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RESEARCH ARTICLE

SEISMIC EVENT OF 23 JANUARY 2024 AND ANALYSIS OF ITS CONSEQUENCES FOR BUILDINGS IN ALMATY

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Abstract. *On January 23, 2024, an earthquake of magnitude M_b =7.27 occurred in China. In Almaty city, it was registered by stations of the engineering and seismometric service of "KazRDICA" JSC and seismic stations of the National Scientific Center for Seismological Observations and Research. What is new is the analysis of instrumental data from seismic stations and the consequences for city buildings based on the results of sample surveys of 188 construction sites. It is established that the intensity of the seismic impact is not less than 5 points. There is no discernible effect of the presence of tectonic faults on the instrumental characteristics of seismic motion in the basement of the building (stations No. 17 'Novaya Ploshchad' and No. 16 'Hotel'). At Station No. 3 "School", abnormally high acceleration values of 88.46 cm/s² and 81.89 cm/s² were recorded at floor level. It was found that the horizontal components of the seismic response have a significant long-period component. There is a peak in the spectral curve at a period of approximately 0.9-1.0 seconds. Even with such an intensity of impact, non-load-bearing structural elements of the building were damaged, which leads to the need to incur financial costs for cosmetic repairs of buildings. An algorithm for carrying out repair and restoration work is presented. It has been established that this type of seismic impact poses a risk to high-rise buildings. Consequently, the earthquake was felt by residents of high-rise and multi-storey buildings. A detailed survey is recommended for a number of buildings, which entails additional costs. The results of the work are useful for understanding ways to solve the problems of earthquake-resistant construction using the results of an analysis of the effects of local earthquakes. It is shown that even with 5-6 magnitude earthquakes, the damage can be significant.*

Keywords: *accelerogram; examination, gain; score; magnitude; impact.*

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ҒЫЛЫМИ МАҚАЛА

2024 ЖЫЛҒЫ 23 ҚАҢТАРДАҒЫ СЕЙСМИКАЛЫҚ ОҚИҒА ЖӘНЕ АЛМАТЫ ҒИМАРАТТАРЫНА САЛДАРЫ ЖАЙЛЫ ТАЛДАУ

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Аңдатпа. *2024 жылғы 23 қаңтарда Қытай аумағында M_b = 7.27 магнитудалы жер сілкінісі болды. Алматы қаласының аумағында оны ҚазҒЗЖИ АҚ инженерлік-сейсмометриялық қызмет станциялары және Сейсмологиялық бақылау және зерттеу ұлттық ғылыми орталығының сейсмикалық станциялары тіркеді. Сейсмикалық станциялардың құрал-саймандық деректерін және 188 құрылыс нысанын іріктемелі зерттеу нәтижелері негізінде қала ғимараттары үшін салдарын талдау жаңалық болып табылады. Сейсмикалық әсердің қарқындылығы кемінде 5 балл екені анықталды. Ғимараттың негізіндегі (17-ші «Новая Площадь» және 16-шы «Hotel» станциялары) сейсмикалық қозғалыстың аспаптық сипаттамаларына тектоникалық жарықтардың бар болуының айқын әсері байқалмайды. 3-станцияда "Школа" еден деңгейінде 88,46 см/с² және 81,89 см/с² шамасындағы ерекше жоғары үдеу мәндері тіркелді. Сейсмикалық жауаптың көлденең компоненттерінде ұзақ периодты маңызды құрамшы бар екені анықталды. Спектрлік қисықта шамамен 0,9-1,0 секундтық периодта шың бар. Әсердің қарқындылығының өзінде ғимарат конструкцияларының көтермейтін элементтері зақымдалды, бұл ғимараттарды косметикалық жөндеу үшін қаржылық шығындарды орындау қажеттілігіне әкеледі. Жөндеу және қалпына келтіру жұмыстарын жүргізу алгоритмі ұсынылған. Бұл типтегі сейсмикалық әсердің биік ғимараттарға қауіп төндіретіні анықталды. Нәтижесінде жер сілкінісін биік және көпқабатты ғимараттардың тұрғындары сезді. Бірқатар ғимараттарға егжей-тегжейлі тексеру жүргізу ұсынылды, бұл қосымша шығындарға әкеп соқтырады. Жұмыс нәтижелері жергілікті жер сілкіністерінің салдарларын талдау нәтижелерін тарта отырып, сейсмикалық төзімді құрылыс міндеттерін шешу жолдарын түсіну үшін пайдалы. Тіпті 5-6 баллдық жер сілкіністері кезінде де зиян елеулі болуы мүмкін екені көрсетілген.*

