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Satbayev University

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ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
РЕСПУБЛИКИ КАЗАХСТАН
Satbayev University

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НАН РК сообщает, что научный журнал «Известия НАН РК. Серия геологии и технических наук» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Включение Известия НАН РК. Серия геологии и технических наук в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по геологии и техническим наукам для нашего сообщества.

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NEW METHODS TO PROTECT YEAR-AROUND OPERATION CANALS FROM SNOW

Abstract. On the canals of year-around operation, severe snowdrifts concentrated on the surface of the ice cover simultaneously affect both thermal and static loads. When ice melts intensively from the lower surface in areas of accumulation of snow masses, and also due to an increase in the static load from snow, longitudinal cracks form on the ice. The snow saturated with water rising up along the cracks, and a gradual sinking of the snow-ice mass occurs. All this leads to decrease in canal capacity, and in some cases to complete blockage of the flow section by snow-ice mass. The purpose of the paper is to find new ways to protect the canal drift and create an impervious canal profile in areas heavily covered in snow. Snow deposition in the canal bed occurs gradually, starting from the edge of canal closest to the snow collection basin side, followed by an increase in the snowdrift shaft in the direction of the wind as snow blizzard arrives to the canal. We propose the method of protecting the canals from snowdrifts by changing the transverse profile of the canal in the sections highly covered by snow. The transverse canal profile is changed by adding a berm to it with a slope coefficient equal to the coefficient the leeward slope and a height equal to the depth of the canal from the leeward slope depending on exact establishing the limit position of the surface of the snowdrifts, at which the canal is blown without snow deposition, regardless of the amount of snow transfer. The proposed methods can be applied in areas of snow transfer on watering and irrigation canals designed for year-around operation.

Key words: ice cover, berm, slope coefficient, canal depth, snow deposition.

Introduction. On the canals of year-around operation, powerful snowdrifts concentrated on the surface of the ice cover simultaneously affect both thermal and static loads. As ice melts intensively from the lower surface in areas of accumulation of snow masses, and also due to an increase in the static load from snow, longitudinal cracks form in the ice. The snow is saturated with water rising up along the cracks, and a gradual sinking of the snow-ice mass occurs. All this leads to a decrease in canal capacity, and in some cases to complete blockage of the flow section by snow-ice mass.

In such areas, a powerful blockage field is formed, which prevents the flow of water through the water supply path below this section. Above the ice jam, the water level rises sharply, which leads to emergency situations. On the Irtysh-Karaganda canal, over the period of its operation, such phenomena have been repeatedly observed. For example, in the winter of 1971-1972, on canal No. 38 (146-155 km of the route) as a result of blockage of the flow section of the canal by snow-ice accumulations, a powerful ice jam with a total length of about 5 km was formed. As a result of this phenomenon, water supply through the canal was stopped until the end of April. Attempts to eliminate the jammed area with an explosion or mechanical cleaning by excavators did not produce the expected effect. Firstly, the access roads to the canal were covered with snow, secondly, the length of the boom of power shovel of the excavator did not allow to completely clear the canal and, thirdly, the snow jam area was quite long (3830 m). they succeeded in eliminating the snow jam area with a series of dynamic pumping only after the onset of thaws before the flood (the third decade of April).

In 1974-1978 VNIIG was engaged in the research of the issue and development of snow protection measures on the Irtysh-Karaganda canal. In their work, a detailed analysis of the causes of snow-ice difficulties on canals of year-around operation was given and a set of engineering measures to prevent them was proposed. The essence of these measures is the construction of contour snow lines in the form of fences and forest belts. They also proposed a method for arranging a section of a canal not covered by snow, including the construction of an additional canal passing in a deep excavation for accumulation of snow [1].

In recent years, scientists of the Kazakh Scientific Research Institute of Water Management and the Taraz State University named after M.Kh. Dulati have dealt with issues of snow protection of hydraulic structures, including canals. On the basis of long-term field and laboratory research carried out on existing canals, as well as analysis and generalization of the experience of snow protection means at other objects of the national economy, methods of protection of hydraulic structures from snow wreaths are proposed [2-4].

