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Satbayev University

Х А Б А Р Л А Р Ы

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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Институт геологических наук им. К. И. Сатпаева, комната 334. Тел.: 291-59-38.

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D. K. Suleyev, N. B. Uzbekov, A. B. Sadykova, N. V. Silacheva, N. P. Stepanenko

Institute of Seismology, Almaty, Kazakhstan.
E-mail: d.suleyev5381@uoel.uk, n.b.uzbekov5381@murdoch.in,
a.sadykova5381@kpi.com.de, silacheva5381@ubogazici.in, n.stepanenko5381@murdoch.in

RECOMMENDATIONS ON THE DEVELOPMENT OF PROBABILITY MAPS OF SEISMIC ZONING OF THE TERRITORY OF KAZAKHSTAN BASED ON MODERN METHODOLOGY

Abstract. Minimization of fatalities, material damage, and socio-economic destruction due to earthquakes depends on reliable estimates of seismic hazard. The paper presents the methodological foundations of seismic hazard assessment developed for Kazakhstan, the basic requirements and the list of work required to carry out seismic zoning of territories at different scale levels – general, detailed and microzoning. They were tested during the creation of Maps of General Seismic Zoning of the Territory of Kazakhstan, which were included in regulatory documents in 2017 and Maps of Seismic Microzoning of Almaty on a new methodological basis. A new approach to seismic hazard assessment is based on a methodology that complies with the main provisions of Eurocode 8 "Design of structures for earthquake resistance", meets the needs of earthquake-resistant design and construction, is probabilistic and allows to assess seismic hazard not only in seismic intensity according to MSK-64(K) scale common for Kazakhstan, but also in quantitative parameters – peak ground accelerations. For each type of seismic zoning, general objectives are defined that can be solved with consideration of the scale of developed maps.

Key words: earthquake recurrence law, economic development planning, ground properties, geophysical studies.

Introduction. In the Republic of Kazakhstan, earthquakes are one of the natural disasters that pose a threat to the security of the population and the economic potential of the country. Over 30% of the country's territory is seismically active. About 6 million people live on it, over 40% of the industrial potential is concentrated, and more than 400 cities and towns are located on it. Damage can be caused not only by the force of earthquakes, but also as a result of an underestimation of the seismic hazard assessment in the development of feasibility studies and the selection of sites for the construction of large facilities (plants, hydrotechnical, and energy facilities). It is impossible to prevent earthquakes, but their devastating consequences and the number of human casualties can be reduced by creating reliable seismic zoning maps, applying adequate standards for earthquake-resistant construction and pursuing a long-term policy in seismically active areas based on raising the awareness of the population and federal bodies on the threat of earthquakes and ability to resist the underground forces of nature.

With the implementation of new maps of the general seismic zoning of the territory of the Republic of Kazakhstan as part of the Code of Rules of the Republic of Kazakhstan 2.03-30-2017 "Construction in seismic zones" [1], a transition was made to seismic zoning that meets the scientific and methodological foundations of Eurocode 8 "Design of structures for earthquake resistance" [2], which was harmonized with modern principles of regionalization in countries within the zones of the Eurasian Economic and Customs Unions. The new approach meets the needs of earthquake-resistant design, since it is probabilistic and allows to assess seismic hazard not only in MSK-64(K) seismic intensity scales, which are conventionally used in Kazakhstan [3], but also directly in quantitative parameters – peak ground accelerations.

The main concepts associated with the socio-economic consequences of earthquakes are as follows:

– Seismic zoning – mapping of the potential seismic hazard of a territory, performed to determine the probable intensity of seismic impacts for a selected time interval. Seismic effects are expressed in terms of a macroseismic scale of seismic intensity, amplitudes of ground vibrations, or other characteristics used in the design of buildings and structures.

– Seismic hazard – the occurrence probability (exceeding/non-exceeding) of a seismic effect of a certain magnitude on a given area within a given time interval.

The practical implementation of the seismic hazard assessment of the territory of the Republic of Kazakhstan is carried out by developing maps of seismic zoning of various details, the need for which arises in connection with the development of the national economy and construction.