Түйінді сөздер: *акселерограмма; зерттеу; күшейту; балл; магнитуда; әсер ету.*

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НАУЧНАЯ СТАТЬЯ

СЕЙСМИЧЕСКОЕ СОБЫТИЕ 23 ЯНВАРЯ 2024 ГОДА И АНАЛИЗ ПОСЛЕДСТВИЙ ДЛЯ ЗДАНИЙ АЛМАТЫ

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Аннотация. *23 января 2024 года на территории Китая произошло землетрясение магнитудой M_b =7.27. На территории города Алматы оно было зарегистрировано станциями инженерно-сейсмометрической службы АО КазНИИСА и сейсмическими станциями Национального научного центра сейсмологических наблюдений и исследований. Новым является анализ инструментальных данных сейсмических станций и последствий для зданий города на основании результатов выборочных обследований 188 строительных объектов. Установлено, что интенсивность сейсмического воздействия не менее 5 баллов. Отсутствует заметное влияние наличия тектонических разломов на инструментальные характеристики сейсмического воздействия в подвальной части здания (станции №17 «Новая площадь» и № 16 «Гостиница». На станции № 3 "Школа" выявлены аномально высокие величины ускорений в уровне покрытия 88.46 см/с^2 и 81.89 см/с^2. Выявлено, что горизонтальные компоненты сейсмического воздействия имеют значительную длиннопериодную составляющую. Имеется пик спектральной кривой на периоде примерно 0.9-1.0 сек. Даже при такой интенсивности воздействия получили повреждения не несущие элементы конструкций здания, что приводит к необходимости выполнения финансовых затрат для косметического ремонта зданий. Приведен алгоритм выполнения ремонтно-восстановительных работ. Выявлено, что такого типа сейсмическое воздействие опасно для высотных зданий. Поэтому землетрясение ощущалось жильцами высотных зданий и зданий повышенной этажности. Для ряда зданий рекомендовано проведение детального обследования, что влечет за собой дополнительные затраты. Результаты работы полезны для понимания путей решения задач сейсмостойкого строительства с привлечением результатов анализа последствий местных землетрясений. Показано, что даже при 5-6 балльных землетрясениях ущерб может быть значительным.*

Ключевые слова: *акселерограмма; обследование; усиление; балл; магнитуда; воздействие.*

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1 INTRODUCTION

According to the operational data of the Seismic Information Collection and Processing Center of the Institute of Geophysical Research of the National Nuclear Center of the Republic of Kazakhstan (IGR NNC RK), an earthquake occurred in China on January 23, 2024 at 00 h. 09 min. Astana time (January 22 at 18 h. 09 min. GMT).

The coordinates of the epicenter are 41.23 degrees north latitude, 78.59 degrees east longitude. Magnitude M_b=7.27. The earthquake occurred 260 km south-east of Almaty city. The depth is 13 km (Figure 1).

The earthquake was felt in Central Asian countries (Kyrgyzstan, Kazakhstan, Uzbekistan, Turkmenistan, Tajikistan), Azerbaijan, India, and Russia.

In Almaty city, the earthquake was felt with an intensity of at least 5 points.

