THE EFFECT OF CRASH BARRIER ON THE SNOW DEPOSITS OF HIGHWAYS

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ABSTRACT RÉSUMÉ

In this paper, the problem of snow deposits estimation after blizzards on highways with crash barrier is analyzed. Two possible variants of crash barrier works during blizzards were identified. The variants depend on the scheme of snow removal next to the barrier. The effect of both variants on snow deposits was studied.

The observations were made on the experimental sections of highways during winter. The observations were made with the help of video cameras. The snow volume was defined on the results of snow surveys.

In the result of study the nomogram for predicting the snow volume which will deposit on the road surface at the known snowbring volume was developed. The recommendations for winter maintenance of highways with crash barrier are presented.

1. INTRODUCTION

When there is a snowfall it deposits on the road surface evenly. During blizzards snow accumulation depends on the roads direction, the snow transfer direction, the cross-section of subgrade and the snow protection.

Snow deposits should not be formed on the roads embankment. Therefore, the snow cover height with a probability of exceeding 5% and the subgrade width are taken into account when designing roads.

If the embankment height satisfies the condition that snow is not deposited on the road during blizzard [1]

$$H \geq h_{5\%} + \Delta h, \tag{1}$$

where H is the embankment height, m; $h_{5\%}$ is the snow cover height with a probability of exceeding 5%, m; Δh is the parameter which depends on the road surface width, m.

While blizzards the snow accumulation is due to reducing the speed windsnow flow during the passage towering obstacles. The amount of accumulated snow depends on the windsnow flow speed and embankment geometric parameters [2, 3, 4].

The calculation of snow deposit is done through snow loss caused by change of speed of windsnow flow

$$SL = 1 - \left(\frac{V}{V_f} \right)^3, \qquad (2)$$

where SL is the snow loss; V_f is the field wind speed, m/sec; V = $V(x, y)$ is the speed of windsnow flow in the point with coordinates x and y over embankment , m/sec.

However, the modern highways have several rows of crash barrier on the entire road to ensure traffic safety. In the winter, this leads to the fact that all roads embankment which are not protected from snow blizzards with forests, are blocked by snow.
A large amount of snow is accumulated during blizzards on the road with crash barriers. Models for the calculation of the snow amount on the road surface should consider the presence of the crash barriers and their effect on the snow deposits on highways.

The problem of snow deposits estimation after blizzards on highways with crash barrier is analyzed. Two possible variants of crash barrier works during blizzards were identified. The variants depend on the scheme of snow removal next to the barrier.

At the first variant, a condition of complete removing of crash barrier from snow must be implemented. In this case crash barrier will work as blow-snow fence. At the second variant, snow is not removed from the crash barrier. So, crash barrier will work as entire, snow accumulation fence.

In this paper, the dynamic of snow deposits formation on the road surfaces for both variants is presented.

2. SNOW DEPOSITS ON THE ROAD SURFACE WHILE COMPLETE REMOVING OF CRASH BARRIER FROM SNOW

The results of the theoretical studies and observations led to the conclusion that most of the snow during a blizzard is transferred into the layer of 2,0 m height above the ground [5, 6]. About 98% of snow is transferred up to 0.8 m height that is through the crash barriers.

The effect of the crash barrier on the snow deposits includes:

- The wind speed in the area of blowing out snow through the crash barrier exceeds then field wind speed by 30-50%;
- Snow deposits on the leeward side of the crash barrier are more likely to occur at a distance of up to 10÷15H (H – the height of the crash barriers);
- Snow deposits on the windward side of the crash barriers are more likely to occur at a distance of up to 5H;
- The zone of full snow blown out is formed around crash barriers on the leeward side at a distance of 1,5÷2,0H;
- The minimum speed of windsnow flow is achieved at a distance of about 5H, where the first snow deposits occur and snow drifts begin to form.

The crash barriers has a light transmission which is equal to the ratio of the lower clearance area to the total area [6]

$$y = S_1 / S \quad (3)$$

where y is the light transmission of crash barriers; S_1 is the lower clearance area of crash barriers; S is the total area of crash barriers.

At the standard crash barrier height 0,8 m and the lower clearance height 0,5 m, their light transmission is 0,6. The standard crash barrier is shown in Figure 1.

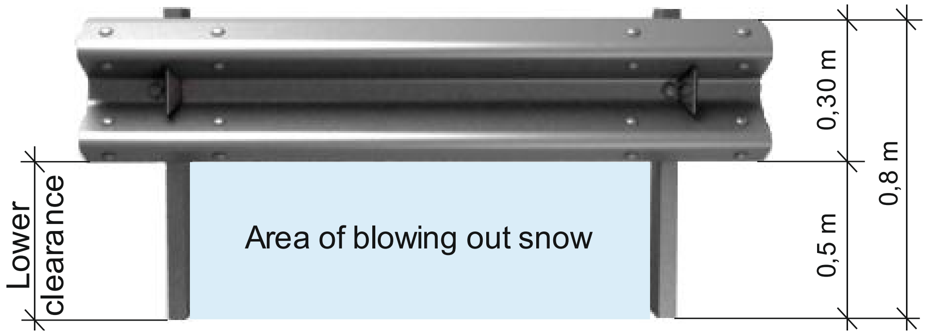


Figure 1 – The standard crash barrier

The modeling of snow deposits made with complete removing of crash barrier from snow. The consistency and form of snow deposits in the blow-snow barriers are shown in Figure 2.