Materials and methods. For a specific section of the canal, considering the volume of snowfall unlimited, we can determine the state of the maximum filling of the canal bed with snow. But not always the amount of incoming snow to the canal is sufficient for its filling to the limit position. If the total volume of snow arriving during the winter period is less than the maximum accumulating capacity of the canal, then its cross section is not completely filled to the maximum position, but partially. In order to estimate the parameters of snow wreath during partial drift from the maximum possible, having data on the volume of snowdrifts and the geometric parameters of the canal cross section, it is necessary to establish the sequence of filling (dynamics of drift) of the canal with snow as snow mass arrives. The dynamics of snowdrift is closely related to the occurrence of a blizzard [5].

Snow deposition in the canal bed occurs gradually, starting from the canal edge closest to the snow collection basin side, followed by an increase in the snowdrift shaft in the direction of the wind as blizzard snow arrives at the canal. This picture of the sequence of filling the canal bed with snow during blizzards is fully confirmed by the results of field research performed on existing canals [6]. Figure 1 shows the profile of snowdrift in the canal named after K.I. Satpayev as it fills during the winter.

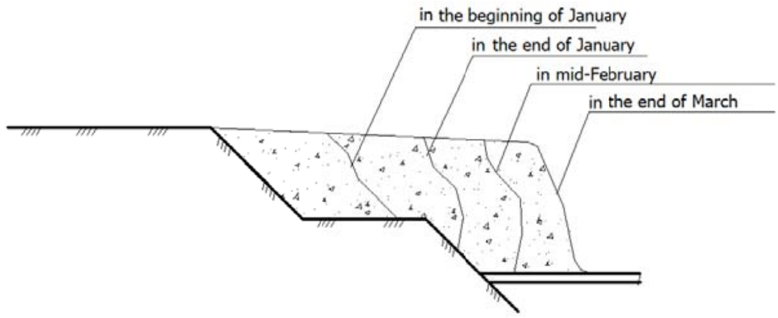

Figure 1 – Snowfall profile in canal bed

As can be seen from figure 1, the front edge of the unfinished snow drift is a steep slope with a peak-like protrusion in the upper part. Incomplete snow drifts are limited during blizzards from above by a straight flow, in the front edge – by a circulation flow. A peak-like protrusion of snowdrift is formed at the junction of these two flows.

Significant practical importance in evaluating the maximum snow tolerance of canals, is the exact establishment of the extreme position of the surface of the snowdrift (snow slope). Snowdrifts in the canal bed from all sides, except for the upper surface, form a circle around the cross section of the canal and take its form. Having determined the position of the snow slope and having data on the design parameters of the canal cross section, with sufficient accuracy we can determine the cross-sectional area or the volume of snowdrift per unit length of the canal, and estimate the load from the snowdrifts on the ice cover. As observations have shown, the slopes of snowdrifts fluctuate in rather large limits depending on various factors. First of all, the slope of the surface of the snowdrift depends on the speed of the incident flow, at which the drift was formed on the physicomechanical properties of the snow particles involved in the snowdrift transport.

Snowdrift transfer begins with the appearance of a critical speed. The condition for the onset of particle surface transfer is expressed by A.K. Dune [5] (Eq. 1):

$$v_n < \alpha \sqrt{s_0 \left(\frac{\rho_s}{\rho}\right) g\delta + \frac{\tau_\varepsilon}{\rho}} \quad (1)$$

where v_n – wind speed at which particle transfer is not yet occurred; α – dimensionless coefficient depending on the characteristics of the surface vortex layer and the wind velocity profile; S_0 – volume concentration of particles on the surface of the snow cover; ρ_s, ρ – accordingly, the mass density of particles and air, g – gravity acceleration, m/s^2; δ – particle size, m; τ_ε – adhesion between particles and the underlying surface.

