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Satbayev University

ХАБАРЛАРЫ

ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
РЕСПУБЛИКИ КАЗАХСТАН
Satbayev University

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Қазақстан Республикасы Ұлттық ғылым академиясы «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. Webof 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.

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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DEVELOPMENT OF AN INFORMATION AND ANALYTICAL SYSTEM "GEOTECHNICAL MONITORING OF THE SOIL CONDITION OF RESIDENTIAL BUILDINGS AND STRUCTURES"

Abstract. The relevance of the stated topic of scientific research is determined by the need to develop a high-quality system of geotechnical monitoring of the condition of soils of residential buildings and structures in order to form and provide the necessary information to assess the real geothermal regime of soils of residential buildings and structures. The main purpose of this scientific research is the formation and provision of timely comprehensive information about the geothermal condition of soils in the area of the residential buildings, which is essential when planning and conducting construction work in the permafrost zone. The methodology of this research work is based on a combination of system analysis of the main aspects of the development of an information and analytical system for geotechnical monitoring of soil conditions in the area of construction of residential buildings with an analytical study of the basic principles of construction of residential facilities in regions located in the permafrost zone and characterised by specific climatic conditions. The main results obtained in this research work should be considered the established sequence of development of an information and analytical system for geotechnical monitoring of the condition of soils of residential buildings and institutions, which is essential for the functioning of urban utility systems of cities located in permafrost regions and solving the problems of accumulation and editing of information about geothermal tubes and sampling from the ground at various depths.The results obtained and the conclusions formulated on their basis are of significant practical importance for employees of construction organizations who, by the nature of their activities, are faced with the need to develop and implement an effective information and analytical system for monitoring the state of soils in permafrost regions where residential facilities are planned to be built.

Key words: geotechnical monitoring, permafrost, geotechnical system, residential buildings and structures.

Introduction. The development of the information and analytical system (IAS) «Geotechnical monitoring of the condition of soils of residential buildings and structures» is focused on the accumulation, storage and processing of information, the formation and provision of information about the geothermal regime of soils of residential buildings. At the same time, this system should provide input of general information about a residential facility, such as its address, name, building number, time of commissioning. In addition, the input and storage of general information on the geothermal regime of residential buildings should be provided, namely, the entry of both archival information for the period of operation of residential buildings and current data, indicating critical changes in ground temperatures [1]. At the same time, it is planned to obtain information about measurements of temperature wells directly from the archives of management companies, as well as from the management of housing and communal services [2].

In general, when forming an assessment of the overall stability of the geotechnical system, timely identification of hidden destructive processes that can have a destructive impact on residential buildings and structures erected in this region is of great importance. In this context, it is necessary to take into account the possibility of calculating such mathematical indicators as the bearing capacity of foundations, soils. Also calculations on thawing and freezing. At the same time, part of the data is withdrawn from the database during calculations, the other part is entered manually, or taken from the building code [3].

Today, in the conditions of constant changes in the surrounding world, it is of particular relevance to conduct systematic monitoring of the geotechnical condition of buildings and structures related to the housing stock. This leads to the development of trends towards monitoring data on the condition of residential facilities in real time using modern information and analytical systems developed and implemented in the context of the development of modern electronic computing technology in general. In addition, continuous monitoring of the condition of sites located in areas of permafrost using modern geotechnical techniques is essential [4]. At the same time, the quality of monitoring the condition of soils of residential buildings and structures largely determines the actual condition of these facilities during operation, since errors made during this procedure negatively affect the operation of housing stock facilities in the future, often causing a premature violation of the integrity of these facilities and the fall of residential structures into a state of emergency [5].