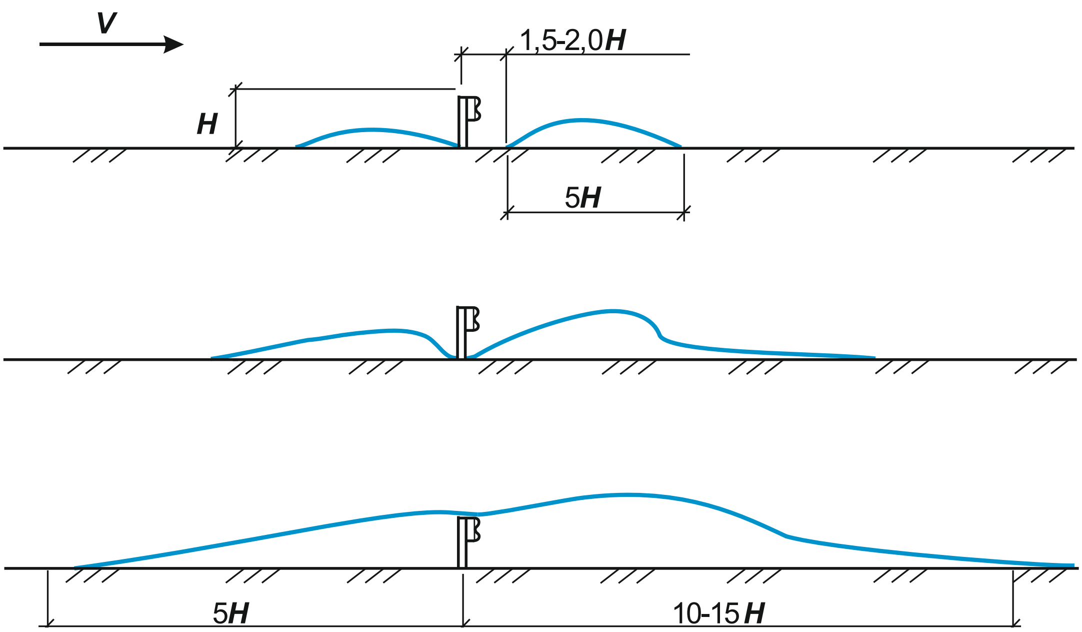


Figure 2 – Consistency and form of snow deposits for the blow-snow barriers with light transmission 0,6

The schemes of snow drifts on highways depend on the wind direction are shown in Figure 3. Highways have a width of 35,5 m, four traffic lanes, dividing lane of 11 m width and three rows of crash barriers.

