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# EXPERIMENTAL MODELING OF SNOW ACTION ON UNIQUE CONSTRUCTION FACILITIES

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**Abstract**
**Introduction**: In modern civil engineering, repetitive architecture gives way to unique buildings. However, the available laws and regulations do not provide any recommendations for setting loads on unique construction facilities. The foregoing is fully true for snow loads as well. The Regulations “Loads and Actions” include a method to calculate snow loads for standard roof shapes. **Methods:** This paper proposes a method of experimental modeling for snowdrifts and snow deposits on complex roof shapes that differ from the standard shapes described in the Regulations, using wind tunnels of architectural and construction type. This method provides clear recommendations on experimental studies with the use of wind tunnels. **Results:** It was tried and tested in the building of a sports center under design. During the study, patterns of snowdrifts and snow deposits formation were also obtained.

**Keywords**
Aerodynamics, wind tunnel, snow actions, snow deposits, experimental studies, snowdrifts.

## Introduction

Technological advances together with the development of computer modeling in construction made it possible for architects to design unique buildings in terms of their shape. However, this achievement raised a number of issues before engineers and designers regarding the development of design documentation. When erecting a building with original spatial forms, additional studies are required on the impact of natural and man-made factors, including wind and snow actions (Shishkina and Kaloshina, 2018; Shumeyko and Kudinov, 2013).

Nowadays, one of the most important design tasks is to account for the snow load on complex roofing having a shape that differs from the primitive elements listed in the Regulations SP 20.13330.2016 “Loads and Actions” (Ministry of Construction of Russia, 2016; Popov et al., 2016). This is due to the fact that, in buildings with non-standard roofing, it is impossible to predict snowdrifts with analytical methods (Churin and Gribach, 2016).

The snow load on the roof surface is determined as the snow weight per unit of area. This value depends on climatic conditions in the built-up area. However, elements that prevent snowdrifts on the roof surface are also important in determining the snow load.

## Methods

This paper proposes a method for experimental studies of snow action on buildings, performed in the Large Research Gradient Wind Tunnel (Churin and Gribach, 2016).

According to this method, a study shall be performed as follows:

1. Analysis of meteorological and topographical data in the built-up area;
2. Design and creation of a scaled-down model for the studied facility;
3. Experimental modeling of the snow cover to determine basic patterns of snowdrifts and snow deposits formation on the roof surface of the studied facility. The shapes of snow bags are analyzed to decompose the roof surface into primitive elements, and then the snow load is determined for these elements in accordance with the Regulations.
4. Development of conclusions and recommendations based on the findings.

Experimental determination of basic patterns of snowdrifts and snow deposits formation on the roof surface of construction facilities includes the following steps:

— a uniform layer of the model material (wood powder 200, bulk density — 200 kg/m3, moisture — 3.5–4%) with a thickness of 1–1.5 mm is applied to the model;

— the flow velocity increases uniformly from 0.1 to 7.9 m/s (up to Level 4 according to the Beaufort Wind Scale), the model material moves from the smooth painted surface at the wind velocity of 3.4 m/s. The velocity is controlled using appropriate verified equipment. When model material begins to drift, the flow velocity becomes steady, and air blowing continues until the formation of distinctive snow deposits. The starting points of drifting and formation of distinctive snow deposits are determined visually;

— photos of snowdrifts are made;

— the model turns in the tunnel with a pitch corresponding to the experimental conditions (as a rule, the most distinctive wind directions at the construction site in winter are considered). The process of model material application and air blowing is repeated for each angle;

— based on the results of the experimental modeling, distribution patterns of the coefficient *μ* are built for further calculation of the snow load.

Particular attention should be given to the selection of special substances modeling snow. For instance, Isyumov (1979) used bran as the substance modeling snow in wind-tunnel testing in order to study snowdrifts at the lower level of a two-level roof at different wind velocities and directions.

