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DETERMINING SNOW CAPACITY OF SNOW PROTECTION FACILITIES ON ROADS IN THE MOUNTAINOUS AREA

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Abstract. The article deals with the snow capacity of snow protection facilities. The purpose of the given work is to determine the snow capacity of snow protection facilities on roads in the mountainous area. To carry out theoretical studies there were applied analytical methods. The article presents a general form of formulas for determining the snow-retaining capacity and the snow capacity of snow protection facilities through well-known geometrical parameters and there were offered protective means against snowdrift.

Keywords: snow, snow-retaining capacity, snow protection facility, snow sediment, road, mountainous area.

Introduction

An effective method of snow control on the roads is preliminary snow retention. For example, one forest belt with four lines can hold up to 150 m^3 of snow. Wind breaks on the roads are often arranged close to the roadbed, so contributing to snow drifts on the roads. The road in such cases is within the zone of intensive formation of snow deposits.

With the open agricultural landscape, snow events often result in increased volumes of congestion and safety hazards. Blowing and drifting snow can lead to lane blockages, icy conditions, and narrow travel lanes. Snow events tend to lead to increased crash rates, especially for run off the road crashes. In the ten-year crash data (2006-2015) for this segment, approximately 25 percent of the crashes occurred during snow or ice covered road conditions (US Highway, 2018).

Snowdrifts can cause loss of vehicle control, reduce sight distance on curves and at intersections, obscure signs, cause ice formation, reduce effective road width, and render safety barriers ineffective. Blowing snow is the primary cause of icy roads in windexposed areas – melting extracts diurnal solar radiant heat stored in the pavement and substratum, and the quantity of snow blowing across a road can be hundreds of times greater than direct snowfall. Studies on Interstate Highway 80 in Wyoming indicate that over the last 10 years, up to 25% of all crashes occur during blowing snow in areas without snow fences, compared to 11% in areas protected by fences (Tabler, 2003).

To resolve this problem, it is necessary to reconstruct the existing snow control landscaping, which is associated with the allocation of land, the value of which is growing rapidly. This puts temporary facilities that do not require land on the forefront of the snow-drift control. Adding snow fencing will create a barrier to snow drifting during windy conditions to mitigate the existing hazard, making it much safer to drive in the winter (US Highway, 2018).

In exposed windy locations, snow blowing onto a road adds greatly to the cost of snow and ice control. Although costs vary widely, mechanical snow removal typically costs about 3.4 EUR per metric ton. For comparison, a snow fence 1.2 m tall can retain 12.5 metric tons per meter of length (Tabler, 2003).

Living snow fences are an agroforestry practice similar to windbreaks (USDA, 2011) that uses rows of trees or shrubs to trap blowing snow in drifts before it reaches a road (Heavey, Timothy, & Volk, 2014). Plantings of trees, shrubs and native grasses located along roads are living snow fences. Properly designed and placed, these living barriers trap snow as it blows across fields, piling it up before it reaches a road.

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Structural snow fencing is best suited for sites that are not conducive for tree and shrub plantings. The following factors may preclude the use of living snow fences (Gullickson, 2018):

- Herbicide concerns;
- Unavoidable tile lines;
- Soil pH above 8.0;
- Soil salinity and/or salt spray;
- Soils types that are too compacted, wet, dry an/or rocky to permit normal root development;
- Presence of a deer wintering area that raises the threat that a living snow fence will be browsed to the point that the living snow fence never reaches the required fence height.

Structural snow fencing uses a synthetic rail and wood or steel posts to create the fence. A polyethylene material with bonded cables inside to create the synthetic rail. Posts are spaced according to the height of the fences, but are typically 3.0–4.5 meters apart (Living Snow Fences, 2018).

The most common way of snow-drift control is temporary wooden latticework panels that in the course of a 120-year period of application have outdated by all indicators. They have a number of significant drawbacks. It is a small snow capacity and snow drift, which determines a great complexity in their operation. For a long time, the use of such tools have proved to be ineffective due to insufficient development of the theory of formation of snow deposits because of the high complexity and low scrutiny of the process of high-drag barriers interaction with one- and two-phase gas flows. Despite a large number of studies, up to the present moment there has not existed a theoretical way to determine the basic operational performance of snow protection facilities such as snow-retaining capability and snow capacity that can be determined only experimentally (Goncharenko, Prusenko, & Skorchenko, 1999).