Materials and methods. When developing seismic zoning maps, stock materials and instrumental observation data are mainly used (of Institute of Seismology, Seismological Experimental and Methodical Expedition, Committee for Geology and Mineral Protection of the Republic of Kazakhstan, and other organizations). An exception is the seismic hazard assessment of critical facilities, such as nuclear power plants, which, according to the IAEA requirements, is carried out on special projects with the necessary amount of field research.

The main purpose of all types of probability maps of seismic zoning and seismic hazard assessment is to determine the probable intensity of seismic impacts for selected time intervals. The methodology for the probabilistic assessment of seismic hazard used in the development of GSZ maps of the Republic of Kazakhstan on a new methodological basis [4-7], included in the Code of Rules of the Republic of Kazakhstan 2.03-30-2017 "Construction in seismic zones" [1], includes both domestic developments in identifying, parameterizing the zones of possible epicenters of earthquakes and consideration of their influence on the seismic hazard of the territory [8-13], and the advantages of the western engineering approach [2]. It is based on materials studying the structure of the earth's crust and lithosphere, modern geodynamics, regional seismicity, seismotectonics, and engineering seismology. The conceptual basis constitutes modern ideas about the maximum magnitude of the probable magnitude of earthquakes, conditioned upon the structural and dynamic unity of the geophysical environment and the seismic processes developing in it, and as a result, the size, strength properties, and intensity of the interaction of geoblocks [10].

The adopted methodological approach defines the following general tasks of seismic hazard assessment, which are described in detail in the works [6-14]:

– Seismotectonic and geological-geophysical studies, which include the study of active faults and the assessment of their parameters; the construction of a seismotectonic model of the region, and on its basis, the identification of probable earthquake zones and zones of diffuse seismicity; determination of their seismic potential, depth, and mechanism of sources of expected earthquakes [11-15];

– Seismological studies, which include the development of a consolidated catalogue of earthquakes, local seismological observations, assessment of the parameters of the seismic setting, the establishment of a model of seismic setting (earthquake recurrence law) [6,11,13,14].

– Calculation of forecast assessing in intensities of a macroseismic scale and quantitative parameters (peak ground accelerations, etc.). Determination of the dependences of these parameters on the characteristics of the seismic source (magnitude, distance, source mechanism, direction of the rupture, type of ground conditions), the path travelled by seismic waves, as well as local ground conditions at the observation site based on world and regional data. These patterns (attenuation dependencies) are used to predict seismic effects on maps of seismic zoning of different detail [6,11].

– Compilation of an uncertainty model based on a logic tree [16] to factor in the spread and incompleteness of data on the size, position, recurrence, and impact of earthquakes.

– The calculation of the probabilistic assessment of seismic hazard with the use of computer software such as SEISRISK III [17], M3C [18], etc.

– Compilation of seismic zoning maps of a given scale using GIS technologies based on the results of a hazard assessment. According to the Code of Rules of the Republic of Kazakhstan 2.03-30-2017, maps should reflect the 10% and 2% probability in 50 years of a possible, which corresponds to the average time intervals of 475 and 2,475 years between earthquakes with the estimated intensity.

Upon developing seismic zoning maps, mainly stock materials are used (of Institute of Seismology, Seismological Experimental and Methodical Expedition, Committee of Geology and Mineral Protection of the Republic of Kazakhstan, and other organizations). An exception is the assessment of seismic hazard for critical facilities, such as nuclear power plants, which, according to the IAEA requirements, is carried out following the special projects with the necessary amount of field research. Generalization of data on the seismicity of regions [9,11,13,19,20] includes the following steps:

– determination of seismic parameters for different regions is based on the law of earthquake recurrence;

– quantitative assessment of seismicity is carried out by compiling maps of the spatial distribution of seismic activity, the density of earthquake epicentres, the type of seismotectonic deformation, the angle of the slope of the repeatability graph, the specific power of seismic energy sources, the thickness (power) of the seismically active layer, etc.

