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Operation of Track Sections in Avalanche Hazardous Areas by the Example of the Serebryansky Track

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Abstract. *The fight against avalanches and the elimination of their consequences is urgent. The purpose of the article is to develop measures for preventing avalanches, especially sudden but not only planned ones. The subject of the study is snow avalanches, their volumes, and their causes. The result of the study is the development of standard technological flowcharts for snow removal work on the backbone network of the NC KTZh JSC. Freight trains travel 1000 km per day. It is necessary to increase this speed to 1200 km/day. The nominal FTI amounted to 75 trillion tenge in 2020; in 2024 it will be 106 trillion tenge. This will require transportation of construction materials and minerals, gasoline and diesel fuel, grain and flour, fertilizers, seeds, herbicides and pesticides, crop and livestock products.*

Keywords: *snow, slope, avalanche, avalanche zone, avalanche body, shock wave, avalanche volume.*

Introduction

Such regions of Kazakhstan as the Almaty, the Turkestan, the Zhambyl, the East Kazakhstan regions are classified as avalanche hazardous.

These areas have the developed economy and transport system (roads and railways), a tourist and mountaineering cluster.

Knowledge about such a phenomenon as an avalanche, the concepts of avalanche hazardous territory, the avalanche body, avalanches and their volumes, as well as the destructive power of avalanches are of great importance for ensuring the safety of trains and vehicles, the preservation of the roads themselves in good condition, the life and health of people. This poses the need for transport and the other departments, for example, tourism and emergency situations departments, to introduce certain measures and actions against spontaneous avalanches, which can cause irreparable losses. That is, there is a constant need to predict and to prevent planned avalanches to ensure the safety of transport structures.

From the scientific point of view, these issues are dealt with by scientists and specialists from the Institute of Geography and Water Security, the Academy of Logistics and Transport, from the practical point of view by the Ministry of Emergency Situations, the NC KTZh JSC, the NC KazAvtoZhol JSC.

The subject of the study is snow avalanches, their volumes, and their causes.

The task is a joint study of avalanches represented by the Academy of Logistics and Transport, the Institute of Geography and Water Safety JSC of the Ministry of Education and Science of the Republic of Kazakhstan, the NC KTZh JSC for the development of automated systems of forecasting avalanche danger located at weather stations.

Weather stations must be located in the areas with maximum avalanche danger to develop an electronic database of weather data regarding the temperature, precipitation, accumulated snow, humidity, and wind conditions. Weather stations will transmit data online and alert the relevant services in case of occurring dangerous parameters.

The article uses meteorological developments of the Institute of Geography and Water Security, the experience in operating the track on the Serebryanskaya track maintenance department in winter conditions.

The result of the study was the development of Standard technological floecharts for snow removal work on the main railway network of the NC KTZh JSC [7].

Materials and methods

Ensuring safety in the areas with snow accumulation (in avalanche-prone areas).

To ensure safe, continuous, uninterrupted and smooth movement of trains at the maximum established speeds, the railway track must always be in good condition and comply with the requirements of the Technical Operation Rules [1].

In Kazakhstan, the avalanche-prone sections cover the area of 104 thousand km2. They are located in the East Kazakhstan (EKR), the Almaty, the Turkestan and the Zhambyl regions.

Let's dwell on the basic concepts and definitions.

Snow avalanche is the process of moving the snow cover (stratum) from the slope of a mountain. When moving, an avalanche consists of an avalanche body and a dust cloud.

Avalanches do not have a wide variety of forms characteristic of landslides, therefore the classification schemes proposed for avalanches are basically similar to each other and differ only in individual details and in the description of the movement mechanism. Unlike landslides, avalanches are fast-moving events that occur every winter in mountainous areas where there is heavy snowfalls [8].

The avalanche body is a snow cover that has come into motion. When an avalanche moves, a snow cloud and a shock wave appear. This only happens at very high speeds (more than 100 km/h).

A snow cloud (a dust cloud) presents snowflakes raised into the air and hiding the body of the avalanche as it moves.

