ISSN 2518-170X (Online)
ISSN 2224-5278 (Print)

NEWS OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN, SERIES OF GEOLOGY AND TECHNICAL SCIENCES

№6
2025

ISSN 2518-170X (Online)
ISSN 2224-5278 (Print)

CENTRAL ASIAN ACADEMIC
RESEARCH CENTER

N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN, SERIES OF GEOLOGY AND TECHNICAL SCIENCES

6 (474)

NOVEMBER – DECEMBER 2025

THE JOURNAL WAS FOUNDED IN 1940

PUBLISHED 6 TIMES A YEAR

ALMATY, 2025

«Central Asian Academic Research Center» LLP is pleased to announce that "News of NAS RK. Series of Geology and Technical sciences" scientific journal has been accepted for indexing in the Emerging Sources Citation Index, a new edition of Web of Science. Content in this index is under consideration by Clarivate Analytics to be accepted in the Science Citation Index Expanded, the Social Sciences Citation Index, and the Arts & Humanities Citation Index. The quality and depth of content Web of Science offers to researchers, authors, publishers, and institutions sets it apart from other research databases. The inclusion of News of NAS RK. Series of Geology and Technical Sciences in the Emerging Sources Citation Index demonstrates our dedication to providing the most relevant and influential content of geology and engineering sciences to our community.

«Орталық Азия академиялық ғылыми орталығы» ЖШС «ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы» ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруда. Web of Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді геология және техникалық ғылымдар бойынша контентке адалдығымызды білдіреді.

ТОО «Центрально-азиатский академический научный центр» 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.

News of the National Academy of Sciences of the Republic of Kazakhstan. Series of geology and technology sciences.
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)
Owner: «Central Asian Academic Research Center» LLP (Almaty).
The certificate of registration of a periodical printed publication in the Committee of information of the Ministry of Information and Communications of the Republic of Kazakhstan № KZ50VPY00121155, issued on 05.06.2025
Thematic scope: *geology, hydrogeology, geography, mining and chemical technologies of oil, gas and metals*
Periodicity: 6 times a year.
http://www.geolog-technical.kz/index.php/en/

«ҚР ҰҒА» РҚБ Хабарлары. Геология және техникалық ғылымдар сериясы».
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)
Меншіктеуші: «Орталық Азия академиялық ғылыми орталығы» ЖШС (Алматы қ.).
Қазақстан Республикасының Ақпарат және коммуникациялар министрлігінің Ақпарат комитетінде 05.06.2025 ж. берілген № KZ50VPY00121155 мерзімдік басылым тіркеуіне қойылу туралы куәлік.
Тақырыптық бағыты: *Геология, гидрогеология, география, тау-кен ісі, мұнай, газ және металдардың химиялық технологиялары*
Мерзімділігі: жылына 6 рет.
http://www.geolog-technical.kz/index.php/en/

«Известия РОО «НАН РК». Серия геологии и технических наук».
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

Собственник: ТОО «Центрально-азиатский академический научный центр» (г. Алматы).

Свидетельство о постановке на учет периодического печатного издания в Комитете информации Министерства информации и коммуникаций и Республики Казахстан № KZ50VPY00121155, выданное 05.06.2025 г.

Тематическая направленность: *геология, гидрогеология, география, горное дело и химические технологии нефти, газа и металлов*

Периодичность: 6 раз в год.

http://www.geolog-technical.kz/index.php/en/

CONTENTS

NEWS OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC
OF KAZAKHSTAN, SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224–5278
Volume 6. Number 474 (2025), 180–194

https://doi.org/10.32014/2025.2518-170X.579

UDC 622.242.2

© Sh.M. Medetov, 2025.
Atyrau University of Oil and Gas named after Safi Utebayev,
Atyrau, Kazakhstan.
E-mail: medetov.76@mail.ru

SAFE TRANSPORTATION OF A DRILLING RIG DURING ROCKFALLS

Medetov Shokan — Candidate of Technical Sciences, Associate Professor of the Industrial and Technological Faculty of Atyrau University of Oil and Gas named after Safi Utebayev, Atyrau, Kazakhstan,
E-mail: medetov.76@mail.ru, orcid.org/0009-0002-0137-228X.

Abstract. The article discusses the specifics of the transportation of drilling rigs in mountainous and hilly areas of the Mangystau region, characterized by difficult terrain and an increased probability of rockfalls. Such conditions create significant risks for equipment and personnel, which requires the development of scientifically sound methods to improve transportation safety. The purpose of the study is to form recommendations on choosing the optimal ways to move drilling equipment along the slopes in the presence of rockfall threats. The analysis of existing engineering solutions, regulatory requirements and natural factors affecting transportation safety is carried out. Based on a system of differential equations, the dynamics of the movement of falling rocks is described, which made it possible to determine the trajectories of possible impacts and areas of potential impact on transported equipment. The parameters of the protective "shelf" are calculated and dependencies are proposed for choosing the width of the protective zones in accordance with the height and angle of the slope. Special attention is paid to engineering methods of protection, including strengthening slopes, installing retaining structures and rockfall barriers. The results obtained are aimed at reducing the risk of damage to machinery, increasing the safety of personnel and minimizing emergency production costs. The practical significance of the study lies in the applicability of the developed recommendations in the design of drilling rig transportation routes and engineering slope protection, as well as in the use of the proposed methods in educational, analytical and design research activities.