It is known that formation of snow deposits is due to the braking action of obstacles against the oncoming snow-wind stream. This action takes place on a particular part of the length and height of the flow on both sides within some limits of the zone of aerodynamic effects. The larger the zone is, the longer the length of the stream will be where the speed is reduced, and the more snow deposits will be formed around the obstacles (Bileush, Nishhuk, & Shtekel, 2000; Byalobzheskij, Dyunin, & Plaksa, 1983).

To identify the space and evaluate the frequency of avalanches is only possible owing to characteristic signs that they leave behind them if the chutes, on which avalanches occur, are devoid of vegetation and have distinct shapes.

In the case of gentle slopes and small pools snow mass gathering can be prevented using the transverse defensive walls and stone outfitting (Byalobzheskij et al., 1983). In some cases, if there is a favorable terrain, the avalanche can be directed to one side of the road, using protection walls, avalanche-breakers. Avalanche dams are constructed in the form of mounds with securely fenced slopes from 10 m to 15 m.

Capital structures that securely protect the roads from snow avalanches are galleries (Kungurcev, 1961). Galleries are designed on steep slopes. The roof of the gallery is designed in the form of a lean-to roof equal to or greater than the downhill slope. This design provides free skidding of snow mass on the roof without effort.

Galleries are mainly constructed closed made of prefabricated concrete elements.

The work purpose – to determine the snow-capacity of snow retaining facilities on the roads in mountainous areas. To carry out theoretical studies there were applied analytical methods.

1. Research of snow capacity of snow retaining facilities

According to the theory of turbulent stream, the length of the windward zone and the leeward zone of aerodynamic performance is a function of the square of the mid section of the obstacle, which can be expressed in terms of height (Kungurcev, 1961).

In accordance to the experimental data collected during numerous studies, the length of windward deposits in the proximity of any snow-retaining facilities approximately equals 10 heights of the obstacle (Kungurcev, 1961). This allows to consider with sufficient accuracy

$$l = C_1 H_0 ,$$

where l – length of the windward part of snow deposits, m; C_1 = 10 – dimensionless constant factor; H_0 – height of snow-retaining facility, m.

Regarding the leeward zone, where a larger part of the joint volume of snow deposits is formed, until recently there has not been a consensus about its size even according to experimental data.

The process of obstacle interaction with a biphasic snow-wind flow over time is accompanied by the solid snowfall phase, i.e. formation of snow deposits on both sides. Increasing the height of windward snow deposits defines proportional reduction of the obstacle that interacts with an oncoming flat snow-wind flow. This pattern can be written in the form

$$d(F_0 - F) = Z dh_n ,$$

where F_0 – mid sectional area of the obstacle, m^2; F – area of interaction of the obstacle with the flow, m^2; Z – unit of length, m; H_n – height of snow deposits on the leeward side, m.

At a constant speed of the blizzard the deposited amount of snow per unit of time or increase of the volume of snow deposits is permanent. For each meter of the snow-protection line length there is brought a certain amount of snow, which is equal to the total flow of the blizzard Q_{max}, m^3/s.

According to numerous experiments the longitudinal profile of snow deposits before snow accumulation by barriers has the shape of a triangle (Bileush et al., 2000; Kungurcev, 1961). Increase of the volume of snow retention therefore spreads over slightly extending space of formed snow deposits. In addition, over time the amount of snow that moved past the barrier due to reducing of F increases, so the process of snow deposits heightening can be written in the form of the following dependence

$$h(T) = a_3T^3 + a_2T^2 + a_1T + a,$$

where: h – height of snow deposits, m; $a...a_3$ – constant dimensionless coefficients; T – time, s.

For snow protection it is recommended to use barriers that are flushed from below with a clearance space of 0.3–0.5 (Byalobzheskij, 1983). According to the authors' data and (Goncharenko, Prusenko, & Skorchenko, 1999), barriers with smaller of the given values of clearance have a higher snow capacity and greater sparsity of the bottom of the midsection area. In these cases, the following dependence is typical

$$dh_n = dh_p,$$

where h_p – height of the leeward side of snow deposits, m.

According to the theory at a constant speed the length of snow deposits from the downwind side of barriers do not change over time (Bileush et al., 2000). In accordance with the experimental data obtained by the authors and other researchers, the length of snow deposits remains virtually unchanged in the range of velocities of 6–15 m/s. In view of this and the triangular form of the profile of snow deposits, using expressions previous two formulas we can present the formula for determining the snow-retaining capacity of barriers:

$$N = C_3F_0\frac{dh}{dT},$$

where N – snow retaining capacity, m^3/s; $C_3 = C_1 + C_2$ – dimensionless constant coefficient.