The purpose of the laboratory test was to study the effect of snowdrift on open reclamation canals. For this, such instruments and devices were used. Mechanical fan system: tangential helical ventilation unit YGFC60.183, electric voltage 220V, 50Hz, 0.27A; power 25W, rotation speed 1300 rpm, air flow 140 m^3/h, drum diameter 60 mm, drum length 183 mm (figure 2).

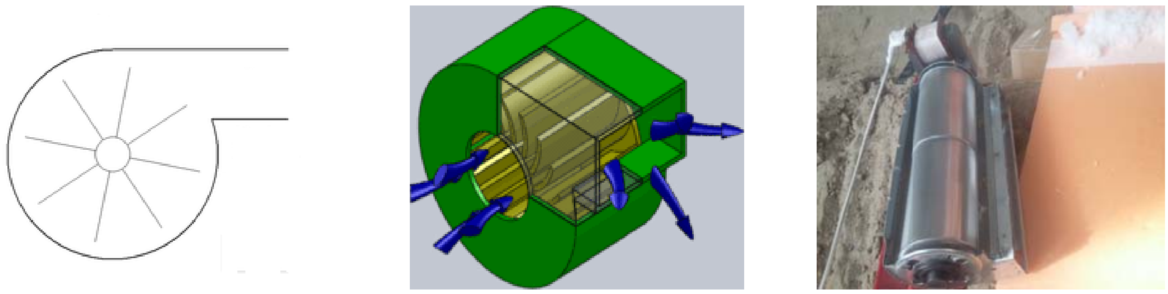

Figure 2 – Tangential helical ventilation unit

During the experiments, 4 ventilation units were used. The units were arranged for the S12-MK research stand. The ventilation unit speed was determined by an electronic anomometer and its maximum value reached 6.2 m/s. Turning on the tangential ventilation unit, the model was aimed at snow, which was directed into the opposite open reclamation canal (figure 2). Two types of canal model were made of penoplex material: a trapezoidal section with a length of 120 cm, a slope of 1:1, a depth of 11 cm and a width of 16 cm, as well as a canal model passing through a recess.

Results and discussion. According to the results of field observations of various authors, snow transport begins at wind speeds in the boundary layer of 2-5 m/s [2,5,7-14]. The formula for the initial snow transfer rate (1) is valid for horizontal terrain. On canals, the surfaces of snowdrifts, depending on their location, have positive or negative slopes relative to the direction of the wind. If the slope of the surface of the snowdrift in the direction of the wind is directed downward, then more favorable conditions are created for the movement of snow particles, which occurs at lower flow rates, compared with horizontal terrain. In such cases, the snow slope at the extreme position becomes steeper.

Let`s onsider the condition for the formation of the marginal snowdrift from the windward side of the spoil band. The wind stream, approaching the spoil band, smoothly goes around it from above. According to the experimental data from the continuity of flow (Eq. 2) stream jets around a spoil bank change their direction:

$$\psi_{(y)} = \int_0^y v dy\,, \quad (2)$$

The speed at each point of the jet can be divided into horizontal and vertical components v_x and v_y. The steeper the slope, the greater the vertical component. The resultant velocity is (Equation 3):

$$v = \sqrt{v_x^2 + v_y^2}\,. \quad (3)$$

The windward slope of the spoil band can be divided into two zones: the snow deposition zone and the snow blowing zone. In the deposition zone, the vertical velocity component v_y deflected by the slope, less than the hydraulic size of snowflakes ω. During snowstorms, in case of horizontal terrain, wind simultaneously acts by force (Eq. 4):

$$P_w = \frac{Kv^2}{2g} \quad (4)$$

and friction force in the opposite direction to the wind, equal (Eq. 5):

$$P_{fr} = Gf_{fr}, \quad (5)$$

where v – wind speed; G – snowflake weight; f_{fr} – coefficient of friction of snowflakes on the underlying surface.