Keywords: drilling rigs, transportation safety, rockfall, Mangystau region, engineering protection methods

© Ш.М. Медетов*, 2025.
Сафи Өтебаев атындағы Атырау мұнай және газ университеті,
Атырау, Қазақстан.
E-mail: medetov.76@mail.ru

ТАСҚҰЛАУЛАР КЕЗІНДЕ БҰРҒЫЛАУ ҚОНДЫРҒЫСЫН ҚАУІПСІЗ ТАСЫМАЛДАУ

Медетов Шоқан — техника ғылымдарының кандидаты, Индустриалды-технологиялық факультетінің қауымдастырылған профессоры, Сафи Өтебаев атындағы Атырау мұнай және газ университеті, Атырау, Қазақстан,
E-mail: medetov.76@mail.ru, orcid.org/0009-0002-0137-228X.

Аннотация. Мақалада күрделі рельефпен және тас құлау ықтималдығының жоғарылауымен сипатталатын Маңғыстау облысының төбелі және таулы аудандарындағы бұрғылау қондырғыларын тасымалдау ерекшеліктері қарастырылды. Мұндай жағдайлар жабдықтар мен персоналға айтарлықтай қауіп төндіреді, бұл тасымалдау қауіпсіздігін арттырудың ғылыми негізделген әдістерін әзірлеуді талап етеді. Зерттеудің мақсаты - құлау қаупі болған кезде бұрғылау жабдықтарын көлбеу жерлерде жылжытудың оңтайлы әдістерін таңдау бойынша ұсыныстар қалыптастыру. Қолданыстағы инженерлік шешімдерге, нормативтік талаптарға және тасымалдау қауіпсіздігіне әсер ететін табиғи факторларға талдау жүргізілді. Дифференциалдық теңдеулер жүйесіне сүйене отырып, құлаған тау жыныстарының қозғалыс динамикасы сипатталды, бұл мүмкін болатын соққылардың траекториясын және тасымалданатын жабдыққа әсер ету аймақтарын анықтауға мүмкіндік берді. Қорғаныс «сөресінің» параметрлері есептелді және биіктік пен көлбеу бұрышына сәйкес қорғаныс аймақтарының енін таңдау үшін тәуелділіктер ұсынылды. Инженерлік қорғаныс әдістеріне, соның ішінде беткейлерді нығайтуға, тірек құрылымдарын орнатуға және құлауға қарсы тосқауылдарға ерекше назар аударылды. Алынған нәтижелер техниканың зақымдану қаупін азайтуға, персоналдың қауіпсіздігін арттыруға және аварияларлық-өндірістік шығындарды азайтуға бағытталған. Зерттеудің практикалық маңыздылығы бұрғылау қондырғыларын тасымалдау маршруттарын жобалауда және беткейлерді инженерлік қорғауда, сондай-ақ ұсынылған әдістемелерді білім беру, талдау және жобалау-зерттеу қызметінде қолдануда әзірленген ұсыныстардың қолданылуында жатыр.

Түйін сөздер: бұрғылау қондырғылары, тасымалдау қауіпсіздігі, тасқұлау, Маңғыстау облысы, инженерлік қорғау әдістері

© Ш.М. Медетов*, 2025.
Атырауский университет нефти и газа имени Сафи Утебаева,
Атырау, Казахстан.
E-mail: medetov.76@mail.ru

БЕЗОПАСНОСТЬ ТРАНСПОРТИРОВКИ БУРОВОЙ УСТАНОВКИ ПРИ КАМНЕПАДАХ

Медетов Шокан — кандидат технических наук, ассоциированный профессор Индустриально-технологического факультета, Атырауский университет нефти и газа имени Сафи Утебаева, Атырау, Казахстан,
E-mail: medetov.76@mail.ru, https://orcid.org/0009-0002-0137-228X.

Аннотация. В статье рассматриваются особенности транспортировки буровых установок в горных и холмистых районах Мангистауской области, характеризующихся сложным рельефом и повышенной вероятностью камнепадов. Подобные условия создают существенные риски для оборудования и персонала, что требует разработки научно обоснованных методов повышения безопасности транспортировки. Целью исследования является формирование рекомендаций по выбору оптимальных способов перемещения бурового оборудования по склоновым участкам при наличии угроз камнепадов. Проведён анализ существующих инженерных решений, нормативных требований и природных факторов, влияющих на безопасность перевозок. На основе системы дифференциальных уравнений описана динамика движения падающих горных пород, что позволило определить траектории возможных ударов и зоны потенциального воздействия на транспортируемое оборудование. Рассчитаны параметры защитной «полки» и предложены зависимости для выбора ширины защитных зон в соответствии с высотой и углом откоса. Особое внимание уделено инженерным способам защиты, включая укрепление склонов, установку удерживающих конструкций и противокамнепадных барьеров. Полученные результаты направлены на снижение риска повреждения техники, повышение безопасности персонала и минимизацию аварийно-производственных затрат. Практическая значимость исследования заключается в применимости разработанных рекомендаций в проектировании маршрутов транспортировки буровых установок и инженерной защите склонов, а также в использовании предложенных методик в образовательной, аналитической и проектно-исследовательской деятельности.

Ключевые слова: буровые установки, безопасность транспортировки, камнепад, Мангистауская область, методы инженерной защиты

Introduction. The oil and gas industry occupies a key place in the economy of Kazakhstan, being the main source of state budget revenues and a driver of the country's economic growth. Rich oil and gas reserves concentrated in such fields as Tengiz, Kashagan and Karachaganak provide Kazakhstan with the status of one of the world's leading hydrocarbon producers (Niyazbekova at all, 2018).

