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Living Snow Fences: International Practices

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ABSTRACT

In winter, in the countries with snow covered regions, one of the main tasks of road maintenance is to combat snow deposits, snowpacks and snowdrifts on the roadway. Living snow fences consisting of tree and shrub plantings are among known world practices to protect roads against effects of snow deposits. They are environmentally friendly, durable and have great snow retention capacity. However, there are several constraints regarding application of those practices.

The analysis of the design, spacing and planting schemes refers to Russian and foreign living snow fences used to protect highways, considers the features, advantages, and disadvantages of living fences in different countries. Japanese and American designs are reviewed as international experience. The influence of the state of trees on the efficiency of their snow-retaining function has been determined. As a result, the need for monitoring and proper maintenance of existing living snow fences throughout their life cycle was confirmed using the examples of surveys of forest plantations in Kazakhstan and in Volgograd region of the Russian Federation.

The author presents promising directions for improving the structures and planting schemes of snow storage living fences, namely, an integrated approach to their design as of a protection not only against snowdrifts, but also against pollutants. Such solutions include the design of protective living fences using only tall shrubs, providing the best blowing of roadside areas and dispersion of contaminants. Another solution is to complement the species planted within living fences with willow and corn. Besides, referring to global climate changes, an important task for modern science has been identified, that is to update the current standards for the design of living fences under the current meteorological conditions.

Recommendations on the use of mathematical modelling with the help of computer software are suggested regarding development of new configurations of living fences, assessment of their effectiveness, as well as on the adoption of modern technologies such as video cameras and drones during field tests.

Keywords: transport, living snow fences, snow protection, snow transport, snow fighting, winter maintenance of highways.

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INTRODUCTION

To provide safe and uninterrupted traffic on roads in winter, many countries with cold climates fight snowdrifts on the roadway. The snow element is mainly typical for areas of very difficult and especially difficult snow fighting according to the zoning of the territory of Russia [1; 2]. Globally, Canada, Japan, Kazakhstan, Scandinavian countries, the USA, and others face the same challenge.

For more than a century of use, snow-retaining plantation forests have proved to be the most effective tool of protection against snowdrifts. The design of living snow fences is carried out based on quantitative assessment of the parameters of blizzard activity and the degree of snowdrift extent on highways. Each country has its own peculiarities of choosing the spacing scheme and the range of species to be planted.

It is important to note that it is at the stage of designing new construction or reconstruction of highways that it is necessary to proceed with planting of living snow fences. At the stage of operation of already built and existing highways, only monitoring and minor adjustments of the adopted design decisions are possible.

The *objective* of the study was to reveal promising direction allowing to improve the design and planting schemes of living snow fences considering an integrated approach to their design as of a protection not only against snowdrifts, but also against pollutants.

RESULTS

The widespread use of tree and shrub plantings is due to their significant snow-retention capacity, they are environmentally friendly and have an unlimited service life. Nevertheless, along with significant advantages, there are some constraints for their use. Those constraints include unfavourable soil and geological conditions, location of a road in vicinity of agricultural land, significant land areas allocated for the plantings (the width of those areas [in Russia], according to the recommendations of ODM 218.5.001-2008[1] and ODM 218.2.045-2014[2], is from 15 to 100 m from the edge of the roadbed to forest plantations plus the width of the planting itself, depending on the volume of snow transport). The normative values are approved based on scientific works [1–3], carried out in the second half of the 20th century. Besides, additional snow protection measures must be provided for the period of growth of young seedlings to a state of mature plant during new construction or reconstruction of highways.

Russian Experience of Using Tree and Shrub Plantings

Regulatory schemes for planting living snow fences, rules for reinforcing existing plantings, assortment and requirements for planting material are stipulated in the national recommendations of ODM 218.2.045-2014. The selection of design and schemes is based on the volume of snow transported to the road.

An important factor in effective operation of living snow fences refers to monitoring and maintenance during the period of their operation. Young seedlings, under the influence of negative factors, may not reach the required size or undergo drying out and decay, the shrubs may be non-pubescent. Upon reaching maturity, trees become sparse and can be damaged during the life cycle. Increase in density of trees and shrubs is reached by cutting boughs or increasing the number of rows of trees [3]. According to ODM 218.011-98[3], works to strengthen the existing living snow fences comprise soil cultivation, considering regional agrotechnical requirements, the planting (sowing) of plants, the addition of crops, and agrotechnical care of the plantings.

