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The Meteorological Data for Designing of Snow Protection on the Roads

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ABSTRACT

Aiming at the problem solving of road protection and snow plowing in Russia, the proposed paper presented mathematical models for determination of the blizzards parameters. The main blizzard parameters were determined using the study results conducted by the authors and other researchers. The meteorological data from State Meteorological Stations is needed to determine the blizzards parameters. The list of meteorological data is presented. The meteorological data is used to conduct the special calculations. Calculation results are presented in the form of climatic road maps, the practical work maps is possible with the use of GIS technology.

Keywords: Roads, blizzard, snow protection, snow drifting volume, snow accumulation volume, road climatic map, GIS technology.

1 INTRODUCTION

Snowdrifts often form on the roads of Russia after blizzards in winter. Snowdrifts reduce the vehicle speed, worsening traffic conditions. Traffic interruptions occur during the intense and prolonged blizzards. In order to conduct effective snow-related maintenance of roads, it is necessary to know the estimated blizzards parameters (blizzards intensity and duration, volumes of snow drifting and snow accumulation on the roads).

The presented paper is focused on the systematic approach to the definition of estimated blizzards parameters, using the meteorological data necessary for the determination of estimated blizzards parameters. Mathematical models for the calculation and statistical processing of modeling results are carried out. Calculation results are presented in the form of climatic road maps, the practical work maps is possible with the use of GIS technology.

2 THE ESTIMATED BLIZZARDS PARAMETERS AND THE MODELS FOR CALCULATION

The main blizzard parameters were determined using the study results conducted by the authors and other researchers. Their characteristics are given in Table 1 [1,2,3,4,5].

The observation data from meteorological stations is needed to determine the parameters.

Data selection from the tables performed under the following constraints that correspond to the physical processes of snow drifting during a blizzard: atmospheric phenomena – snow, sleet, all types of blizzards; wind speed – more than 5 m/s; air temperature – below 0^0 C. The wind direction in the calculation is taken by 16 rhumbs. Data selection is made no less than for 15 years of observation. The meteorological data is used to conduct the special calculations.

For the detection of snow accumulation volumes the method of the summarized snow transfer suggested by D.M. Melnik is used [6]. The method takes into consideration the intensity of snow transfer, which depends on the wind speed and the time of a snowdrift with the given intensity.

Parameter name	Parameter physical characteristic	Parameter effect for winter road maintenance
Blizzard duration	Time of an actual snowfall and snowdrift	- choice of snow plowing technology - number of cycles for snow plowing (work of snowplows)
Wind speed	Determines the snowdrift intensity	- intensity of snow accumulation on the road - time between cycles of snow removal
Wind direction	Determines the snowdrift direction	- defining the road sections with possible snow drifts
Intensity of snowdrift	Amount of a snowdrift per unit time per unit area during a blizzard which is perpendicular to the wind snow flow stream	- intensity of snow accumulation on the road - time between cycles of snow removal
Volume of snowdrift	Amount of a snowdrift through the front unit length which is perpendicular to the wind direction at the time of a blizzard	- amount of snow removal
Snow accumulation volume for the winter period	Snow amount which is brought to one side of the road during the entire winter period	- amount of snow which need to be kept away by using the snow protective structures
Snow accumulation volume for a single blizzard	Snow amount which is brought to one side of the road during a single blizzard	- amount of cleaned snow - number of cycles for snow plowing (work of snowplows)
Estimated snow accumulation volume	Snow accumulation volume with the exceeding probability obtained as a result of the statistical processing of snow accumulation volumes data	- selecting the type of snow protection (permanent or temporary) - selecting a machine type for snow plowing

Table 1. The estimated blizzards parameters

To estimate the blizzards parameters the statistical analysis of the modeling results is carried out. The method of Federal Service for Hydrometeorology and Environmental is used for statistical processing. Based on the calculation results the descending series of parameters are compiled. The three-parameter gamma-distribution is taken for smoothing of empirical data and extrapolation of calculated parameters [7]. The integral curve characterizes the probability of exceeding the existing values of parameter and represents the integral of binomial distribution curve of continuous random variables. Statistical processing resulted in acquisition of the parameters of estimated blizzard were obtained, i.e. the snow accumulation volume on a section of an road, the blizzard duration with a different probability of exceeding, and the snow accumulation volume during the winter period. Special attention has been given to blizzards with the maximum values of parameters.

The analysis of the blizzard dynamics shows several blizzard splashes during the winter period. And only a few blizzards with large snow accumulation volumes were allocated among blizzards with minor volumes. These few blizzards played a major role in the formation of snow cover on the auto road. Therefore, the probability of occurrence of blizzards with extreme parameters must be considered by winter road maintenance.