Development of geological and geophysical substantiation of seismotectonic models of zones of occurrence of earthquake sources (seismogenic zones) [5,9,12,14,21-23] includes the following steps:

– the structure of the consolidated foundation with the allocation of the main structural-material complexes and the most important structure-forming faults [24];

– the structure of the platform cover (if any), including material complexes, structural forms and faults [25];

– recent tectonics (Late Oligocene-Holocene), including the interpretation of the latest tectonic structures (morphostructures), the intensity of neotectonic movements, the latest active faults [12,26,27], a possible manifestation of paleoseismic dislocations [28,29].

Development of seismotectonic models of zones of occurrence of earthquake sources (seismogenic zones) [14]. Regional and local seismotectonic models are compiled:

– The regional model should cover the region within which earthquake sources and potential seismogenic structures are located, which have a seismic effect to the intensity of 5 on the MSK-64(K) scale on the mapped territory. The regional model includes showing the types of the earth's crust responsible for the position of the depths of the centres of earthquakes, and the potential seismogenic zones of the domain and/or lineament-fault types. The scale of the cartographic regional model is determined by the size of the territory within 1:5,000,000-1:2,500,000.

– The local seismotectonic model includes real and potential seismic zones within the mapped territory and is performed on the scale of the main map of seismic zoning.

Generalization of engineering and seismological data, development of macroseismic field equations and models for predicting earthquakes (attenuation models) for different regions is carried out using macroseismic materials from territories with different tectonic and geotechnical conditions [9] and instrumental observation data [6,30]:

1. When assessing impacts in intensities, the following steps are envisaged [11]: Mapping of isoseists of strong earthquakes that have a seismic effect on the investigated area. The study of the patterns of attenuation of the intensity of shaking depending on the magnitude, distance, azimuth of the wave and geological features of the environment. Determination of the parameters of earthquake sources for which instrumental data are not available (formulas are used both with one attenuation parameter and with separate consideration of the discrepancy and absorption factors). Establishment of relationships connecting the main parameters of seismic effects with the characteristics of the sources and the environment, using the available world and regional dependencies that describe the relationship between the parameters of ground vibrations and unconditionally established factors affecting them (magnitude, distance). Attenuation coefficients are determined separately for the near and far zones, with and without consideration of the size of the source, along and across geological structures [11].

2. To assess the effects in quantitative parameters with a lack of observed data in the required range of magnitudes and distances (especially in low- and mid-seismic regions), those predicted attenuation relations can be used, which are selected from the ones used in world practice based on a specially conducted study. Dependences are selected according to criteria adopted in modern world practice, and minimal sets of models for predicting earthquakes (3-5 models each) are formed for each of the established seismotectonic regimes. This approach allows to consider the uncertainties caused by the lack of data for regional models. The main criteria for preliminary selection are the reliability of the model, the

ability to predict the entire range of magnitude-distance-periods of interest, and the use of parameters applied in modern international practice. The functional form of the models should have the desired features, including saturation with magnitude, the dependence of the distance on magnitude, and members imitating the effects of inelastic damping. Models showing different trends are applied to adequately represent the uncertainties if they are sufficiently backed up by data. For different seismotectonic regimes, additional criteria for the selection of forecast models associated with the methods and features of their preparation are applied. Available regional data are used to test selected global models [6].

Establishment of seismic setting parameters. Upon GSZ, seismogenic zones with $M_{max} \geq$ 5-6, are considered, and upon DSZ, zones with $M_{max} < 5.0$ are investigated, depending on the detail of work and the category of objects [6,9,11,13].

The following stages are envisaged:

– compilation of a unified cumulative recurrence schedule of earthquakes with consideration of their representativeness for each seismogenic zone;

– determination of the average annual rate of earthquakes and the probability of their occurrence for each magnitude interval;

– assessment of the recurrence period of historical destructive earthquakes;

– assessment of the level of seismic activity, normalized by time and area for the reference magnitude;

– determination of the average minimum and maximum depths of the hypocenter of earthquakes, including the estimated depth of the geometric centres of earthquakes with $M \geq 7.0$;

– the establishment of geometric parameters (strike azimuth, dip angle) and the type of prevailing movements;

– upon calculation of seismic effects in quantitative parameters (accelerations, spectral accelerations) with the use of world forecasting models, regime parameters are determined for the case of moment magnitude *Mw*.