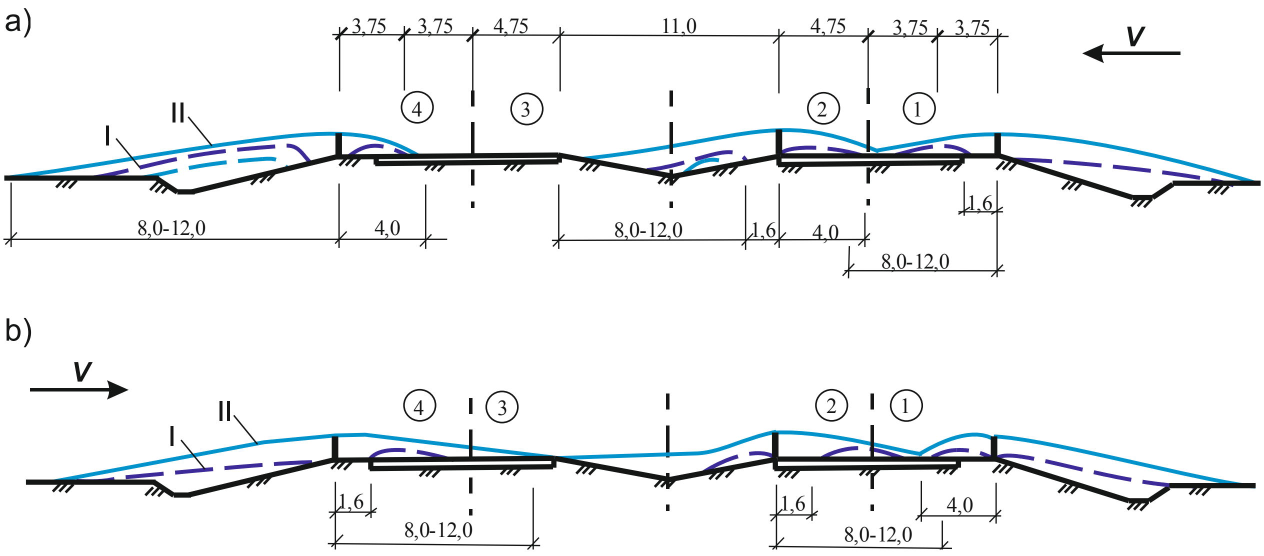


Figure 3 – Schemes of snow drifts on highways depend on the wind direction:
a) with wind direction on the right of the road; b) with wind direction on the left of the road;
1, 2, 3, 4 are numbers of traffic lanes; **I** – the surface snow cover after the passage of previous blizzard; **II** – the surface snow cover after blizzards with volume of snowbring more 30 m^3/m and without snow removal

When complete removing of crash barrier the first snow drifts will be formed in the cuvette. Then they will be formed on the 1st, 2nd and 4th lanes and the dividing lane. The calculations showed that at the crash barrier height of 0.8 m the snow deposits length on the windward side will be 4.0 m, and on the leeward side from 8 to 12 m.

The calculations show that for any wind direction three lanes (1,2,4) and the dividing lane are located in the snow deposits zone. The main reason for their formation is the presence of the crash barriers working as blow-snow fence. The snow accumulates less only on the third lane [7].

Thus, if there are 4 rows of crash barriers on the road surface width 35,5 m then the entire road surface is located in the snow deposits place. This result also is correct for the road surface width of 27.0 m and three rows of crash barriers.

The calculations showed that after intense blizzards with snowbring volumes of more than 30 m^3/ m, and if the snow is nit removed during a blizzard, the entire road will be filled with snow up to the height barriers. In this case, the volume of snow deposits on subgrade will be 20-25 m^3/m, and on the road surface will be 10-15 m^3/m.

3. SNOW DEPOSITS ON THE ROAD SURFACE WITH SNOW UNDER CRASH BARRIERS

If the place under the crash barriers is filled with snow which was removed from the road then the crash barriers will work as entire, snow accumulation fence.

At the beginning of blizzard snow deposits are formed before entire barriers in the area of low-speed windsnow flow. In the process of filling the zone before barriers snow deposits begin to accumulate immediately after the barriers in the area of reverse movement of the windsnow flow. The intensive snow accumulation continues until these zones are not filled. The consistency and form of snow deposits at the entire barriers are shown in Figure 4.

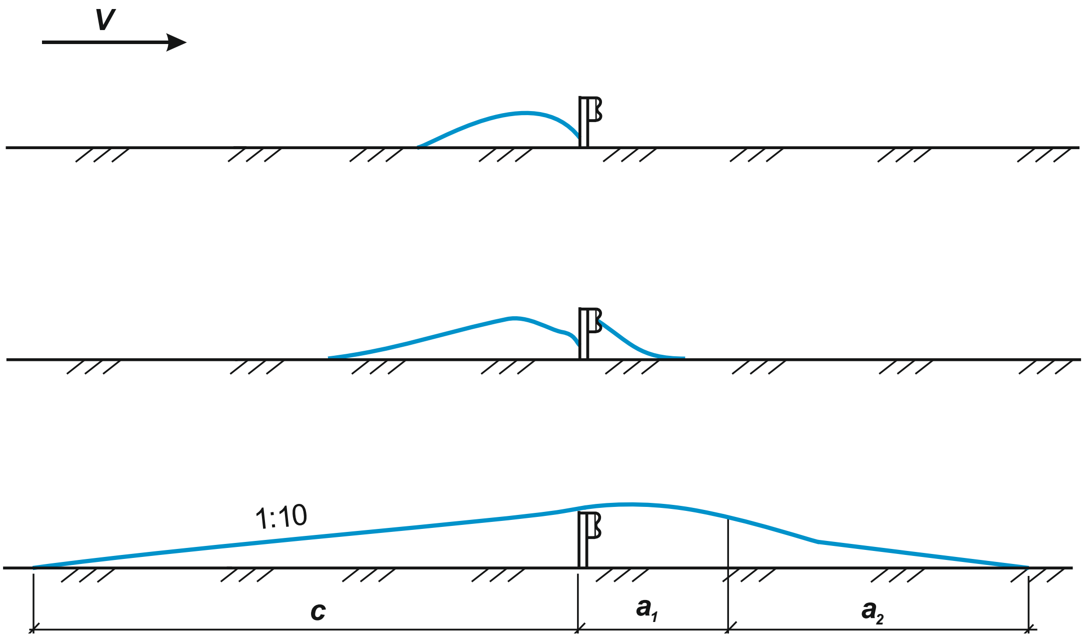


Figure 4 – Consistency and form of snow deposits at entire barriers

The modelling of snow deposits next to crash barriers filled with snow was made. The slope of the snow surface in front of the entire barriers at the full filling of it with snow is 1:10 [6]. The length of the leeward zone of snowdrifts behind entire barriers depends on the wind speed.