Materials and methods. At the first stage of this research work, the analysis of available publications devoted to the theoretical issues of developing a high-quality system of geotechnical monitoring of soils of residential buildings in areas with permafrost is carried out. In addition, at this stage of research work, a systematic analysis of the main aspects of the development of an information and analytical system for geotechnical monitoring of the condition of soils in the area of construction of residential buildings is carried out, which makes it possible to qualitatively determine the range of tasks of scientific research and its main directions. At the next stage of this research work, an analytical study of the basic principles of building residential facilities in regions located in the permafrost zone and characterised by specific climatic conditions is carried out, which involves considering the possibility of developing a special web application for accumulating and editing information about geothermal tubes and their measurements at various depths. In addition, at this stage of scientific work, an analytical comparison of the results obtained during this scientific research is carried out with the results and conclusions of other researchers on related issues related to monitoring the condition of soils of residential buildings and structures erected in permafrost regions.

At the final stage of this scientific work, on the basis of the results assigned during it, final conclusions were formulated, summarising the entire complex of scientific research works and acting as their objective reflection. The conclusions reflect the main aspects of creating an information and analytical system for geotechnical monitoring of residential buildings, which can be effectively used in the future for scientific research in the field of housing and communal construction and the construction of residential facilities in permafrost regions.

Results. Visual Studio Code and PyCharm Community programming environments were used to design the client side of the user interface (frontend) and the logical hardware and software part of the service (backend), respectively. Frontend is written in JSX and is a one-page website that is based on the React web framework developed by Facebook, Inc. In order to avoid having to develop the entire site design on our own and to reduce the time spent on development, the Material-UI library is used, which is a ready-made set of visual components [6].

The backend is written in Python. The Flask microframe work developed by Ronacher Armin is used for URL routing. This microframework is lightweight, popular and has been supported by the developer since 2010 to the present. Flask's minimalism allows it to be customised and used for a wide range of tasks, which is important for possible project expansion. The Postgre SQL DBMS is used as a database, which contains a Post GIS tool that allows storing and processing geographical data from an open source OpenStreetMap [7]. In order to simplify the process of using database objects, the code uses ORM SQL Alchemy. The backend uses a microservice architecture, which allows it to be expanded modularly. The interaction of frontend and backend is carried out using the REST architecture, which allows organising effective microservice interaction.

When the user launches the web application, the authorisation form opens. When the user enters the correct authorisation data, a GIS map of the Norilsk Industrial Region opens. The scale is changed by scrolling its wheel, clicking on the «+» and «-» buttons in the upper left corner of the map. Blue markers indicate houses that have geothermal data stored in the system. Clicking the left mouse button on the marker at the bottom right opens a brief information about the selected house in the form of an address. If it is necessary to add a new house to the system, the user clicks on the required house on the map. A marker appears in place of the selected house. In the lower right corner, there is a brief information about a particular house (its address) and a button for adding a house. When clicking on this button, the house is added to the system and a marker is displayed in its place. In the upper right corner of the GIS map there is a text input field. This field is used to search for a specific address of the house on the map. When the user enters the address of the house and clicks on the search button, the map view automatically focuses on the found house. In the case when a non-existent address of the house is entered, a dialogue box appears indicating that the house could not be found.

In the system under development, it is possible to view the geothermal record of the selected house. To do this, it is necessary to select the house whose data is present in the system and click on the “House record” button at the bottom right of the screen. At the bottom of the record form there is a table containing the parameters of measuring temperature tubes for a certain date at each depth at which the measurement was made (Figure 1). Measurements with readings greater than zero are highlighted in red (as these are measurements characterising an unfavourable foundation condition). Orange highlights the measurements, the readings of which are zero.