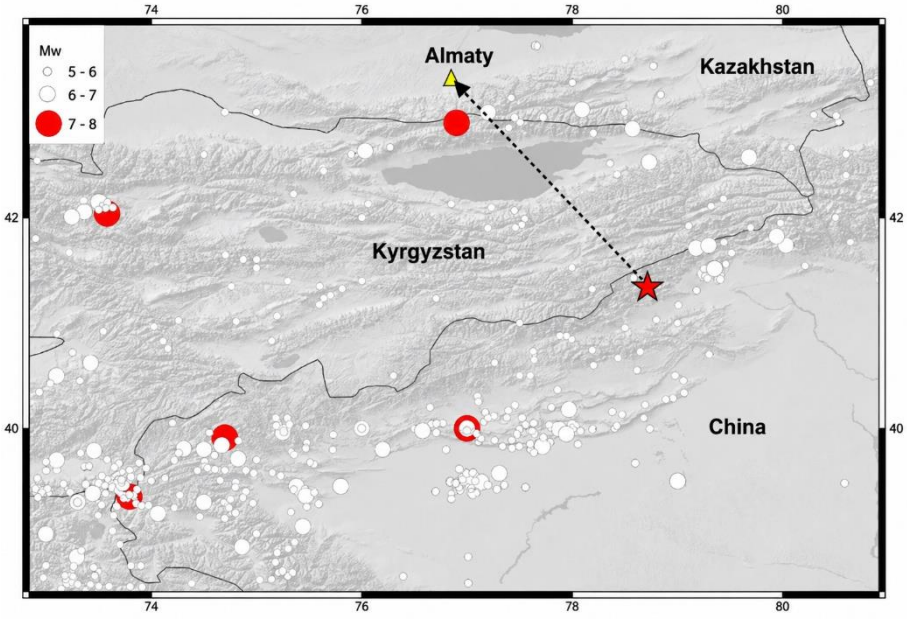


Figure 1 - Location of the earthquake on January 23, 2024 (according to the Data Center of the IGR NNC RK [https://kndc.kz/index.php/home-ru/kndcnews/227-operativnaya-informatsiya-o-proizoshedshem-zemletryasenii-23-01-2024-g]

Aftershock 1. According to the operational data of the Data Center of the IGR NNC RK on January 23, 2024 at 00 h. 42 min. Astana time (January 22 at 18 h. 42 min. GMT), an aftershock occurred. The coordinates of the epicenter are: 41.20 degrees north latitude, 78.81 degrees east longitude. Magnitude M_b =6.34.

Aftershock 2. According to the operational data of the Data Center of the IGR NNC RK on January 23, 2024 at 01 h. 36 min. Astana time (January 22 at 19 h. 36 min. GMT), an aftershock occurred. Coordinates of the epicenter: 40.95 degrees north latitude, 78.68 degrees east longitude. Magnitude M_b =5.86

Aftershock 3. According to the operational data of the Data Center of the IGR NNC RK on January 23, 2024 at 02 h. 29 min. Astana time (January 22 at 20 h. 29 min GMT) an aftershock occurred. Coordinates of the epicenter: 40.92 degrees north latitude, 78.78 degrees east longitude. Magnitude M_b =5.34.

The Chinese earthquake of January 23, 2024 was felt by almost all residents of Almaty city, both in multi-storey and individual residential buildings. Many people felt the shaking of buildings. Hanging objects were swinging in the apartments. Panic began among the population, and many people began to leave the buildings and the city. Traffic jams have formed in the underground car parks of apartment buildings and the main streets of Almaty city. There were queues at gas stations.

The tragic consequences of the devastating earthquakes in Turkey in February 2023 played an

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important role in people's panic.

The intensity of the earthquake on January 23, 2024 in Almaty on the MSK-64 (K) scale [1] was:

–based on people's reactions - 5 points;

–based on instrumental data from acceleration recordings of the KNDC seismometric station of the IGR NNC RK - 5 points;

–based on the instrumental data of the acceleration records of the seismometric stations of "KazSRDICEA" JSC - 5 points (at least).

Thus, it can be concluded that the intensity of the Chinese earthquake effect on January 23, 2024 in Almaty city on the MSK-64 (K) scale [1] was at least 5 points.