The calculations for different wind speeds during blizzards were made; the results are presented in Table 1.

Table 1 – The length of the leeward zone of snowdrifts behind entire barriers

Wind speed, m/c	a_1, m	a_2, m	c, m	The length of the leeward zone of snowdrifts (a_1+a_2), m
5	H = 0,8	5H = 4,0	10H = 8,0	4,8
10	2H = 1,6	8H = 6,4	10H = 8,0	8,0
15	3H = 2,4	12H = 9,6	10H = 8,0	12,0
20	4H = 3,2	18H = 14,4	10H = 8,0	17,6
25	5H = 4,0	26H = 20,8	10H = 8,0	24,8

During blizzards the snow deposits are formed initially in the first row of crash barriers on the embankment slope, and then in the barrier area, behind the barrier on the shoulder, and only then snow deposits accumulate on the road surface. Snow accumulates next to the crash barriers. The length of deposits at 0.8 m height of barriers will be about 8 m.

The snowdrifts will not form on the road while blizzards with little snowbring volumes.

The schemes of snowdrifts on the road surface next to crash barriers filled with snow with a different direction of windsnow flow and with wind speed of 10 and 20 m/s while blizzards are shown in Figure 5.

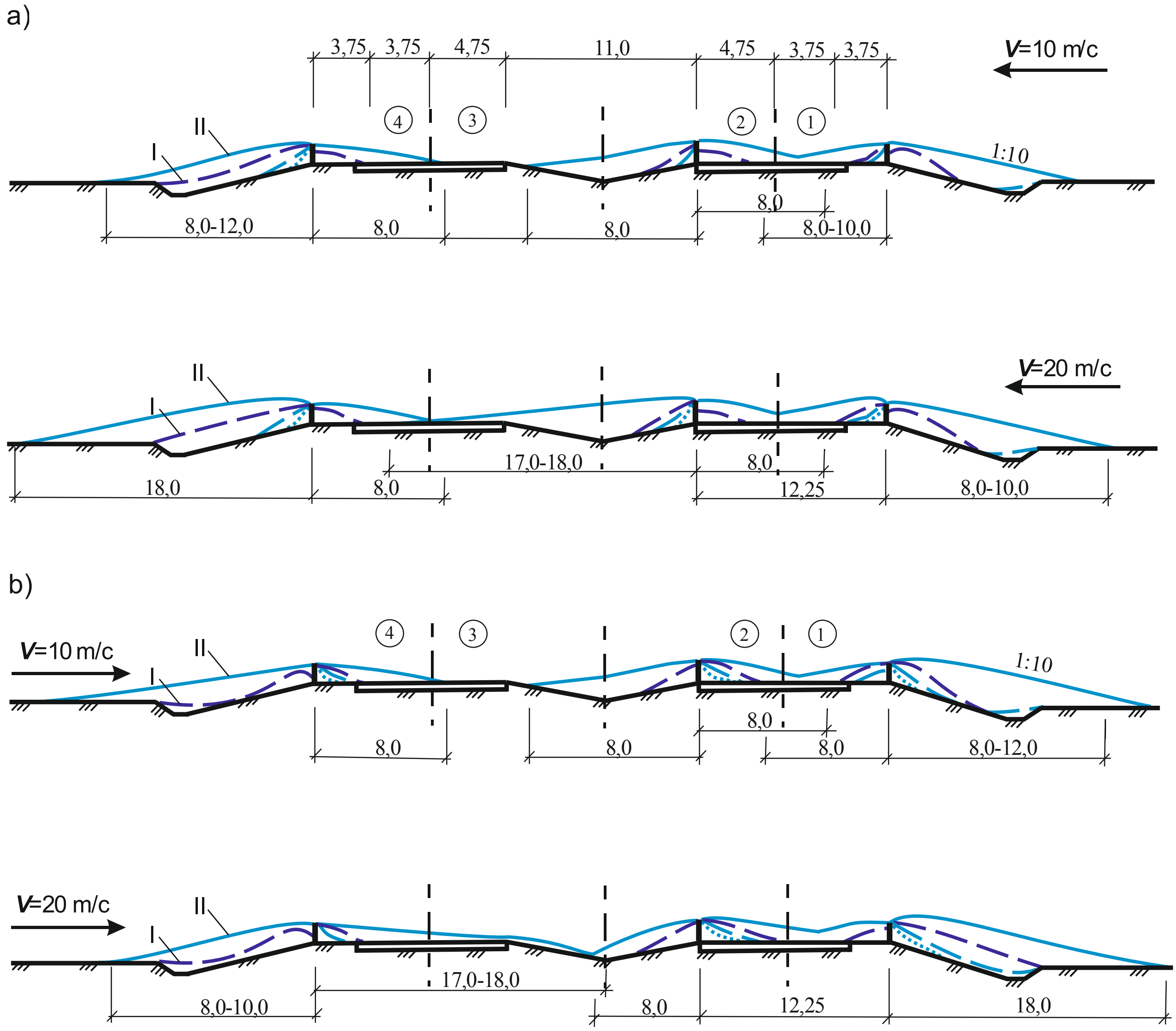


Figure 5 – Schemes of snowdrifts on the road surface next to crash barriers filled with snow with a different direction of windsnow flow: a) with wind direction on the right of the road; b) with wind direction on the left of the road; 1, 2, 3, 4 are numbers of traffic lanes; **I** – the surface snow cover after the passage of previous blizzard; **II** – the surface snow cover after blizzards with volume of snowbring more 30 m^3/m and without snow removal

The snow will accumulate more on the 1, 2, and 4 traffic lanes at the wind direction on the right and on the left of the road, because the length of the leeward zone of snowdrifts behind the crash barriers on the right shoulder overlaps the windward zone of barriers.

The left side of the road has less snowdrifts, because the 3 traffic lane will be in the area of snow deposits only at the wind direction on the left of the road and wind speed more than 15 m/c.

4. THE OBSERVATIONS ON EXPERIMENTAL SECTIONS OF THE ROAD