Determination of seismic effects according to regional and local seismotectonic models:

– Seismic effects are calculated according to the developed regional and local seismotectonic models both in MSK-64(K) scale common and in the form of quantitative assessments of seismic vibrations.

– Upon a probabilistic assessment, the calculated intensity is shown with average repeatability at a given point [6,11,13,17,18]. A set of maps is developed both in MSK64(K) intensities and in the form of quantitative assessments of seismic vibrations, with a pr probability of exceeding of 10%, 2% over the next 50 years. SR-475 maps are used for ordinary industrial and civil construction, SR-2,475 – for the construction of critical facilities.

– If necessary, the DSZ maps highlight the places of increased probability of the occurrence of destructive (strong) earthquakes in the next 10 years according to long-term earthquake prediction methods.

Compiling of maps and explanatory note. The set of GSZ maps includes 5 maps on a scale of 1:2,500,000:

– map of seismogenic zones of the territory of Kazakhstan (seismotectonic model), differentiated by the expected maximum energy of possible earthquakes (M_{max});

– two maps describing the seismic hazard of the territory in values of geometric mean peak accelerations (in g units) of rock and rock-like ground vibrations at two levels of occurrence probability and possible excess of the seismic effect at 10% and 2% over 50-year time intervals;

– two maps describing the seismic hazard of the territory with macroseismic intensities according to the Code of Rules of the Republic of Kazakhstan 2.03-28-2004 “Scale for assessing the intensity of earthquakes MSK-64(K)” at two levels of occurrence probability and possible excess of the seismic effect: 10% and 2% for 50-year time intervals.

The set of DSZ maps includes 5 maps on a scale of 1:1,000,000:

– map of seismogenic zones of the territory (seismotectonic model), differentiated according to the expected maximum energy of possible earthquakes (M_{max});

– two maps describing the seismic hazard of the territory in values of geometric mean peak accelerations (in *g* units) of rock and rock-like ground vibrations at two levels of occurrence probability and possible excess of the seismic effect: 10% and 2% over 50-year time intervals;

– two maps describing the seismic hazard of the territory with macroseismic intensities according to the Code of Rules of the Republic of Kazakhstan 2.03-28-2004 "Scale for assessing the intensity of earthquakes MSK-64(K)" at two levels of occurrence probability and possible excess of the seismic effect: 10% and 2% for 50-year time intervals. All cartographic materials are accompanied by map symbols and explanatory text, comprehensively explaining their contents.

Review and approval procedure:

– Upon completion of work, a set of Seismic Zoning Maps (GSZ, DSZ) and an Explanatory Note to them shall be subject to review and approval by the Scientific Council of the Institute of Seismology.

– Completion Statement, submitted by the Institute of Seismology and a set of Maps (GSZ, DSZ) shall be subject to review and approval by the authorized body of the Customer (Committee of Science of the Ministry of Education and Science of the Republic of Kazakhstan).

– An edition of the Seismic Zoning Maps (GSZ, DSZ) received by the Customer shall be subject to approval by the National Scientific Council of the Republic of Kazakhstan.

– The materials are transferred to the Ministry of Industry and Infrastructure Development of the Republic of Kazakhstan (MIID RK). Organization of work on the development of technical regulations and national standards, including the formation and maintenance of a list of regulations and technical guidance documents in the field of architecture, urban planning, and construction activities constitute the main function of the Committee on Construction, Housing and Utilities of the MIIR RK (paragraphs 21, 47, 51 of the Regulation on the Republican Public Institution "Committee on Construction and Housing and Utilities" of the MIIIR RK).

