a metal surface in the absence of lateral constraint. It was revealed that the curves have a slightly smaller angle of inclination compared to the curves in Fig. 2. The maximum load is 800 kg. The adhesion of ice to a metal surface is 0.0185 MPa, and in the presence of an anti-icing coating - 0.0055 MPa.

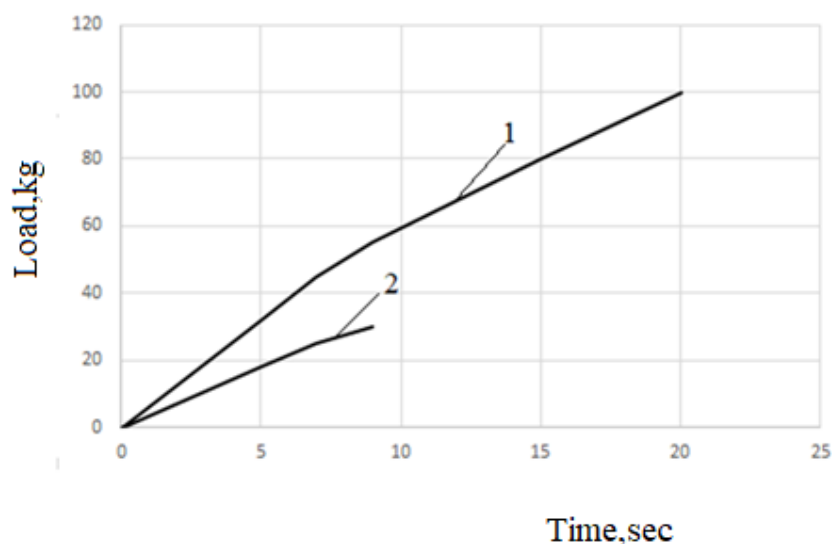


Figure 3. Deformation dependences when testing ice for shear in the absence of lateral constraint: 1- metal hydrophilic surface; 2 - a metal surface with coated on the basis of anti-icing composition

Thus, the technique for assessing ice adhesion to the surface under lateral constraint conditions yields overestimated results and does not in some cases reflect the actual working conditions of ice. Therefore, further shear tests were carried out in the absence of lateral constraint.

According to another technique, adhesion of ice to shift was determined by determining the force required to shear a metal plate from ice. Water was poured into a container of a certain volume and

covered with a metal plate. Water was frozen in the freezer. The adhesion of ice to the test material was calculated by the formula

$$W=P/S, \quad (2)$$

where P is the force applied to shift the plate from ice, S is the area of the metal plate (the area of contact of ice with the surface).

In addition, the adhesion of ice to the surface was determined by the method of avulsion of washers.

The effect of temperature at the time of the test on ice adhesion was also investigated. The research results are shown in the Table 2.

Table 2. Ice adhesion according to test temperature

Surface name		Test method					
		Shift			avulsion		
		Test temperature, (° C)					
		18-20	12-13	7-8	18-20	12-13	7-8
Galvanized iron		0.07	0.0625	0.0430	0.068	0.063	0.045
Galvanized iron	with anti-icing coating	0.022	0.0185	0.0127	0.02	0.019	0.011
Metal-plastic		0.0132	0.0115	0.0093	0.0128	0.01	0.0079
Metal-plastic with anti-icing coating		0.0042	0.0037	0.0029	0.0039	0.0031	0.0026

The analysis of the experimental data shown in the table indicates that, regardless of the test method, the presence of an anti-icing coating reduces ice adhesion by 3.03-3.49 times. An increase in test temperature leads to a significant decrease in ice adhesion. So, the adhesion of ice to shear to galvanized iron at a test temperature of 18-20 ° C is 0.07 MPa, and at a test temperature of (7-8) ° C - 0.043 MPa. The decrease in adhesion is 61.4%. In the presence of an anti-icing coating, the adhesion reduction is 57.7%. A more significant decrease in ice adhesion is observed with the use of metalloplastics, comprising 69-70.4%. It follows that it is possible to compare the results of evaluating ice to surfaces only by indicating the test temperature.

The shear strength of ice with a concrete surface at a temperature of -18 ° C is $R = 0.93$ MPa, and in the presence of an anti-icing coating - 0.279 MPa. The test results show that the shear and of avulsion of washers methods give almost the same values.

4. Conclusion

It was established that the test method for shear adhesion of ice to the surface and the test method for peeling give the same values of adhesion. Raising the test temperature reduces ice adhesion. This should be considered when conducting the test.

References

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