3 THE MODELS FOR CALCULATION OF COEFFICIENT OF SNOW LOSSES FROM MELTING AND EVAPORATION

The winter seasons in Russia are characterized by the alternation of the air temperatures over zero degrees, thus the snow volume near roads depends on the air temperature change. For the account of snow volume change it is proposed to calculate the "Coefficient of snow losses from melting and evaporation". The definition of this parameter is done according to the data observation of the snow cover characteristics, i.e. the snow height and density. A snow mass per 1 m^2 (Q) is calculated by the formula:

$$Q = h \cdot \delta, \tag{1}$$

where h is snow cover height, m; δ is the snow cover density, g/m^3.

Reduction of the snow mass in the time period between blizzards:

$$P_i = Q_{\max} - Q_{\min}, \tag{2}$$

where P_i is the decrease of the snow mass, g/m^2; $Q_{\max}$ is the maximum of the snow mass per unit area (g/m^2) ; $Q_{\min}$ is the minimum of the snow mass per unit area (g/m^2).

The total reduction of the snow mass during the winter period is equal to the sum:

$$P = \sum_{i=1}^{m} P_i, \tag{3}$$

where n is the number of periods between blizzards during the winter period.

The coefficient of snow losses from melting and evaporation for the entire winter is calculated by the formula:

$$K_P = \frac{P}{Q_{\max}}. \tag{4}$$

The average long-term value of the coefficient is determined for practical calculations.

The volume of snow accumulations for the entire winter, considering the decrease of the snow mass, is calculated by the formula:

$$Q = W_{sb} \cdot (1 - K_P) \cdot \frac{\delta_s}{\delta_{av}}, \tag{5}$$

Where W_{sb} is the volume of the snow accumulation on a road at the end of the winter period from one direction; δ_s is average density of new snow, δ_s=0,17 g/cm^3; δ_{av} is average density of the snow cover (g/cm^3).

The average annual snow density can be found, using the meteorological station data about the density changes during the winter, by the formula:

$$\delta_{av} = \frac{\sum_{i=1}^{k} \delta_i}{T_s}, \tag{6}$$

where δ_i is the density of snow accumulation in one test (g/m^3) ; k is the number of density estimations during the entire winter; T_s is the number of observation years.

The proposed models allow to calculate the blizzards parameters which are essential parameters for snow protection maintenance and design on the roads of Russia. The computer program *"Blizzards"* was specially developed for that kind of calculations [8]. The program has a modular structure, which allows to correct the separate modules or add a new ones. These modules can be used as independent programs for calculation. The initial data and the calculation results are stored in the databases with specific structures. This allows using the data in other calculations and receiving the reports of various forms.

4 THE EXPERIMENTAL VERIFICATION OF THE MODELS

The experimental verification of the models has been done for the three seasoned road sections. During the experimental work adequateness of the models was tested according to the snow volume measurements.

The snow survey methodology provides the determination of the actual snow volume on the embankments subgrade according to the snow cover height and snow length parameters on the basis of their geometric parameters [9]. Tachometry has been conducted to determine the embankments geometrical parameters at selected seasoned road sections. Determined marks: subgrade verge, the bottom cuvette and land marks in field at a distance of 15-20 m from the cuvette embankment. In winter, with the leveling rods, the snowdrift height in the typical points of the land cross-sections and in the points of snowdrift shape and height change were measured, snow shafts was measured on the verge. Simultaneously, the snow density detection in snow accumulation zones was done using the cutting ring.

The cross sections on experimental open roadways and snow accumulation profiles were used for the calculation of the actual snow volume by their geometric shapes [9].

Snowdrift measurements were performed after the intense blizzard or in the late winter. If the snowdrift measurements were made in late winter with taking into account the determining of the snowdrift volume, the snow losses from melting and evaporation during thaws affected the changes in snowdrift density.

The convergence of the calculated and actual data on snowdrift volume is about 88% in average [9]. Therefore, we can conclude about the possibility of applying the model for solving tasks of winter road maintenance.

5 THE ROAD MAPS WITH BLIZZARDS PARAMETERS

For solving the practical problems the most convenient way of submitting the calculations results are in the form of maps form with isolines representing the estimated blizzards parameters [10,11]. The total number of such maps is 18.

The calculation of isolines and drawing them on the map was automated by using the methods of creation of the digital terrain models. To calculate the program complex «CREDO Roads» from joint venture «Credo-Dialogue» was used.

Models are created in the following sequence:

- Bitmapped substrate is created in the program TRANSFORM, i.e. a map of the roads network and location of the weather observation points.
- Bitmapped substrate is exported to the program CREDO Roads to digitize.

The locations of meteorological stations served as control points for the digitizing maps. Numerical values of climatic parameters are given in control points. The model of one climatic parameter is constructed in each layer. This allows to observe simultaneously the change in the parameters distribution on the given territory and application of the additional data on the generated model.