When the condition is met $P_w \leq P_{fr}$ snowflake is at rest. With increasing wind force at $P_w > P_{fr}$ snowflake will be transferred. On inclined terrain (both on the ascent and on the descent), the conditions for equilibrium and transfer of snowflakes are different compared to horizontal terrain. The force of the wind acting on sloping terrain, taking into account (Eq. 6) equals (Eq. 7):

$$v^{\varphi} = \frac{U^{(\varphi)}}{\cos\varphi} \quad (6)$$

$$P_w^{(\varphi)} = \frac{K(U^{\varphi})^2}{2g\cos^2\phi}, \quad (7)$$

where φ – the angle of inclination of the underlying surface; $U^{(\varphi)}$ – horizontal component of wind speed.

The friction force of snowflakes on the underlying surface on an incline is (Eq. 8):

$$P_{fr}^{(\varphi)} = G\left(\cos\varphi\, f_{fr} \pm \sin\varphi\right). \quad (8)$$

In formula (8), the plus sign corresponds to the ascend, and the minus sign to the descent of the underlying surface in the direction of the wind. The value of the critical wind speed, respectively, for the windward and leeward slopes, we find from the condition of equality of forces acting on the snowball (Eq. 9) or horizontal component (Eq. 10):

$$v_{cr}^{(\varphi)} = v_{cr}\sqrt{\cos\varphi \pm \frac{\sin\varphi}{f_{fr}}} \quad (9)$$

$$U_{cr}^{(\varphi)} = v_{cr} \cdot \cos\varphi\sqrt{\cos\varphi \pm \frac{\sin\varphi}{f_{fr}}} \quad (10)$$

where v_{cr} – critical wind speed corresponding to the beginning of snow transfer, v_{cr} = 3 – 5 m/s; $U_{cr}^{(\varphi)}$ – horizontal component of speed corresponding to the beginning of snow transfer.

On an inclined surface with a descent, the friction force of a snowflake on the underlying surface decreases compared to horizontal terrain, while when climbing it increases. Having determined the value of the initial snow transfer rate, and using the law of a rectilinear increase in the thickness of the boundary layer, we can find the slope coefficient of the snow drift. The equation of averaged turbulent motion in the boundary layer by G.N. Abramovich [15] obtained in the form of the formula (Eq. 11):

$$\frac{U}{U_0} = 0.017^{-\phi} + 0.6623e^{\frac{\phi}{2}}\cos\left(\frac{\sqrt{3}}{2}\right)\phi + 0.228^{\frac{\phi}{2}}\sin\left(\frac{\sqrt{3}}{2}\right)\phi \quad (11)$$

We have filed applications to obtain patents for a utility model for such methods and designs as, a method of protecting canals from snowdrifts, a method of protecting canals passing in recesses from snow drifts, a method of protecting canals from snowdrifts and groundwater, a device for accelerating ice formation on a canal [5,17-19]. A method of protecting canals passing in the recesses from snow drifts [17]. The proposed method of snow protection is implemented as follows. Cut the ground of the windward (2) edge at a distance (Eq. 12) from the edge of the recess with a slope $m_0 h\sin\alpha$ as shown in Figure 2.

$$L = m_0 h\sin\alpha \quad (12)$$

With such transverse profiles, snowdrifts fill only ditch (6) and on the transitional part (1) of the canal non-accumulative snow transfer during snowstorms is provided. The principle of the method of protecting the canals passing through the recesses from snow drifts is as follows. The transverse profiles of the canals passing through the recesses consist of the transitional part of canal (1), the slope of the recess (2), the line for cutting the windward edge of the recess (3), the line of limiting snow drift before the cutting of the windward edge (4), the contour of the soil cut of the windward edge (5) and deposition of snow drift in the ditches (6) (figure 3).

