ISSN 2518-1491 (Online),
ISSN 2224-5286 (Print)

ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫНЫҢ

Д.В. Сокольский атындағы «Жанармай,
катализ және электрохимия институты» АҚ

Х А Б А Р Л А Р Ы

ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
РЕСПУБЛИКИ КАЗАХСТАН
АО «Институт топлива, катализа и
электрохимии им. Д.В. Сокольского»

N E W S

OF THE ACADEMY OF SCIENCES
OF THE REPUBLIC OF KAZAKHSTAN
JSC «D.V. Sokolsky institute of fuel, catalysis
and electrochemistry»

SERIES
CHEMISTRY AND TECHNOLOGY

1 (445)

JANUARY – FEBRUARY 2021

PUBLISHED SINCE JANUARY 1947

PUBLISHED 6 TIMES A YEAR

ALMATY, NAS RK

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Қазақстан Республикасы Ұлттық ғылым академиясы "ҚР ҰҒА Хабарлары. Химия және технология 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. Webof Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Химия және технология сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді химиялық ғылымдар бойынша контентке адалдығымызды білдіреді.

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ISSN 2518-1491 (Online),
ISSN 2224-5286 (Print)

Меншіктенуші: «Қазақстан Республикасының Ұлттық ғылым академиясы» Республикалық қоғамдық бірлестігі (Алматы қ.).

Қазақстан Республикасының Ақпарат және қоғамдық даму министрлігінің Ақпарат комитетінде 29.07.2020 ж. берілген **№ KZ66VPY00025419** мерзімдік басылым тіркеуіне қойылу туралы куәлік.

Тақырыптық бағыты: ***химия және жаңа материалдар технологиясы саласындағы басым ғылыми зерттеулерді жариялау.***

Мерзімділігі: жылына 6 рет.
Тиражы: 300 дана.

Редакцияның мекенжайы: 050010, Алматы қ., Шевченко көш., 28; 219, 220 бөл.; тел.: 272-13-19; 272-13-18,
http://chemistry-technology.kz/index.php/en/arhiv

Редакцияның мекенжайы: 050100, Алматы қ., Қонаев к-сі, 142, «Д. В. Сокольский атындағы отын, катализ және электрохимия институты» АҚ, каб. 310, тел. 291-62-80, факс 291-57-22, e-mail:orgcat@nursat.kz

Типографияның мекенжайы: «NurNaz GRACE», Алматы қ., Рысқұлов көш., 103.

«Известия НАН РК. Серия химии и технологий».

ISSN 2518-1491 (Online),
ISSN 2224-5286 (Print)

Собственник: Республиканское общественное объединение «Национальная академия наук Республики Казахстан» (г. Алматы).

Свидетельство о постановке на учет периодического печатного издания в Комитете информации Министерства информации и общественного развития Республики Казахстан **№ KZ66VPY00025419**, выданное 29.07.2020 г.

Тематическая направленность: ***публикация приоритетных научных исследований в области химии и технологий новых материалов.***

Периодичность: 6 раз в год.
Тираж: 300 экземпляров.

Адрес редакции: 050010, г. Алматы, ул. Шевченко, 28; ком. 219, 220; тел. 272-13-19; 272-13-18,
http://chemistry-technology.kz/index.php/en/arhiv

Адрес редакции: 050100, г. Алматы, ул. Кунаева, 142, АО «Институт топлива, катализа и электрохимии им. Д.В. Сокольского», каб. 310, тел. 291-62-80, факс 291-57-22, e-mail:orgcat@nursat.kz

Адрес типографии: «NurNaz GRACE», г. Алматы, ул. Рыскулова, 103.

News of the National Academy of Sciences of the Republic of Kazakhstan. Series of chemistry and technology.

ISSN 2518-1491 (Online),
ISSN 2224-5286 (Print)

Owner: RPA "National Academy of Sciences of the Republic of Kazakhstan" (Almaty).

The certificate of registration of a periodical printed publication in the Committee of information of the Ministry of Information and Social Development of the Republic of Kazakhstan **No. KZ66VPY00025419**, issued 29.07.2020.

Thematic scope: ***publication of priority research in the field of chemistry and technology of new materials***

Periodicity: 6 times a year.
Circulation: 300 copies.