A shock wave (an avalanche wind) is a stream of air pushed out by the avalanche body. It can spread hundreds of meters ahead of the avalanche.

Avalanche deposits (or snow deposits) are snow and loose debris carried from the slopes by an avalanche.

Spontaneous avalanches occur due to natural causes, when the snow cover on the slopes loses stability due to unfavorable meteorological or snow conditions.

Triggered avalanches are caused by external forces (humans, animals, explosions). It is easy to trigger an avalanche. This makes avalanches different from the other natural hazards [2].

In the international risk assessment system, there are several gradations with three or five points. Typically, an «avalanche risk» is acceptable, increased and unacceptable. If the risk is acceptable (low), there is no need to organize avalanche protection. In case of increased risk, it is necessary to do. If the risk is unacceptable (high), protecting the population and facilities can be more expensive than relocating to a safe location.

An avalanche risk assessment is necessary for organizing avalanche control measures.

The avalanche catchment area or the avalanche center is a fixed place where avalanches are regularly recorded. It is divided into the origin zone, 35-450, the transit zone, 20-300 and the deposition zone, less than 150. In such avalanche catchments as a funnel or a tray, avalanches are of the canalized (tray) type. On slopes without a clearly defined drainage channel, wasp-type avalanches are observed (according to the classification by G.K. Tushinsky). Complex avalanche catchments with branching drainage channels are called dendritic; several avalanche centers having a common deposition zone are called an avalanche basin [2].

Results and discussion

The Serebryanskaya track maintenance department is located in the East Kazakhstan region.

The Kazakhstan part of the Altai Mountains is a vast mountainous region occupying most of the East Kazakhstan region. It consists of several large ridges. The mountainous regions of the East Kazakhstan region include the Tarbagatai, Sauyr, Kalbinsky, Western and Southern Altai ridges. The Kazakhstan Altai is characterized by large snow cover over a large mountain area and a wide variety of genetic types of avalanches. In all the mountainous regions of Eastern Kazakhstan, avalanches are possible, with the exception of the territories of intermountain basins. Avalanche activity, as in any mountains, depends on the type of terrain. The mountains of Eastern Kazakhstan are characterized by three types of relief.

1. Alpine (2000-4500 m): sharply dissected, not widely distributed (the Belukha mountain massif, watersheds of the Southern Altai ridges, the Kholzun ridge, etc.). The highest of them are occupied by glaciers and snowfields, individual slopes reach the steepness of 40-700, and the height of avalanches is 1000-1500 m. This belt is characterized by severe avalanche hazard. Avalanches occur annually, in some areas several times during the winter. Extremely avalanche-prone areas include the basins of the Gromotukha rivers, the upper reaches of the Turgusun and Belaya Berli, the Ivanovsky ridge, etc.

2. Mid-mountain (1000-2000 m): sharply

dissected with a dense network of erosional ravines, having a wider distribution. It is developed in the middle reaches of the Berli and Buktyrma rivers and stretches in a narrow strip to the west in the upper part of the northern slope of the Tarbagatai and Sarymsakty ridges. It occupies significant areas of the Kholzun ridge and the eastern part of the Ivanovo ridge. The maximum avalanche catchment areas reach 1 million m3 or more, and the steepness of the slopes is 25-600. One of the features of the middle mountains is the presence of separate continuous avalanche areas, up to several kilometers long. This belt is characterized by areas with significant or severe avalanche hazard. In the areas with significant avalanche activity, isolated avalanches occur annually, and a mass avalanche occurs at least once every 5 years.

3. Low-mountain (300-1000 m): rugged, steeply sloped terrain, most developed in the valley areas of the Ertis and Buktyrma rivers, on the southern slopes in the Southern Altai system (Kalbinsky ridge). The avalanche catchment areas are small and range from 5 to 200 thousand m^2. In this type of relief, both southern treeless slopes (avalanches occur here mainly in the form of wasps) and northern, often leeward slopes, where flume avalanches predominate, are dangerous for avalanches. The steepness of the slopes has a wide range, from 20 to 450, and the height difference from 50 to 500 m. Low-power avalanches with the volume of up to 500 m^3 occur here almost every year, even several times during the winter. This belt is also characterized by areas with moderate avalanche danger: no more than once every 5-7 years (for example, along the Ust-Kamenogorsk–Serebryansk and Ust-Kamenogorsk–Samarka highways), the Novo-Ust-Kamenogorsk–Zyryanovsk railway section.