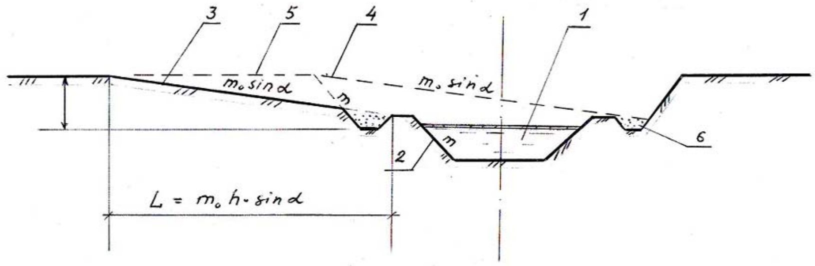

Figure 3 – The protection scheme of the canals passing on the recesses from snowdrifts

The snow shaft is formed in the recesses with a certain slope, called the natural slope of the snow drift m_0, numerically equal to 8-12, depending on the wind speed and the initial snow transfer speed. In oblique winds, due to the preservation of the slope in the direction of the wind, the coefficient of natural slope of the snowdrift, taken along the normal to the recess, is equal to $m_0 h \sin\alpha$, where α – is the angle of attack of the wind. In this case, when the slopes of the underlying surface are corresponding to $m_0 h \sin\alpha$, snow deposits during snowstorms will not occur.

The method to protect the canal from snowdrifts and groundwater [18] by placing forest belts along the canal differs from other methods in a way that placed along the irrigation and watering canals plantings of well-blown forest strips without shrubs protects from the prevailing wind, preventing the accumulation of snowdrifts and snow and rise in groundwater possible from this. Such conditions are created when the forest belts protect the canals well from snow drifts and a significant part of the vertical filtration flow from the canals supplying groundwater will be intercepted by the roots of the trees and the harmful effects of irrigation water will be suspended.

Larger canals of year-around operation, designed to transport water in the early spring, suffer, as a rule, from snowdrifts. Smaller canals, operating only during the growing season, usually suffer from drifts by products of wind erosion – soil, saltwort plants, garbage [1]. The characteristics of the canal network are considered from the perspective of their influence on the wind flow. Having estimated the nature of the wind flow around the canal cross sections, we can predict the canal insertion. In areas of recesses with an intermediate berm, a decrease in the wind velocity in the boundary layer occurs at a certain distance from the canal, depending on which side the central bogie passes, that is, a wide intermediate berm. The widths of the intermediate berm are 1.0 and 8.0 respectively.

At the zero marks, the “dip” of the wind flow into the recess occurs directly from the edge of the recess of the canal. In the latter case, the width of the recess at the top is small, it is equal, respectively, to the width of the canal at the top, whereas in the previous case (with an intermediate berm), the decrease begins at some distances from the canal bed. In the sections of the cut-and-fill-embankment and embankment, the canal bed is raised above the level of the adjacent terrain. Therefore, the wind stream before flowing around the recess of the canal, narrows vertically, due to heap in bulk. The narrowing of the flow in turn causes a corresponding local increase in flow rate. The unevenness of the relief and the non-compliance of the general slope of the site with a longitudinal slope of the canal bottom is primarily the reason for such a wide variety of types of canal sections according to the conditions of the canal's location relative to the earth's surface. For this reason, even over the length of one canal, several types of sections can be found, according to the location of their canal relative to the mark of the adjacent territory.

Conclusions. The aim of the research was to create an uncoverable canal profile in areas heavy snow coverage. Snow deposition in the canal bed occurs gradually, starting from the edge of canal closest to the snow collection basin side, followed by an increase in the snowdrift shaft in the direction of the wind as blizzard snow arrives to the canal. This picture of the sequence of filling the canal bed with snow during blizzards is fully confirmed by the results of field tests performed on existing canals. Having established the patterns of snowdrift formation, having information about the amount of snow entering the canal, the speed of winter winds and the state of the snow cover for a specific area, we can calculate the snowdrift parameters with sufficient accuracy for any date and at any stage of snow removal.

The paper gives the theory, methods, research results, new methods and designs of patents for a utility model for such methods and designs as, a way to protect canals from snowdrifts, a way to protect canals passing through recesses from snowdrifts, a way to protect canals from snowdrifts and groundwater, a device to accelerate ice formation on the canal. These designs of the proposed devices are quite possible using available technical means based on the current level of technology and knowledge, because its design is quite simple, and the implementation of such devices has long been well mastered by relevant enterprises at various levels.