Editorial address: 28, Shevchenko str., of. 219, 220, Almaty, 050010, tel. 272-13-19; 272-13-18,
http://chemistry-technology.kz/index.php/en/arhiv

Editorial address: JSC «D.V. Sokolsky institute of fuel, catalysis and electrochemistry», 142, Kunayev str., of. 310, Almaty, 050100, tel. 291-62-80, fax 291-57-22, e-mail: orgcat@nursat.kz

Address of printing house: «NurNaz GRACE», 103, Ryskulov str, Almaty.

N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES CHEMISTRY AND TECHNOLOGY
ISSN 2224-5286
Volume 1, Number 445 (2021), 112 – 118 **https://doi.org/10.32014/2021.2518-1491.14**

UDC 378 (075.8): 625.855

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SUBSTANTIATION OF APPLICATION OF ANTI-ICE CHEMICAL REAGENTS ON AUTOMOBILE ROADS WITH CEMENT CONCRETE COVERING

Abstract. In this paper, we consider the problem associated with the fight against slipperiness on roads with a hard type of road surface. It is known that on cement-concrete surfaces, the length of the braking distance is up to 10 times longer than on a snow roll formed on asphalt-concrete surfaces. This phenomenon is especially dangerous in winter, as a sharp increase in humidity (as a result of warming) significantly reduces the strength properties of cement concrete. Chloride de-icers are highly hygroscopic. Being in the pores of cement concrete, chemical solutions begin to absorb moisture from the atmosphere. In asphalt concrete, such phenomena are practically absent. Moisture, which is located in the pores of cement concrete, on its surface occurs "staining" and peeling.

In the article, the authors pay special attention to the climatic conditions of Kazakhstan. The average air temperature of the coldest month on average in the Akmola region is 25-27oC, in the Eastern region-31-36oc, in the North– -26-29 OS, and in the South-3-10 OS. Annual precipitation amounts to 260-300, 340-370, 300-340 and about 150 mm, respectively. the duration of the cold period in the year varies between 6-7, 6-7, 5-6 and 3-4 months. It is climate factors that make it difficult to use chemical reagents as anti-icing materials on roads with a cement-concrete surface.

This article discusses the theoretical basis for the destruction of the crystal structure of snow and ice formations from the influence of chemical reagents. They established a natural dependence of the freezing force of snow and ice formations on the impact of various types of salt solutions. Also, laboratory studies have established the effect of the concentration of salt solutions on the loss of strength of cement concrete over time.

Key words: slippery, peeling, chipping, cement concrete strength, deicing chemical reagent, concentration of solutions.

Relevance. At present, roads of national significance with a hard surface type have significantly increased on the territory of Kazakhstan. During the operation of these roads, the requirements for maintenance and road safety are also increasing. Especially affected by adverse conditions for the movement of cars, often occurring in the winter period, when traffic on the roads is complicated by the appearance of various types of snow and ice formations. For roads with asphalt concrete pavement, chemical reagents do not pose a significant danger, since bitumen-containing materials practically do not pass liquid chemical solutions into the body of road clothing. In contrast, the cement concrete coating is easily exposed to moisture absorption. Thus, chemical solutions, easily penetrating into the body of cement concrete, contributes to the damage of the coating. This process in climatic zones with a sharply continental climate especially exacerbates the likelihood of cement stone peeling, followed by concrete painting (peeling) and loss of strength due to the low stability of this material. Novelty: chemical deicing reagents have been selected experimentally and their optimal ability has been established, which do not affect the strength properties (peeling, chipping, etc.) of cement concrete.

Problem statement. To determine the effect of anti-icing chemicals on the destruction of cement concrete and the selection of the chemical reagent and its optimal concentration for roads with cement concrete coating, depending on natural and climatic conditions.

Methods for analyzing the structure of destruction of snow and ice formations from the influence of chemical solutions and their influence on the reduction of strength properties of cement concrete coatings. To explore the above factors, the test was conducted in three stages: first, theoretically grounded structural changes, i.e. destruction of crystal structures of snow-ice formation from the action of solutions of chemical reagents; second, a visual assessment of concrete degradation (flaking, spalling) from exposure to solutions of anti-icing agents; third, determining loss of strength of samples of cement concrete from the effects of chemical solutions at different concentrations. ***Theoretical bases of destruction of the crystal structure of a snow-ice formation from the influence of chemical reagents.*** The use of chemical reagents to combat snow and winter slipperiness is based on the fact that when exposed to ice and snow, chemical reagents, having internal energy, cause the destruction of the crystal structure of the ice, as a result, the ice melts and forms a solution with the reagents [8-10].