1.1 An overview of 5-6 point seismic events in Almaty city. Suusamyr earthquake on August 9, 1992

The Suusamyr earthquake occurred on August 9, 1992 at 08 h. 04 min. 36 sec. local time (UTC+6) in Kyrgyzstan, in Panfilov district of Chui region, the magnitude is M=7.5 with an intensity at the epicenter of 9.5-10 points on the MSK-64 scale. This event, in terms of the size of the source and the released energy, became one of the strongest, along with the Chatkal earthquake of 1946 M =7.5, for the entire period of instrumental observations in Kyrgyzstan. The earthquake was felt throughout Kyrgyzstan and neighboring countries - Tajikistan, Uzbekistan and Kazakhstan.

The earthquake started with a strong underground rumble, as if an explosion had occurred. The hum, noise, and cracking were so strong that household items, chimneys, stoves, and walls and roofs of houses could not be heard falling. The concussion tossed people sitting on the ground, but people who got to their feet could not stand on their feet. According to residents, at the time of the earthquake, "waves" ran through the ground, as if the surface of the soil became bumpy and then straightened. Cracks appeared on the earth's surface in the epicentral zone, and massive landslides, rockfalls, and landslides were observed in the mountains. Rock "shots" were also observed here, after which holes with a diameter of up to 0.5 m remained on the surface, framed by an annular shaft of crushed rocks. The terrain has changed significantly. A large sinkhole up to 50 m wide has appeared at the bottom of the valley, which is bounded by undulating uplifts from the south. The height of the lifts is up to 2.7 m, the length is up to 500 m. The ramparts, crossing the riverbed in the west, partially blocked it and formed a new channel of the Suusamyr River.

In the cities of Almaty, Taraz, and Tashkent, the intensity of the Suusamyr earthquake on August 9, 1992 ranged from 5 to 6 points on the MSK-64(K) scale, 5 points in Shymkent city, and 4 to 5 points in Talgar city.

1.2 Lugovskoe earthquake on May 23, 2003

The Lugovskoe earthquake of May 23, 2003 occurred in the southern part of the territory of the Republic of Kazakhstan, 350 km west of Almaty city, 100 km east of Taraz city, at Lugovoi station of Turar Ryskulov district of Zhambyl region, at coordinates 43o 00′ north latitude, 72o 44′ east longitude [2,3].

The magnitude of the earthquake was 5.4 with a depth of (according to various estimates) from 4 to 8 km.

The intensity of the earthquake manifestation in the macroseismic epicenter ranged from 7 to 8 points (according to the macroseismic part of the MSK-64 scale [1]).

In the first 7 hours after the earthquake, 75 aftershocks with an intensity of 2 to 4 points occurred in the epicentral zone. By May 26, the number of aftershocks decreased to 27 per day. The strongest aftershock was recorded on May 26, 2003 with an intensity of 4 points.

Lugovskoe earthquake was local in nature and noticeable damage to buildings (up to destruction) was observed mainly within the territory of T. Ryskulov district of Zhambyl region.

The earthquake caused light, moderate and severe damage to buildings (including 9707 residential buildings) in an area of at least 1000 km2 with an average radius of at least 20 km. In the area most affected by the earthquake, there are seven rural districts, in which 42 869 people lived. As

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a result of the earthquake, 3 people died and 26 were injured. All the victims were children of school and preschool age.

The economic damage caused by the earthquake amounted to 15,6 billion tenge, or about $105 million. Kazakhstan has independently dealt with the aftermath of the earthquake.

In Almaty city, the intensity of the Lugovskoe earthquake on 23.05.2003 ranged from 3 to 4 points on the MSK-64(K) scale.