Oil and gas exports make up a significant part of the country's foreign trade balance, attract foreign investment and develop infrastructure. The oil and gas sector provides jobs for a large part of the population, not only directly, but also through related industries such as transport, processing, mechanical engineering and service Services. In addition, revenues from the oil and gas sector are sent to the National Fund of the Republic of Kazakhstan, which contributes to the strengthening of the country's financial stability, the development of social infrastructure and the implementation of major state programs. In the context of global energy transformation, the oil and gas industry also plays an important role in diversifying the economy and switching to more sustainable energy sources.

Thus, the oil and gas industry is a strategic sector of the national economy of Kazakhstan, having a significant impact on the economic development, social stability and international positions of the country (Saipov at all, 2017). Therefore, much attention is constantly paid to the growth rate of the oil and gas industry in our country. To solve the tasks of accelerating the growth of this industry, it is necessary to introduce many new fields into development, as well as sharply increase the volume of drilling operations for oil and gas. Drilling of oil and gas wells is a key stage in the process of hydrocarbon production and plays a fundamental role in the functioning of the oil and gas industry. This process provides access to underground oil and gas deposits, which makes it possible to obtain natural resources that serve as the basis for the production of fuel, chemical products and other industrial materials. Drilling rigs are used for drilling oil and gas wells (Nikolaev at all, 2009).

After the drilling of the well is completed, the drilling rig is transported to another drilling point. Transporting a drilling rig from one drilling point to another is a complex process that requires careful preparation and coordination. Depending on the design features of drilling equipment, mass and size, given distances and deadlines, condition of roads and other conditions, transportation is carried out in most cases by its own track, tow truck, heavy cargo trailer (Berdyguzhin at all, 2022). Huge reserves of oil and gas are concentrated in Mangystau region. Rich deposits of minerals are located on the territory of the region. Reserves of mineral raw materials are unique and practically unparalleled in World geology due to their diversity, the capacity of deposits, the convenience of their development. The main types of minerals are oil and liquefied petroleum gas. Most of the deposits are concentrated in the area of the New River City and on the Bozachi Peninsula. On the territory of Mangystau region, 59 oil and gas fields were explored, including: Aksaz, Aktoty, Arystanovskoye. The explored oil reserves in the region exceed 3 billion tons. In addition, large oil reserves are expected to be found on the shelf of the Caspian Sea off the coast of the Region (Melihov, 2018).

In order to fulfill the tasks set by the Government of the Republic of Kazakhstan for drillers to increase the volume of drilling operations, drilling of oil and gas wells is carried out not only in flat areas, but also in mountainous and hilly areas. The mountainous relief is characterized by the undulating nature of the Earth's surface, forming bumps (Hills) with an absolute height of up to 500 m, a relative height of more than 25-200 m and a predominance of a slope of 2-3°. Hills, as a rule, consist of hard rocks, the tops and slopes of which are covered with a thick layer of loose rocks. The depressions between the hills are wide, flat or covered pools. Mangystau region has such a relief.

Mangystau region really has a unique relief - this is a combination of flat territories with mountainous and even rocky areas. Areas such as the Ustyurt plateau and the Bozjyra gorge stand out, which are characterized by steep slopes and cliffs. The features of this terrain create additional difficulties in drilling and transporting equipment, including an increased risk of flooding. These natural phenomena can not only slow down the process of transporting heavy equipment, but also threaten the safety of personnel and the integrity of equipment.

In mountainous and hilly areas, as, for example, in the areas of the Mangystau region of Kazakhstan, careful preparation of routes is required, which includes the assessment of geological risks, the development of strengthening measures and the use of specialized equipment capable of working in difficult conditions.

The relevance of this problem is due to the need to ensure the continuity of drilling operations and reduce downtime due to delays in the transportation of equipment. In addition, the competent organization of Transportation allows you to reduce the costs associated with the repair of equipment and the elimination of the consequences of emergency situations caused by flooding.

Thus, the development of effective methods and strategies for transporting drilling rigs in conditions of unstable relief is an important component of successful work in the oil and gas industry.

Research materials and methods. To ensure the safety of transportation of drilling equipment in conditions of high risk of flooding, an analysis of existing scientific and engineering solutions presented in educational and scientific sources on the problems of transportation of heavy equipment in mountainous and hilly areas was carried out. Particular attention was paid to works that consider the dynamics of flooding and methods of protection against them. Also, regulatory documents and standards governing the safety of transportation in difficult natural conditions were analyzed. To simulate the falling behavior of stones, a differential equation has been developed that describes the dynamics of their inclined movement. The equation takes into account such parameters as the angle of inclination of the surface and the coefficient of friction. This makes it possible to assess the trajectory of movement and zones of influence on transport equipment. After compiling the differential equation, its integration was carried out to obtain analytical and numerical solutions characterizing the trajectory and speed of movement of stones. Based on the data obtained, it is possible to determine the most dangerous sections of the transportation route and calculate the zones of possible damage, determine the width of the shelf to protect the drilling rig from falling stones on them, as well as the speed at which the stone falls on it.

Discussion of results. The article was discussed and submitted for publication to the Faculty of Atyrau oil and gas University named after Safi Utebayev.

The development of territories with a complex relief is often associated with the need to take into account adverse natural effects, among which is the process of flooding.

