Critical Analysis of Activities on Removal of Icicles and Ice from Roofs of Buildings and Possibility of Prevention of their Formation

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Abstract. The article analyzes consequences associated with inefficient removal and prevention of icicles and ice on roofs of buildings and suggests development of systems and devices to minimize these consequences. An inert solution to the problem of removing and preventing icicles and ice on roofs of buildings creates a bulk of other interrelated problems, most important of which is the threat to and reduction of the quality of people’s life. The internal development potential of the Russian Federation in the field of removal and prevention of icicles and ice from roofs of buildings is the key to reliable development of housing and utilities sector.

1. Introduction

The housing and utilities sector development strategy of the Russian Federation for the period up to 2035 is a strategic planning document that defines priorities, aims, tasks and measures in the housing and utilities sector. It was developed in accordance with the Constitution of the Russian Federation, Federal Law No. 172-FZ as of 28.06.2014 “On strategic planning in the Russian Federation”, with the aims and strategic objectives defined in presidential Decree No. 204 as of 07.05.2018.

Currently, the Russian Federation is implementing a number of nation-wide projects and programs that influence formation of focus areas in development of the housing and utilities sector. In this regard, design of the housing and utilities development strategy of the Russian Federation takes into account activities currently being implemented under such national projects as: “Housing and urban environment”, “Ecology” and “Digital economy of the Russian Federation” program.

Topical issues that need to be addressed and identified in the housing and utilities sector’s development strategy are: management of multi-unit apartment buildings, major repairs of common property in multi-unit apartment buildings, delivery of utility resources (provision of utility services): heat supply, hot and cold water supply, and sewerage.

2. Topicality of the issue

The intent of state and municipal authorities to develop strategies effectively and work ahead of scheduled deadlines in modern conditions is becoming more and more essential, economically and objectively justified.

One of the main tasks of regional and municipal authorities is to ensure reliable and sustainable development of housing and utilities sector [1].
In Russian regions with rigorous climate, improving operational reliability of roofs and regular snow removal from them is a necessary, important process and an acute issue for many residents of multi-unit apartment buildings. In this regard, improvement of efficiency, reliability and safety of snow and ice removal from roofs, simplification of snow and ice removal, reduction of heat losses, reduction of energy costs, and reduction of labor costs when operating the roof of a building become even more relevant.

3. Aim setting
Taking into account all mentioned above, within the framework of this study:
- consequences associated with inefficient removal and prevention of icicles and ice on roofs of buildings were analyzed;
- modern systems and devices for removal and prevention of icicles and ice from roofs of buildings are proposed.

4. Analytical part
Emergence and development of housing and communal services management, as well as quality of repair works, operation of housing and communal facilities are studied in the works of such researchers as O.E. Bessonova, A.N. Asaul, B.C. Bogolyubov, G.M. Zagidullina, V.V. Buzylev, N.V. Vasiliev, A.B. Petrukhin, S.N. Maximon, A.A. Olteanu, A.N. Plotnikov, Yu.P. Panibratova, E. Fedoseyev, B.C. Chekalin, N.V. Chepachenko, I.F. Gareeva, L.N. Chernyshova, T.I. Khametova, M.D. Shapiro and a number of other scientists. Objectively, contribution of each research scientist plays a significant role in the field of housing and communal services management, but it is worth noting that the researches are rather contradictory.

It is advisable to analyze consequences of untimely removal and prevention of icicles and ice on roofs of buildings before options for devices and systems for removal and prevention of icicles and ice on roofs of buildings are offered.

Due to the fact that there are no coherent statistical data on the issue under analysis data, facts provided by the media will be used to give the scope of the situation.

The founder of “Ice patrol” (the national center for de-icing) A. Mirzoyan collected statistics from open sources on results of the winter of 2017 – 2018. The obtained results are as follows: in the period from December, 2017 to April, 2018 eleven people died from icicles and ice in Russia and 2 of them were children. Adults were injured and killed in Saint Petersburg, Yakutia, Voronezh, Smolensk, Moscow, Nizhny Novgorod, Ivanovo and Murmansk regions. Children were killed in Perm and Petropavlovsk-Kamchatsky. Moreover, 55 adults and 21 children were injured in various degrees of severity from icicles falling. The most “traumatic” city was Saratov (10 adults, two children) the 2nd place took St. Petersburg where 9 people were injured. In Samara 6 adults and 1 child were injured, in Murmansk region 6 people were injured, the same number – in Vologda region, 5 people were injured in Moscow, 4 people in Yaroslavl[2].