O'Rourke et al. (O'Rourke et al., 2004, 2005; Thiis and O'Rourke, 2012) studied snowdrift velocities on roofs of different shapes in a water flume using crushed walnut shells and obtained good agreement when comparing the results with those of field studies.

They also considered the matters of establishing the estimated snow loads. O'Rourke's papers provided the basis for structural analysis considering snow loads in American standards (American Society of Civil Engineers, 2005).

Professor A. A. Semenov and PhD students at the Ufa State Petroleum Technological University, together with experts from UNICON Novosibirsk Department, carried out experimental studies of the snow load on the roofs of cylindrical tanks in a special wind tunnel of architectural and construction type. They used wood powder as the model material (Porivaev et al., 2012).

In addition to the studies of the snow action on the roofs of buildings and structures, we should mention studies of snowdrifts in urban pedestrian areas. Such studies were conducted in Japan at the Hokkaido Building Research Institute (Setoguchi, 2011). The territory in the northern part of Japan was studied. It is a cold and heavy snowfall region where many cities experience snowstorms. Setoguchi modeled not only snow loads but also snowdrifts. The designed area should be comfortable for pedestrians. It should be barrier-free (i.e., accessible for the elderly and the disabled). Therefore, it should accumulate as little snow as possible. Besides, the area should have commercial buildings and information boards and signs. The experiment was aimed at choosing the most optimal location of the facilities in the area so that to ensure no snow piles in the pedestrian areas and easy snow removal. Snow was modeled using white soil powder since its properties are similar to those of snow in Japan. In the course of the study, several location options for the facilities were considered. For each option, snow cover and snowdrift distribution patterns were obtained, and the optimal design of the area was chosen. The resulting design minimizes the negative effect of snow actions on the designed area.

**Results**

This paper describes testing of the method described above, using the building of a sports center being designed in Yekaterinburg as an example (Fig. 1).

According to Step 1 of the method, the climatic region (I-V), the prevailing wind directions (western and north-western), and the average annual wind velocity (3 m/s) were determined in the development area.

Then, based on the initial data, a model of the studied facility was designed and created (Pomelov et al., 2016). Considering the dimensions of the test section of the wind tunnel, the model scale of 1:150 was chosen as the maximum possible scale under the blockage conditions. The studied model was rigidly mounted on an automatic turntable in the test section of the wind tunnel at the 0-degree mark relative to the direction of the ram air (Fig. 2).

Then, the study was conducted: a uniform layer of the model material (wood powder 200, bulk density — 200 kg/m$^3$, moisture — 3.5–4%) with a thickness of 1–1.5 mm was applied to the model. After the wind tunnel engines were started and the wind velocity reached 6–7 m/s, air blowing was performed until the formation of distinctive snow deposits on the roof surface. The results were recorded by the experimental group. In accordance with the experimental conditions, full-circle exposure along the wind direction with a pitch of 90° was performed. Photos of snowdrifts at different wind directions are provided below. Based on these, it is possible to obtain data on the snowdrift types, as well as directions and volumes for each type of snowdrift (Churin and Gribach, 2016).

