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SAFETY REQUIREMENTS FOR SNOW LOAD ON UNIQUE TRANSPORT INFRASTRUCTURE FACILITIES

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Abstract

Introduction: Wind-induced snow drift is the main reason behind the non-uniform snow load on a snow-covered area. As known, snow load poses a serious hazard to the roofing of buildings and structures. According to the applicable regulatory documents, snow loads for non-standard roofs must be determined based on the results of model tests in wind tunnels. **Purpose of the study:** We aimed to study snow load on a unique transport infrastructure facility — the world's first cross-border cable car connecting Blagoveshchensk in Russia to Heihe in China. **Methods:** We performed model tests to study snow accumulation and drifting with the use of a unique research setup — the Large Gradient Wind Tunnel, courtesy of the National Research Moscow State University of Civil Engineering. **Results:** Based on climate analysis and tests under different wind attack angles, we obtained distribution patterns for snow deposits on the roofing of the unique transport infrastructure facility under consideration and derived the values of the coefficient μ (the coefficient of transition from the weight of the snow cover on the ground to the snow load on roofing).

Keywords
Snow deposits, snow drifting, transport safety, physical modeling, wind tunnels.

Introduction

The world's first cross-border cable car connecting Blagoveshchensk in Russia to Heihe in China was designed to run across the Amur River, which marks the border between eastern Russia and China (Fig. 1).

Snow load poses a serious hazard to the roofing of residential, public, and industrial buildings (Churin and Gribach, 2016). As winter sets in, various regions of the Russian Federation report accidents involving roofing collapse due to snow load.

Thus, in northern regions with a long cold season, prone to heavy snowfall, structural engineers need accurate estimates for snow load redistribution on the roofs of unique buildings and structures under the action of wind.

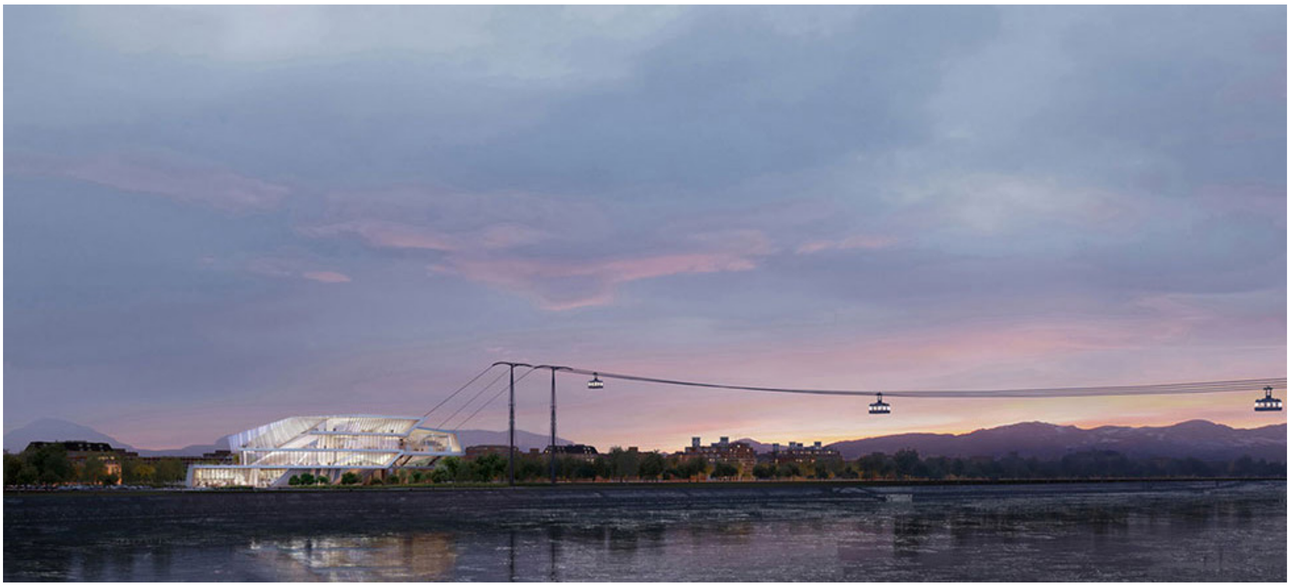

Fig 1. Design of the unique cable car connecting Blagoveshchensk in Russia to Heihe in China