1.3 Kapshagai earthquake 2011

On May 1, 2011, at 08 h. 31 min. local time, residents of Almaty city felt an earthquake, the intensity of which in the city was 4-5 points [4,5]. The epicenter of the earthquake was located south of the Kapshagai reservoir. This earthquake was felt by the majority of the city's population. The peculiarity of the earthquake on May 1 was that after it, during the whole day and the subsequent night, tangible tremors of low intensity were repeatedly repeated, which, of course, increased the anxious state of people. So, already 34 minutes after the first shock, the vibrations were repeated with an intensity of 2-3 points, six hours later with an intensity of 3-4 points. By the evening of May 1, residents felt at least 6 vibrations from the earthquakes.

Parameters of the Kapshagai earthquake on May 1, 2011 (according to the data of the IGR NNC RK [4]):

– time in the hearth T_0 = 2 h. 31 min. 28 sec. (UTC+6);
– epicenter coordinates: 43.62 degrees north latitude, 77.70 degrees east longitude;
– magnitude M_b = 5.6;
– depth is 22 km.

With an earthquake intensity of up to 6 points, noticeable fluctuations in the territory of Almaty city last for several seconds (rarely up to 20 seconds). Most often, such earthquakes manifest themselves in the form of a fairly strong and sharp shock.

1.4 Global earthquakes

The earthquake of February 6, 2023 in Turkey was one of the most devastating earthquakes of the century due to the extensive structural damage and large-scale destruction observed in southeastern Turkey. The large-scale destruction, including the complete collapse of numerous structures, is explained by several factors: the seismotectonic features of the region [6], the complex mechanism of the earthquake source, successive major shocks, shortcomings in earthquake-resistant design, poor-quality building materials and unfavorable geotechnical conditions. These factors acted both individually and in combination, significantly enhancing the overall effect [7,8].

There are numerous instrumental recordings of this earthquake both on the free surface of the Earth's crust and on buildings. One of the most notable features of the earthquake in Pazarchik on February 6 was the exceptionally high values of vertical acceleration recorded by numerous researchers [9].

In paper [10], the engineering characteristics of strong seismic vibrations obtained during these earthquakes are analyzed. The study systematically reveals the effect of amplification of spectral acceleration near faults in the earthquake sequence, explains the characteristics of the effects of super-thrust ground vibrations, reveals a significant feature of the amplification of response spectrum values caused by acceleration pulses associated with the direction of sub-thrust ruptures, and simultaneously reveals the nonlinear characteristics and evolution of soil liquefaction in typical areas.

The causes of damage in reinforced concrete buildings were analyzed in [11] in terms of the quality of materials, structural solutions of buildings and details of reinforcement units. The standards of earthquake-resistant construction in Turkey, adopted in 1975, 1998, 2007 and 2018, which apply to a significant part of the country's buildings, are considered. The damaged buildings were assessed for compliance with earthquake-resistant standards in Turkey. Field observations have shown that these standards, in particular with regard to fittings, were ignored. In addition, designers should avoid such design errors as the creation of gaps in the frames, the location of the main axis of strength of

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vertical elements mainly in one direction, insufficient support of stairs and the influence of neighboring buildings.

2 MATERIALS AND METHODS

The main materials of this work are instrumental recordings of stations of the engineering seismometric service of "KazRDICA" JSC and seismic stations of the National Scientific Center for Seismological Observations and Research.

The key methods are methods of processing instrumental records of seismic stations of the above-mentioned organizations. It is assumed that the spectra of reactions will be constructed. A comparison is performed with the results of the analysis of previous earthquakes of the same intensity.

In this case, the mathematical packages SCILAB (freely distributed) version scilab-2026.1.0.bin.x64.

3 RESULTS AND DISCUSSION

Data from the engineering and seismometric service of "KAZRDICA" JSC

A network of digital and analog seismometric stations is located in the buildings of the engineering and seismometric service of "KazRDICA" JSC in Almaty city.

Tables 1, 2, and 3 show the peak acceleration values for three digital stations of the engineering and seismometric service of "KazRDICA" JSC. The ground conditions at the three stations are average. The "INSTITUTE" station is located in a 5-storey frame building with a reinforced concrete frame, and the "ABAI" station is located in an 11-storey building with a steel frame. The "HOTEL" station is installed in a 25-storey building with the rigidity core of the "Kazakhstan" Hotel. The stations are equipped with digital instrumentation and measuring systems.