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ЖЫЛ БОЙЫ ҚОЛДАНЫСТАҒЫ КАНАЛДАРДЫ ҚАР БАСҚЫНЫНАН ҚОРҒАУДЫҢ ЖАҢА ӘДІСТЕРІ

Аннотация. Жыл бойы қолданыстағы каналдағы мұз жамылғысының бетіндегі қатты омбы қар жылулық және статикалық салмаққа бір уақытта әсер етеді. Қар жиналған жердегі беткі қабаттың астында мұз қарқынды ерігенде және қардан статикалық салмақтың ұлғаюына байланысты мұз бетінде созылған жарықтар пайда болады. Суланған қар жарық бойымен жоғары көтеріліп, қар мен мұз массасы жайлап төмен түсе бастайды. Мұз бетіндегі қар басқынының үлкен көлемдегі концентрациясы әсерінен мұз кептелістері пайда болып, каналдың өткізгіштік қабілеті төмендейді, ал кейбір жағдайларда тіптен тоқтап қалады. Көктем уақытында омпы қардың қарқынды еруі ағынды судың қосымша мөлшерінің пайда болуына ықпал етеді, ал бұл ірі каналдарда судың тепе-теңдігін сақтауда маңызды рөл ойнайды және ол көктемгі уақытта сумен қамтамасыз етуді жоспарлау кезінде ескерілуі тиіс. Сонымен қатар күртік қар еріген кезде қар суынан жер каналдары бермдері мен еңістерінің белсенді микроинтіректі эрозиясы байқалады. Басты ғимараттан суды алу кезінде еріген қар ағыны көлемінің азаюы көктемде апаттық жағдайға әкелуі мүмкін. Аталған мәселелер мақаланың өзектілігін көрсетеді. Соңғы жылдары Қазақ су шаруашылығы ғылыми-зерттеу институты мен М.Х. Дулати атындағы Тараз мемлекеттік университетінің ғалымдары гидротехникалық құрылымдарды, соның ішінде каналдарды қардан қорғау мәселелерімен айналысып келеді. Іс жүзіндегі каналдарда жүгізілген көпжылдық далалық және лабораториялық зерттеулердің, сонымен қатар халық шаруашылығының өзге объектілерінде қардан қорғау тәсілдерін қолдану тәжірибесін жалпылау мен талдау негізінде қар басқынынан гидротехникалық құрылымдарды қорғаудың тәсілдері ұсынылып отыр.

Мақаланың мақсаты – каналды қар басудан қорғаудың және қатты қар басқан учаскелердегі каналдың өткізбейтін пішінін құрудың жаңа әдістерін табу. Аталмыш мәселені зерттеудегі басты әдіс іс жүзінде бар каналдарда жүргізілген натуралық сынақтар болып саналады. Бұл боранда каналдың қарға толу тізбегінің келесідей бейнесін анықтауға мүмкіндік берді. Канал арнасына қардың толуы кезең-кезеңмен орын алады, яғни қар жинауға арналған бассейніндегі ең жақын орналасқан каналдың шетінен басталып, күртік қар қалыңдығы жел бағытына сай және қарлы боранның каналға жақындауына байланысты бірте-бірте өседі.

Эксперименттерге қарай отырып келесідей қорытынды жасауға болады: каналдарды қар басудан қорғайтын конструкцияға берілген патент тиімділігін көрнекі түрде дәлелдеді. Нәтижесінде қатты қар басқан учаскелердегі каналдың көлденең пішінін өзгерту арқылы каналдарды күртік қардан қорғаудың әдісі ұсынылып отыр. Каналдың көлденең пішіні қар көшкіні көлеміне тәуелсіз, қарсыз да үрленетін канал болған жағдайда күртік қар бетінің шектік қалпын дәл анықтауға байланысты ық болатын жаға еңісі коэффициентіне тең еңістік коэффициентімен және ық болатын жаға еңісінен басталатын канал тереңдігіне тең биіктікке сай үйіндіні қосу арқылы өзгертілген.

