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ESTIMATED BLIZZARDS PARAMETERS FOR WINTER ROAD MAINTENANCE

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Statement of the problem. The main research objective is to define the estimated blizzards parameters using the meteorological data necessary for the determination of estimated blizzards parameters. The presented paper shows mathematical models for the calculation and statistical processing of modeling results.
Results. The paper presented mathematical models for the determination of the estimated blizzards parameters (blizzards duration, volumes of snow drifting and snow accumulation on the roads). The presented modeling results were verified experimentally on the seasoned road sections. The list of meteorological and road data is presented. The snow survey methodology was shown.
Conclusions. The estimated blizzards parameters influencing the road reliability and traffic safety during the winter period were determined using the system approach basis. The experimental verification of the models showed the possibility of applying the model for solving tasks of winter road maintenance.

Keywords: Roads, Blizzard, Snow Accumulation Volume, Meteorological Data.

Introduction

For the purpose of providing road safety in winter the road service team carries out a complex of activities. The standards in force for winter service presuppose timely removal of ice sediments and clearing of the road surface from snow.

The main type of winter slipperiness on most of the territory of Russia is snow deposits. The intensity of the snow blockades depends on large number of factors, both weather and road. The quantitative estimation of those factors is an important problem. 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.

System approach to defining the estimated blizzards parameters. For the study of snowdrifts formation on the roads the subsystem *"Environment – Road"* (E-R) was considered. The solution of the given problem can be solved with the use of common approaches to the theory of complex systems modeling [1, 2].

The law of functioning of the subsystem R-E can be presented by a generalized operator f which transforms a set of internal independent parameters of the subsystem into the external, dependent variables.

The amount of snow accumulation K_{SP} (that accumulates after a blizzard or due the snow drifting to a road during the whole winter) is taken as the output parameter in the solving problem. The internal parameters of the system are the road and meteorological factors influencing the snow accumulation volume on the road section. The general model is the following:

$$K_{SP} = f(\bar{h}(t), \bar{a}(t), t), \tag{1}$$

where K_{SP} is a quantity of snow accumulation on the road surface; f is the law of system functioning; $\bar{h}(t) = \{h_1(t), h_2(t),...,h_k(t)\}$ is the vector parameter of external environment (meteorological parameters); $\bar{a}(t) = \{a_1(t), a_2(t),...,a_k(t)\}$ is the vector parameters of the system own factors (road parameters); t is time.

Internal system parameters are divided into two groups: meteorological and traffic. Weather conditions determine the impact of the external environment, while traffic parameters determine the snow accumulation on the road during a blizzard [3, 4, 5, 6].

The environment parameters are presented in Table 1.

Table 1

Components of the vector of weather factors

Components of the vector of weather factors	Parameter name	Parameter symbol	Unit
$h_1(t)$	atmospheric phenomenon (type of precipitation)		
$h_2(t)$	starting time of the phenomenon	t_n	hour
$h_3(t)$	ending time of the phenomenon	t_k	hour
$h_4(t)$	wind speed	V	m/sec
$h_5(t)$	wind direction	α_i	compass point
$h_6(t)$	blizzard type		
$h_7(t)$	air temperature	T	^{0}C
$h_8(t)$	duration of the phenomenon	t	hour
$h_9(t)$	blizzard intensity	I	m^3/sec
$h_{10}(t)$	snow drifting volume	δ	t/m^3
$h_{11}(t)$	snow accumulation volume (left on the road)	$W_{b.l}$	m^3/m
$h_{12}(t)$	snow accumulation volume (right on the road)	$W_{b.r}$	m^3/m
$h_{13}(t)$	volume of snow accumulation during the estimated blizzard	W_b	m^3/m

A part of the meteorological factors vector (h_1 – h_7) can be obtained using the observation data from the State Meteorological Stations. The other components (h_8 – h_{13}) are determined by calculation.

The traffic parameters can be obtained from the road project, technical data, diagnostic results or by special road inspection and. They are presented in Table 2.