An insignificant avalanche hazard (individual avalanches in exceptionally snowy winters) is characteristic of the mountainous area northeast of Lake Zhaisan in the Narymsky ridge [2] with an avalanche with the volume of 100 m^3, 1-2% people die, with the volume of 500 m^3 50%, and with the volume of 1000 m^3 70% [3].

The destructive power of avalanches can be seen in Table 1.

The probability of avalanche formation depends on natural factors, the main ones being the steepness and roughness of the slope and the height of the snow cover.

Traditionally, an avalanche is understood as a rapid mass of snow with a dust cloud. But an avalanche can be in the form of a sheet shift, in the form of a snow board. A snow board is a scientific glaciological term that means the compressed top layer of snow. This layer of snow, under certain conditions, shifts over the underlying, loose layer. A snow board can move very long distances: tens, hundreds of meters.

Ninety-nine percent of avalanche events fall between 25 and 45 degrees of the slope steepness.

Figure 1 shows the dependence of the conditional probability of avalanche formation on smooth grassy slopes on the snow angle [3].

If the slope has the steepness of less than 25°, then the probability of avalanche formation does not exceed 0.1% per year. In the range of 25-30° it quickly increases, reaching the maximum at 35°, and then 45° remains high and constant. On slopes that are steeper than 45°, the probability of avalanche formation drops sharply, since snow does not linger here and the snow cover does not form.

Thus, under the most favorable conditions, the probability of avalanche formation on slopes above 25° is less than 0.1% per year. There are cases of avalanches from more gentle slopes. This value differs significantly from that recommended by other authors: 17°.

The probability of avalanche formation can be above zero even with the snow cover height of 10 cm. This took place in the Trans-Ili Alatau in the period from 1973 to 1988. They had small volumes, point separations, and were not dangerous to a person or structure.

As shown in Figure 2, with increasing snow

Table 1 – Possible damage depending on the volume of the avalanche

Avalanche volume, type	Possible damage	Vertical fall	Volume, m^3	Impact pressure, Pa
Small snow slide	Safe	10	1-10	Lower than 10^3
Small avalanche	Swamps, injures or kills a person	$10\text{-}10^2$	$10\text{-}10^2$	10^3
Medium avalanche	Destroys a wooden building or vehicles	10^2	$10^3\text{-}10^4$	10^4
Large avalanche	Destroys a village or a forest	10^3	$10^5\text{-}10^6$	10^5
Extreme avalanche	Plows up the riverbed, destroys the city	$10^3\text{-}10^4$	$10^7\text{-}10^8$	$10^5\text{-}10^6$

depth, the proportion of avalanche-active slopes increases [3].

Figure 2 shows that the characteristic feature is a wide variation in the probability of avalanches from year to year with a constant snow depth. With a snow cover height of 80 cm, from 5 to 30% participate in avalanche formation; with avalanche-active slopes over 140 cm from 25 to 80%. The dependence reveals the constancy of the avalanche formation probability at a snow height of more than 150 cm. Under these conditions, it is equal to an average of 50% at standard deviation of 15%.

The likelihood of avalanches in deep snow is explained by the absence of loosening horizons at the a depth of more than 200 cm from the upper boundary of the snow layer.

With such a thickness of snow, the loosening processes are damped due to the compaction of the snow cover due to the mass of the overlying layers. Thus, in the formation of avalanches from snow boards, loose layers play an exceptional role; the upper layer (150-200 cm) always participates in avalanche formation, regardless of the total thickness of the snow cover.

The roughness of the underlying surface affects the probability of avalanche formation only up to a certain thickness of snow necessary to level out the unevenness. This limit is approximately equal to the characteristic height of irregularities.