The values of PGA accelerations in the basement parts of the building characterize the intensity of the seismic impact. Figure 2-4 shows spectral curves for accelerograms of the "INSTITUTE" station. The spectral curves were calculated using the SCILAB mathematical system based on the explicit Runge-Kutta method of 4-5 orders of accuracy.

According to the MSK-64(K) seismic scale, acceleration values of 12-18 cm/s^2 mainly correspond to the intensity of the seismic impact of 4 points [1]. However, the acceleration value of 17.92 cm/s^2 falls within the acceleration range corresponding to the intensity of 5 points (16-35 cm/s^2). In addition, it is necessary to take into account the significant effective duration of seismic action in excess of 50 seconds - usually for 4-5 magnitude earthquakes, the effective duration does not exceed 10 seconds. Therefore, the intensity of the seismic impact should be estimated as 5 points, which corresponds to the intensity of the impact on the descriptive part of the scale according to the reaction of people and their environment.

Another way to estimate the seismic intensity is to use the macroseismic field equation from the MSK-64(K) scale or empirical dependencies linking the kinematic characteristics of the impact with the scores.

The equation of the macroseismic field has the form

$$I = 1.5M_{LH} - 4lg\sqrt{(h^2 + \Delta^2)}+4 \quad (1)$$

where I - is the calculated seismicity in points at a point (rounded up in points at a point during calculations),

M_{LH} - the magnitude of surface waves, usually determined by the horizontal component of the surface wave on medium-period equipment,

h - the depth of the hearth in kilometers, Δ - the epicentral distance in kilometers.

There is a relationship between M_{LH} and M_W

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$$M_{LH} = \frac{M_W}{0.696} - 2.595 \quad (2)$$

here M_W is the moment magnitude [12]. Relation (2) is taken from [13].

Accepted M_W=7.0, h=13 km, Δ=260 km. According to formula (1), the intensity value I=5.454 points. However, the significant duration of the earthquake is not taken into account here.

There is also an empirical relation of F. F. Aptikaev [14], written down to estimate the lower limit of the intensity value

$$i = 2.5 \log(pga) + 1.25 \log(d, 10) + 1.05 - s \quad (3)$$

The use of formula (3) seems logical due to the fact that the MSK 64(K) scale is based on the results of F. F. Aptikaev.

Here d - the effective duration, PGA - the peak accelerations from Tables 1-3, s - a parameter that takes into account the variation of empirical data. At d=30 sec, s=0.5 and PGA=17.92 cm/s^2 (Table 1) the earthquake intensity i=5.53 points or rounding up exactly 5.5 points. This is a bottom-up estimate - the lower bound. Note that the intensity estimates calculated using formulas (1) and (3). Thus, the earthquake intensity in the city can reasonably be estimated as at least five points, or rather 5-6 points.

It should be noted that the region where the epicenter of the earthquake is located has the ability to generate earthquakes with a magnitude of up to 8. With such an earthquake magnitude, the intensity of ground vibrations can exceed 7 points. Given the spectral characteristics of such earthquakes, they can be dangerous for high-rise buildings with an oscillation period of 1 second or more.

3.1 Earthquake intensity by acceleration values at digital stations

The values of the vertical components of the impact in the basement parts of the building practically coincide and do not exceed the values of the horizontal components of the seismic impact, which corresponds to global patterns (Figure 2,3).

The values of horizontal accelerations in the roof levels at the No 1 “INSTITUTE” station are 118.52-99.52 cm/s^2, which are 5.55-9.71 times higher than the acceleration values in the basement.

The accelerograms in the basement level show the presence of two groups of seismic waves. Moreover, the second group of waves corresponds to a greater magnitude of accelerations. Therefore, the spectral curves in the basement level are characterized by two acceleration maxima.

