# CITY PLANNING, PLANNING OF VILLAGE SETTLEMENT

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## CRUST REMOVAL ON THE CORNICES OF METAL ROOFS

**Statement of the problem**. The presence of ice crusts and icicles on roofs is a problem that needs addressing since they reduce roof durability and compromise safety of people and properties under cornices of roofs. The problem of theoretical justification and practical use of a power effective method of defrosting of cornices of metal roofs has been solved in the present paper.

**Results**. The main problems regarding the formation of ice crusts and icicles on cornices of metal roofs are considered. The analysis of the influence of various factors on their formation is provided. These factors are the temperature of the inside and outside air, speed of the air at various geometrical sizes of intake and exhaust apertures, heat losses of the loft space, condition of the engineering equipment in the loft, etc. The conducted research showed that it is possible to defrost metal folded roofline by the application of the whole complex of measures which include changing the ventilation mode, increasing the height of the wall arches, rooftop snow retention, a winter funnel and pasting of roof cornices using the materials with a large wetting angle.

**Conclusions**. The study of the mechanism of ice formation and of the ways of water drainage from roofs allowed us to propose a new effective method of preventing roof icing. The energy saving solutions were used for defrosting of metal roof cornices. These solutions are based on the utilization of warm air streams of natural ventilation of building premises.

**Keywords**: defrosting, snow melting, ventilation, overflow pipe in a roof, roof space, humidity conditions, heat losses.

## Introduction

Crust on roof cornices causes thaw water drainage pipes to clog and as a result, we get deposits and icicles forming in sewage drainage pipes and funnels. In Moscow region a season of heavy snowfalls can last as long as five months, from November to April. Snow accumulates on flat as well as pitched roofs. If no appropriate maintenance is provided, large amounts of snow can accumulate on the roofing and with this coupled with winds there are likely to be snow roofings protruding over the edge of the roof. These cornices are not stable and can fail at any moment in time even under their own weight. An icicle of 2 kg coming off from a five-storeyed building has the speed of 60 km/h as it approaches the ground. Large masses of snow are damaging and cause high maintenance costs to repair many of the elements of the roofing itself and also life-threatening.

Therefore developing an effective method of preventing roofs from icing seems absolutely crucial.

There are three known ways to prevent icicles: not to allow water into the cold edge of the roof; get snow to thaw at a slower rate on the flat roof plane; decrease the amount of snow that accumulates on the eaves. In order for 1kg of snow to thaw, latent heat of 336 kJ is necessary. It can make its way to where snow is thawing in three ways: as the temperature of the outside air increases; with sunrays at the temperature of no less than 0 C; from emissions inside the building.

From the physics viewpoint, there are two ways to prevent icicles from forming: artificial cooling of the roof or routing a guaranteed roundabout way for water along the heated path. The second way was chosen for the study presented in this paper.

**1. Conditions for icing forming on cornices of metal roof**s.

A rise in the temperature of over 0 C or sunrays at the temperature of less than 0 C can contribute to how the upper layer of snow thaws. Melting water in the upper layer cannot immediately make its way into a drainage well system and drain. When soaking, snow increases its volumetric mass and its heat conductivity changes as thawing takes place. Depending on its volumetric mass that ranges from 100 to 700 kg/m$^3$, heat conductivity of snow varies from 0.0293 to 0.712 Watt/m $^0$K.

If there is no way for melt water to quickly escape the roofing, it freezes at negative temperatures and turns into ice. Since the conditions necessary for melting (the melting rate) of ice and snow differ, a short-term operation and scattered operation of a heat source may result not in melting but, on the contrary, a larger ice jam. This mechanism of snow crust can cause ice dams, jams and icicles of dozens of meters in length and of hundreds of kilos in weight [1].

Water at negative temperatures is attracted to everything with metal in it and the same goes for drainage well system.

Heat penetrating inside the building affects the way the lower snow layer melts. The operation of anti-ice systems at the temperatures lower than -18– -20 C is normally not needed, since this is when ice formation does not occur.

Daily temperatures of the air vary up to 15 C and a change in the range of +3– +5 C in the daytime and of -6– -10 C at night is conducive to ice formation. The lower threshold of the range can be as low as -10– -15 C if there are large heat flows coming from the roofing. In the springtime this can also be the sunlight. Surfaces of clear snow and ice reflect most of the sunlight coming in but even a tiny amount of mud can contribute to the absorption coefficient (decreases the reflection coefficient).