Ұсынылып отырған әдістер жыл бойы пайдалануға есептелген суару және суландыру каналдарындағы қар басқан учаскелерде қолданыла алады. Техникалық күй, құрылым материалдары мен жабдықтардың жеткілікті болуы, сонымен қатар заманауи технологиялар мен білім ұсынған әдісті күртік қар таралған учаскелерде іс жүзінде қолдануға мүмкіндік береді. Осыған ұқсас конструкцияларды ендіруді әртүрлі деңгейдегі сәйкес кәсіпорындар әлдеқашан жақсы игерген.

Түйін сөздер: мұз жамылғысы, берма, еңістік коэффициенті, канал тереңдігі, қар тұндыру.

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НОВЫЕ СПОСОБЫ ЗАЩИТЫ ЗАНОСИМОСТИ КАНАЛОВ КРУГЛОГОДИЧНОГО ДЕЙСТВИЯ

Аннотация. Сильные сугробы на каналах круглогодичной эксплуатации, сосредоточенные на поверхности ледяного покрова, одновременно влияют как на тепловые, так и на статические нагрузки. При интенсивном таянии льда с нижней поверхности в местах скопления снежных масс, а также из-за увеличения статической нагрузки от снега на льду образуются продольные трещины. Снег, насыщенный водой, поднимается вверх по трещинам и происходит постепенное опускание снежно-ледяной массы. Концентрация больших объемов заносов на поверхности ледяного покрова приводит к снижению пропускной способности каналов из-за образования ледяных заторов, а в некоторых случаях и к их полной остановке. Интенсивное таяние сугробов в весенний период приводит к образованию дополнительного объема стока, который играет важную роль в водном балансе крупных каналов и который необходимо учитывать при планировании водоснабжения в весенний период. Также при таянии сугробов наблюдается активная микрорычажная эрозия откосов и берм земляных каналов от талой воды. А занижение объема стока от талого снега при заборе воды из головного сооружения может привести к аварийным ситуациям весной. Перечисленные проблемы и делает данную статью актуальной. В последние годы ученые Казахского научно-исследовательского института водного хозяйства и Таразского государственного университета имени М.Х. Дулати занимались вопросами снегозащиты гидротехнических сооружений, в том числе каналов. На основе многолетних полевых и лабораторных исследований, проведенных на существующих каналах, а также анализа и обобщения опыта применения снегозащитных средств на других объектах народного хозяйства, предложены способы защиты гидротехнических сооружений от снежных венцов.

Целью статьи является поиск новых способов защиты канала от заноса и создания непроницаемого профиля канала на участках, сильно покрытых снегом. Ведущим методом к иследованию даной проблемы стали натурные испытания, проведенные на существующих каналах. Они позволили выявить следующую картину последовательности заполнения канала снегом во время метели. Отложение снега в русле канала происходит постепенно, начиная с края канала, ближайшего к краю бассейна для сбора снега, с последующим увеличением вала сугроба по направлению ветра по мере приближения снежной метели к каналу.

Из экспериментов можно сделать вывод, что полученный патент на конструкцию против снежного покрова каналов, наглядно доказал свою эффективность. В результате предлагается способ защиты каналов от сугробов путем изменения поперечного профиля канала на сильно заснеженных участках. Поперечный профиль канала изменен путем добавления к нему насыпи с коэффициентом уклона, равным коэффициенту подветренного уклона, и высотой, равной глубине канала от подветренного откоса, в зависимости от точного установления предельного положения поверхности сугробов, при котором канал продувается без снега, независимо от количества снегопереноса.

Предлагаемые способы могут применяться на участках снегопада на поливных и оросительных каналах, рассчитанных на круглогодичную эксплуатацию. Техническое состояние, наличие достаточного количества строительных материалов и оборудования, а так же современные технологии и знания позволяют реализовать предложенный способ на участках распространения сугроба. Внедрение подобных конструкций давно хорошо освоено соответствующими предприятиями различного уровня.

Ключевые слова: ледяной покров, берма, коэффициент уклона, глубина канала, осаждение снега.

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