A changeable climate, anthropogenic impact, seismic processes occurring in the bowels of the earth can lead to dangerous consequences in the form of the accumulation of rocks and land masses.

Sources provide several explanations for the concept of collapse (Magomedov, 2024):

1. Collapse - the collapse of large stone blocks, fragments of rocks, as well as the free fall of stones on mountain slopes under the influence of gravity (ZHirenko at all, 2018);

2. Collapse (collapse) – a certain volume of stones that fall freely from the surface of a rock;

3. Bouldering is a type of movement of land masses in which debris is separated from the parent rock, descending, jumping and rolling down.

In the domestic literature, the definition of «collapse» is very rare, often such a term as «collapse»is used (SHeina at all, 2015).

Collapse - separation and collapse of rock blocks from steep slopes.

Collapse, like collapse, is an exogenous Geodynamic process caused by external factors acting on the surface of the lithosphere or in its upper layers (Yang at all, 2017). The difference between these two terms can be explained as follows: if large pieces fall or roll, it is a collapse; when a large mass of rocks that are crushed, mixed in motion, falls on a slope, it is a collapse. The trajectory of the collapse process should be considered in contact with the surface, and collapse, as a type of processes, is characterized by a movement that has lost contact with the mother sex (Žabota at all 2020).

Rock fall refers to gravitational geological processes - processes of changing the Earth's surface under the influence of gravity. The process of falling a stone is a type of surface processes.

Analyzing domestic and foreign experience, the main factors of the occurrence of flooding can be divided into two groups: natural and man-made, which, in turn, are divided into short-term and long-term (Figure 1) (Dorren, 2003).

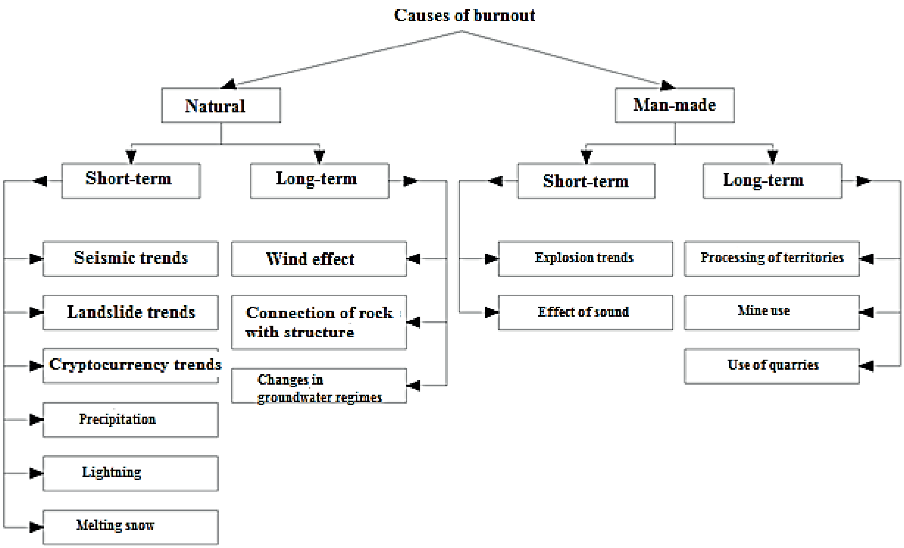

Figure 1 - Causes of burnout

Most often, rock collapse is a consequence of the development of rock weathering processes on slopes. Under the influence of physical weathering processes, cracks often develop in rocks. Temperature stresses (especially daily temperature fluctuations), as well as water, play an important role in the development of this process. Freezing in cracks, it develops lateral pressure, which creates additional conditions for further fragmentation of the rock massif and the separation of individual blocks.

The collapse poses a serious threat when transporting drilling rigs, especially in mountainous and hilly areas, such as some parts of the Mangystau region of Kazakhstan. The impact of flooding can be considered from several sides:

1. Equipment damage:

Stones can damage not only the drilling rig itself, but also auxiliary equipment (tractors, platforms, etc.). Damage can range from small dents to serious deformations that affect the operation of the equipment.

2. Risks for employees:

The collapse poses a threat to drivers and service providers. This requires strict adherence to safety measures and the use of protective structures on vehicles.

3. Delays in logistics:

The risk of flooding can lead to changes in routes or transportation stops, which increases the time and costs of delivering equipment to the drilling site.

4. Rising costs:

Additional costs may arise due to the installation of protective screens, strengthening of roads, as well as the need to insure equipment and personnel against the risk of flooding.

When transporting a drilling rig in mountainous and hilly areas, «shelves» should be organized to protect them from flooding, that is, to ensure a certain distance from the edge of the hill to the highway. To determine the width of the» shelf « b and the speed v_c at which the stone falls on it, we construct the differential equation of the movement of the stone from the top of the hill (figure 2.).