The observations were made on the experimental sections of roads during two winter periods on the site of the federal highway M-4 "Don" Moscow - Voronezh - Rostov-on-Don - Krasnodar – Novorossiysk. The road connects the central and northern regions of the European part of the country with the North Caucasus, the Black Sea coast and the port of Novorossiysk. Highway M-4 "Don" has a length of 1,589 kilometers.

The part of the federal highway M-4 "Don" Moscow - Voronezh was taken for the study. It has a length of 536 km.

The experimental site crosses the territories of Moscow, Tula, Lipetsk and Voronezh regions. The federal highway M-4 "Don" Moscow – Voronezh has 4 traffic lanes, divided reverse traffic and road crossings on different levels. Characteristics of the highway site are shown in the Table 2.

Table 2 – Characteristics of the federal highway M-4 "Don on the site Moscow – Voronezh

The name of parameter	The characteristic of parameter
Road category	I B
Length, km	536
Number of traffic lanes	4
Subgrade width, m	27,5
Road surface width, m	7,5 x 2
Shoulder width, m	3,75
Dividing lane width, m	5÷11,0

Experimental works include:

- The observation by video cameras placed on the highway
- The special snow surveys, measurement of the snow height after the blizzards and snowfalls
- Analysis of data from automatic road meteorological stations located on the highway

Road weather stations and video cameras transmit the information in real time about the situation on the road through the video surveillance system. The collection of information about the weather conditions are made with automatic road meteorological stations.

18 complex stations were installed on the experimental site they consist of automatic road meteorological stations and video cameras. The scheme of the federal highway M-4 "Don" on the site Moscow - Voronezh with indication of complex stations placement is shown in Figure 6.

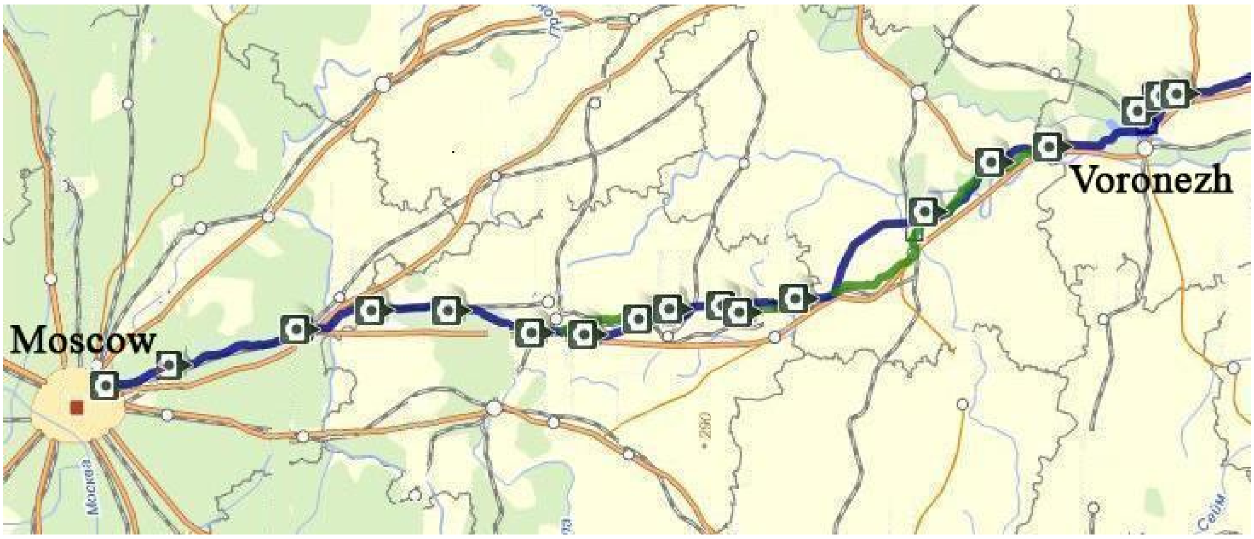


Figure 6 – The scheme of the federal highway M-4 "Don" on the site Moscow - Voronezh with indication of complex stations placement