It should be noted that there have been no significant earthquakes in Almaty city for 6 years.

These instrumental recordings can be used to build models of remote high-intensity earthquakes.

Table 1 - Acceleration PGA at the No 1 “INSTITUTE” station, cm/s^2 [Author's material]

Direction	Basement	Roof
OX	12.21	118.52
OY	17.92	99.52
OZ	7.76	10.63

Table 2 - Acceleration PGA at the No 11 “ABAI” station, cm/s^2 [Author's material]

Direction	Basement	Roof
OX	9.78	23.80
OY	11.75	40.04
OZ	7.21	13.28

Table 3 - PGA acceleration at the station No. 6 “HOTEL”, cm/s^2 [Author's material]

Direction	Basement	2nd floor	6th floor	18th floor	21st floor	25th floor

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OX	13.25	21.81	21.60	13.69	41.40	60.25
OY	0.94	15.55	31.01	13.38	50.44	62.92
OZ						18.75

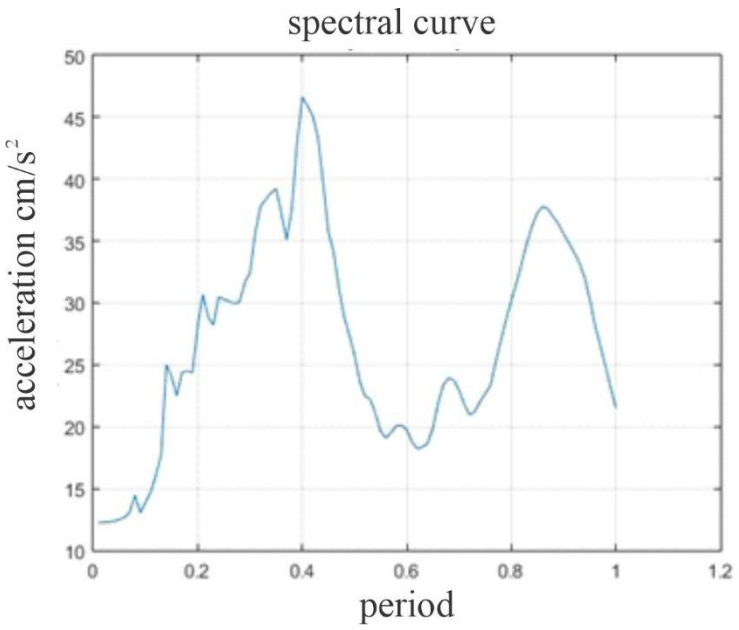


Figure 2- Spectral curve of the accelerogram at the No. 1 "INSTITUTE" station, OX, basement [Author's material]

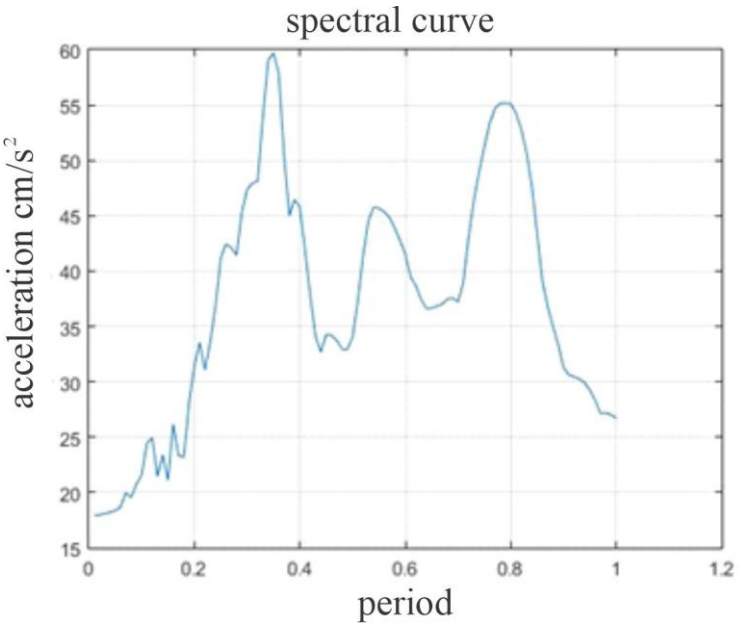


Figure 3 - Spectral curve of the accelerogram at the No. 1 "INSTITUTE" station, OY, basement [Author's material]