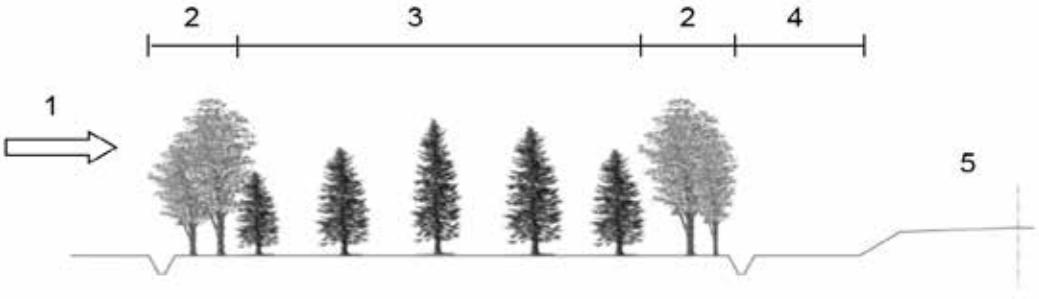
For example, according to [4] field studies of the state of roadside forest plantings were carried out in Volgograd region in 2019 along R-22 «Caspian» (Moscow–Astrakhan) and R-228 (Volgograd–Syzran) highways, which made it possible to establish their poor condition, stunted growth, degradation. and dry treetops on both road segments.

In such cases, tree and shrub plantings are subject to immediate reforestation felling to ensure their renewal and coppice generation. Since living fences, as a rule, are located in the right-of-way of a motor road, the responsibility for performance of these works lies with road maintenance services, which, in turn, do not always have competent specialists in this area on

[1] ODM [Road industry's methodological document] 218.5.001-2008. Methodical recommendations for protection and cleaning of roads from snow.

[2] ODM [Road industry's methodological document] 218.2.045-2014. Recommendations for design of forest snow-retaining plantations along highways.

[3] ODM [Road industry's methodological document] 218.011-98. Public roads. Methodical recommendations for landscaping of highways.



Pic. 1. Standard width woods of living fences in Japan: 1 – direction of the prevailing wind in winter, 2 – fast-growing broadleaf trees, 3 – evergreen trees, 4 – snow-piling area, 5 – road [5, p. 37].

their staff. As a result, living fences are not able to fully function as snow retention instruments.

Foreign Experience of Using Tree and Shrub Plantings

In many foreign countries with a cold and snowy climate, living snow fences snow-retention forest plantations are also used as protection against snowdrifts on highways. The rules for their application in each country are determined based on meteorological and hydrogeological conditions, as well as on the features of the terrain and characteristics of the adjacent territory.

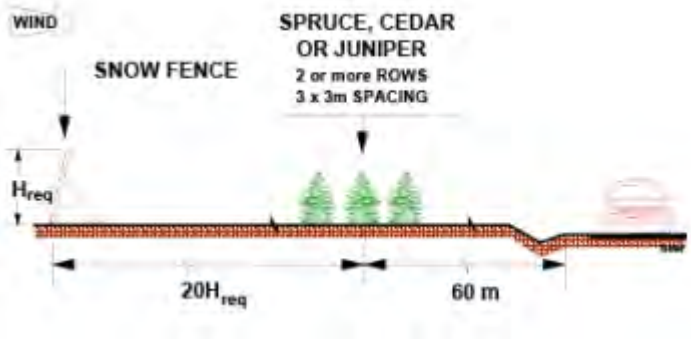
For the purpose of snow fighting in Japan, for example, living snow fences and «snowbreak woods» are very actively used for protection of highways. In 2009, the length of living snow fences on the highways of the island of Hokkaido was about 80 km [5]. However, the standard width of living fences is 10, 20 or 30 m [5; 6] (Pic. 1). Based on the works of Russian specialists [1; 2], it can be assumed that such small distances are possible with small amounts of snow transport since in such cases the snow storage capacity of living fences is small, and a snow plume may come out onto the carriageway of the highway.