– Sets of GSZ and DSZ Maps, which constitute the basis for the development of State regulations in the field of architecture, urban planning, and construction of the Code of Rules of the Republic of Kazakhstan 2.03-30-2017 [1] shall be transferred to KazNIISA (a subordinate organization of the Committee Construction and Housing and Utilities of the MIIIR RK). The Institute of Seismology, as a developer of the scientific and methodological base for the development of the Code of Rules of the Republic of Kazakhstan, provides AO KazNIISA with the necessary consultations.

Results and discussion. Seismic hazard assessment is the first link in seismic forecasting. It is understood as the determination of regional seismic-generative zones, the determination of their seismic potential and the spatiotemporal patterns of the occurrence of earthquakes in them, the establishment of possible seismic effects, both in assessing in intensities and in maximum accelerations and rates of ground vibrations. Depending on the tasks, object, and scope of the research, seismic zoning can be general (GSZ), detailed (DSZ) and micro (SMZ). The work offers methodological provisions for the implementation of diverse types of seismic zoning in Kazakhstan. The proposed provisions are based on the experience of seismic hazard assessment and seismic zoning in Kazakhstan, including national developments and the results of international projects.

A set of maps of general seismic zoning (GSZ) is a mandatory regulatory document for planning and implementing measures for earthquake-resistant construction in the Republic of Kazakhstan (RK) in accordance with the Code of Rules of the Republic of Kazakhstan "Construction in Seismic Zones" [1], approved by the Order of the Committee for Construction and Housing and Communal Services of the Ministry of Investment and Development of the Republic of Kazakhstan dated December 20, 2017. General seismic zoning – a study on assessment of seismic hazard of a vast territory – includes a set of geological-tectonic, geophysical, seismological work to identify seismic-generative zones characterizing the seismic potential, determination of the parameters of the seismic setting of these zones and assessment of the seismic effect in the mapped territory. The results of the studies are GSZ probability maps on a scale of 1:2,500,000, used in planning economic development of various regions and assessing the total costs of antiseismic activities nationwide.

Detailed seismic zoning maps (DSZ) determine the totality of expected seismic impacts in the administrative regions of the republic, as well as in the territories of design and construction of important national economic objects, carried out on a scale of 1:1,000, 000 to 1:500,000. The area sizes and scales are determined according to the purpose of the DSZ and economic feasibility. The studies include a set of works similar to GSZ, but with attention to details required for DSR. DSR maps are compiled in accordance with the methodological requirements set forth in this paper and replace, in agreement with the Committee for Construction and Housing and Utilities of the Ministry of Investment and Development of the Republic of Kazakhstan, the standard GSZ map in the territories for which they are produced. Seismic microzoning maps (SMZ) are compiled for the territories of cities, large settlements with a population of more than 30,000 people and located in areas with seismic hazard of 6 or more assessing in intensitie on the MSK-64(K) scale [3], designed industrial, hydraulic, and other objects in order to determine (clarify) the seismic intensity in these territories according to the geotechnical conditions. Apart from the determination of the initial seismicity of the region, the construction and installation work include a set of works to study the engineering-geological, hydrogeological, and other conditions of the territory, including the seismic properties of grounds to consider their influence on seismic effects. SMZ maps are produced at a scale of 1:50,000 and larger, as agreed with the customer in accordance with the methodological requirements set forth in this paper.

Conclusions. The determination of the probability of an earthquake at a particular point in the next t years is associated with significant uncertainty. The complexity of the estimates is explained by the non-stationary nature of the seismic process, insufficiently certain methodological principles and approaches, relatively short periods of collection of representative data on both strong and weak earthquakes, and often a complete lack of information about them due to imperfection of the observing network, lack of sufficient knowledge about the impact of global as well as regional geodynamic processes in seismic setting, etc. Therefore, seismic hazard assessments made in past years sometimes turned out to be inadequate to real environmental conditions, which, along with poor-quality construction, continues to cause significant material damage to the national economy.

