Snowbreak fence modelling

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Abstract. The purpose of this work is to study a snowbreak fence model based on standing wave effects. The article offers a new snow protection model based on aerodynamic effects, using the principle of a standing air wave. According to the laws of physics, a standing wave can occur either at the end of a closed pipe or at the end of an open pipe. The standing wave in an open pipe can be calculated by gas dynamics formulae. A similar effect occurs in arranging the snow protection with apertured shields. The results of a model experiment are presented to justify the retention of snow masses before the apertured shield. Two options of shields were considered, namely, standard and modified. The modified option was found more effective.

1. Introduction
The snow drifts and the fight against them are urgent problems in many countries [1–5]. The geometric characteristics of snow break fences play an important role in this regard [6]. Usually roads and railways are protected from snow drifts by shelter forests. In cases where this is impossible, roads are protected by installing snow-retaining structures. The regulatory documents for motor roads [7] and railways [8] provide for the installation of snow-retaining shields and fences consisting of shields. Snow-covered road sections are evaluated by two parameters: a cross-section of the road or the roadbed; and the estimated annual volume of snow per one linear meter of the road. The first parameter sets the snow drifting criterion, and the second one sets the snowdrift extent. The first parameter depends on the road cross-section, and the second one, on the natural conditions in the area. Avtodor (Russian Highways) recommends installing two-panel shields of 4–5 m with a blow-through aperture of 0.6–0.7 m and one-panel shields with a blow-through aperture of 0.5 m. RZD (Russian Railways) recommends installing only one-panel shields of 4.4–5.4 m with blow-through aperture of 0.4 m. Thus, it may happen that different companies install different shields in the same area.

2. Methods
The study is based on the physical mechanics of liquids and gases, the theory of standing wave formation in gaseous media, the comparative analysis and the simulation modelling. The materials used were publications in the field of gas dynamics, physical mechanics, construction of snow break fences, existing snow retention standards for motor and rail transport.
3. Results

3.1. Solid shield solution
Modelling is of great importance to solve snow protection issues [9]. The snow protection problem falls within the domain of spatial problems, so it can be solved using geodata [10] and spatial modelling [11]. Solid shields and apertured shields are used to design snow break structures. Figure 1 shows the cross-section of a non-apertured shield.

![Figure 1. Snow accumulation in front of a non-apertured shield.](image)

In figure 1, A is the shield height (cross-section). The lines indicate the accumulated snow masses. As experience shows, they have a sigmoid shape. The initial snow accumulation is shown as a dashed line and corresponds to level C1. As snow falls, the level of snow accumulation increases, described by curve C2. It is shown in figure 1 by the solid line. Here, we have \( A > C1 \) and \( A > C2 \). A critical situation occurs when the snow reaches the level described by curve C3 (bold line). At the level \( C3 = A \), the snow either falls over the shield (\( C3 > A \)) or knocks the shield to the ground. What is also crucial is the accumulation of snow directly on the shield.

3.2. Gas flue model of apertured shield
With an aperture, the air can blow through the shield and repel the snow masses from it. To analyze the blow-through effect, let us turn to the theory of mechanics [12]. The blow-through effect is caused by the occurrence of a standing wave repelling the wind flow. The standing wave can occur not only at the closed end of a pipe, but also at the open end. The gap between the snow retention shield and the ground is comparable to an open pipe. In an incident wave, the standing wave displacement changes according to the following law [12, p. 704]:

\[
\xi_1 = X_0 \sin \omega(t - x/v)
\]

In Expression 1, \( v \) is the velocity of wave propagation, \( x \) is the distance from the open end of the pipe, in our case from the gap between the shield and the ground, \( X_0 \) is the amplitude and \( \omega \) is the wave frequency. In a reflected wave, the displacement changes as described by the following equation:

\[
\xi_2 = X_0 \sin \omega(t - (2l - x)/v)
\]

When resonant, the resulting displacement is

\[
\xi_2 = 2X_0 \cos \omega (l - x)/v \sin \omega(t - l/v)
\]

The amplitude is distributed according to the cosine law rather than the sine law as with a fixed rod. At \( x = l \), the amplitude reaches its maximum (2 \( X_0 \)). Expression (3) is applicable for pure vibrations. In a real environment, there are dissipation and attenuating vibrations. The attenuation process is simulated by an exponent that suppresses the standing wave propagation. Figure 2 shows a standing wave according to Equation 3 with the attenuating exponential component. The wave occurs when the air flow
is directed towards the shield. The standing wave shown in figure 2 occurs in front of the shield blowhole. The presence of oscillation loop results in the portable snow masses shifting away from the shield.

![Figure 2](image)

**Figure 2.** Occurrence of a damped standing wave on the apertured shield.

In figure 2, A stands for the shield cross-section. The shield contains a resonant gap that generates a standing wave. L is the distance from the shield. Due to the standing wave, the distribution of snow masses in front of such a shield differs from the distribution of snow masses in front of a solid shield (see figure 1). This distribution is shown in figure 3.

Figure 3 shows two sections of shields A and B. Section B corresponds to the sections of standard shields according to [1, 2]. The accumulation of snow is indicated by dashed curve C2. Section A differs in that a part of the shield is raised above the ground creating a greater resonance effect similar to Expression 3. The accumulation of snow mass for this option is indicated by solid curve C1. In this case, the volume of accumulated mass is greater than at C2, and it is further away from the shield. Therefore, in practice, it is possible to install a narrow barrier (0.2 to 0.3 m) under the shield and it will increase the standing wave effect and shift the snow mass in contrast to the standard option.

![Figure 3](image)

**Figure 3.** The distribution of snow on the apertured shield with different shield design relative to the ground.
4. Conclusion
To implement the method, it is required to estimate the elasticity of the snow mass carried by the wind [13]. To do this, one should make an empirical fitting of the transfer coefficient and the attenuation coefficients. Intrinsically, there is the effect of repulsion. In times of the USSR, this effect was studied by the Kazakhstan Railways in cooperation with the Novosibirsk State Transport University (NIIZHT). Those studies confirmed the effect of repulsion. Not only wooden structures, but even waste from the Omsk Tire Factory were used as shields. The main point in this approach is to create the aerodynamic quality and the resonance effect.

The proposed model of the apertured shield can be used in agriculture to organize snow retention in agricultural fields.

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