Besides, parts of the roofing that are clear of snow can have a very low reflection coefficient and intense melting can take place in the snow interlayer. According to the Met report, there were about 70 occasions of the temperature rising over 0 $^0$C over the last winter season in Moscow. Daily temperature oscillations of over 0 $^0$C cause the air and water sewers respectively to cool off fast. The mass of the snow on the roofing and elements of the roofing itself can retain a positive temperature for a while resulting in a temperature drop between the water sewers and central part which is conducive to ice formation. A feature of the reflective capacity of the material is an albedo *A*, which is the relation of the radiation *R* reflected off the radiation surface to the total radiation that this surface *Q* gets:

$$A = R/Q\ (100\ \%).$$

For fresh and dry snow $A = 80$– 85; for clean and wet snow $A = 50$– 55; for an aluminum sheet $A = 48$; for galvanized steel $A = 36$. Therefore, the greater albedo is, the more heat the material absords, the more it heats up and ages. Besides, barren parts of the roofing heat up fast and melting is confined to the outside of the layer. This is the reason why ice formation is faster in spring than it is in autumn.

There are natural reasons as well that are conducive to ice formation even on an ideal roof. The most important one is solar radiation that gives rise to unbalanced temperature conditions (for the central regions it is most pronounced in the spring months) and daily temperature oscillations over 0 $^0$C. The combination of human and natural factors makes ice formation possible over the entire winter season.

Heat emission takes place on any roofing. Snow melting can be avoided by extra heating of the loft aperture and stopping heat coming in from the engineering equipment into the loft space. Heat emission is least noticeable in roofs with a ventilated loft (cold-pitched roof). However, loft spaces have recently been used as a living space (attic) or as a store room for the heating, ventilation and conditioning equipment, which caused the requirements for the traditional roof construction to change dramatically. These construction considerations are not always taken into account by planners and architects. A poor performance of thermal insulation and no air holes result in the fact there is snow slowly melting under the snow lying on the roof (which does a nice thermal insulation job). This also occurs on the entire roof surface, except the eaves. Those could be called warm-pitched roofs. Therefore, ice formation is common in a wider temperature range, which basically is something to watch out for as there might be icicles forming over the entire cold season.

While developing and installing an anti-icing system, it should be borne in mind that a planner should make provisions for water to make its way freely so that it could escape the roof and water drains. How fast ice builds up depends much on the geometry of a roof: complex multi-floor roofs with lots of towers, valleys, attic windows cause snow to build up and put drain water leaving the roof on hold. Some authors argue that in order to prevent ice formation on roofs, it is necessary that there are conditions for curbing snow of considerable thickness. They think that roof slopes should be designed to be no less than with no interior angles (valleys), horizontal areas protruding over collar of roof windows and pockets. But those conditions are not in agreement with the architectural plans [2]. Even in cold-pitched roofs with attics as not living spaces there can be snow melting resulting in ice formation since in cold loft spaces there are usually pieces of equipment that emit heat and pipes laid (they are commonly poorly insulated). Warm air is supposed to be blown away by the ventilation. In fact there can be stagnation areas under the roof where warm air accumulates and heats up parts of the roof.

As snow melts as a result of solar radiation and when the temperature goes over zero, ice formation can be slowed down by ventilating the loft space. However, some of the studies suggest that in the spring and autumn-winter season this is not really beneficial. As a teel sheet is exposed to sunlight, there is snow melting even at low temperatures of the air outside.

As buildings are used, it should be made imperative to properly maintain ventilation holes of loft spaces and always keep them open for ventilation and clear of water and snow. To keep the temperature and moisture mode under control, ventilation is normally improved by having different holes installed. The area of the section of a roof dormer and holes should be equal or more than 1/300 of the loft space area. Near-eave hole are designed as holes between the cornice and roof from 5 to 10 cm high or as individual holes in the near-eave part of the wall with necessary grids to prevent snow from finding its way in there or by individual exhaust pits (pipes) with weather vanes. The construction solutions for holes or intake-exhaust pits are the authority of the leading architect who seeks to preserve the visual image of the building. It is therefore not possible to design extra roof dormers, holes and pits.

The system of water drains, which is normally behind the projection of the building walls, has no extra heating and particularly water sewage pipes that are exposed to winds. Hence negative temperatures of the air outside can cause the temperature of the centre of the roof to be positive. Melt water under a layer of snow drains into sewers and freezes and thus stops water from draining further. Cold attic disconnects the roof surface from the heat of the building. Even an perfectly effective performance of thermal insulation and snow of up to 10 cm causes an oscillation between the air outside and roof surface to be 6 $^0$C, i.e. at the outside temperature of -5 $^0$C there can be snow melting and ice forming [3].