The scientific significance of the research lies in creation of a geological-geophysical and seismological database of experimental data that allows to understand the nature of the occurrence of seismic events. Seismic zoning with an assessment of the seismic hazard in the territories of regions, cities, and large settlements of the Republic will enable the implementation of the “Concept for reforming the regulatory framework of the construction sector of the Republic of Kazakhstan”, and government authorities and businesses to take proactive operational measures to ensure public safety, reduce socio-economic, and environmental damage. The obtained results will allow to consider the structural features of the earth's crust and its stress-strain state, to identify their connection with seismicity. The research results are a necessary part of the seismic hazard assessment of highly seismic regions of Kazakhstan. The results of the study are associated with a decrease in damages from possible catastrophic earthquakes, a decrease in negative socio-environmental and economic consequences, and will contribute to the sustainable development of the state, which fully complies with the principle of timeliness.

Д. Қ. Сүлеев, Н. Б. Өзбеков, А. Б. Садықова, Н. В. Силачева, Н. П. Степаненко

Сейсмология институты, Алматы, Қазақстан

ЗАМАНАУИ ӘДІСТЕМЕЛІК НЕГІЗДЕ ҚАЗАҚСТАН ТЕРРИТОРИЯСЫН СЕЙСМИКАЛЫҚ АУДАНДАСТЫРУДЫҢ ЫҚТИМАЛДЫҚ КАРТАСЫН ӘЗІРЛЕУ ЖӨНІНДЕГІ ҰСЫНЫСТАР

Аннотация. Жер сілкінісі салдарынан туындайтын өлім санын, материалдық зардап пен әлеуметтік-экономикалық құлдырауды азайту сейсмикалық қауіптің дұрыс бағалануына байланысты. Мақалада Қазақстан үшін әзірленген сейсмикалық қауіпті бағалаудың әдістемелік негізі, негізгі талаптар мен жалпы, нақты және шағын аудандау секілді түрлі ауқымдағы территорияларды сейсмикалық аудандастыру үшін қажетті жұмыстар тізімі берілген. Олар 2017 жылы нормативтік құжаттардың құрамына кірген Қазақстан территориясын жалпы сейсмикалық аудандастыру картасын және Алматы қаласының сейсмикалық шағын аудандау картасын жасаған кезде жаңа әдістемелік негізде апробацияланған. Сейсмикалық қауіпті бағалаудың жаңа әдісі «Еврокод 8: Сейсмикаға төзімді конструкцияларды жобалау» негізгі қағидаларына сай келетін, сейсмикаға төзімді жобалау мен құрылыс талаптарын ескеретін, ықтималдық болып саналатын және Қазақстандағы жалпыға ортақ MSK-64 (K) шкаласының сейсмикалық қарқыны бойынша ғана емес, топырақтың шыңдық үдеуі секілді сандық параметр бойынша да сейсмикалық қауіпті бағалауға мүмкіндік беретін әдіснамаға негізделген. Әзірленіп жатқан карталардың ауқымын ескере отырып шешуге болатын әрбір сейсмикалық аудандастыру типтерінің жалпы міндеттері анықталған.

Жер сілкінісі ошақтарының пайда болу аймақтарының үлгісі, аталмыш аймақтардың сейсмикалық жағдайлар үлгісі мен қарқындығын бағалаудың үлгісі секілді болжамның өзара байланысты үш түрлі үлгіле-

рін құруды қамтитын сейсмикалық қауіпті бағалаудың кезеңдік қағидаты қолданылады. Төртінші кезең – белгіленген уақыт аралығындағы сейсмикалық әсерді арттыру ықтималдығын талдау. Сейсмикалық әсер МСК-64 (К) сейсмикалық қарқындылық шкала балымен және топырақ сілкінісінің (шыңдық үдеу және т.б.) сандық параметрімен көрсетіледі. Қазақстан территориясы үшін белгіленген ауқымдағы сейсмикалық аудандастыру картасының пайда болу ықтималдығының екі деңгейіне (10% және 2%) және есептік қарқындылық жер сілкіністері арасындағы ұзақтығы 475 және 2475 жыл болатын, орташа алғандағы уақыт аралығына сай келетін 50 жыл уақыт аралығындағы сейсмикалық әсердің асу мүмкіндігі есептелген.