The patterns of snow deposition given in Appendix B to the Regulations SP 20.13330.2016 (and other standards, e.g., Eurocodes) (American Society of Civil Engineers, 2005) cover only a limited number of the most common types of profiled sheeting for roofing. The cable car terminal under consideration falls into the category of unique construction facilities, and according to cl. 10.4 of the Regulations SP 20.13330.2016 "Loads and Actions", the patterns of snow load distribution on roofing and the values of the coefficient μ must be set forth in the special recommendations based on the results of model tests in wind tunnels or data published in technical literature.

In this paper, we adopt patterns of snow load distribution based on the results of model tests in a wind tunnel.

Methods

To perform model tests, a model of the facility under consideration was designed and manufactured (Fig. 2). Considering the dimensions of the test section, we chose the maximum possible scale of the model with account for blockage conditions. The model was mounted on an automatic turntable in the test section of the wind tunnel.

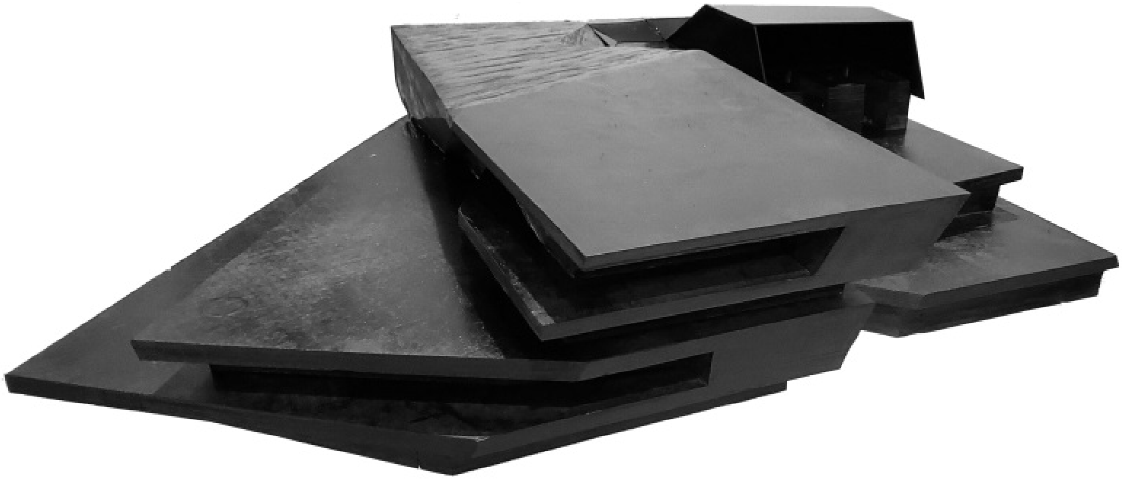

Fig. 2. Model of the facility under consideration

Fig. 3. Characteristic areas of snow deposits, wind angles: 0° (N) and 45° (NW)

Wind-induced snow drift is the main reason behind the non-uniform snow load on a snow-covered area (O'Rourke et al., 2004, 2005; Thiis and O'Rourke, 2012). Snow drifting results in areas with masses of snow carried away and areas of snow accumulation (so-called snow bags). Their location is mainly related to the roofing (profiled sheeting) configuration and wind direction (Li et al., 2022).

During snow load formation, non-uniform snow deposits as well as snow blowing and falling off the roofs can be observed (even in the case of single-span buildings) (Jiang et al., 2020). These phenomena are taken into account in the standards of most countries by the coefficients μ (the coefficient of transition from the weight of the snow cover on the ground to the snow load on roofing), which mainly depend on the inclinations of roofs and level variations.

We performed model tests with the use of a unique research setup — the Large Gradient Wind Tunnel, courtesy of the National Research Moscow State University of Civil Engineering.