Ведомость по дому

	Скважина	Квартал	Год	Месяц	День	1м	2м	3м	4м	5м	6м	7м	8м	9м	10м	11м	12м
	АБ-1/2	1	2019	Февраль (2)	18	-0.4	+0	+0	+0	+0	+0	+0	-0.2	-0.4	-0.6	-0.6	-0.8
		1	2020	Февраль (2)	13	+1.55	+2.75	+1.94	+0.34	-0.13	-0.25	-0.29	-0.47	-0.4	-0.67	-0.7	-0.8
	БВ-4/5	1	2018	Февраль (2)	11	-1	+0	+0	+0	-0.6	-0.8	-1	-1	-1	-1	-1	-1
		1	2019	Февраль (2)	18	-0.2	+0	+0	-0.2	-0.6	-0.6	-0.6	-0.8	-0.8	-1	-1	-1

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Fig 1.Table with geothermal measurements

In the upper right area of the table there is a button that opens a window with a filter. There is an option of multiple data filtering. For more convenient data analysis, there is a separate “quarter” field that allows filtering data quarterly. The developed functionality of the application makes it possible to build a geothermal graph for any well. This can be done by clicking on the “Create graph” button to the left of the well.Figure 2 shows the graph for the well «АБ-1/2».

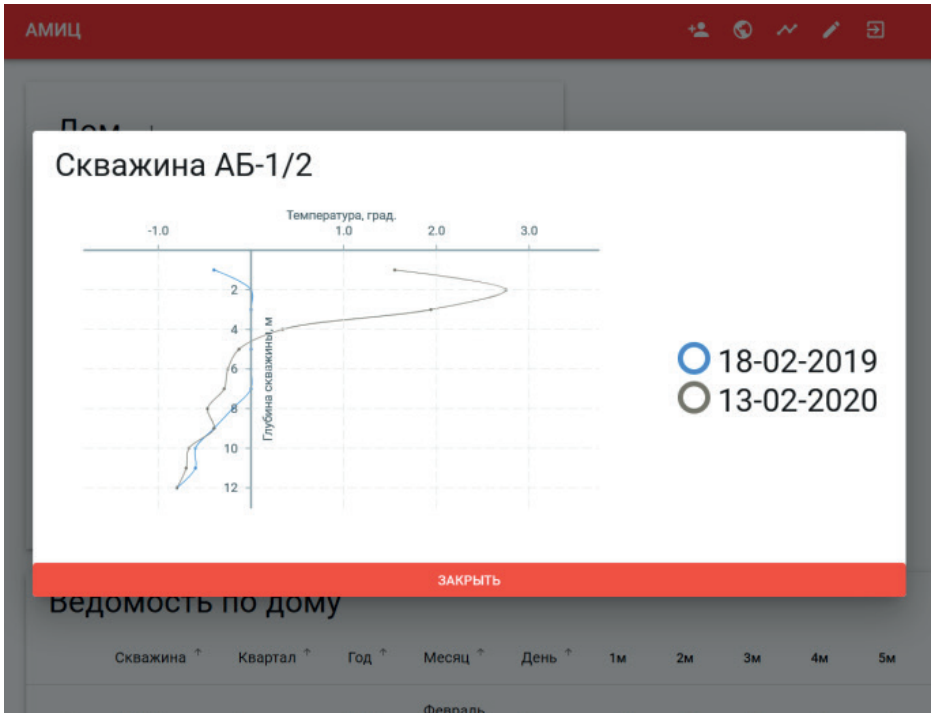
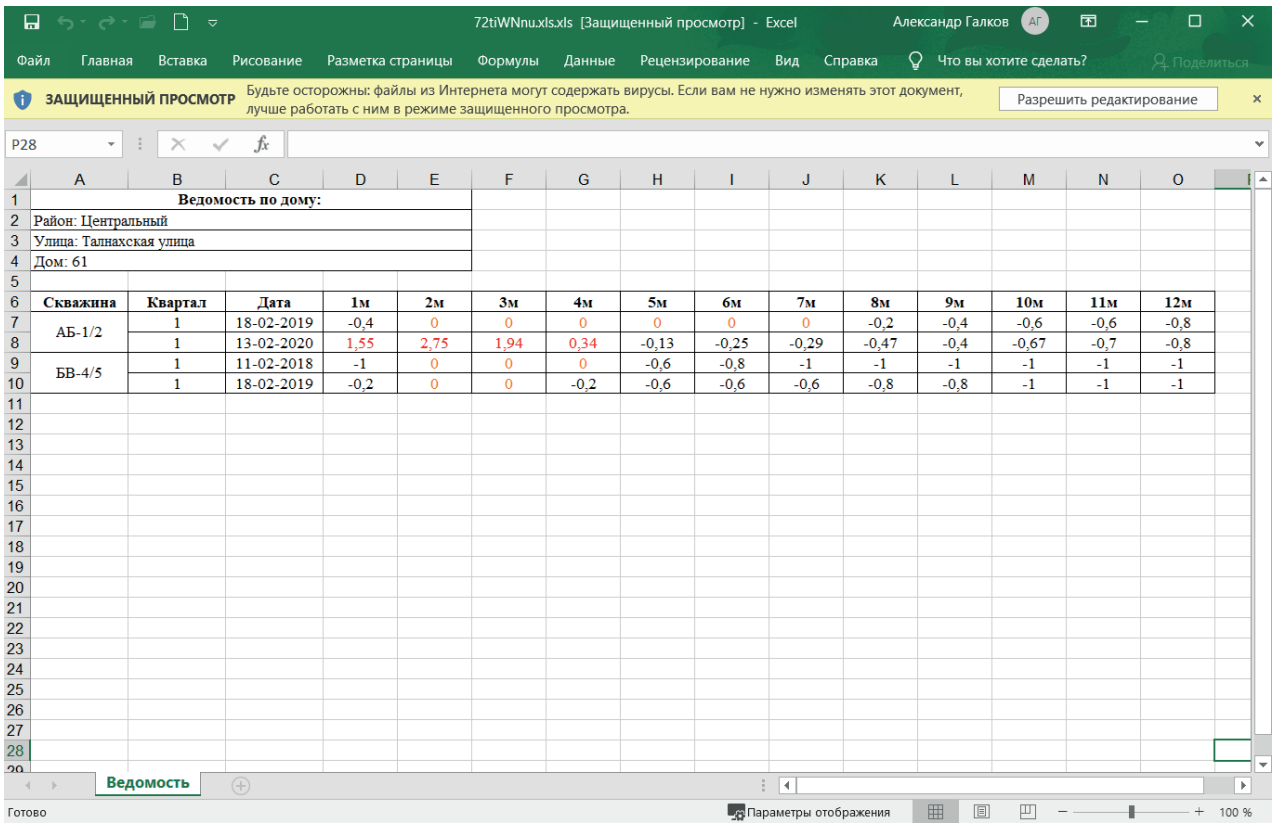