Table 2

Components of the vector of road factors

Components of the vector of road factors	Name of parameter	Unit
$a_1(t)$	road direction	compass point
$a_2(t)$	working mark (height of embankment, depth of ditch)	H
	geometrical parameters of cross-section of road	
$a_3(t)$	slopes ramp of ditch	m_1
$a_4(t)$	slopes ramp of embankment (ditch)	m_2
$a_5(t)$	slopes ramp of ditch of ditch	m_3
$a_6(t)$	width of ditch	l_1
$a_7(t)$	width of ditch shelf	l_2
$a_8(t)$	depth of ditch	h
$a_9(t)$	width of road shoulder	a
$a_{10}(t)$	width of carriageway	b
$a_{11}(t)$	width of road surface	B
$a_{12}(t)$	cross-section slope of carriageway	i_1
$a_{13}(t)$	cross-section slope of road shoulder	i_2
$a_{14}(t)$	availability and type of snow protection	—

The models for the calculation. For the detection of snow accumulation volumes the method of the summarized snow transfer suggested by D.M. Melnik is used [7]. 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.

The volume of snow transfer in winter period (W_t) is calculated by the formula:

$$W_t = \frac{t}{m} \sum_{i=1,(V>5)}^{m} C \cdot V_i^3 = I_c \cdot t, \tag{2}$$

where t is the summary duration of blizzards for winter period, hour; m is the number of measurements of the wind speed during blizzards (at speeds over 5 m/sec); C is an empiric factor which is equal to 0,00046 when the average density of the fresh brought snow is 0,17 m^3/m; V_i is the wind speed during blizzards, m/sec; I_c is the average intensity of blizzards during the entire winter period (m^3/m hour).

The volume of the snow accumulation on an auto road at the end of the winter period from one direction (W_{sb}) is calculated according to the formula:

$$W_{sb} = W_t \cdot \sin\left(\alpha_r - \alpha_i\right), \tag{4}$$

where α_r is the direction of the highway, degrees; α_i is the direction of the wind, degrees.

The volume of the snow accumulation at one side of the auto road in winter (W_b) is calculated according to the formula:

$$W_b = \sum_{i=1}^{7} W_{sb,i} \cdot \sin(\alpha_д - \alpha_i), \tag{5}$$

where W_b is the amount of snow brought to one side of the road (m^3/m); $W_{sb,i}$ is the snow drifting volume by one compass point (m^3/m); α_i is the azimuth of compass points, degree; α_r is road azimuth, degree.

For each road direction the number of compass points in which the snowdrift is calculated equals 7. Counting the volume of snow transfer, winds blowing at an angle less than 30˚ are not taken into consideration. Figure 1 gives the scheme of calculating of directions from which the snow is brought to one side of the auto road directed northward.