The closed contour is created to build the model. Three-dimensional surface and its two-dimensional image in the lines interpolation (isolines) form are constructed inside of the contour. Isolines represent the equal parametrical values in the different points of the terrain (in the first approximation). Isolines increment can vary for different layers. Its value depends on the variability of climatic factors, accuracy of its calculation, and given tasks.

The program CREDO Roads allows to build 2D models in the form of cuts (sections) along road axis and to display any parameter distribution on the road as a line graph. The map fragment with the estimated snow accumulating volume for roads towards the north (left), to the south (right) is shown in Figure 1.

6 CONCLUSION

The maps with the blizzard parameters can be used to solve the following problems: detection of road sites with possible snow drifts; designing different variants of snow protection; planning snow removal; calculation of resources for winter road maintenance. The method of creation of digital terrain models and displaying of the information on maps makes possible the use of the results in the form of GIS technology. The calculation results in the program CREDO Roads after their export into a GIS system and automatic conversion of the calculation results allow to display the data in the Earth surface coordinates and put them together with the data from roads.

The meteorological data necessary for calculating of estimated blizzards parameters was determined. The mathematical models for the calculation and statistical processing of the modeling results were presented. The results are presented in the form of maps which can be used in special GIS projects for the winter road maintenance.

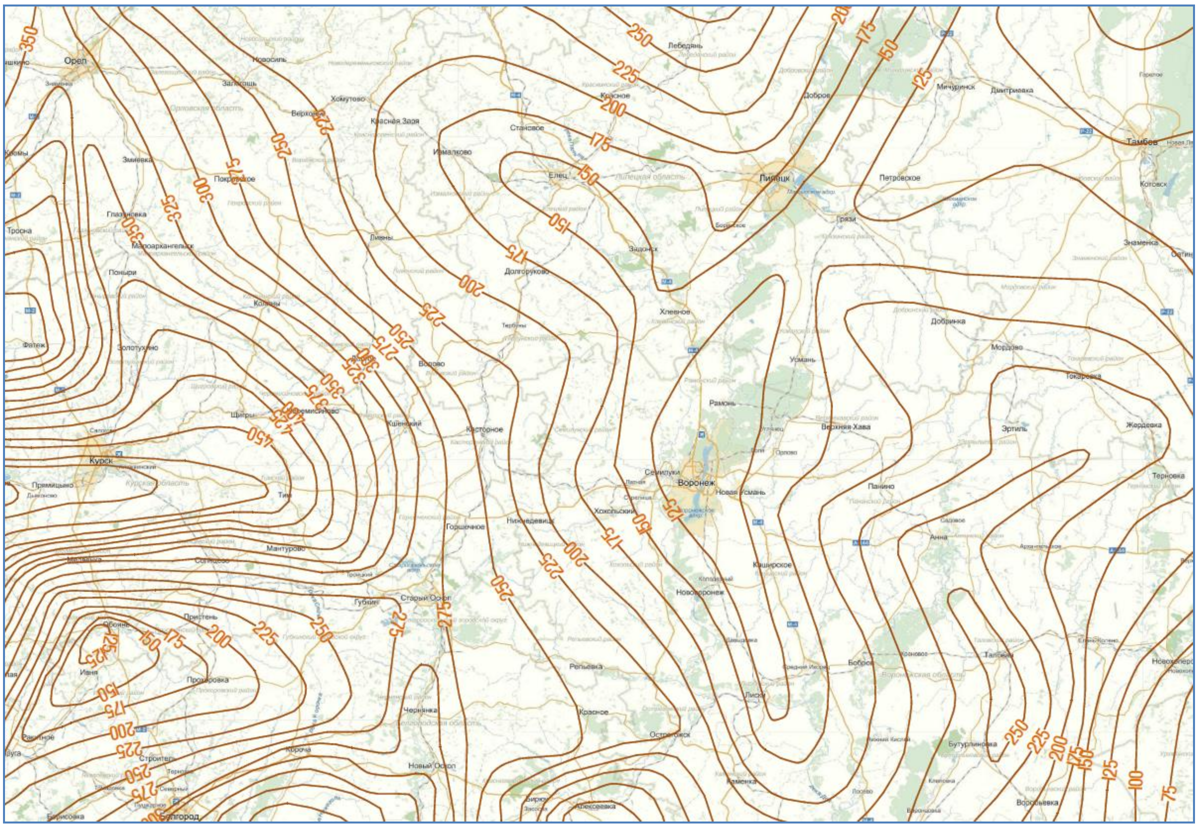

Figure 1. The distribution map of estimated snow accumulation volumes for roads towards the north (left) to the south (right)

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