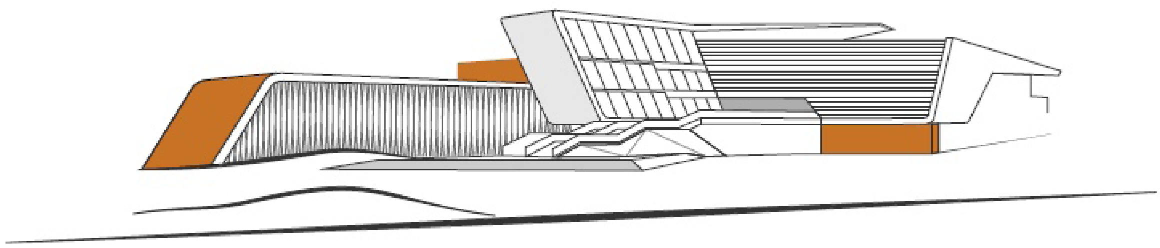

Figure 1. Facility under consideration

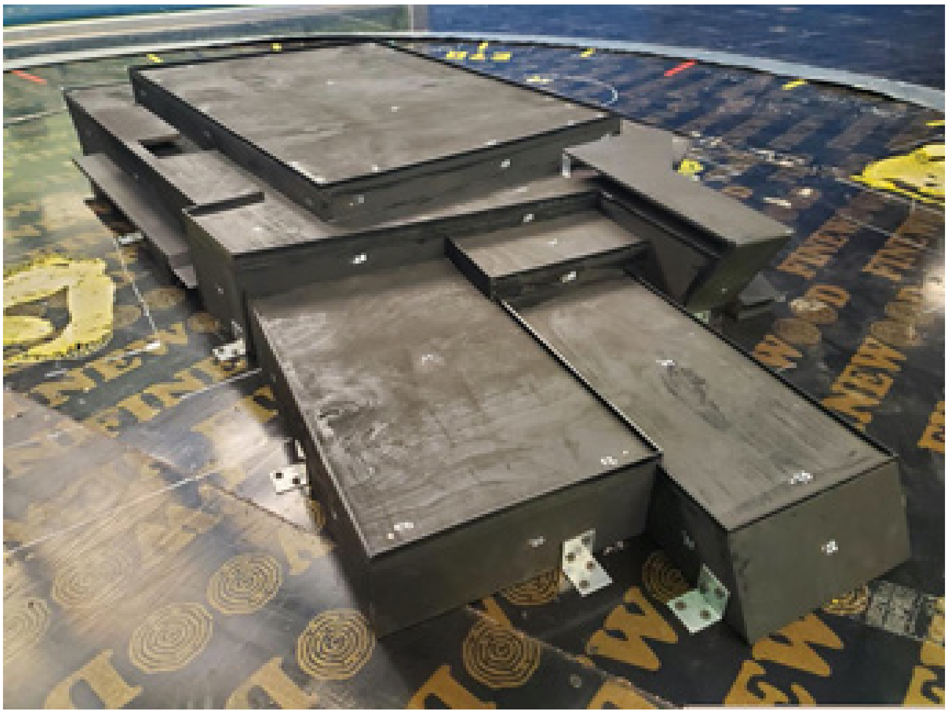

Figure 2. Model of the studied facility

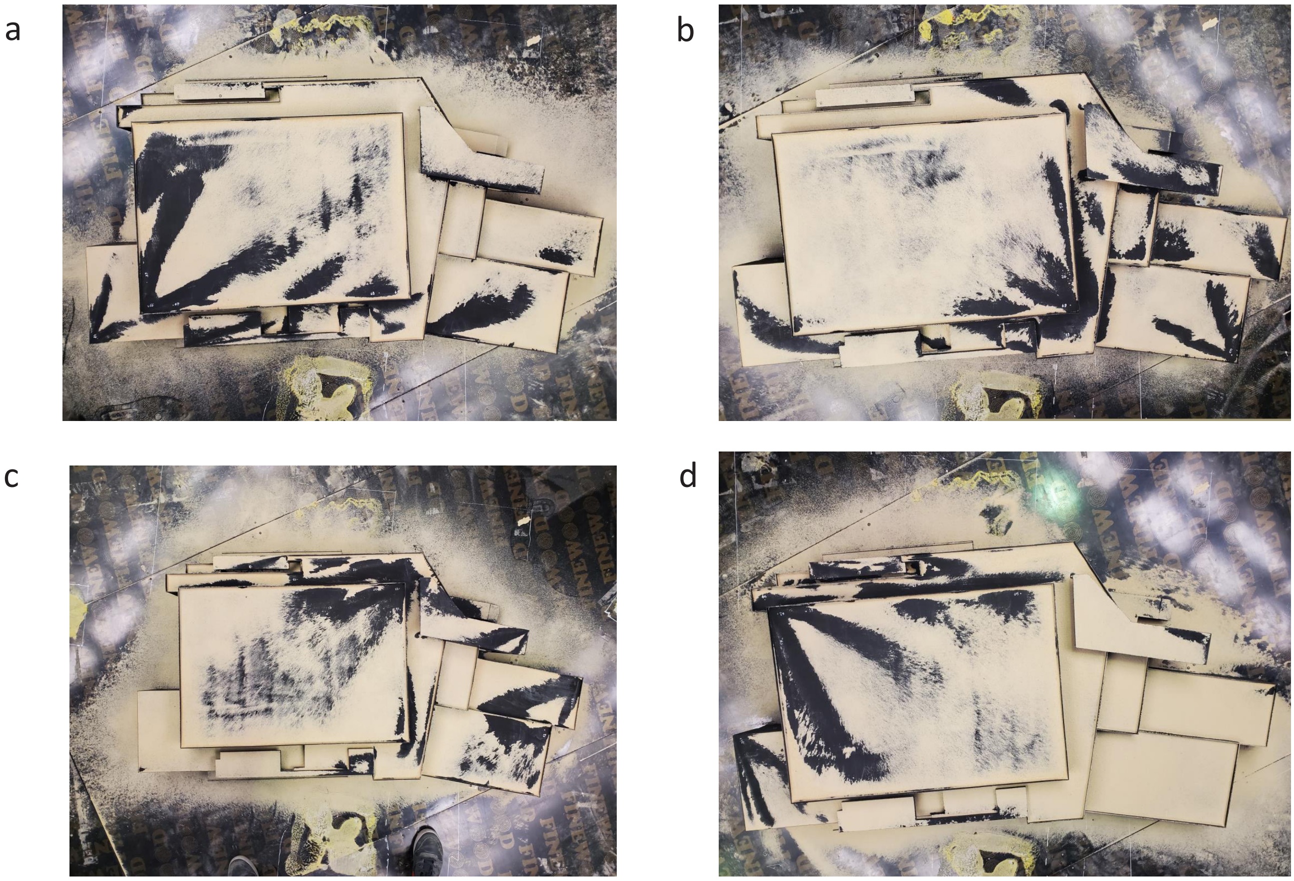


Figure 3. Distinctive zones of snow deposits at the following angles of the ram air: a — 0°, b — 90°, c — 180°, d — 270°

Taking into account the climatic analysis conducted, the distinctive wind directions in the development area in winter are the western (model position angle — 0°), north-western (model position angle — 45°), and south-eastern directions (model position angle — 225°). For these directions, diagrams of snow deposits on the roof surface of the studied facility were made after a series of aerodynamic tests (Fig. 4).