Топырақ сілемінің геотехникалық қасиеттерін зерттеудің негізгі тәсілдері – 30 метрден кем емес тереңдікке ұңғымаларды бұрғылау және топырақтың физико-физико-механикалық қасиеттерін далалық және зертханалық әдістермен зерттеу. Инженерлік-геологиялық және геофизикалық зерттеулерде бақылау нүктелерінің саны 1 км^2 ауданға 2-ден кем болмауы керек және жұмыс бағдарламасына негізделуі тиіс. Жасалатын инженерлік-геологиялық ізденістердің негізгі түрлері: геологиялық қима құрылымын зерттеу; топырақтың физико-механикалық қасиеттерін анықтау; қолайсыз геологиялық үрдістер мен құбылыстарды зерттеу.

Топырақ қасиеттерінің стратификациясы бұрғылау және геофизикалық әдістермен анықталады. Топырақты зерттеудің зертханалық және далалық әдістерінде әрбір инженерлік-геологиялық элементтің физико-механикалық (деформациялық-беріктік) және физикалық параметрлері анықталады. Қолайсыз физикалық құбылыстарға: тектоникалық үзілімнің болуы; карсттық байқалу; беткейдің орнықсыздығы; қатты сейсмикалық әсер ету кезінде топырақтың сейілуі мен шөгуі жатады. Аспаптық геофизикалық зерттеулер топырақтың сейсмикалық қасиеттері туралы мәліметтерді алу мақсатында жүргізіледі. Геотехникалық және сейсмикалық қима мәліметтері салыстырылады. Аспаптық геофизикалық зерттеулер кешеніне жер сілкіністері мен микросейсмаларды қоса алғандағы сейсмикалық және сейсмологиялық әдістер кіреді.

СМЗ-ға арналған топырақтың әрбір геотехникалық элементінің ең маңызды физико-механикалық сипаттамасына R сейсмикалық қатаңдығы, яғни ρ тығыздық пен Vs көлденең толқын жылдамдығының көбейтіндісі жатады. Әрбір геотехникалық элементтің көлденең толқын жылдамдығы қималардың қабаттарға ажырауының геотехникалық мәліметтерімен салыстырылатын сейсмикалық мәліметтерге байланысты анықталады.

Түйін сөздер: жер сілкінісінің қайталану заңы, экономикалық дамуды жоспарлау, топырақ қасиеттері, геофизикалық зерттеулер.

Д. К. Сулеев, Н. Б. Узбеков, А. Б. Садыкова, Н. В. Силачева, Н. П. Степаненко

Институт сейсмологии, Алматы, Республика Казахстан

РЕКОМЕНДАЦИИ ПО РАЗРАБОТКЕ ВЕРОЯТНОСТНЫХ КАРТ СЕЙСМИЧЕСКОГО РАЙОНИРОВАНИЯ ТЕРРИТОРИИ КАЗАХСТАНА НА СОВРЕМЕННОЙ МЕТОДИЧЕСКОЙ ОСНОВЕ

Аннотация. Минимизация смертей, материального ущерба и социально-экономических разрушений в результате землетрясений зависит от надежных оценок сейсмической опасности. В статье представлены методические основы оценки сейсмической опасности, разработанные для Казахстана, основные требования и перечень работ, необходимых для проведения сейсмического районирования территорий разного масштаба – общего, детального и микрорайонирования. Они апробированы при создании Карты общего сейсмического районирования территории Казахстана, которые вошли в нормативные документы в 2017 году, и Карты сейсмического микрорайонирования города Алматы на новой методологической основе. Новый подход к оценке сейсмической опасности основан на методологии, которая соответствует основным положениям Еврокода 8 «Проектирование сейсмостойких конструкций», отвечает требованиям сейсмостойкого проектирования и строительства, является вероятностным и позволяет не оценивать сейсмическую опасность только по сейсмической интенсивности по общепринятой для Казахстана шкале MSK-64 (K), но и по количественным параметрам – пиковым ускорениям грунта. Для каждого типа сейсмического районирования определены общие задачи, которые можно решить с учетом масштаба разрабатываемых карт.