For comparison, if the roughness of a rocky slope is 40 cm, then the probability of an avalanche on it with the snow layer of 70 cm will be proportional to the probability of an avalanche on a grassy slope with the roughness of 10 cm and the snow height of 40 cm.

It is more difficult to observe the process of avalanches on slopes covered with bushes and forests.

For a slope overgrown with bushes, it has been established that to remove the effect of roughness, it is necessary to accumulate snow

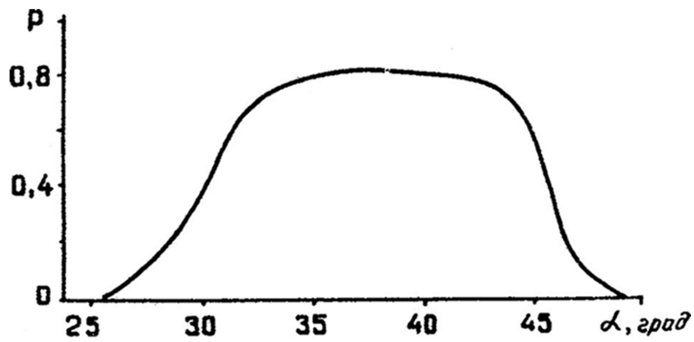

Figure 1 – Probability P of avalanche formation on various slope steepness a with the snow height of 100 cm

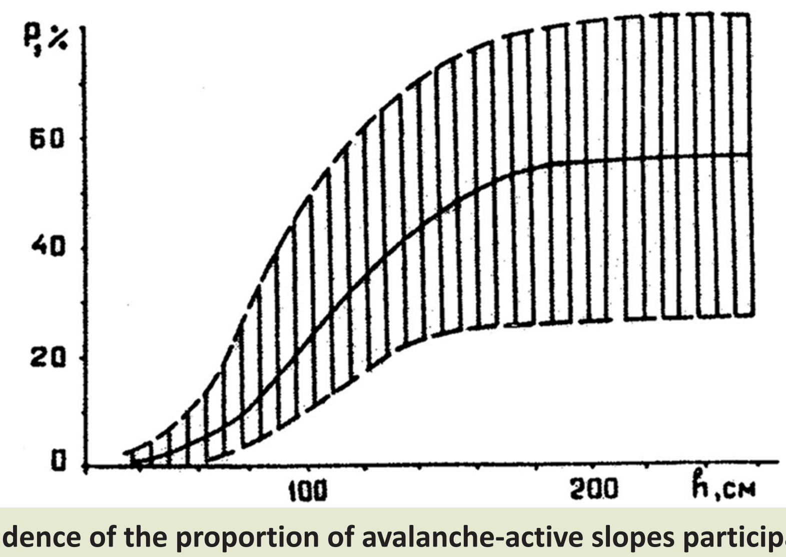

Figure 2 – Dependence of the proportion of avalanche-active slopes participating in avalanche formation P on the snow cover height h

on it at 50-70% of the height of the bushes. This mass of snow bends the branches of the bush, and they can no longer hold layers of snow.

The presence of coniferous forest is not a guarantee that there will be no avalanches.

Let's say the height of the trees is 15-20 meters, and the snow is from 6 to 8 meters, then avalanches form between the trees, and not under the crowns.

On forested slopes, avalanches occur mainly with a point release, and not on a large area (snow board). The area of 100 m2 is sufficient for the occurrence of avalanches that have the energy to break trees. At first, the snow slide flows around the tops of trees sticking out of the snow, and then, picking up speed, breaks them.

Observations of avalanches in Kazakhstan (Trans-Ili Alatau) show that their number per 1 km2 of a slope steeper than 25 degrees on grassy slopes is 10 times greater than on those overgrown with trees.

Using the above-described probabilities of avalanche formation at different snow heights, slope steepness and type of underlying surface, one can compile a table (Table 2) and find the probability of avalanches on any slope of the study area, in our case Altai [3].

The thickness of the snow layer, the angle of inclination of the slope, the type of slope (grassy, rocky, etc.), the length of the avalanche-prone area, the run and the kilometer on which this section is located along a given path distance are given in Table 3 [7].