Currently, Japanese scientists continue to study the effectiveness of living snow fences depending on the composition of species, condition of plants during operation, and planting schemes. So, the study [5] comprised the results of a survey regarding, i.e., causes of wilting of the trees, the influence of the direction of winds, of sunshine on plants' growth and, consequently, assessment of the snow storage capacity of the living fence under such conditions.

Living snow fences are also widespread in the northern states of the USA. According to the report of the American scientist Ronald D. Tabler [7], depending on the volume of snow transport, the minimum plant height should vary from 1,2 to 2,8 m, and the distance between the edge of the roadbed and plantings should vary from 30 to 90 m. The author recommends planting additional rows of shrubs during the growth of young seedlings (Pic. 2), or the installation of snow retention devices (Pic. 3).

R. D. Tabler [7] also proposed planting shrub rows in a staggered pattern on steep embankments (Pic. 4). His followers [8; 9] extended this solution

Pic. 2. Temporary scheme for strengthening the planting of young trees with shrub rows [7, p. 234].



Pic. 3. Temporary scheme for placement of temporary snow fence to protect and reinforce young trees [7, p. 233].

for areas with steep slopes (1:1.5), such as approaches to bridge structures. The proposed configuration of trees and shrubs to reduce snowdrifts consists of a row of vegetation at the toe of the embankment followed by one or more rows on the embankment slope (Pic. 5). The number of rows depends on the geometry of the embankment. Obviously, this scheme must be applied with caution, providing visibility on the road.

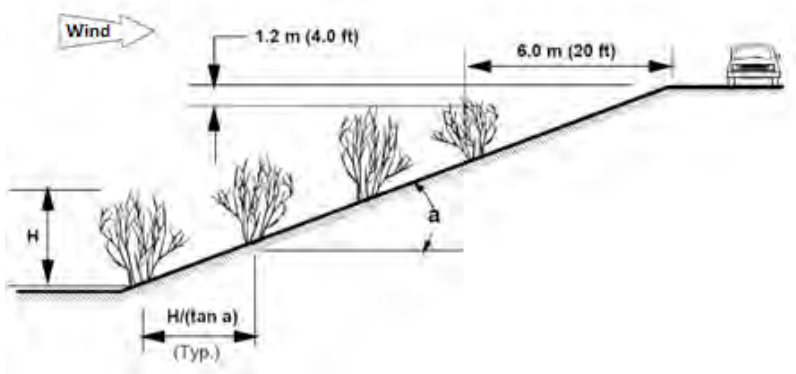
In the Republic of Kazakhstan, the issue of combating snowdrifts is extremely acute. Climatic conditions and the features of the country's territory determine large volumes of snow transported to the roads in winter (in the steppe zone of Northern Kazakhstan, from 300 to 600 m^3/m, and in some areas even up to 800–1200 m^3/m of snow are brought to roads). Roadside living snow fences protect from snowdrifts the motor roads (59,7 thousand hectares) and railways (66,8 thousand hectares). The norms and rules for planting living snow fences are generally similar to those in Russia. Existing living snow fences protect 30 % of all the roads. However, according to research [10], in recent years, work on creation of living snow fences is practically not carried out, and the existing plantings due to insufficient care, unauthorised felling by the population require reconstruction and restoration. This circumstance, in turn, confirms the need for proper maintenance of plants to ensure their efficiency.

Promising Directions to Improve Living Snow Fences

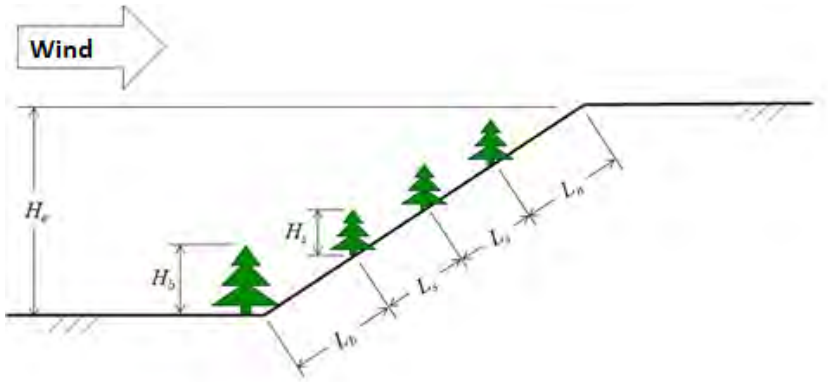
In addition to the retention of snow during the period of blizzard activity, living snow fences can influence the degree of concentration of harmful substances. With an integrated approach to design, living fences are capable of simultaneously ensuring snow resistance of the motorway, reducing concentration of exhaust gases and, as a result, improving the environmental characteristics directly above the roadway [11].