Fig 2.Geothermal graph for the well «АБ-1/2»

In the upper part of the house record form, information about the specific address of the house is displayed: district, street, house number, minimum/maximum depth of the foundation, year of construction.To the right of the word “House”there is a button for uploading a statement for a specific house in Microsoft Excel. Clicking this button will generate a house record sheet in Microsoft Excel file format (Figure 3).



Скважина	Квартал	Дата	1м	2м	3м	4м	5м	6м	7м	8м	9м	10м	11м	12м
АБ-1/2	1	18-02-2019	-0,4	0	0	0	0	0	0	-0,2	-0,4	-0,6	-0,6	-0,8
	1	13-02-2020	1,55	2,75	1,94	0,34	-0,13	-0,25	-0,29	-0,47	-0,4	-0,67	-0,7	-0,8
БВ-4/5	1	11-02-2018	-1	0	0	0	-0,6	-0,8	-1	-1	-1	-1	-1	-1
	1	18-02-2019	-0,2	0	0	-0,2	-0,6	-0,6	-0,6	-0,8	-0,8	-1	-1	-1

Fig 3.The record on the house in the Microsoft Excel programme.

User always can return to the GIS map form is possible by clicking on the “Back” button in the browser (usually on the top left of the screen) or clicking on the planet icon in the red menu at the top. There is a possibility to open a button that allows editing information about a particular house and its wells. On the left of each well in the table there are buttons for deleting, editing, and viewing measurements. At the top right of the table there is a button for adding a new well (the “+” button). By analogy with the form of a house record, there is an option for filtering data.

When the Add Well button is pressed, a dialogue box opens in which the data for the well to be added must be entered. Well will be recorded in the database by entering the required data and click on the “Save” button. If user clicks on the dark background, the dialog box will close. Clicking on the measurement editing button (to the left of the well name column) opens a form for editing measurements of the corresponding well (functionally similar to the form for editing data about the house and wells).

In the case when the user is authorised as an administrator who has the rights to create accounts, the “Add user” button is located on the red panel at the top. Clicking on this button opens a new user registration form. It requires entering a username, password, as well as the rights of a new user. A new user account is added to the system by click on the “Save” button. If there is a need to log out of the current account (for example, to log in later under a different account), one must click on the “Log out” button located in the upper right part of the screen. By clicking on this button, the user will again be taken to the authorization form, where, if necessary, one will be able to enter under a new account.

Thus, the development of an information and analytical system for geotechnological monitoring of the condition of residential buildings makes it possible to qualitatively monitor the processes of preserving information about the geothermal regime of soils of residential buildings erected in permafrost regions, which is important from the point of view of its practical use in the design and construction of cities in these regions.

Discussion. The characteristic technogenic impact of megacities and developed industrial production inevitably led to changes in the relief of urban areas, increase the load on the geological environment by buildings and structures, technogenic increase in the water content of rocks and surface runoff, loads associated with vibrations, etc. All of the above technogenic processes in their combined effect negatively affect the overall stability of the geological environment, and, consequently, urban development, which necessitates constant geotechnical monitoring to identify and prevent the occurrence of emergencies. Geotechnical monitoring is necessary to assess the quality of functioning and overall reliability of the geotechnical system, timely detection

and prevention of the development of emergency situations and assessment of the correctness of forecasts, established calculation methods and principles of making design decisions. Geotechnical monitoring should always be carried out using automated systems, the basic requirements of which are outlined and regulated in the relevant standards [8].

The formation of a general assessment of the stability of a geotechnical system involves the mandatory identification of potential destructive processes that can disrupt its overall equilibrium [9]. This implies mandatory accounting in the geotechnical monitoring system of the behaviour of both a specific geological environment and residential buildings erected in permafrost regions [10]. These two aspects influence each other, for this reason, the identification and prediction of the initial stages of geological processes that pose a danger to the constructed housing stock is of great importance from the point of view of ensuring the safety of construction work and the qualitative solution of the problems of long-term operational use of the erected buildings. In this context, improving the efficiency of geotechnical monitoring of residential buildings and structures, provided that the analysis of the identified data on the actual course of deformation processes in soils, as well as careful and timely processing, is the main task in the development of modern information and analytical systems, the qualitative solution of which is impossible without a well-established and efficiently functioning algorithm for processing information obtained during geotechnical monitoring [11].

The use of permafrost as a basis for the construction of residential buildings and structures is subject to two fundamental principles. The first of them is the desire to preserve the soil cover in the permafrost zone in its natural, pristine state, the second concerns the prospects for the development of a building structure, taking into account the foundation of the building in a thawed state. The final choice is made taking into account the data obtained when comparing the calculated indicators of a technical and economic nature, carried out in order to increase the overall efficiency of the economic decisions made. It should be noted that the first option is the most popular and involves spending the least amount of money. At the same time, it involves maintaining the soil in a frozen state, which requires maintaining this principle both directly during construction work and during the subsequent operation of a residential structure [12]. A similar principle finds its application in situations where there is an economic need to maintain permafrost in its pristine state. The construction of foundations of buildings on sandy soils has shown high practical efficiency due to the fact that these cannot be attributed to plastic-frozen. In such situations, a system of additional measures is often used to reduce the temperature parameters of the base of the building to the values obtained during preliminary calculations, in addition, these foundations structurally provide for plastic deformations of the building, possible over time under high loads [13].