According to SNiP [4], avalanche zones are divided into five areas: 1 – areas with significant avalanche danger: avalanches occur frequently and annually; 2 – areas with average avalanche danger: the avalanche network is depleted, avalanches do not occur every year; 3 – areas with low avalanche danger: avalanches occur in isolated places and in heavy snowy winters; 4 – areas with potential avalanche danger (currently safe but can become avalanche dangerous due to deforestation, excavation on slopes, etc.); 5 – non-avalanche hazardous areas.

The result of the study was the development of standard technological flowcharts for snow removal work on the main railway network of the NC KTZh JSC.

The Serebryanskaya track maintenance department is located in the 1st type of avalanche hazardous areas.

In the same SNiP [4], the Serebryanskaya department has the volume of snow transfer from 600 to 1000 m^3/m during the winter.

In the same source [4] one finds out that Zyryanovsk and Ust-Kamenogorsk stations have the maximum average speed, 5.7 m/sec, which makes the 4 point on the Beaufort scale, the wind is moderate.

The railway line Oskemen-1 – Zyryanovsk passes through a very complicated terrain region of the Altai Mountains. The roadbed is in plan limited on one side by the waters of the Ust-Kamenogrsk and Bukhtarminsk reservoirs, and on the other side by the steep slopes of mountain ranges, the presence of which provides a certain danger for train traffic due to the presence of rock falls, snow avalanches, mudflows and landslides. Over the course of 172 kilometers, there are 367 curved sections of the route. There are a large number of artificial structures on the Serebryanskaya track department, among them metal bridges – 16 pieces, reinforced concrete bridges – 48 piec-

Table 2 – Probability of avalanche formation (%) depending on the state of the underlying surface, slope steepness and snow height

State of the underlying surface	Slope steepness, deg	Snow height, cm								
		10-30	30-70	70-100	100-150	150-200	200-250	250-300	300-500	Over 500
Ice, firn, grass, rubble	20-25	0.1	0.1	0.2	0.5	0.7	0.7	0.7	0.7	0.7
	25-30	0.2	1.0	6.0	10	20	20	20	20	20
	30-45	1.0	3.0	20	35	55	55	55	55	55
Stones with the average diameter of 30-50 cm, bushes 50-100 cm high	20-25	-	-	0.1	0.1	0.2	0.5	0.5	0.7	0.7
	25-30	-	0.1	0.2	1.0	6.0	10	10	20	20
	30-45	-	0.1	1.0	3.0	20	35	35	55	55
Trees 15-20 m high with a projective cover of more than 70%	20-25	-	-	-	0.1	0.1	0.1	0.1	0.1	0.5
	25-30	-	-	-	0.1	0.3	0.5	0.5	2.0	5.0
	30-45	-	-	0.1	0.5	1.0	2.0	2.0	10	20

Table 3 – Characteristics of avalanche areas on the Serebryanskaya track maintenance department

No	Run	Km	Length, m	Av. snow accumulation, cm	Slope type	Note
1	Novo-Ust-Kamenogorsk – Yermakovka	21, 22, 26, 27, 28, 30, 31, 33	400	0.7-1.2	rocky, stony	Height from 15 to 25 m, slope from 45 to 85 degrees
2	Yermakovka – Ognevka	41, 49, 58, 60	200	0.5-1.1	rocky, stony	Height from 20 to 125 m, slope from 35 to 75 degrees
3	Ognevka – Serebryanka	71, 72, 73, 74	250	0.8-1.3	rocky, stony	Height from 10 to 75 m, slope from 30 to 90 degrees
4	Zavodinka-Turgusun	144, 146, 147, 157, 158, 161	320	1.5-2.0	rocky, stony	Height from 15 to 75 m, slope from 25 to 85 degrees
5	Turgusun-Zyryanovsk	165, 166	160	1.8-2.2	rocky, stony	Height from 6 to 15 m, slope from 30 to 85 degrees

es, tunnels – 2 pieces, culverts – 168 pieces, retaining and catching walls – 80 pieces, existing landslide galleries – 12 pieces, unfinished galleries – 2 pieces, with the length of 385 m on 47 km pk 1 – 75 m, at 71 km pk4 – 310 m [7].