Integrating formula $N = C_3F_0\frac{dh}{dT}$, we obtain a formula for determining the snow capacity of snow-retaining facilities:

$$W = CF_0\int_0^T dh,$$

According to the theory (Byalobzheskij et al., 1983) and the data obtained by the authors the height of snow deposits at the final moment of time $T_c = T$ of the process of snow deposits formation equals the height of the snow-retaining facility, that is:

$$h_k = H_0.$$

This makes it possible to submit a general form of expressions for determining the snow-retention capability and the snow capacity of snow protection facilities through the known geometrical parameters. Substituting in formulas ($N = C_3F_0\frac{dh}{dT}$) – ($W = CF_0\int_0^T dh$) $\frac{dh}{dT}$ for $\frac{dF}{dT}$ in accordance with formula ($d(F_0 - F) = Zdh_n$), after some transformations we obtain

$$N = C_5F_0\frac{d(F_0 - F)}{dT},$$

where $C_5 = \frac{5}{Z}\left(\frac{1}{1-P} + 22{,}5\right)$ – dimensionless coefficient; P – clearance space of the snow protection facility in fractions of a unit.

Then:

$$W = C_5F_0,$$

The validity of expression is confirmed by experimental data obtained by the authors and other researchers. Thus, according to the expression formula ($W = C_5F_0$) the maximum snow capacity of wooden lattice shields with P = 0.3 is 36.16 m^3, and according to the majority of authors, it is 36 m^3 (Bileush et al., 2000; Kungurcev, 1961).

Avalanche protection structures rely on vertical and horizontal components of the pressure from the impact and weight of snow slide (Kungurcev, 1961).

To determine the approximate estimated speed of an avalanche they use formula:

$$v = \sqrt{2qz},$$

where z – the distance that is determined, using the dependence:

$$z = H_B - \frac{H}{L}l_B,$$

The parallel pressure angle, N/m^2 on the surface of the avalanche-breaker, blasting dam or the direction wall is determined by the formula:

$$P_r = \frac{\gamma v^2}{2q}\sin^2\alpha,$$

where γ – the proportion of snow, N/m^3; for snow that has just fallen, $\gamma = 0{,}3\cdot10^4$ N/m^3; for old snow $\gamma = 0{,}4\cdot10^4$ N/m^3; for wet snow $\gamma = 0{,}5\cdot10^4$ N/m^3; α – the angle between the direction of avalanches and surface structures, deg.

Avalanche pressure on the roof of galleries is determined by the formula:

$$P_b - \gamma h_\pi \cos\beta,$$

where h_π– the thickness of the avalanche layer; β – gallery roof angle to the horizontal plane.

Conclusions

1. To develop effective recommendations for protection of roads in the mountainous area from snowdrifts it is necessary to determine the snow capacity of snow protection structures.
2. According to recommendations (MP P B.2.3-218-02071168-776:2010, 2010) we will adopt the following protective measures against snowdrift: placement of walls and other structures to prevent blowing of snow from the surrounding areas into basins that prevents the accumulation of snow on the slopes and in ravines; afforestation of snow retention pools, placing ditches, walls, retaining walls along the movement of snow to prevent its replacement; snow mass removal by guide walls sideward away from the structure to be protected.

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SNIEGO APSAUGOS ĮRENGINIŲ NAUDOJIMAS KALNUOTOSE KELIŲ VIETOVĖSE

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Santrauka

Straipsnyje aptarimas sniego apsaugos įrenginių naudojimas kalnuotų vietovių keliuose. Darbo tikslas – sniego apsaugos įrenginių efektyvumo skaičiavimai ir jų pritaikymas kalnuotuose kelio ruožuose.
Atliekant teorinius tyrimus buvo taikyti analizės metodai. Straipsnyje pateikiamos pagrindinės sniego apsaugos įrenginių ir sniego sulaikymo pajėgumo kalnuotuose kelių ruožuose skaičiavimo formulės, išreikštos gerai žinomais geometriniais parametrais. Buvo pasiūlyta apsauga nuo sniego pusnių.

Reikšminiai žodžiai: sniegas, sniego sulaikymo pajėgumas, sniego apsaugos įrenginiai, sniego užklotas, kelias, kalnuotos vietovės, pusnis.