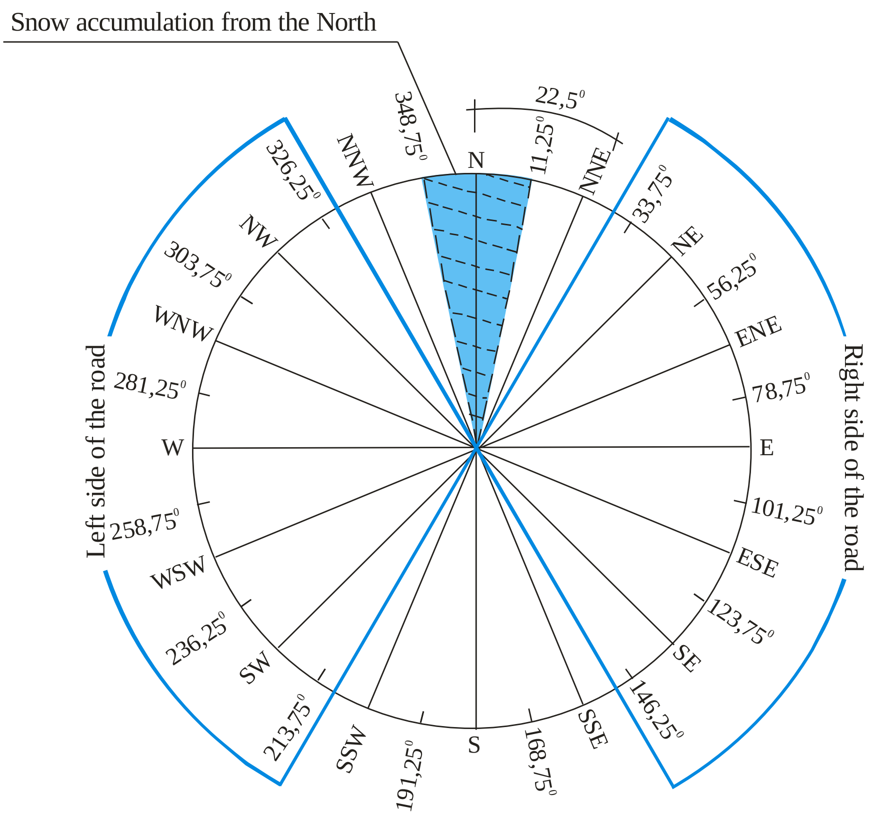

Fig. 1. Scheme of the calculation of snowdrift on the road directed northward

The zone of each direction (at 16 compass points) is determined by the sector with the arc of 22,5˚.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 [8]. Based on the calculation, the results the descending series of parameters are compiled.

For each series unit the empirical probability of exceeding is calculated

$$p_э = \frac{m}{n+1} \cdot 100\%, \quad (6)$$

where m is the serial number of series unit; n is the length of series (number of observation years).

The three-parameter gamma-distribution is taken for smoothing of empirical data and extrapolation of calculated parameters [8].

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

$$P(x) = \frac{\beta^{\alpha}}{\Gamma(\alpha)} \int_{x_0}^{\infty} \overline{x}^{\alpha-1} \cdot e^{-\beta \cdot x} \cdot dx, \quad (7)$$

where $\Gamma(\alpha)$ is the gamma function or Euler integral of the second kind.

Statistical processing resulted in acquisition of the parameters of estimated blizzard were obtained, i.e. the snow accumulation volume on a section of a highway, 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 seasoned road section was selected for the study of blizzard characteristics, a meteorological station was identified (experimental site is located within the area of the meteorological station), and meteorological station data from 42 winters has been received. On the basis of the meteorological station data the modeling and statistical analysis were conducted. The maximum snow accumulation volumes for each year and the estimated snow accumulation volumes with different probability of exceeding were determined.

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, 10]. Tachometry has been conducted to determine the embankments geometrical parameters at selected seasoned road sections. The determined marks are subgrade verge, the bottom ditch and land marks in field at the distance of 15—20 m from the ditch embankment. In winter, with the leveling rods, the snowdrift height at the typical points of the land cross sections and at the points of snowdrift shape and height change were measured, snow shafts were measured on the verge. Simultaneously, the snow density detection in snow accumulation zones was performed 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, 10].

Snowdrift measurements were performed after the intense blizzard or in 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 data obtained from meteorological stations for corresponding winter periods were used to calculate the volume of snow accumulation. The calculation results are shown in Table 3.

The convergence of the calculated and actual data on snowdrift volume is about 88% in average [9, 10]. Therefore, we can conclude about the possibility of applying the model for solving tasks of winter road maintenance.

Table 3

Results of the experiment

Name of the road	Location of road section, km	Volume of snow deposits (left), m^3/m		Convergence, %	Volume of snow deposits (right), m^3/m		Convergence, %
		snow survey	calculation		snow survey	calculation	
The site of the highway "Crimea" in the Orel region	306+850	11,86	8,84	74,7	15,00	10,04	66,9
	308+100	13,02	11,13	85,5	16,74	13,27	79,3
	308+400	14,47	16,97	82,7	15,92	17,27	91,5
	309+350				13,55	13,79	98,2
	313+055				28,30	22,03	78,1
	317+260	8,26	7,74	93,7	20,50	16,50	80,5
Kursk-Saratov road in Voronezh region	171+200	16,91	16,83	99,5			
	179+440	15,22	11,92	78,3			
	179+900	14,61	15,85	91,5			

Conclusions

The estimated blizzards parameters influencing the road reliability and traffic safety during the winter period were determined using the system approach basis. The meteorological data necessary for calculating of estimated blizzards parameters was determined.

The volume of snow deposits moved to the ditch and on the slopes during the snow removal work was not taken into account in the numerical experiment. The analysis of the results showed that the convergence will be increased with the availability of data about snow removal operations. Therefore, we can conclude the possibility of the use of models for applications and further researches of snow deposits on roads.

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