In the theoretical justification, we consider two cases: the first, the interaction of particles of a solute with a solvent, i.e., the process of solvation; the second, with water. Here, the process is considered as hydration between water and snow-ice formation. The dissolution of solid sodium chloride (or other chemical materials) in water can be divided into the following stages:

1. The destruction of the ice crystal from the action of chloride solutions, i.e. sodium chloride can be divided into the following free ions:

$$NaCl\ (\text{тв.}) \rightarrow Na^+ + Cl^-$$

a) hydration of these ions:

$$Na^+ + pH_2O \rightarrow Na^+(H_2O)p\ (\text{solution}); \quad (1)$$

$$Cl^- + qH_2O \rightarrow Cl^-(H_2O)q\ (\text{solution}). \quad (2)$$

b) the resulting expression

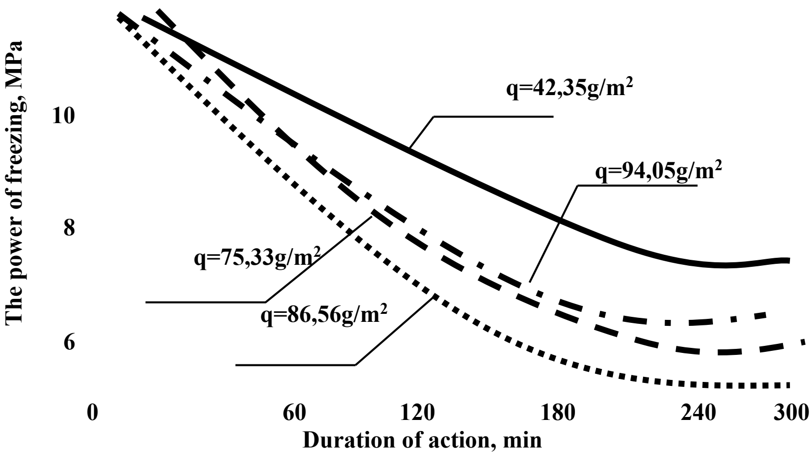
$$NaCl(\text{sol.}) + (p+q)H_2O \rightarrow Na^+(H_2O)p\ (\text{solution}) + Cl^-(H_2O)q\ (\text{solution}). \quad (3)$$

One of the main tasks of practical use of chemical solutions in the fight against slipperiness is to reduce the freezing force of the snow-ice formation, i.e., changing its molecular structure (weakening of the hardness, reducing the density, etc.). This is due to the duration of the reagent's entry with snow *(t_p)*, distribution density (*q*), solution concentration *(C_p)*, normal shear stress by grader blade *(σ)*, the coefficient of internal friction *(tg)*, the adhesion of the material *(C)* in Addition, the value of the freezing force of ice (or snow) may also depend on the temperature and humidity of the air. The freezing forces of ice when shifting the grader blade can be represented in the form of a diagram (figure 2). In the theory of using chemical reagents, it is known that as the salt affects the ice, the freezing forces weaken *(τ)* between its crystals and the ice crust softens [11].

High quality snow removal can be achieved only if the snow does not lose its bulk properties *(C)*. In this case, the state of the loose body and, consequently, the newly fallen snow, is characterized by the equation:

$$\tau = \sigma tg\varphi + C. \quad (6)$$

a) sodium chloride solution



б) magnesium chloride

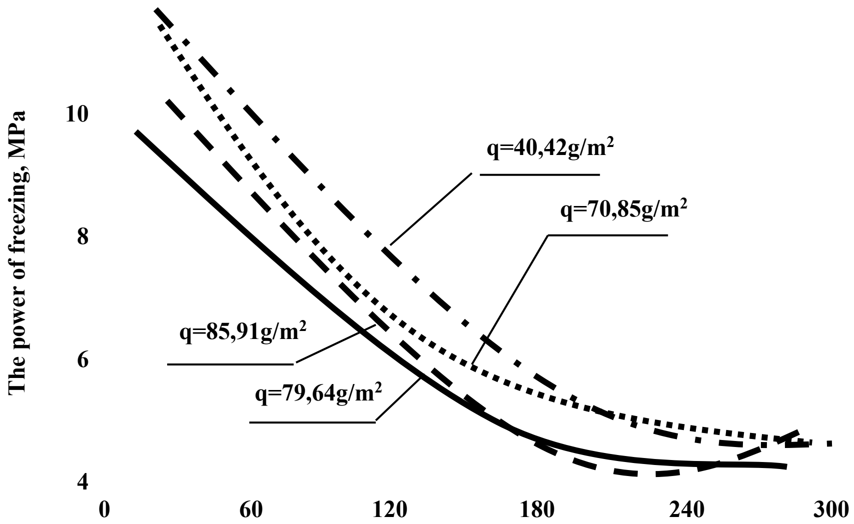


Figure 2 – Dependence of the freezing force of snow and ice formations from exposure to various types of salty solutions with the shift of the grader blade