There are potential icing zones that are different in the same building as the effect warm air has is dotted. These can be zones of intensive icing, zone of moderate and yet stable icing and zone of accumulating snow. Snow lying on the roof melts because of the heat coming down from the loft as a result of insufficient thermal insulation. Another contributor to ice formation is the structure of water drainage pipes, i.e. a curve in a pipe inadvertently results in a snow jam. Melt water starts overflowing the water drainage pipes, which results in heavy icicles. On the edge of the roof over the zone of heat from the building and having a much lower temperature, water starts to freeze. There is a constantly growing water barrier for melt water and this is conducive to ice formation.

Some researchers suggest special compositions should be used to prevent ice formation in eaves. These surfacings (e.g., organic-silicon) protect the roof from solar radiation and decrease adherence of ice, dust and oily substances with the roof material. The surface of any body gets soaked as it comes in contact with water. If the edge angle of wetting is over 90$^0$, the surfacing is hydrophobic and water rolls down the surface. The most dramatic example of such wetting is a lotus leaf. Lotus leaves and its flowers do not get soaked (always keep dry) since their surface consists of microvalleys of about 10 mkm ($10^{-6}$ m) in height and microvalleys themselves are covered in microfibers that contain a layer of wax-like substances (cuticles). There are current technologies which are similar in effect to this: water repels from the surface of the support with vertically fitted carbon nanopipes. Surfaces of the lotus type have a wetting angle of up to $150^0$. Its high cost is a factor standing in the way of it being widely used. Silicon-hydrib polymers obtained by the molecular joining method have in their structure organic and organic-silicon macromolecules connected with chemical bonds (Si-C) and prone to negative outside factors (hydrolytic effect of water, UV-radiation, etc.) are commonly used these days for hydrophobization of cornice eaves.

However, hydrophobic property of these anti-icing mixes declines significantly due to the environmental effects (UV, rains, etc.) during the process of operation as well as the property of the material itself (cracking, spalling of metals, sweating of hydrophobic additive).

This disadvantage in the system of melt water removal off the lower part of the roof (placing a cold gutter outside the building) is the reason for ice formation since the temperature of the pipe and flunnel is always lower than that of the roof surface (the roof surface is heated up by the heat from the loft space). Clogging of the exhaust duct by ice in the pipe and flunnel causes the stagnation and subsequent freezing of water over the entire roof and possible overflowing and icicles on the rooftops. It can therefore be argued that icicle formation starts with clogging of the water drainage system.

After looking into the reasons for ice formation on roofs, the authors suggest counteracting the reasons underlying ice formation but not just the process itself [4 6].

**2. Preventing ice formation of roofings by using warm air escaping a building**

Even an ideal heat moisture mode of the loft space (necessary thermal insulation of the aperture and engineering equipment on the loft, ventilation of the loft) causes heat losses and is not really helpful in achieving the temperature balance inside and outside the loft. There are thus the same conditions for snow and ice melting on the roof at negative temperatures and during spring thaw.

The thing to particularly watch out for is melt water making its way into the drainage pipes. As water freezes, water drainage flunnels will be clogged and there will be ice building up over them and over the entire roof as well. The object study here was (supervised by the head of LLC Spetsteplokhimzashita V.P. Protasov) was a water drainage system of a building as a starting point of ice formation.

We argue that the biggest dilemma underlying icicle formation is the removal mechanism of melt water from the roof: if there are not present on a cold-pitched roof, icicles and dams will have nowhere to come from. This is why we suggest the structure to prevent all of these from happening (Fig. 1):

1. Installing a wall sewer flute of a bigger size on the eave along the loft space cut (at the end of the heated roofing zone);

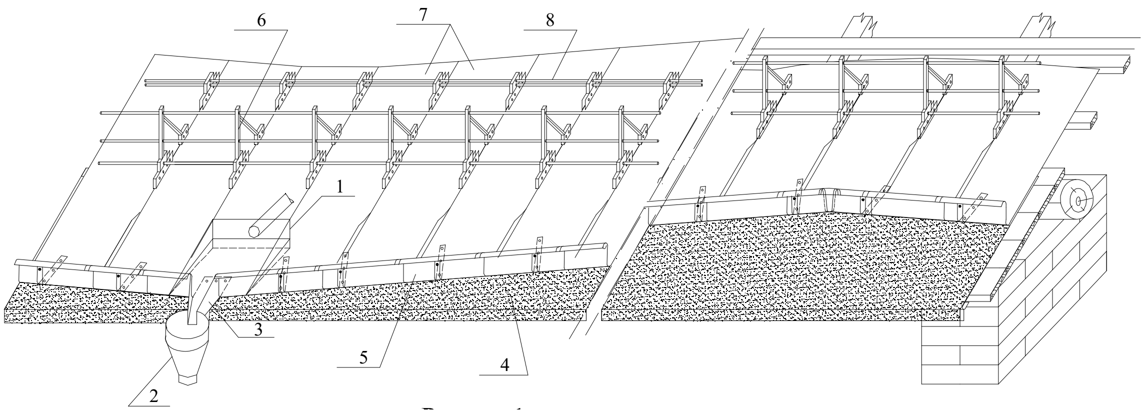


**Fig. 1.** The structure to prevent ice formation on roofs:
1 winter flunnel; 2 flunnel; 3 boot; 4 rolling roofing material with a surfacing;
5 flute of an ordinary roofing; 6 snow retention aperture;
7 ordinary roofing; 8 snow retention