The collection of videos and photos is made with the help of video cameras during the winter. The condition of roads surface is observed especially while blizzards and heavy snowfalls.

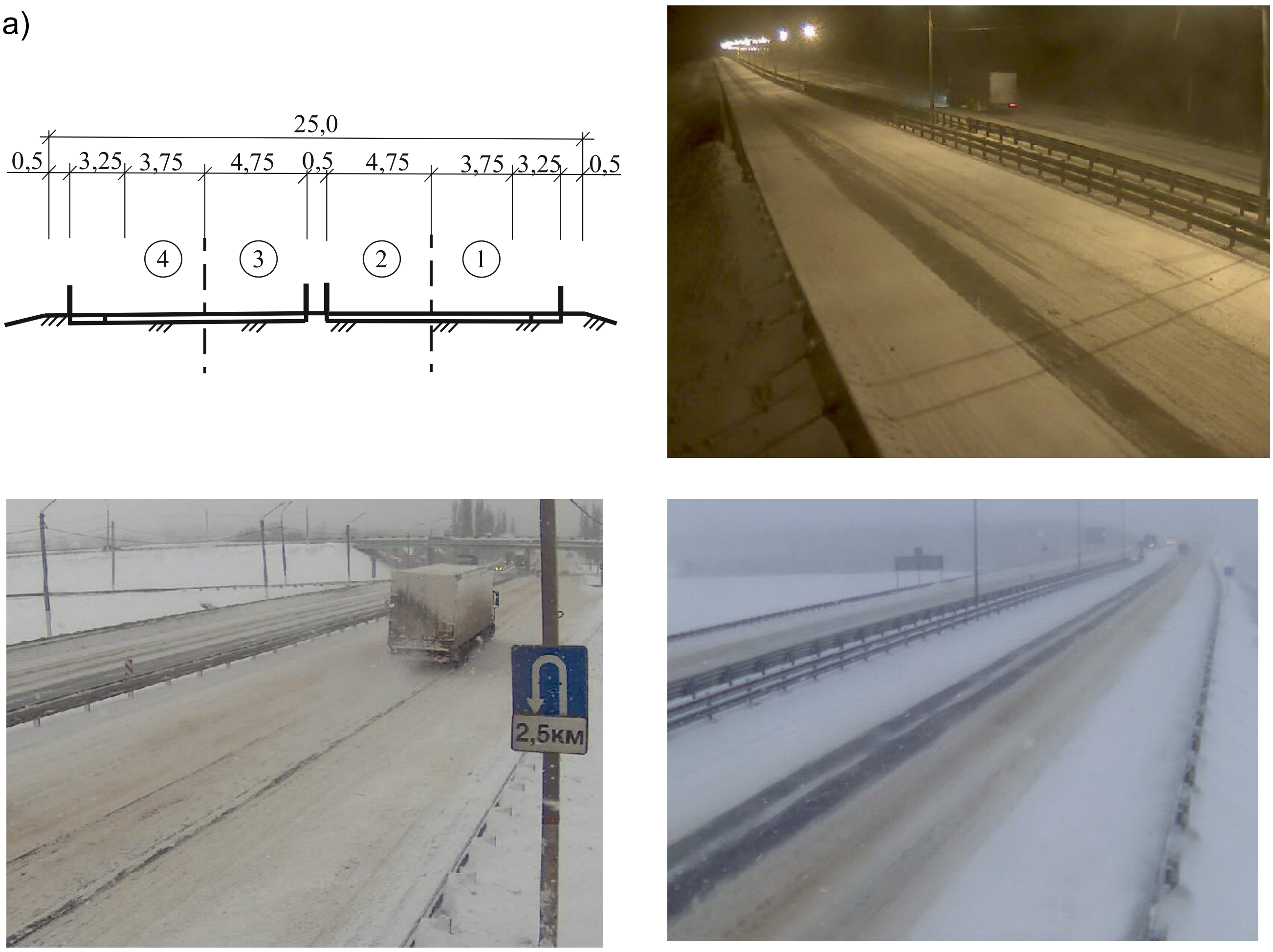
Experimental snow survey works were conducted in three phases:
1. In summer – the tacheometry of embankment cross sections in relative or absolute heights on experimental road sites was made; embankments marks, ditches bottom marks, marks on the embankments slopes and the land marks at a distance of 15-20 m from the embankments ditches were determined; the location of the crash barriers was defined.
2. Embankments cross sections were drafted.
3. In winter – measurement of the snowdrifts thickness after intense blizzards, snowfalls and in the end of the winter was made; measurements of the snowdrifts thickness in the characteristic points of the land cross-section; in the points where the snow shape and thickness change; as well as measurements of snowdrifts on the subgrade were done.