Clearing the track of snow on stretches to eliminate the consequences of snow avalanches on the track should be, as a rule, carried out by snow clearing units of the branch of the NC KTZh JSC, the Serebryanskaya track maintenance department [9].

Workers of the department monitor the condition of avalanche control devices and structures, supervise the avalanche-prone area, maintaining the passport form PU-9, in accordance with the local Guidelines approved by the head of the Serebryanskaya track maintenance department [10].

Conclusions

1. It is necessary to continue studies in this area.
2. It is necessary to continue engineering measures along the track: in terms of preparing avalanche warning and avalanche protection structures to build 2 galleries and to increase the length of retaining walls at 73 and 58, 59, 60 kilometers with the length of 300 m each. It is also necessary to complete the unfinished galleries at 47 km pk1 – 75 m, at 71 km pk4 – 310 m.
3. To strengthen preventive measures: survey work, avalanche monitoring and forecasting, artificial avalanche release, installing automated weather stations in dangerous areas.
4. The Department of Track and Facilities of the NC KTZh JSC should rank track departments, taking into account their work in the winter; improve staffing, funding, supplying modern snow removal machines, etc.
5. Where possible, it is needed the afforestation of slopes, i.e. providing forest plantations.
6. There is required further study of the effect of earthquakes and wind speed on avalanches.
7. According to the international system of risk assessment (avalanche hazard), the Serebryanskaya track maintenance department is classified as increased hazardous; there is needed organization of avalanche protection.

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Серебрянск жолының мысалында көшкін қаупі бар аудандарда жол учаскелерін пайдалану

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Аңдатпа. *Қар көшкінімен күрес және олардың зардаптарын жою өзекті болып табылады. Мақаланың мақсаты – қар көшкінін, әсіресе кенеттен, бірақ тек жоспарлы түрде болғандардың алдын алу шараларын әзірлеу. Зерттеу пәні – қар көшкіндері, олардың көлемі, түсу себептері. Мақалада География және су қауіпсіздігі институтының әдістемелік әзірлемелері, Серебрянская жол дистанциясы тәжірибесінің практикалық тиімділігі пайдаланылады. Зерттеу нәтижесінде «ҚТЖ» ҰК» АҚ магистральдық желісіндегі қардан тазалау жұмыстарының типтік технологиялық карталары әзірленді. Жүк пойыздары тәулігіне 1000 км жол жүреді. Бұл жылдамдықты тәулігіне 1200 км-ге жеткізу керек. Өңдеу өнеркәсібі мен құрылыс саласы дамиды, олардың өсімі 4,7% деңгейінде болады. Номиналды ЖІӨ 75 трлн теңге, 2020 жылы 106 трлн теңгені құрады.*

Кілт сөздер: *қар, еңіс, көшкін, көшкін қаупі бар аймақ, көшкін денесі, соққы толқыны, көшкін көлемі.*

Эксплуатация участков пути в лавиноопасных районах на примере Серебрянской дистанции пути

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Аннотация. *Борьба со снежными лавинами и ликвидация их последствий являются актуальными задачами. Целью исследования статьи является разработка мероприятий по недопущению схода лавин, особенно внезапно, а только запланированных. Предметом исследования являются снежные лавины, их объемы, причины схода. Результатом исследования стала разработка типовых технологических карт на работы по снегоборьбе на магистральной сети АО «НК «ҚТЖ». В сутки грузовые поезда проходят 1000 км. Необходимо довести данную скорость до 1200 км/сутки. Номинальный ВВП составил 75 трлн тенге в 2020 году, в 2024 году составит – 106 трлн тенге. Все это потребует перевозки строительных материалов и полезных ископаемых, бензина и дизтоплива, зерна и муки, удобрений, семян, гербицидов и пестицидов, продуктов растениеводства и животноводства.*

Ключевые слова: *снег, склон, лавина, лавиноопасная территория, тело лавины, ударная волна, объем лавины.*

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