The characteristic wind speeds at which snow drifting was analyzed were in the range of 3.4–8 m/s.

To simulate snow, it is recommended to use wood powder with a particle size of 50–250 μm and moisture content of 3.5–4%, drifting from a smooth painted surface at a wind speed of 3.4 m/s (Poddaeva, 2021).

As a result of long-term exposure of the model covered with a thin layer of wood powder to the air flow at a speed of 6–7 m/s, a pattern of characteristic snow deposits was generated.

The shapes of snow bags are analyzed to decompose the roof surface into primitive elements, and then the snow load is determined for those elements.

When the model is blown from different directions, snow is subject to the impact of wind in accordance with the wind rose in the particular region. During the tests, the turntable made a full circle in increments of 45°. Below we present photos of snow drifting under different wind directions. Based on these photos, it is possible to obtain data on the snow drifting type as well as directions and volumes of snow transported for each type of snow drifting.

Results

The photos of snow distribution patterns are given below (Figs. 3–5).

The transition from qualitative patterns to quantitative values of the shape coefficient μ is carried out for the most unfavorable loading configurations. These configurations are chosen based on both the analysis of test results and climatic data. A detailed methodology for the analysis of experimental studies is given in a paper by Lebedeva et al. (2020). The results of climate analysis performed in the construction area show that the characteristic wind directions in winter are as follows: from the east (model setting angle: 270°), from the north-east (model setting angle: 315°), and from the south-east (model setting angle: 225°).

Fig. 4. Characteristic areas of snow deposits, wind angles: 0° (N) and 270° (E)

Fig. 5. Characteristic areas of snow deposits, wind angles 315° (NE) and 225° (SE)

Based on the results of the wind tunnel tests, we calculated potential volumes of snow drifting with account for the roofing shape and drew up diagrams of snow deposits on the roofing of the facility under consideration for those directions (Fig. 6).

Discussion

During the study, we performed physical modeling of snow drifting and accumulation on the roofing of a unique transport infrastructure facility — the Blagoveshchensk–Heihe cross-border cable car terminal. We designed and manufactured a physical model of the facility under consideration, presented a methodology for snow drifting and accumulation modeling in wind tunnels, took photos of the characteristic areas of snow deposits under different angles, and based on the results, drew up diagrams of snow deposits on the roofing of the facility under consideration for different wind directions. Based on the results obtained, we also derived the maximum value of the coefficient μ (the coefficient of transition from the weight of the snow cover on the ground to the snow load on roofing).

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All tests were carried out with the use of equipment of the Head Regional Shared Research Facilities and the Large Gradient Wind Tunnel, courtesy of the National Research Moscow State University of Civil Engineering.