The following devices and equipment were used for conducting experimental studies: a set of hydrometers for determining the density of the solution, high-precision electronic scales, a freezer, and a hydraulic press for testing a sample of cement concrete for strength after holding samples in chemical solutions.

The process of performing tests. Determination of the strength properties of cement concrete under the influence of various types of reagent when distributing them as anti-icing reagents and choosing their optimal concentration. For the experiment, various types of reagents were taken, including non-hygroscopic ones, i.e. technical urea and ammonium acetate

Research result. The selection of reagents was carried out in accordance with [1,2].

Initially, i.e. on *phase one*, in laboratory conditions, in accordance with [3], cement concrete samples of the B30 and B35 grades used for roads with a cement concrete coating were prepared.

On *second stage* anti-icing chemicals were selected and solutions were prepared in laboratory conditions in polyethylene baths with a concentration of 8% (minimum) and 25% (maximum). Here, as anti-icing materials were used: a) traditional chloride materials, such as sodium chloride (NaCl) [4] and 6-water magnesium chloride (bischofite) ($MgCl_2 \cdot 6H_2O$) [5]; b) non-hygroscopic materials, such as ammonium acetate (CH_3COONH_4) [6] and technical urea (urea) ($(NH_2)_2 \cdot CO$) [7].

a)

b)

Figure 3 – Visual view of cement concrete samples after exposure (a) and testing them on a hydraulic press (b)

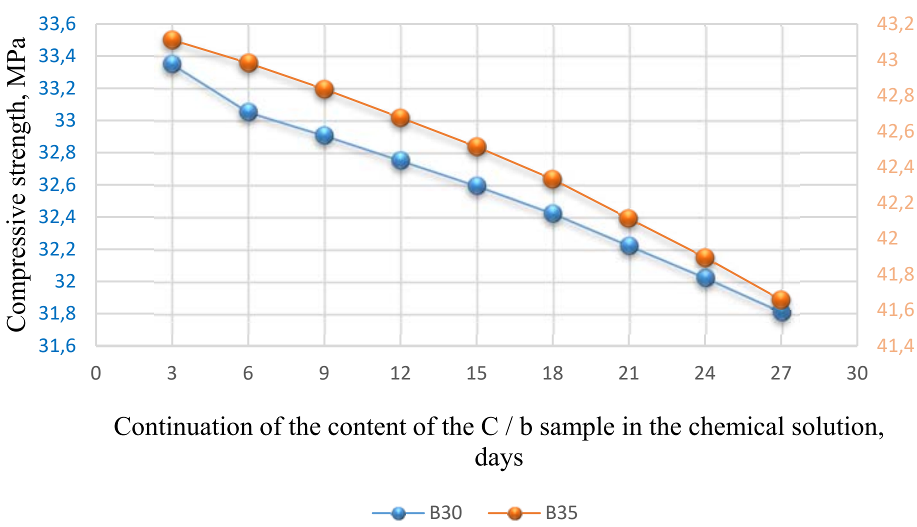
On *third stage* pre-prepared samples were immersed in polyethylene baths with appropriate concentrations and types of solution. Then, from the moment the samples were immersed in the solution, time tracking began. For rice 3A presents the results of the visual assessment. As you can see, not all samples were destroyed. For example, the upper 4 samples and the lower 2 right samples were virtually undamaged, while the lower 2 left samples showed structural damage.

On *fourth stage* cement concrete samples after exposure (in 3-day, week, 15-day, month), were tested by a hydraulic press for compressive strength. The test results are presented on figure 3b.