The construction of a foundation on permafrost implies the need to correctly determine its depth. The variant with gradual thawing of the soil assumes its use in a completely different mode, in which during construction work it does not rise and does not fall when temperature conditions change [14]. In such situations, the deformations do not exceed certain pre-set values. The soil layer in this situation either thaws before the foundation of the building structure is erected, or all calculations of construction work are performed, while the assumption is formed that during the operation of the structure, the base of the building will completely thaw. It is mandatory to calculate the depth of the base of the building structure with an accurate assessment of the depth of the permafrost layer in this area, as well as considering the depth of groundwater and the characteristics of the thawing zone formed directly at the stage of subsequent operation of the building structure.

The construction of foundations in permafrost zones implies the need for engineering and geocryological studies necessary for the formation of adequate and accurate forecasts of the behaviour of soil layers during construction work and during the subsequent operation of a residential building. Engineering calculations assume the mandatory determination of the thermal regime of the soil layers, followed by the determination of the type of foundation. This is necessary for high-quality construction work and ensuring long-term operation of residential structures in permafrost conditions [15].

When performing technological construction works, there is a systematic increase in the total volume of water consumed for irrigation, as well as building materials that provide high-quality thermal insulation. In colder climates, this has a decisive impact on the progress of construction work and the pace at which it can be carried out. In addition, the high-quality functioning of the monitoring system for the condition of residential soils of buildings and structures is of great importance from the point of view of planning construction work in the places of construction of geological objects of oil and gas exploration, which require implementation in the shortest possible time.

Construction works in permafrost regions are associated with numerous technological difficulties caused

by severe weather conditions, as well as poor development of the transport communications network in these regions. It should also be taken into account that conducting construction work in these regions requires a sufficient amount of high-quality fillers necessary in the process of industrial production of high-quality concrete and cement and high strength characteristics. The delivery of these building materials from other geographical regions is associated with a significant increase in transportation costs, resulting in an overall increase in the total cost of reinforced concrete and concrete structures made of these building materials. In addition, the importance of regular monitoring of the condition of soils in the field of residential buildings is also due to such a factor as the impossibility of using fine quartz sands, very common in the described territories, as a basis for the preparation of a concrete mixture, which, in turn, causes numerous difficulties in obtaining sufficiently hard and durable concrete in difficult weather conditions and using traditional production methods.

The construction of residential facilities in permafrost regions with the subsequent operation of these structures requires conducting a preliminary study of the soils at the construction sites in order to obtain information both about their current state and about the real prospects for further operational use. The reason lies in the often extreme weather conditions in the construction regions, which implies low air temperatures and a complex soil structure, which significantly complicates the conduct of construction in such conditions. In conditions of high humidity, the processes of dehydration of building materials are not uncommon, which leads to deterioration of the strength of the entire structure as a whole and possible problems at the stage of further use of already erected and commissioned structures [15].

In general, construction works in the conditions of the far North and permafrost zones are carried out in difficult weather and climatic conditions, which requires appropriate measures to properly organise construction work, which would include conducting a preliminary study of soils in construction sites and subsequent assessment of their condition through the practical application of modern geotechnical soil monitoring systems in the locations of buildings. In the presence of extreme weather conditions, this implies the need to solve a complex economic problem associated with the organisation of construction work and the choice of construction technology, provided that objective information about the real state of soils in these regions is obtained. The qualitative solution of the entire spectrum of such tasks determines the overall efficiency of the construction work carried out, as well as the strict adherence to their deadlines, which is important from an economic point of view. Another important aspect is the accuracy of economic calculations of the values of labour costs and the maintenance of labour resources that were used during construction and in the process of subsequent maintenance of residential buildings and structures. The economic aspect is essential, therefore, the importance of preliminary and ongoing monitoring of the condition of soils in the locations of residential structures should be taken into account even at the design development stage, not to mention further work.