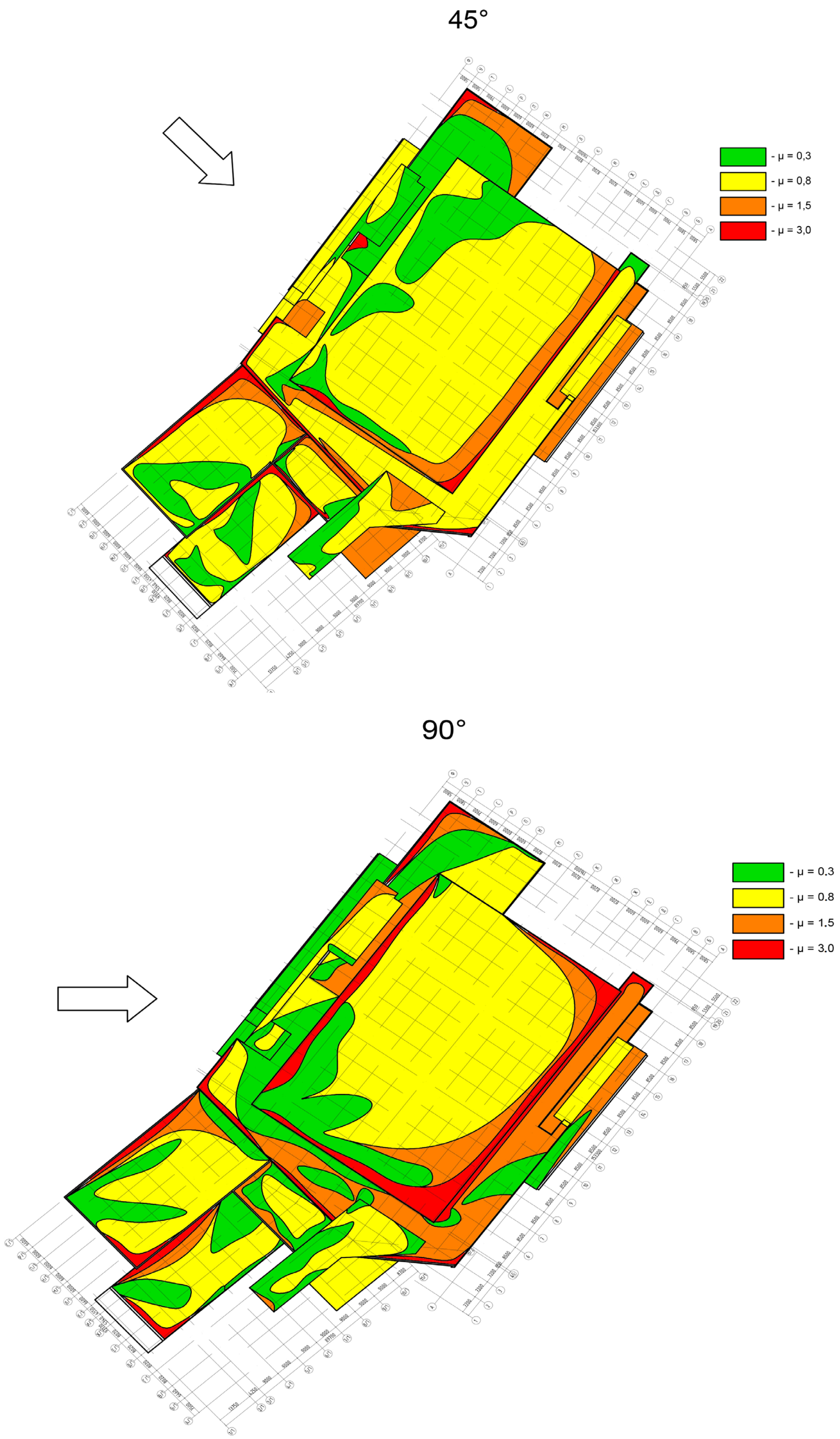


Figure 4. Diagrams of snow deposits

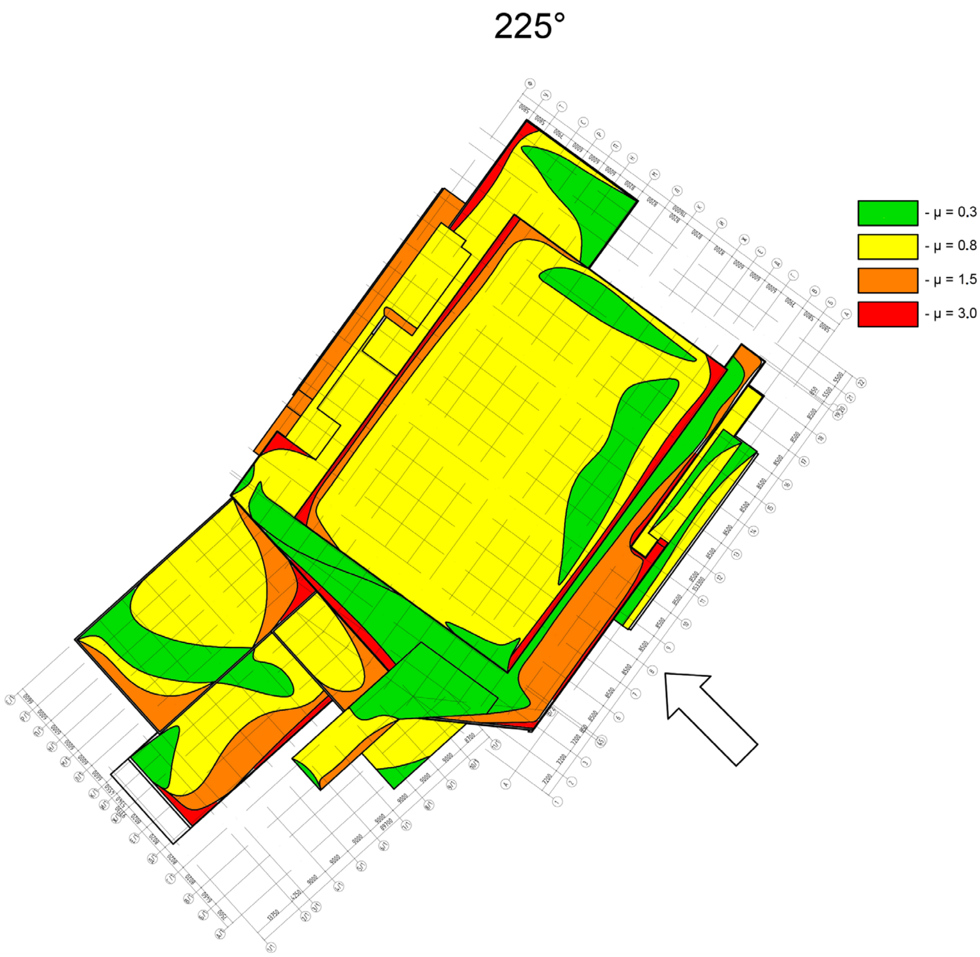


Figure 4. Diagrams of snow deposits

**Discussion**

The paper proposed a method of experimental modeling of snow actions on complex roof shapes, using wind tunnels. It provides clear recommendations on experimental studies of snow actions: the range of ram air velocities in the test section of the wind tunnel during testing, and the material that can be used as snow when modeling snow deposits and snowdrifts. This method was tried and tested in a structure being designed. As a result, distinctive zones of snow deposits were obtained. The method can be applied to facilities with roofs of shapes that differ from the primitive elements listed in the Regulations SP 20.13330.2016 “Loads and Actions”.

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# ЭКСПЕРИМЕНТАЛЬНОЕ МОДЕЛИРОВАНИЕ СНЕГОВЫХ ВОЗДЕЙСТВИЙ НА УНИКАЛЬНЫЕ СТРОИТЕЛЬНЫЕ ОБЪЕКТЫ

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**Аннотация**
В современном строительстве типовая архитектура уступает место нетиповой, в то время как нормативная база не содержит рекомендаций для назначения нагрузок на уникальные строительные объекты. Сказанное выше в полной мере справедливо и по отношению к снеговым нагрузкам. СП «Нагрузки и воздействия» содержит методику расчета на снеговые нагрузки для типовых форм кровель. **Методы:** В работе предложена методика экспериментального моделирования в аэродинамических трубах архитектурно-строительного типа явлений снегопереноса и снеговых отложений на покрытия зданий со сложной кровлей, отличающихся от приведенных в СП типовых форм. Приведенная в статье методика содержит четкие рекомендации по проведению экспериментальных исследований в аэродинамических трубах. **Результаты:** Представленная методика апробирована на здании проектируемого спортивного комплекса. Получены картины снегопереноса и снегоотложений.

**Ключевые слова**
Аэродинамика, аэродинамическая труба, снеговые воздействия, снеговые отложения, экспериментальные исследования, явление снегопереноса.