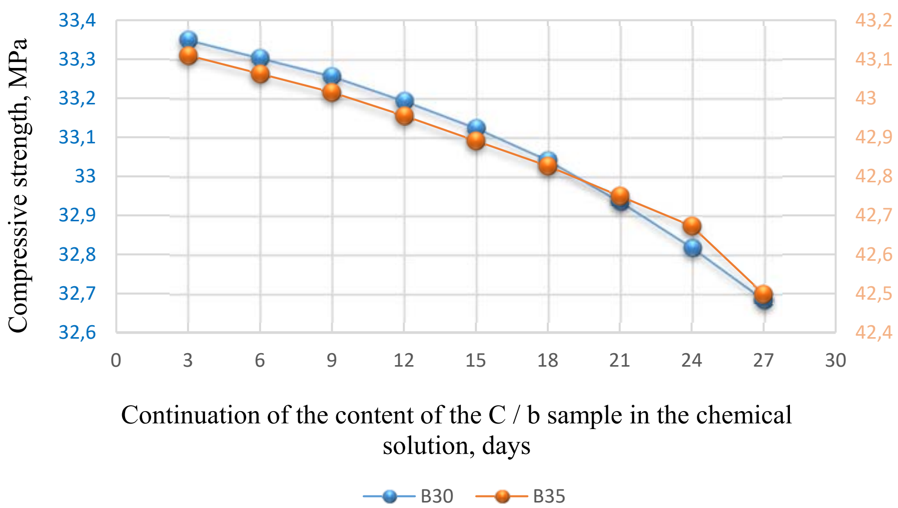
The results of laboratory studies of Kazadi (2019) were carried out on the highway on the road "Western Europe – Western China" (km 70-74) and "Almaty-Ust-Kamenogorsk" (km 27-32) of Kazakhstan, especially on newly operated sites, a relationship was established between the content of cement concrete sample of the B30 and B35 brand in a chemical solution and its strength.

As seen in figure 4, with a maximum monthly retention of 25 %- the concentration of ammonium acetate, the loss of strength of B30 concrete is 4.46 % (figure 4 a), and the B35 grade is 3.37%, the technical urea solution the loss of strength of the B30 grade concrete is 2.01 %, and the B35 grade is 1.42 % (figure 4 b), sodium chloride solution the loss of strength of concrete grade B30 is 3.44 %, and grade B35 is 2.69 %, a solution of 6-water magnesium chloride loss of strength of concrete grade B30 is 3.06 %, and grade B35 is 2.14 % (figure 4 g).

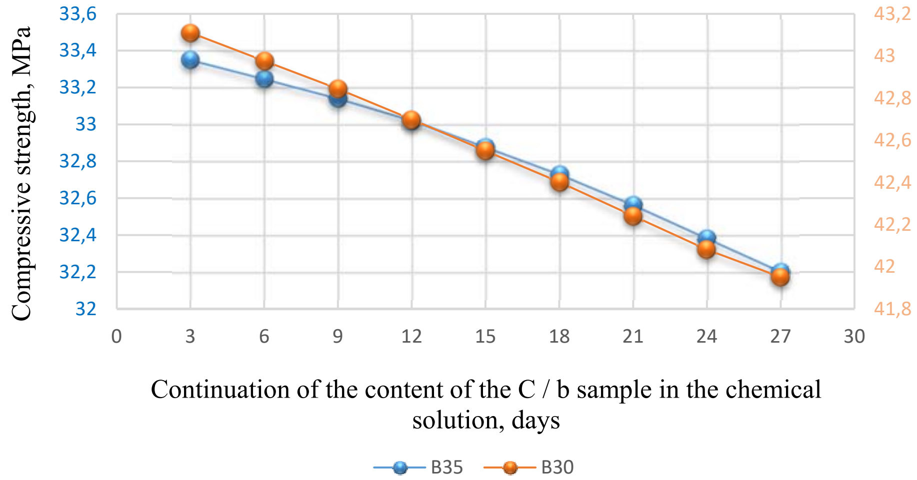
a)



b)



c)