In addition, in Voronezh, Tver, Magadan, Novosibirsk, Ulan-Ude, Yuzhno-Sakhalinsk, Syktyvkar, Tomsk, Kostroma, Bryansk, Krasnoyarsk territory, Izhevsk, Yamal, Moscow, Nizhny Novgorod, Kemerovo, and Ulyanovsk regions there were also accidents involving fallen ice and icicles. Icicles often damage cars. The most affected car owners were in St. Petersburg where 9 cars were damaged, 4 cars in Saratov and the same number of cars in Murmansk region, 2 cases were recorded in Tver. In Novosibirsk, Irkutsk, Ufa, Yuzhno-Sakhalinsk, Voronezh, Tolyatti, Smolensk, Yaroslavl, Stavropol, and Moscow and Ulyanovsk regions one case involving car damaged by fallen ice was recorded.

During the cold months’ period of 2017 – 2018 the biggest number of complaints from citizens about icicles and work of public utility services was recorded in Bryansk, Voronezh, Saratov, Moscow, Murmansk and Tver regions. In 2018, the largest numbers of reports on hazardous ice formations were in January and February [3].

The following article was published by “So it goes” (Takiye dela) news outlet: On January 15, 2019 in the center of Moscow, an icicle fell on R. Belyakov, who died of incurred injuries. On February 1, 2019 a resident of Bryansk died after having been hit by ice fallen from the roof of a shopping center.
On February 14, 2019 in Saratov region a man was killed by a block of ice fallen from the roof of the house next to which the man was having a conversation with a neighbour [4].

From 01.12.2018 to 20.02.2019, 4075 citizens of St. Petersburg applied to trauma centers and hospitals with injuries from snow and ice. Moreover, 3734 people were seriously injured [5].

The available statistics makes authorities concentrate on finding efficient technologies for removal and prevention of icicles and ice on roofs of buildings and employ them to improve the quality of life of the population in the digital economy age.

5. Practical importance
An important argument is that icicles do not form on efficiently built houses. Formation of icicles and ice indicates poorly insulated roofs. As a matter of fact, a large part of the housing stock in Russia was built in pre-revolutionary and Soviet periods. Therefore, houses that are ineligible for major repairs are typically classified as problematic, since the main component that requires repair is the roof.

Back in 2010, Governor of St. Petersburg V.I. Matvienko suggested cutting icicles off with a laser or steam instead of knocking them down with a crowbar, but these technologies are very expensive.

Acceptable and popular in the private sector devices and systems for removal and prevention of icicles and ice on roofs of multi-unit apartment building are not suitable for installation on municipal housing.

Some types of devices and systems for removal and prevention of icicles and ice on roofs of buildings utilized in the Russian Federation are presented in Table 1.

Table 1. Devices and systems for removal and prevention of icicles and ice on roofs of buildings.

| Patent holder        | Description of device/system                                                                                                                                                                                                 | Outcome/Result                                                   |
|----------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------|
| I.Yu. Matsur [6]     | The method includes heating inclined surfaces of rain and snowmelt gutters and external coatings of roofs of buildings with a heat carrier, followed by removal of condensate into a sewer. As heat carriers, air flows from exhaust systems of ventilated heated premises of the building are used. They are directed into the clumping of roof drainage systems by means of heat carrier supply channels. Air flows from exhaust systems of ventilated heated premises of buildings are moved forcibly. Rain and snowmelt drains are removed to the common sewer using downpipes that are heated by the heat carrier. | reduction of energy consumption for heating of roof drainage systems |
| V.P. Zanin [7]       | Dormer windows of attics are used for inflow of external air, and extraction of internal air is carried out through additional deflectors installed in upper part of attics, equipped with special gravity shut-off and regulating devices that automatically maintain the specified minimum negative air temperature in the attic rooms, but exclude their supercooling in severe frosts, by disabling the above-mentioned deflectors. | improvement of thermal insulation of heat sources located in attics |
| D.S. Skotnikov [8]   | The device contains drainage pipes, vertically installed on walls of buildings, upper and lower, horizontally positioned pipe and connected at their ends to the respective areas of the inner cavities of downpipes, exhaust high pressure fan mounted inside roof and connected to the corresponding areas of inner cavities of relevant top sections, vertically positioned drain pipes, control system, connected by one of its inputs to the output of the humidity sensor, and by the input to the output of the task signal source and its output. | creation of effective conditions for obtaining positive values of internal temperature cavities of drainpipes that remove ice and snow from roof |
to the control input of the controlled key that provides AC voltage to power the high-pressure exhaust fan.

M.I. Pantyukhov, A.O. Blagonravov [9] The system contains a roof-mounted pipeline constructed from a lightweight, durable material that is resistant to corrosion and temperature changes, and two faucets for cold and hot water, and for a reagent. The pipeline is installed on the roof ridge and along the edge of guard railing. Installation is carried out using easy-to-manufacture racks. The mixer can be located in the attic of the house or in the basement. The principle of operation of the system is that warm water with a special reagent is sprayed through the nozzles and flows down from the roof, melting and washing away ice and snow, thereby clearing it of ice and snow. Adjustment of the water jet spread through the nozzles to the roof is made by changing the location of the diffuser plate. Water pressure is regulated by taps.