To meet the conditions of snow protection and to reduce concentration of harmful emissions, A. S. Sushkov [12] proposed the design of protective living fences using only tall shrubs (3–6 m) (Pic. 6). In his opinion, such a design will provide the best blowing of roadside areas and will lead to dispersion of contaminants.

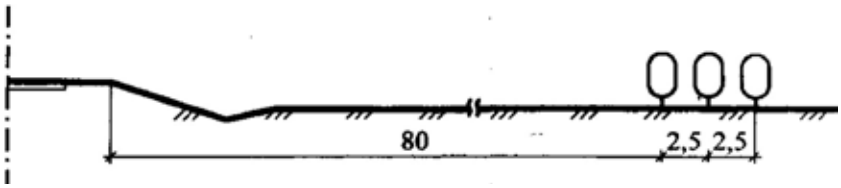
It is important to note the indisputable fact of climate change in general and the need to update the current zoning scheme for the territory of the Russian Federation in terms of the difficulty of



Pic. 4. Pattern of planting shrubs on step embankments [7, p. 235].



Pic. 5. Scheme of plantings at the approaches to bridge structures [8].



Pic. 6. Design of the snow-protective living fence considering dispersion of contaminants [12].

snow fighting on highways. Therefore, another important task of modern science is to clarify the norms for design of living fences at the federal and regional levels, considering the current climatic conditions and relief.

We can also highlight some of the directions of the latest international research. The American scientists have developed the concept of roadside plantings of fast-growing willow [13–15]. The growth rate of willow is several times higher than that of alder, spruce, or pine. In addition to snow retention, willow can perform the protective function regarding water and land resources and to reclaim contaminated soil. The US experience is being considered for implementation in the Republic of Belarus [16].

Another interesting direction of research by American specialists is the inclusion of rows of corn in the composition of living snow fences, as, for example, it is done in the states of Iowa and Wisconsin [17; 18], guided by simplicity and low cost of this method of snow fighting. However, in this case, there can be a higher risk of vandalism by the local population.

Recommendations for Development of Research

When carrying out research on new samples or configurations of living fences, at the first stage, one should resort to mathematical modelling using computer software, which allows testing in the shortest possible time without limiting the number of samples and testing time, does not require to go to «the field». Such programs are based on the Navier–Stokes system of equations describing the motion of a viscous incompressible fluid [19, pp. 139–142]. Ansys Fluent, which is among world leaders, is a computer program that, with a sufficient degree of accuracy, allows simulating a blizzard flow and snow deposits in the area of snow fences. Among Russian domestic developments, one can single out FlowVision [20].

An alternative research method is physical modelling in laboratory conditions, for example, in wind tunnels. Full-scale tests are extremely time consuming and costly, nevertheless, they are necessary to evaluate the performance of new samples under real operating conditions. In the age of modern technology, video cameras, drones, and computing help to conduct field tests by implementing air and ground photogrammetry with subsequent development of a three-dimensional relief model.

SHORT CONCLUSION

For many years, snow storage and retention living fences have demonstrated their efficiency in combating snow on highways in different

countries and, as a result, they significantly reduce the financial costs of winter highway maintenance. In turn, the efficiency depends on a competent project, implementation of plantings, and further proper care.

At the same time, in the context of a lack of land allocation for placement of living snow fences, of a search for a compromise for their use near agricultural lands, and of an increase in the urgency of the environmental problem, the current situation encourages the scientific community to develop and optimise the composition, assortment, design, spacing and implementation schemes of living snow fences.

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