2. Installing a flunnel (let us call it a winter one) over the loft space to divert melt water into the sewage system and simultaneous blockage of water drainage into the existing flunnel with a detachable gate (Fig. 2). Winter flunnel operates during a cold season only. During a spring-autumn season it is sealed hermetically.

Melt water will not freeze due to the heat coming from the sewage system with an average air temperature of 25– 30 C.

Melt water in the wall flute under the snow and ice will not overflow and form icicles on the eave but will escape into the winter flunnel with no dam.

Here, we have snow and ice serving as a heater insulator that enables water to melt on the surface of a metal roofing and divert into the winter flunnel. There is not much melt water so there is basically no risk of the drainage flooding. A heated flunnel functions over the period of possible ice formation;

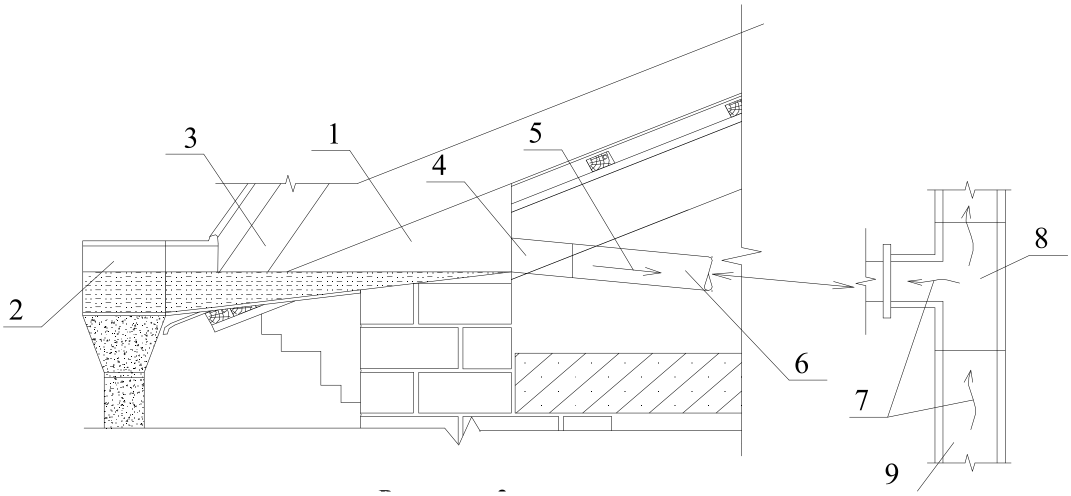


**Fig. 2.** Structure of a winter flunnel:
1 winter flunnel; 2 flunnel; 3 wall flute; 4 water drainage valve;
5 direction of melt water; 6 water drainage pipe;
7 direction of the air in a household drainage system;
8 branch pipe; 9 household drainage pipe

3. In order to prevent snow and ice from falling off the eave and protruding parts of the fa ade, a material with a rough surface needs to be adhered to them which will not allow random snow and ice falling in case of melting and sublimation.

**Conclusions**

1. We have dealt with the major problems regarding ice and icicle formation on metal roofings. The effect that a variety of factors have in their formation were looked into: the temperature of the air inside and outside, speed of the air at different geometrical sizes of intake and exhaust holes, heat losses of the loft space, state of the engineering equipment in the loft, etc.

The study showed that anti-icing of metal folded roofings is attainable with a whole variety of measures that include change in the ventilation mode, increasing the height of the wall flutes, snow retention measures as well as designing a winter flunnel and adhering roofings with materials with a large wetting angle.

2. A new effective method to prevent ice formation on roofs was suggested as a result of the

study into the ice formation mechanism and ways to divert water from roofs. The method does not come with energy costs for the heating of water drainage system in the winter season and is easy to maintain. The use of warm utilized air of sewage pipes and designing a winter flute prevent ice formation on roofs.

3. The detailed studies into the developed method were tested in several buildings in the North-East Moscow from December 2011 to April 2012. No ice and icicle formation was observed on the eaves of metal roofs over the entire period.

4. The suggested method creates safety for people and properties under roofs.

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