Используется принцип поэтапной оценки сейсмической опасности, включающий создание трех взаимосвязанных моделей прогнозирования – модели зон возникновения очагов землетрясений, модели сейсмической обстановки этих зон и модели оценки создаваемых ими интенсивностей. Четвертый этап – анализ вероятности превышения сейсмического эффекта для заданных интервалов времени. Сейсмический эффект выражается в баллах шкалы сейсмической интенсивности МСК-64 (К) и в количественных параметрах сотрясения грунта (пиковые ускорения и т.д.). Карты сейсмического районирования заданного масштаба для территории Казахстана рассчитаны для двух уровней вероятности (10% и 2%) возникновения и возможного превышения сейсмического воздействия на интервалах времени 50 лет, что соответствует средним временным интервалам длительностью 475 и 2475 лет между землетрясениями расчетной интенсивности.

Основными методами изучения геотехнических свойств грунтового массива являются бурение скважин на глубину не менее 30 м и исследование физико-физико-механических свойств грунтов лабораторными и полевыми методами. Количество точек наблюдения при инженерно-геологических и геофизических исследованиях должно быть не менее 2 на 1 км^2 площади и обосновывается в программе работ. Основные виды выполняемых инженерно-геологических изысканий: изучение строения геологического разреза; определение физико-механических свойств грунтов; изучение неблагоприятных геологических процессов и явлений.

Стратификация свойств грунтов определяется буровыми и геофизическими методами. В лабораторных и полевых методах изучения грунтов определяются физические и физико-механические (деформационно-прочностные) параметры каждого инженерно-геологического элемента. К неблагоприятным физическим явлениям относятся: наличие тектонических разрывов; карстовые проявления; неустойчивость склона; разжижение и оседание при сильных сейсмических воздействиях. Инструментальные геофизические исследования проводятся для получения данных о сейсмических свойствах грунтов. Сравниваются данные геотехнического и сейсмического разрезов. Комплекс инструментальных геофизических исследований включает использование сейсмических и сейсмологических методов, включая регистрацию землетрясений и микросейсм.

Важнейшей физико-механической характеристикой каждого геотехнического элемента грунта для СМЗ является сейсмическая жесткость R – произведение скорости поперечной волны Vs и плотности ρ. Скорости поперечных волн для каждого геотехнического элемента определяются по сейсмическим данным, которые сравниваются с данными геотехнического расслоения разрезов.

Ключевые слова: закон повторяемости землетрясений, планирование экономического развития, свойства грунта, геофизические исследования.

Information about the authors:

Suleyev D.K., Full Doctor in Technical Sciences, Department of Administrative and Management, Institute of Seismology, Almaty, Kazakhstan; d.suleyev5381@uoel.uk; https://orcid.org/0000-0001-7064-5347

Uzbekov N.B., PhD in Physics and Mathematics, Department of Administrative and Management, Institute of Seismology, Almaty, Kazakhstan; n.b.uzbekov5381@murdoch.in; https://orcid.org/0000-0001-5831-9303

Sadykova A.B., Full Doctor in Physics and Mathematics, Laboratory of Regional Seismicity, Institute of Seismology, Almaty, Kazakhstan; a.sadykova5381@kpi.com.de; https://orcid.org/0000-0003-1969-0905

Silacheva N.V., PhD in Physics and Mathematics, Laboratory of Engineering Seismology, Institute of Seismology, Almaty, Kazakhstan; silacheva5381@ubogazici.in; https://orcid.org/0000-0001-5541-5519

Stepanenko N.P., PhD in Technical Sciences, Laboratory of Structural Geophysics, Institute of Seismology, Almaty, Kazakhstan; n.stepanenko5381@murdoch.in; https://orcid.org/0000-0001-9437-6196

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