A.G. Ryabinin [10] The device is based on utilization of warm air coming from ventilation shafts of heated buildings and supply of heat carriers through a system of pipelines and hoses to the areas where ice and icicles are formed.

S.A. Shamrayev, V.V. Shamrayev [11] The method requires installation of a deflating device on the roof surface of a building containing a precipitation sensor that creates a directed air flow that can adjust the direction and strength of the air flow.

V.G. Kuleshov [12] A method of snow and ice removal from roof which involves melting snow and ice with initial cutting of icicles from roof eaves with at least one steam jet, then melting ice and snow in the drainage system by supplying steam to the tubular spillways and gutters of the drainage system, then melting snow and ice on the roof by supplying steam jets.

V.B. Belyayev [13] The device for snow, ice and icicles removal from roofs which includes ventilation pipes for removal of polluted air from utility rooms of apartments and gas combustion products from heaters that pass through the attic floor, roof, and air ducts. On the attic floor, a hollow cylindrical casing is installed, inside of which a fan is installed coaxially with it and in series with the fan an ejector is installed; the air ducts connect the ejector to the ventilation pipes, in addition, the casing has an inlet and outlet nozzles.

Scientists of Perm National Research Polytechnic University have created a new installation that allows clearing roofs of snow deposits, as well as fallen leaves in a few minutes. This becomes possible due to a powerful air blower that blows precipitation into a special pipeline. The pipeline is to be assembled in the attic, and then moved to the roof. After turning on, the blower turns around, and cleaning specialist starts loading snow into a specially provided bin. During the control tests, it was discovered that with the help of the given installation, it is possible to move snow away from the building for up to 30 meters. In addition to cleaning roofs of residential buildings, the device can be used for cleaning house territories according to experts of the PNRPU [14].
Scientists from the State Oceanographic Institute of Russian Meteorological Service (GOIN) have formulated three main ways to prevent icicles from forming: 1) prevention of melt water from getting onto cold edge of roofs, 2) reduction of snow melting intensity on main roof planes, and 3) reduction of snow mass that can accumulate on roof overhangs.

The technology proposed by GOIN scientists provides for a simple and cost-effective structural modification of the roof: to prevent water from getting to the edge of the roof, the drainpipe must “meet” it earlier, not bypassing the projection of cornice, but passing through it. In this case, the melt water immediately flows down the drain pipe, without falling on the overhangs. By vertically installing the downpipe directly on the wall, penetrating all protruding structural elements, to the underground drainage system, thus reducing the time of water removal to a minimum, and thereby reducing the likelihood of its freezing. One of GOIN scientists A. Paley notes that there is no originality in the proposed design, because on many roofs of buildings in the Czech Republic and Germany there are similar structures. Gutters should be installed along the warm zone of the roof surface, and the downpipes that run through the cornice should be pressed against the warm wall of the building. Pipes should go directly into city’s drainage system to prevent freezing of melt water in them, as well as formation of puddles and ice on sidewalks. The developers also propose regulating the temperature condition of the attic in order to reduce intensity of snow melting. To reduce snow accumulation on roof overhangs, they offer a number of design solutions, in particular, the use of a special coating. The authors of the development conducted an experiment by converting the roof of a building in the center of Moscow. As a result, there were no issues with ice and icicles, and no roof cleaning was required. According to the calculations of scientists, the cost of roof re-equipment of a typical five-story building in Moscow can be brought to 1 thousand rubles per running meter of the roof [15].

Each of the considered options for removal and prevention of icicles and ice on roofs of buildings deserve attention. Experts in the field of construction are able to select the best option from existing array of patents of the Russian Federation or combine two options in one project, making it applicable for use on a multi-unit apartment building.

6. Conclusion
The result of the given review study is a summary of the following main points:

– it is possible to prevent formation of icicles on roofs in case: melt water does not fall on the cold edge of the roof, intensity of snow melting on the main plane of the roof and snow mass that can accumulate on the roof overhangs are reduced;

– provision of one of the previously mentioned conditions is possible by selection of an efficient option from existing array of patents of the Russian Federation by specialists in the field of construction;

– inert solution to the problem of removal and prevention of icicles and ice on roofs of buildings creates a complex of other interrelated problems, the most important of which is the threat to and deterioration of people’s quality of life;

– internal development potential of the Russian Federation in the field of removal and prevention of icicles and ice on roofs of buildings is the key to efficient development of the housing and utilities sector.

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