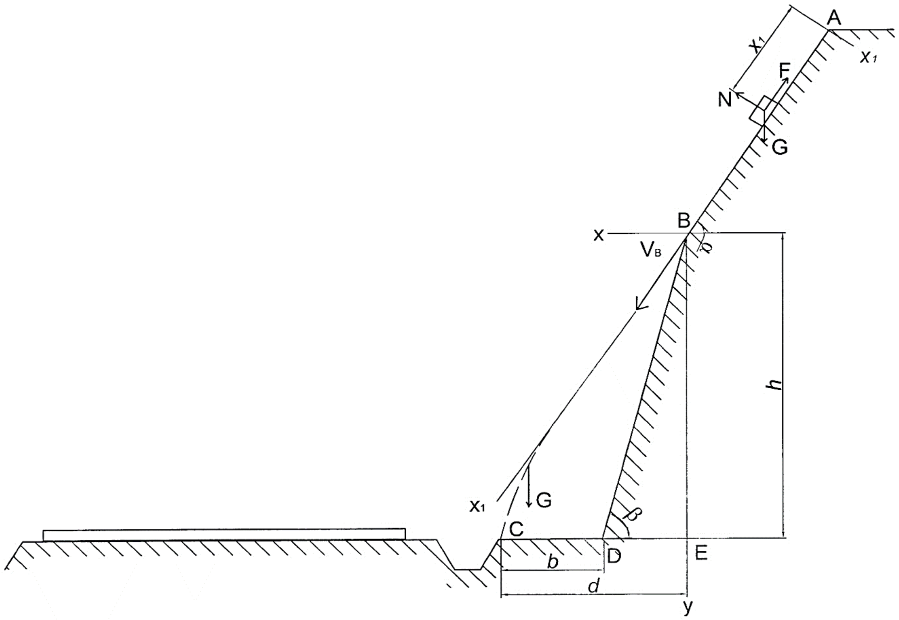

Figure 2 - Model of stone movement from the hill

At site *AB*, the stone slides along the slope, at point *B* there is a separation of the stone from the parent rock, and at site *BC*, the stone falls freely.

So, taking into account the possibility of movement of the stone from the highest point *A* and considering its initial speed $v_0 = 0$, we determine the smallest width of shelf *b* and the speed of the stone falling on it. Along the inclined section *AB*, which forms an angle with a horizon and has a length *l*, the stone moves with τ c (Figure 2).

When solving the problem, we consider the sliding friction coefficient of the stone at the *AB* site to be constant and ignore the air resistance.

Given: $v_A = 0;\ \alpha = 60^{\circ};\ l = 4\,м;\ \tau = 1\,c;\ f \neq 0;\ h = 5\,м;\ \beta = 75^{\circ}.\, b$ and v_c must be defined.

Solution. We consider the movement of the stone at the *AB* site. Taking a stone as a material point, we indicate the forces acting on it (Figure 2): $\vec{G}$ weight, n normal reaction and $\vec{N}$ sliding friction force. We construct the differential equation of stone movement on the section *AB*:

$$m\ddot{x}_1 = \sum X_{i1};\ m\ddot{x}_1 = Gsin\alpha - F.$$

Friction force

$$F = fN,$$

where

$$N = Gcos\alpha.$$

So,

$$m\ddot{x}_1 = Gsin\alpha - fGcos\alpha.$$

or

$$\ddot{x}_1 = gsin\alpha - fgcos\alpha.$$

By integrating the differential equation twice, we get

$$\dot{x}_1 = g(sin\alpha - fcos\alpha)t + C_1;$$

$$x_1 = [g(sin\alpha - fcos\alpha)/2]t^2 + C_1t + C_2.$$

To determine the integration constants, we use the initial conditions of the problem: when $t = 0$, $x_{10}=0$ and $x_{10}=0$.

let's construct the equations obtained during integration for $t = 0$.

$$\dot{x}_{10} = C_1;\ x_{10} = C_2.$$

We find constants:

$$C_1 = 0,\ C_2 = 0.$$

Then

$$\dot{x}_1 = g(sin\alpha - fcos\alpha)t;$$

$$x_1 = [g(sin\alpha - fcos\alpha)/2]t^2.$$

For the moment τ when the stone leaves the site

$$\dot{x}_1 = v_B;\ x_1 = l,$$

that is,

$$v_B = g(sin\alpha - fcos\alpha)\tau;$$
$$l = [g(sin\alpha - fcos\alpha)/2]\tau^2,$$

from the

$$v_B = 2l/\tau,$$

that is,

$$v_B = 2 \cdot 4/1 = 8 \text{ м/с}.$$

We consider the movement of the stone from point B to point C.

We construct the differential equations of its motion, indicating the force of gravity $\vec{G}$ acting on the stone:

$$m\ddot{x} = 0; \quad m\ddot{y} = G.$$

initial conditions of the problem with t = 0:

$$x_o = 0, \qquad y_o = 0;$$

$$\dot{x}_o = v_B cos\alpha; \qquad \dot{y}_o = v_B sin\alpha.$$

We intergrate the differential equation twice:

$$\dot{x} = C_3; \quad \dot{y} = gt + C_4,$$

$$x = C_3 t + C_5, \quad y = gt^2/2 + C_4 t + C_6.$$

we write the resulting equations for t = 0:

$$\dot{x}_o = C_3; \qquad \dot{y}_o = C_4;$$
$$x_o = C_5; \qquad y_o = C_6.$$

In this we find:

$$C_3 = v_B cos\alpha; \qquad C_4 = v_B sin\alpha;$$

$$C_5 = 0; \qquad C_6 = 0.$$

We obtain the following equations of stone velocity projections:

$$\dot{x} = v_B cos\alpha; \qquad \dot{y} = gt + v_B sin\alpha$$

and its equation of motion:

$$x = v_B cos\alpha t; y = gt^2/2 + v_B sin\alpha t.$$

we find the equation of the stone trajectory by subtracting the parameter from the equations of motion. Defining t from the first equation and substituting its value for the second, we get the parabola equation:

$$y = gx^2/(2v_B^2 cos^2\alpha) + xtg\alpha.$$

At the moment of the fall $y = h,\ x = d.$
determining the value of d from the trajectory equation, we find:

$$d_1 = 2{,}23 \text{ м}, \quad d_2 = -2{,}45 \text{ м}.$$

Since the trajectory of movement of a stone is a branch of a parabola with positive abscesses of its points, $d = 2{,}23$ м.
Minimum shelf width

$$b = d - ED = d - h/tg80^{\circ}, \text{ or } b = 1{,}18 \text{ м}.$$

using the equation of motion of the stone $x = v_B cos\alpha t$, we find the time *t* of movement of the stone from point *B* to point *C*:

$$T = 1{,}05 \text{ с}.$$

We find the speed of the stone when it falls through the velocity projections on the coordinate axis:

$$\dot{x} = v_B cos\alpha; \qquad \dot{y} = gt + v_B sin\alpha$$

according to the formula

$$v = \sqrt{\dot{x}^2 + \dot{y}^2}.$$

For the moment of fall $t = T = 1{,}05$ с

$$v_c = \sqrt{(v_B cos\alpha)^2 + (gT + v_B sin\alpha)^2},$$

or

$$v_c = 14{,}9 \text{ м/с}.$$

So, we have determined the width of the "shelf" with a ceiling height of 5 m of course, the question arises: How does the width of the shelf change depending on the height of the ceiling? To answer this question, by converting the parabola equation, we obtain the following quadratic equation:

$$9{,}81d^2 + 5{,}67d - 8{,}93 = 0.$$

Results. As a result of solving this equation at different ceiling heights, we get the "shelf" width and root values (Table 1).

Table 1 - Values of the width of the «shelf « and the roots of the quadratic equation

№ p/p				*d*_ negative	*b*_ negative
1	5	1,86385	0,98222	-2,44196	-3,32360
2	6	2,06579	1,00783	-2,64390	-3,70187
3	7	2,25173	1,01744	-2,82984	-4,06413
4	8	2,42496	1,01435	-3,00307	-4,41369
5	9	2,58778	1,00084	-3,16589	-4,75284
6	10	2,74186	0,97859	-3,31998	-5,08325
7	11	2,88849	0,94889	-3,46660	-5,40620
8	12	3,02863	0,91271	-3,60675	-5,77267
9	13	3,16310	0,87085	-3,74121	-6,03346
10	14	3,29252	0,82394	-3,87063	-6,33921

We construct the dependence of the distances and on the ceiling height (figures 3 and 4).

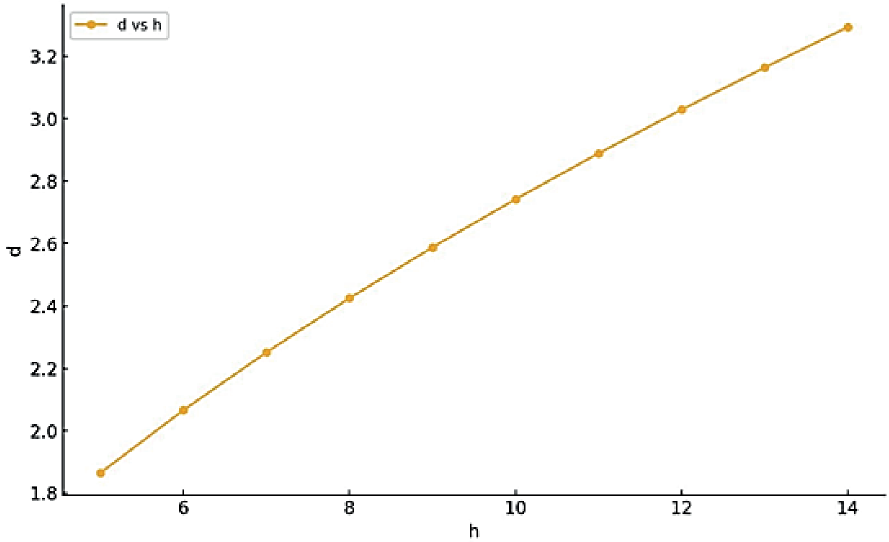

Figure 3 - Dependence of distances on ceiling height *h*

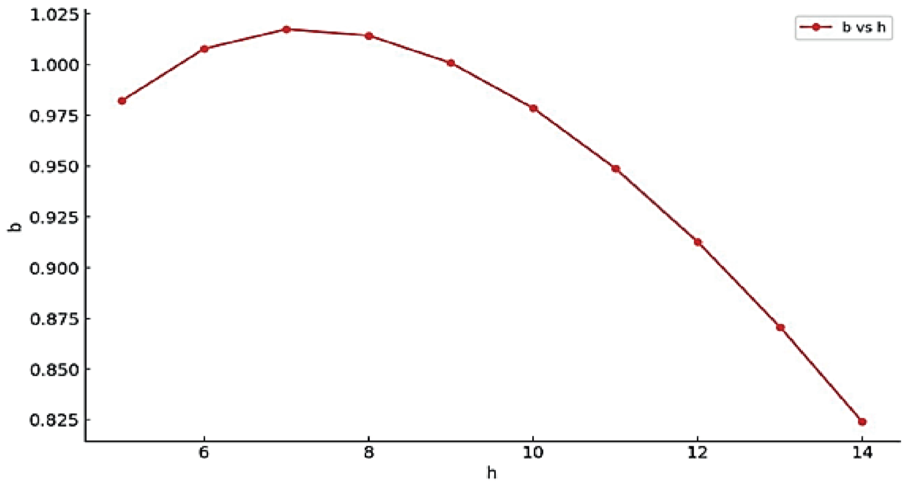

Figure 4 - Dependence of the width of the" shelf " on the height of the ceiling

Discussion. As we can see in Figure 3, as the height of the ceiling increases, the distance , that is, the distance between the separation of the stone from the parent rock and its descent into the "shelf", increases.