Conclusions. The web application, the process of sequential development of which was presented in the course of this scientific work, makes it possible to accumulate and edit information about geothermal tubes and their measurements at various depths. Based on the accumulated information, the web application generates geothermal statements for the house and builds geothermal graphs. The developed system ensures the safety of data by means of access control and the creation of backups. The functionality of the application allows filtering of data (quarterly, monthly, yearly, etc.), which reduces the time required to analyse ground temperature conditions. The subsequent practical application of an information and analytical system for geotechnical monitoring of the state of the soil of residential buildings and the constructed one makes it possible to form a qualitative assessment of the real state of soils under housing facilities located in areas with permafrost, and to assess the prospects for the construction of housing facilities in these regions and their subsequent operation. Further development of such systems contributes to improving the safety of construction work and maintenance of erected residential buildings and structures, as well as contributes to improving the general understanding of the structure of soils under residential buildings and foundations of buildings and structures, which generally has a positive effect on the dynamics of the construction of housing facilities in the permafrost zone and contributes to increasing population density in northern regions with difficult weather conditions.

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«ТҰРҒЫН ҒИМАРАТТАР МЕН ҚҰРЫЛЫСТАР ТОПЫРАҚТАРЫНЫҢ ЖАЙ-КҮЙІНІҢ ГЕОТЕХНИКАЛЫҚ МОНИТОРИНГІ» АҚПАРАТТЫҚ-ТАЛДАУ ЖҮЙЕСІН ӘЗІРЛЕУ

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РАЗРАБОТКА ИНФОРМАЦИОННО-АНАЛИТИЧЕСКОЙ СИСТЕМЫ «ГЕОТЕХНИЧЕСКИЙ МОНИТОРИНГ СОСТОЯНИЯ ГРУНТОВ ЖИЛЫХ ЗДАНИЙ И СООРУЖЕНИЙ»

Аннотация. Актуальность заявленной тематики научного исследования обуславливается необходимостью разработки качественной системы геотехнического мониторинга состояния грунтов жилых зданий и сооружений в целях формирования и предоставления необходимой информации для оценки реального геотермического режима грунтов жилых строений и сооружений. Основной целью данного научного исследования выступает формирование и предоставление оперативной исчерпывающей информации о геотермическом состоянии грунтов в зоне жилых домов, что имеет существенное значение при планировании и ведении строительных работ в зоне вечной мерзлоты. Основу методологии данной научно-исследовательской работы составляет сочетание системного анализа основных аспектов разработки информационно-аналитической системы геотехнического мониторинга состояния грунтов в зоне постройки жилых зданий с аналитическим исследованием основных принципов построения жилых объектов в регионах, расположенных в зоне вечной мерзлоты и характеризующихся специфическими климатическими условиями. Основными результатами, полученными в данной научно-исследовательской работе, следует считать установленную последовательность разработки информационно-аналитической системы геотехнического мониторинга состояния грунтов жилых зданий и учреждений, что имеет существенное значение для функционирования систем городского коммунального хозяйства городов, расположенных в регионах с вечной мерзлотой и решающих проблемы накопления и редактирования информации о геотермических трубках и взятии проб из земли на различной глубине. Полученные результаты и сформулированные на их основании выводы имеют существенное практическое значение для сотрудников строительных организаций, по роду деятельности сталкивающихся с необходимостью разработки и практического внедрения эффективной информационно-аналитической системы мониторинга состояния грунтов в регионах с вечной мерзлотой, на которых планируется возведение жилых объектов.

Ключевые слова: геотехнический мониторинг, вечная мерзлота, геотехническая система, жилые здания и сооружения.

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