During winter the collection of weather information from state meteorological stations and automatic road meteorological stations is produced.

The following parameters are taken into account: type of precipitation, the time of beginning and end of events, wind speed and its direction, the snowfall intensity, the air temperature.
These parameters allow to calculate the snowbring volume and snow deposits amount on the road taking into account the snow accumulation dynamic [2, 3, 4].

Experimental road sites have crash barriers with different scheme placements. The example of variants of crash barriers placements on experimental sites and the results of video observations are shown in Figure 7.

а)



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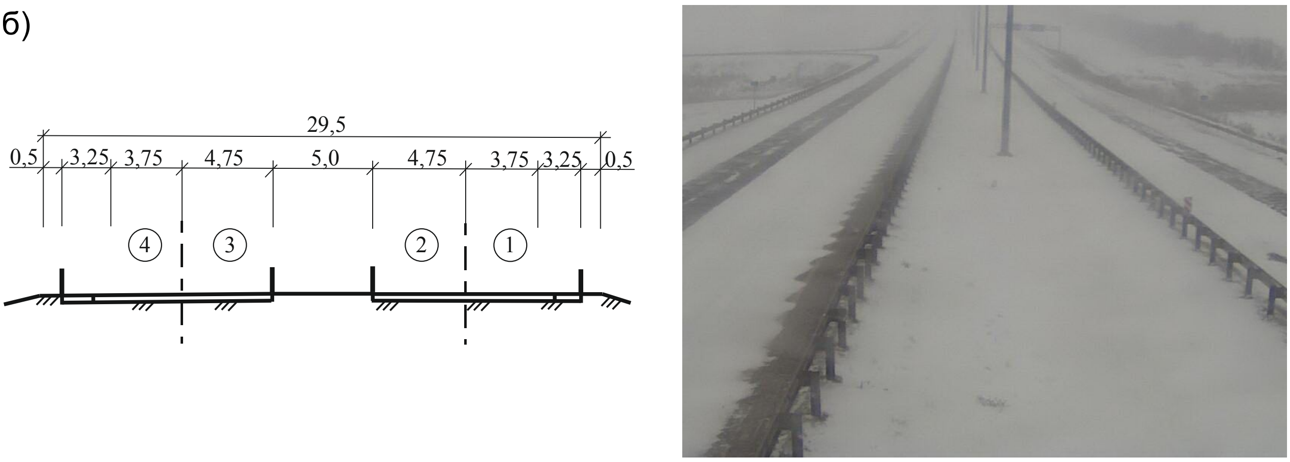

Figure 7 – Variants of crash barriers placement on experimental sites

Video surveillance during winter gave the opportunity to clarify the distribution of snow on the road surface.

5. THE DETERMINATION OF THE SNOW DEPOSITS AMOUNT ON THE ROAD SURFACE

With a large volume of snowbring in a single blizzard and if the snow is not removed during a blizzard, the entire road will be filled with snow up to the height barriers.

The amount of snow deposits on the road surface can be calculated by the formula

$$Q_d = W_{sb} - Q_{sd} - Q_{dl}, \qquad (4)$$

where Q_d is the amount of snow deposit on the embankments road surface; W_{sb} is the snowbring volume in the separate blizzard, m^3/m; Q_{sd} is the snow deposit volume on the leeward slope and in the ditch, m^3/m; Q_{dl} is the snow deposit volume on the dividing lane, m^3/m

The calculation of snow deposit volume on the road surface with width of 35.5 m and dividing lane of 11 m for road embankments with varying heights from 0.1 m to 3.0 m depending on the snowbring volume was made.

The nomogram for predicting the snow volume which will deposit on the road surface at the known snowbring volume was developed. The nomogram is shown on Figure 8.