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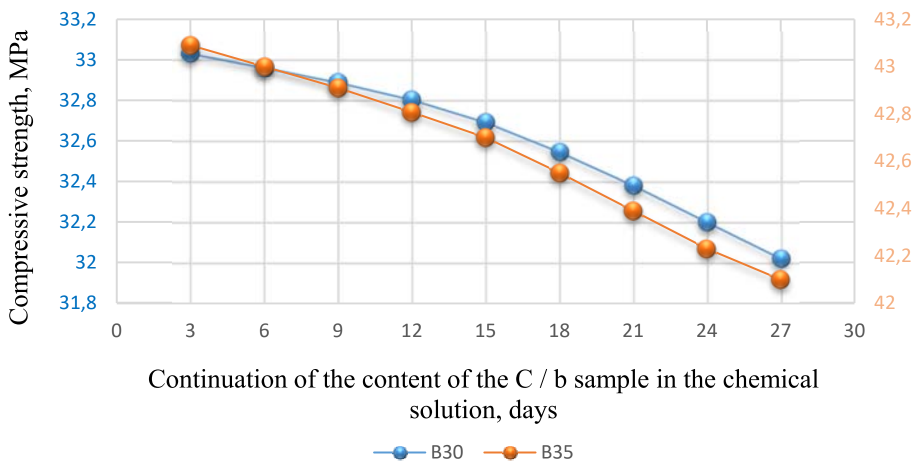

Figure 4 – Loss of strength of cement concrete samples in anti-icing chemical solutions (curves correspond to scales according to the color scheme)

The results of the analysis testing. Thus, the use of chemical reagents very effectively reduces the bonding forces between snow and ice formations and cement concrete coating compared to "pure" ice: at a density distribution q_n=50 g/m^2 chlorides in 10-15 times, and when q_n = 100 g/m^2 in 20-30 times. When using a 3-component anti-icing mixture "Bischofit-Urea-Technical salt", we get the lowest shear force. Liquid de-icing chemicals (brines), in turn, are divided into: weak – 50-150, strong-150-320, very strong-320-500 and extremely saturated more than 500 g / l.

The test results showed that with increasing strength of concrete, their resistance to the effects of chemical solutions increases. For example, with a maximum monthly exposure of 25 % concentration of technical urea solution, the loss of strength of B30 concrete is 2.01 %, and B35 is 1.42%, for the concentration of ammonium-acetic solution. The loss of strength of B30 concrete is 4.46 %, and B35 is 3.37 %, for the concentration of the solution sodium chloride loss of strength, of concrete grade B30 is 3.44 %, and grade B35 is 2.69 %, for the concentration of a solution of 6-water magnesium chloride, the loss of strength of concrete grade B30 is 3.06 %, and grade B35 is 2.14 %.

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ANTI-ICE ХИМИЯЛЫҚ РЕАГЕНТТЕРІН ЦЕМЕНТ ЖАБЫНДЫСЫМЕН БІРГЕ АВТОМОБИЛЬ ЖОЛЫНА ҚОЛДАНУ

Аннотация. Мақалада қатқыл жамылғылы автомобиль жолында пайда болатын қысқы тайғаққа қарсы күресу шаралары қарастырылған. Әдетте, цемент бетонды жолдағы көліктің тежелу жолының ұзындығы асфальт бетонды жамылғыда туындаған тапталған қарға қарағанда 10 еседей жоғары болады. Мұндай жағдайда тайғақ жамылғыға үйкетүзілімдік материалдарды шашу, уақыт созылымына қатысты аса тиімді емес. Ал химиялық реагенттерді қатты (кебу) күйінде немесе оларды құммен араластыру арқылы шашу пайдалану тиімділігін жоғарылата алмайды.

Цемент бетонды жамылғылар тұңғыш рет «Астана-Шортанды» автодаңғылында пайда болды және ұзындығы 238 км құрады. Бұдан кейін мұндай жамылғылар «Батыс Еуропа – Батыс Қытай» халықаралық көлік дәлізінің Қордай айналма жолынан бастап, Түркістанға дейін (жалпы ұзындығы 740 км) салынды. 2016 жылы «Алматы – Өскемен» автожолының «Алматы – Қапшағай» телімі (ұзындығы 67 км) пайдалануға берілді.

Цемент бетонның асфальт бетонға қарағанда су сіңіру қасиеті аса жоғары болады, сол сияқты ылғал өткізгіштігі де жоғары. Мұндай жағдайлар қыс мерзімінде аса қауіпті, өйткені ылғалдың күрт жоғарлауы (немесе жамылғының сулануы) цемент бетонның беріктігіне кері ықпалын тигізеді. Қысқы тайғаққа қарсы қолданылатын хлорлы реагенттердің гигроскопиялық қасиеттері жоғары болады. Сондықтан цемент бетон кеуектеріне енген химиялық ерітінділер ылғалды қоршаған ортадан жинақтап, жамылғы бойына еркін сіңіре алады. Цемент бетонның кеуегіне жинақталған мұндай химиялық ерітінділер жамылғы бетінің үгілуі мен мүжіліуіне тікелей әсерін тигізеді.