From the analysis of Figure 4, the following conclusion can be drawn: with an increase in the height of the ceiling, the width of the "shelf" first increases, and then decreases. The function reaches the highest values with a ceiling height of 6 to 8 m and has a value of 0,98 to 1,015 m.

If for some reason it is not possible to perform a sufficient width of the «shelf», then work should be carried out to protect the territories from the processes of flooding (Legros, 2002).

Preventive measures to protect drilling rigs from collapse processes when transporting should be aimed at eliminating conditions that lead to the separation of blocks from the parent rock (Matsuoka at all, 1999).

It is necessary to highlight the types of wind protection measures:

* diversion of atmospheric, surface and groundwater;

* increase the stability of rocks by tamponage of cracks and karst cavities;

* Organization of monitoring at various levels in areas of intense weather in artificial and natural open area (Marzorati at all, 2022).

Timely monitoring of gravitational processes will allow timely allocation of hazardous areas of mountain slopes, eliminate or reduce the impact of natural and man-made factors on the occurrence of the collapse process (Ge at all, 2020).

Classification of anti-pile structures used as flood protection structures:

1. Retaining structures that are provided to prevent soil displacement, flooding, destruction and clumping when it is impossible or economically unprofitable to change the relief of the slope.

2. Retaining structures and devices (walls, gabions, nets, etc.), which are

provided for the protection of objects from the fall of sediments, rubble, individual rocks.

3. Anti-collapse galleries.

Until recently, galleries were considered the necessary and only technical solution aimed at protecting the crumbling sections of roads, pedestrian paths. Indeed, such structures made of prefabricated, monolithic reinforced concrete and piecework materials are used all over the world as reliable engineering structures.

The advantages of galleries include the following characteristics:

- wide range of applications;
- the ability of the shock-absorbing filling device allows you to soften the impact.

In addition, anti-fall galleries have a number of disadvantages:

- Falling stones with an impact energy of 5000-8000 KJ destroy reinforced concrete structures of galleries;
- large labor costs when building complex structures on slopes;
- high construction cost due to labor costs;
- capital construction entails interference in the existing environmental situation on the slope.

In each specific case, it is necessary to analyze the characteristics of the hill, roads, etc., as well as the available methods of protecting highways from tumbling processes, and choose the most suitable method of protection.

Conclusions. In the course of the study, the features of the transportation of drilling rigs in mountainous and hilly areas with a high risk of flooding characteristic of the Mangystau region of Kazakhstan were analyzed. The main factors affecting the safety of transportation, including geological and climatic conditions, were considered.

1. the main sources leading to collapse have been identified, among which natural ones are distinguished (rock wind, seismic activity, temperature fluctuations).
2. A mathematical model of collapse dynamics based on differential equations has been developed, which allows you to calculate the trajectory of rock collapse, their speed and zones of possible impact on the transported equipment. This data is used to determine the optimal width of the protective "shelves".
3. An analysis of the influence of the height of the slopes on the parameters of protective measures was carried out, which showed: with an increase in the height of the ceiling, first the width of the protective "shelf" increases, reaching a maximum at a certain height, and then it begins to decrease. This makes it possible to optimize engineering solutions depending on the specific conditions of the terrain.
4. Practical measures have been proposed to protect equipment and personnel from the impact of flooding, including the use of retaining and knocking structures (nets, gabions, anti-collapse galleries.

Thus, the methods and recommendations proposed in the work will ensure an increase in the safety and efficiency of drilling rig transportation in case of flooding, which is an important factor for the successful development of oil and gas fields in Kazakhstan.

References

Sh.U. Niyazbekova, O.V. Nazarenko (2018) Current state and prospects of development of the oil and gas sector of the Republic of Kazakhstan [Sovremennoe sostoyanie i perspektivy razvitiya neftegazovogo sektora Respubliki Kazahstan]. Vestnik Moskovskogo universiteta imeni S.YU. Vitte. Seriya 1. Ekonomika i upravlenie. — № 4 (27). — P. 7-14. (in Russ.).

Zh.A. Saipov, R.Z. Fakhrutdinov. (2017) Current state and ways to improve Kazakhstan's oil refining [Sovremennoe sostoyanie i puti sovershenstvovaniya Kazakhstanskoi neftepererabotki]. Vestnik tekhnologicheskogo universiteta. — №10(T20), 2017. — P. 48-52. (in Russ.).

N.I. Nikolaev, A.I. Ivanov. (2009) Improving the efficiency of drilling oil and gas wells in difficult conditions [Povyshenie effektivnosti bureniya neftyanyh i gazovyh skvazhin v oslozhnennyh usloviyah]. Zapiski gornogo instituta. — T.183. — P. 308-310. (in Russ.).

L.B. Berdyguzhin, ZH. Amanbaeva. (2022) Oil and gas fields of Mangystau. [Istoriya neftegazovyh mestorozhdenij Mangistau]. Vestnik Atyrauskogo universiteta imeni Halela Dosmuhamedova. — 66(3). — P. 27-39. (in Russ.).