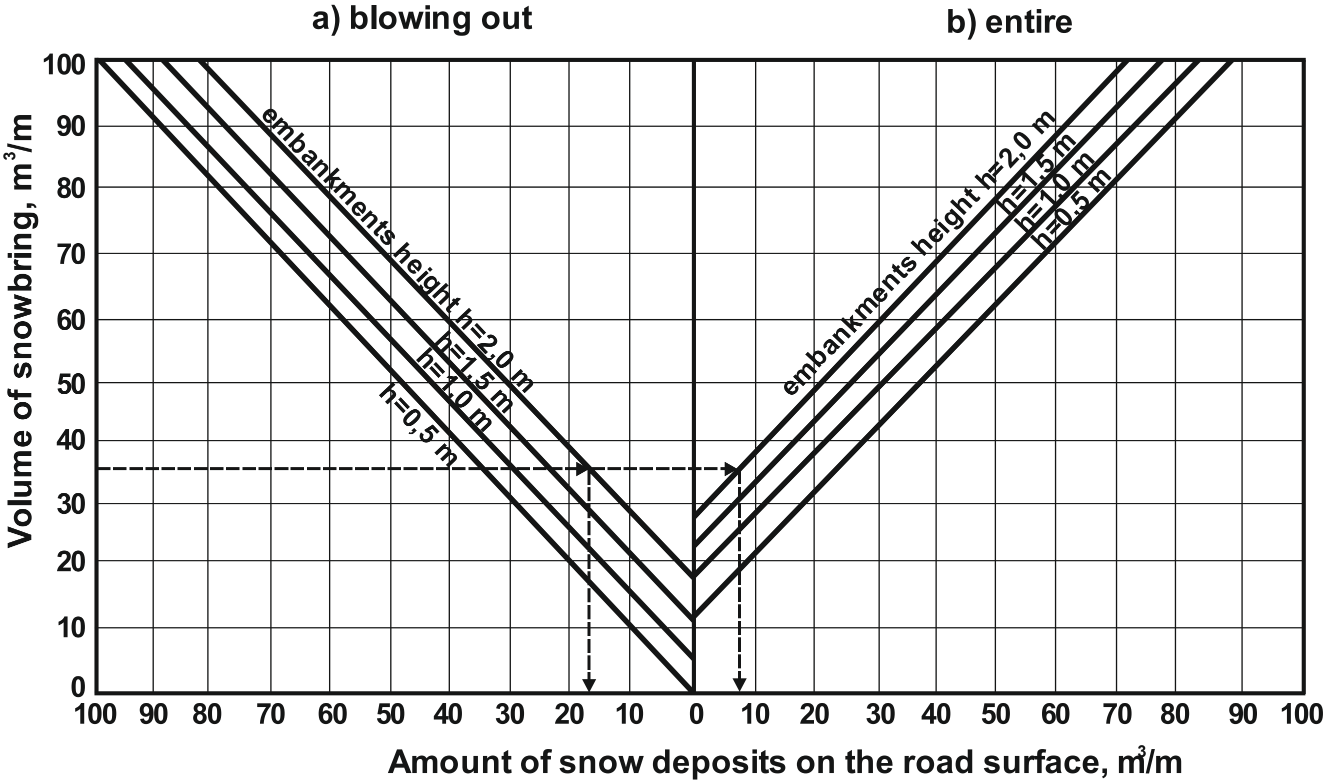

Figure 8 – The nomogram for predicting the snow volume which will deposit on the road surface with width of 35,5 m at the known snowbring volume: a) the crash barrier works as blow-snow fence; б) the crash barrier works as entire, snow accumulation fence

6. CONCLUSION

1. Crash barriers can work as blow-snow fence or as entire, snow accumulation fence.

2. Crash barriers work as blow-snow fence in the beginning of blizzard until snow removal starts or all winter if the full cleaning of barriers from snow is constantly made. In this case, the snow begins to deposit immediately on the road surface that interferes with the traffic.

3. Crash barriers begin to work as entire snow accumulation fence after the first snow removal when the snow fills the lower open part of barriers. In this case, snow drifts begin to form next to barriers and then gradually accumulate on the road surface.

4. The availability and placement scheme of the crash barriers on the highways should be considered when planning the snow removal.

REFERENCES RÉFÉRENCES

1. Construction Norms and Rules 2.05.02-85*. Roads (2013). Branch road norms, Federal road agency, Moscow, Russia, 56 p.
2. Gladysheva O.V. (2008). Determination amount of snow deposit on the road subgrade of embankment. Higher education institutions proceedings. Construction, No.3, pp 82-87
3. Gladysheva O.V. (2008). Estimation amount of snow deposit on the road. Proceedings of SIRWEC 14th International Road Weather Conference. Prague, Czech Republic, pp19-23
4. Samodurova T.V., Gladysheva O.V., Alimova N.U., Shiryaeva S.M. (2012). Snowdrifts formation on road embankments. Proceedings of the 7th International conference «Snow engineering VII», Fukui, Japan, pp 442-449
5. Dunin A.K., (1963). Drifting snows mechanics, Sciences Academy USSR publishing house, 378 p.
6. Kungurtsev A. A. (1961). The snow protection designing on the roads. Avtotransizdat. Moscow, Russia, 108 p.
7. Gladysheva I. A., Samodurova T.V., Gladysheva O.V. (2003). Snow deposits on the highways with crash barriers. Science and Technology in the road branch, No.3, pp 30-32