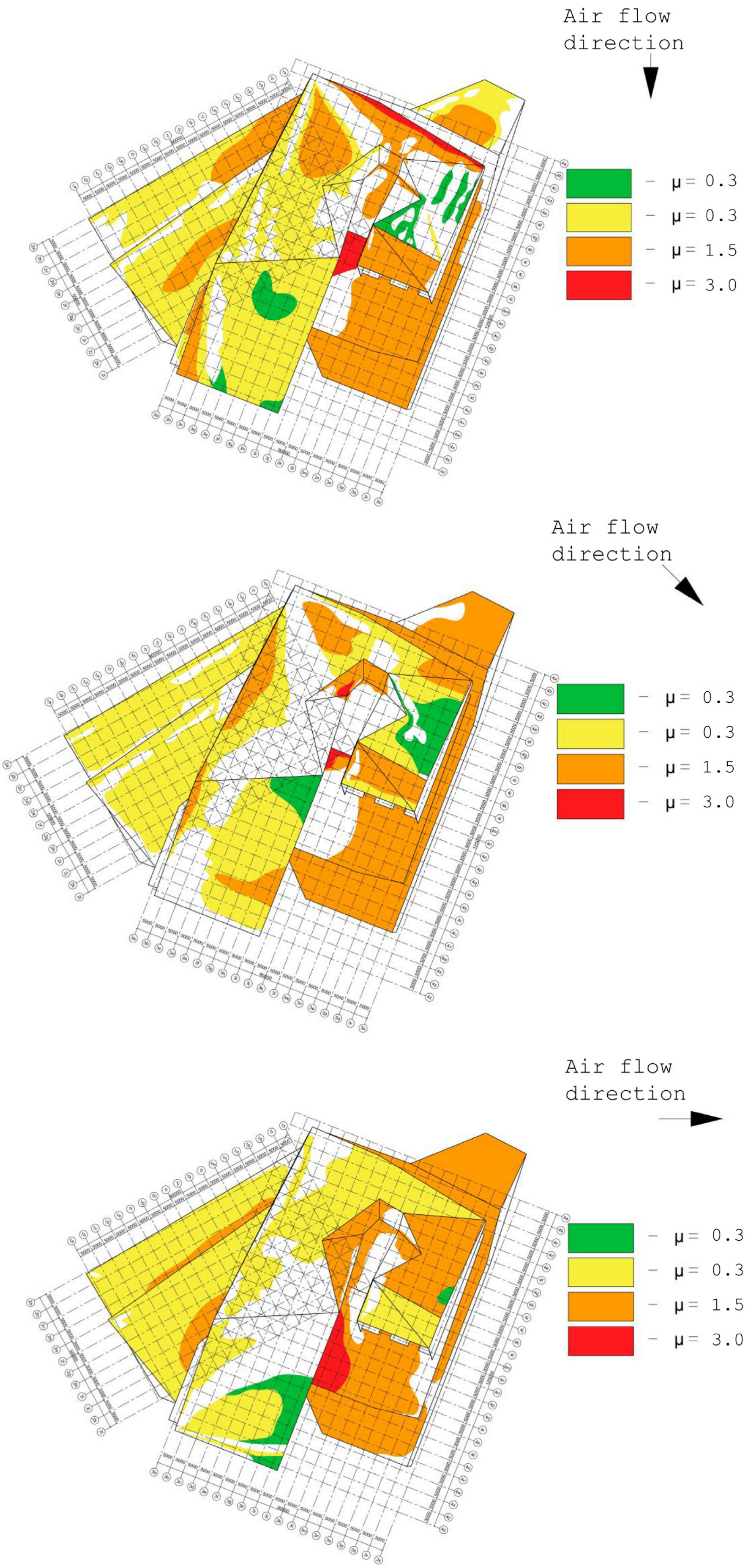

Fig. 6. Diagrams of snow deposits on the roofing of the facility under consideration for different wind directions

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СНЕГОВАЯ БЕЗОПАСНОСТЬ УНИКАЛЬНЫХ ОБЪЕКТОВ ТРАНСПОРТНОЙ ИНФРАСТРУКТУРЫ

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Аннотация
Перенос снега под влиянием ветра является основным фактором, вследствие которого уровень снеговой нагрузки неодинаков по площади покрытия. Снеговая нагрузка представляет серьезную опасность для кровельных покрытий зданий и сооружений. Согласно действующим нормативным документам снеговые нагрузки на кровли нетиповых форм необходимо назначать по результатам модельных испытаний в аэродинамических трубах. **Целью данного исследования** является изучение влияния снеговых воздействий на уникальный объект транспортной инфраструктуры – первую в мире трансграничную канатную дорогу Благовещенск–Хэйхэ, которая соединит Россию и Китай. Были использованы **следующие методы**: проведение серии модельных испытаний для изучения процессов снегообразования и снегопереноса с использованием уникальной научной установки – Большой Градиентной аэродинамической трубы. По **результатам** климатического анализа и проведенных испытаний для различных углов атаки ветра получены схемы распределения снеговых отложений на поверхности кровли уникального объекта транспортной инфраструктуры, получения значения коэффициента μ (коэффициент перехода от веса снегового покрова на поверхности земли к снеговой нагрузке на покрытие).

Ключевые слова
Снегоотложение, снегоперенос, транспортная безопасность, физическое моделирование, аэродинамические трубы.