M.V. Melihov. (2018) The concept of erecting temporary rockfall structures in quarries [Koncepciya vozvedeniya vremennyh protivokamnepadnyh sooruzhenij na kar'erah]. Problemy nedropol'zovaniya. — №2. — P. 130-138. (in Russ.).

M.SH. Magomedov. (2024) Justification of the parameters of the combined engineering protection system of mountain roads from rockfalls [Obosnovanie parametrov kombinirovannoj sistemy inzhenernoj zashchity gornyh dorog ot kamnepadov]. Mezhdunarodnyj nauchnyj zhurnal «Vestnik nauki». — № 6 (75) Tom 4. — *P*. 1313-1319 (in Russ.).

S.A. ZHirenko, A.I. Suhov (2018) Assessment and forecast of rockfall hazards on highways [Ocenka i prognoz kamnepadnoj opasnosti na avtomobil'nyh dorogah]. Vestnik SibADI. — № 2 (34). — P. 75-82. (in Russ.).

T.V. SHeina, E.A. Avdeeva. (2015) Technologies for protecting highways from rockfalls [Tekhnologii zashchity avtodorog ot kamnepadov]. Gradostroitel'stvo i arhitektura. — №1. — T.8. — P. 28-34. (in Russ.).

Yang P., Shang Y., Li Y., Wang H., Li K. (2017) Analysis of Potential Rockfalls on a Highway at High Slopes in Cold-Arid Areas (Northwest Xinjiang, China). Sustainability, 9. — 414 p. https://doi.org/10.3390/su9030414 (in Eng.).

Žabota, B.; Kobal, M. A. (2020) New Methodology for Mapping Past Rockfall Events: From Mobile Crowdsourcing to Rockfall Simulation Validation. ISPRS Int. J. Geo-Inf. 9. — 514 p. https://doi.org/10.3390/ijgi9090514 (in Eng.).

Dorren, L.K.A. (2003) A review of rockfall mechanics and modelling approaches. Prog. Phys. Geogr. 27. — P. 69–87. https://doi.org/10.1191/0309133303pp359ra (in Eng.).

Legros, F. (2002) The mobility of long-runout landslides. Eng. Geol. 63. — P. 301–331. https://doi.org/10.1016/S0013-7952(01)00090-4 (in Eng.).

Matsuoka, N.; Sakai, H. (1999) Rockfall activity from an alpine cli_ during thawing periods. Geomorphology, 28. — P. 309–328. https://doi.org/10.1016/S0169-555X(98)00116-0 (in Eng.).

Marzorati, S.; Luzi, L.; De Amicis, M. (2022) Rock falls induced by earthquakes: A statistical approach. Soil Dyn. Earthq. Eng. — 565–577. http://dx.doi.org/10.1016/S0267-7261(02)00036-2 (in Eng.).

Ge Y., Zhou T., Tang H., Lin Z. (2020) Influence of the impact angle on the motion and deposition of granular flows. Eng. Geol. 275, 105746. http://dx.doi.org/10.1016/j.enggeo. 2020. — 105746 p. (in Eng.).

Publication Ethics and Publication Malpractice in the journals of the Central Asian Academic Research Center LLP

For information on Ethics in publishing and Ethical guidelines for journal publication see http://www.elsevier.com/publishingethics and http://www.elsevier.com/journal-authors/ethics.

Submission of an article to the journals of the Central Asian Academic Research Center LLP implies that the described work has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis or as an electronic preprint, see http://www.elsevier. com/postingpolicy), that it is not under consideration for publication elsewhere, that its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere in the same form, in English or in any other language, including electronically without the written consent of the copyright-holder. In particular, translations into English of papers already published in another language are not accepted.

No other forms of scientific misconduct are allowed, such as plagiarism, falsification, fraudulent data, incorrect interpretation of other works, incorrect citations, etc. The Central Asian Academic Research Center LLP follows the Code of Conduct of the Committee on Publication Ethics (COPE), and follows the COPE Flowcharts for Resolving Cases of Suspected Misconduct (http://publicationethics. org/files/ u2/New_Code.pdf). To verify originality, your article may be checked by the Cross Check originality detection service http://www.elsevier.com/editors/plagdetect.

The authors are obliged to participate in peer review process and be ready to provide corrections, clarifications, retractions and apologies when needed. All authors of a paper should have significantly contributed to the research.

The reviewers should provide objective judgments and should point out relevant published works which are not yet cited. Reviewed articles should be treated confidentially. The reviewers will be chosen in such a way that there is no conflict of interests with respect to the research, the authors and/ or the research funders.

The editors have complete responsibility and authority to reject or accept a paper, and they will only accept a paper when reasonably certain. They will preserve anonymity of reviewers and promote publication of corrections, clarifications, retractions and apologies when needed. The acceptance of a paper automatically implies the copyright transfer to the Central Asian Academic Research Center LLP.

The Editorial Board of the Central Asian Academic Research Center LLP will monitor and safeguard publishing ethics.

Правила оформления статьи для публикации в журнале смотреть на сайтах:
www:nauka-nanrk.kz
http://www.geolog-technical.kz/index.php/en/
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

Ответственный редактор *А. Ботанқызы*
Редакторы: *Д.С. Аленов, Т. Апендиев*
Верстка на компьютере: *Г.Д. Жадырановой*

Подписано в печать 15.12.2025.
Формат 70x90$^{1}/_{16}$. 20,5 п.л.
Заказ 6.

«Central Asian Academic Research Center» LLP
Алматы, Қонаев к-сі, 142