Мақалада авторлар Қазақстанның климаттық жағдайына ерекше назар аударған. Ақмола облысының ең суық айларындағы орташа температурасы минус 25-27 ºС-ты құрайды, шығыс аймағында минус 31-36 ºС, солтүстікте минус 26-29 ºС, ал оңтүстікте минус 3-10 ºС. Жауын-шашынның жылдық орташа мөлшері тиісінше 260-300 мм, 340-370 мм, 300-340 мм және 150 мм, ал жылдың суық мерзімінің ұзақтығы, тиісінше 6-7, 6-7, 5-6 және 3-4 ай. Қыс мерзімде цемент бетон жамылғылы жолдарға химиялық реагенттер шашуға, жоғарыда аталғандай, ауа-райы құбылыстарының әсері орасан зор.

Түйін сөздер: тайғақ, ыдырау, беттік тозу, цемент бетонының беріктігі, тайғақтыққа қарсы химиялық реагент, ерітінділер концентрациясы.

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ОБОСНОВАНИЕ ПРИМЕНЕНИЯ ПРОТИВОГОЛОЛЕДНЫХ ХИМИЧЕСКИХ РЕАГЕНТОВ НА АВТОМОБИЛЬНЫХ ДОРОГАХ С ЦЕМЕНТОБЕТОННЫМ ПОКРЫТИЕМ

Аннотация. В данной работе рассматривается задача, связанная с борьбой со скользкостью на автомобильных дорогах с твердым типом покрытий. Известно, что на цементобетонных покрытиях длина тормозного пути до 10 раз выше, чем на снежном накате, образующемся на асфальтобетонных покрытиях. Применение в таких условиях фрикционных материалов практически не дает желаемого результата из-за его малого времени эффективного действия, а применение химических материалов в твердом (сухом) виде или в составе пескосоляной смеси также не увеличивает их эффективность.

Цементобетонное покрытие впервые появилось на автомагистрали «Астана–Щучинск» длиной 238 км. Затем на участке автомобильной дороги «Западная Европа – Западный Китай», начиная с объездной дороги Кордай до г. Туркестан (протяженность 740 км). В 2016 году ввели в эксплуатацию участок «Алматы–Капшагай» автомобильной дороги «Алматы–Усть-Каменогорск» (протяженность 67 км).

Как известно, цементобетон по сравнению с асфальтобетоном водопроницаемый и его поры легко впитывают в себя влагу. Данное явление особенно опасно в зимнее время года, т.к. резкое повышение (в результате потепления) влаги существенно снижает прочностные свойства цементобетона. Хлористые противогололедные реагенты являются высоко гигроскопичными. Находясь в порах цементобетона, растворы химреагентов начинают впитывать влагу из атмосферы. Такие явления в асфальтобетонах практически

отсутствуют. Влага, находящаяся в порах цементобетона, на его поверхности появляются «выкраши-вание» и происходит шелушение.

В статье авторы особое внимание обращают на климатические условия Казахстана. Средняя температура воздуха самого холодного месяца в Акмолинской области в среднем составляет -25-27 ºС, в восточном регионе -31-36 ºС, в северном – -26-29 ºС, а в южном – 3-10 ºС. Годовое количество осадков соответственно – 260-300, 340-370, 300-340 и около 150 мм, продолжительность холодного периода в году колеблется в пределах: 6-7, 6-7, 5-6 и 3-4 месяцев. Именно климатические факторы усложняют применение химических реагентов в качестве противогололедных материалов на дорогах с цементобетонным покрытием.

Ключевые слова: скользкость, шелушение, выкрашивание, прочность цементобетона, противогололедный химический реагент, концентрация растворов.

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ISSN 2518-1491 (Online), ISSN 2224-5286 (Print)

Редакторы: *М. С. Ахметова, Д. С. Аленов, А. Ахметова*
Верстка на компьютере *Д. А. Абдрахимовой*

Подписано в печать 01.02. 2021.
Формат 60х881/8. Бумага офсетная. Печать – ризограф.
9,5 п.л. Тираж 300. Заказ 1.

Национальная академия наук РК
050010, Алматы, ул. Шевченко, 28, т. 272-13-18, 272-13-19