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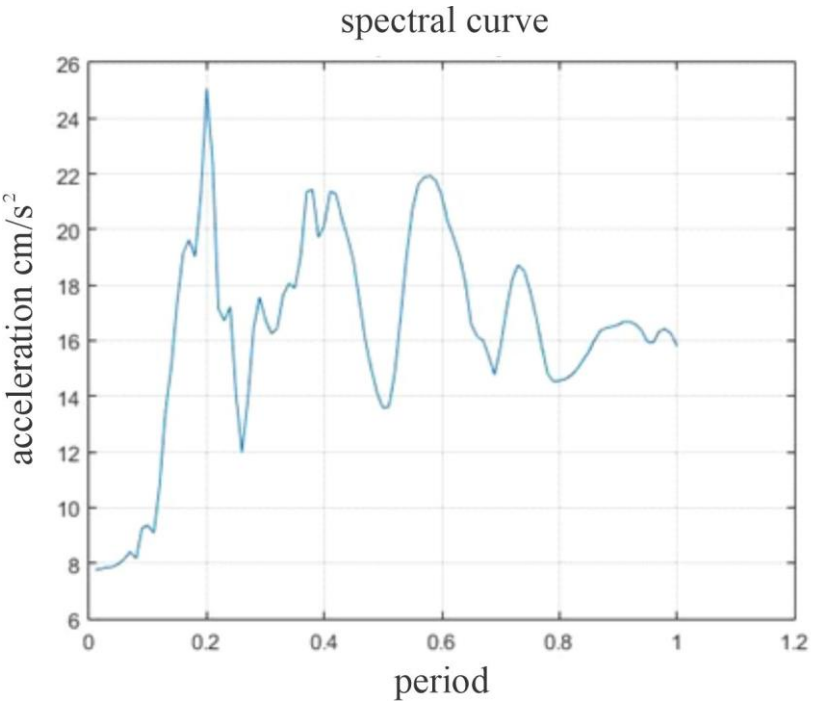


Figure 4 - Spectral curve of the accelerogram at the No. 1 "INSTITUTE" station, OZ, basement [Author's material]

3.2 Earthquake intensity based on instrumental information at analog stations

At stations equipped with analog equipment, displacement values are measured by LDV sensors, and displacement values are measured by OSP sensors. This is sufficient, since in the MSK-64(K) seismic scale there are intensity scales in points according to the specified kinematic parameters.

The maximum acceleration in the basement of the building at station No. 24 "Mynbayev" has 14.6 cm/s2 and at station No. 3 "School" - 17.71 cm/s2. Therefore, the intensity in terms of acceleration values is 5 points, which fully corresponds to the instrumental recordings of digital stations. It should also be noted that according to the instrumental data of the Institute of Geophysical Research of the National Nuclear Center at the "KNDC" station, the peak acceleration value was 19.8 cm/s2, which fully corresponds to the instrumental data of the stations of the engineering and seismometric service of "KazRDICA" JSC, where the maximum was 17.92 cm/s2 (station No. 1 "INSTITUTE").

The amount of displacement in the basement of the building also characterizes the intensity of the seismic impact in points. The intensity of 5 points corresponds to an interval of 0.08-0.32 cm, and 6 points - 0.32-1.25 cm. At station 11 "ABAI", the displacement in the basement is 1.56 cm and 0.5 cm, which corresponds to an intensity of 6 points.

Table 4 - Results of processing of analog earthquake recordings [Author's material]

Station number, building structure, own period, soil at the base of the building	Type of seismometer and galvanometer	Installation location and orientation of the seismometer	Period of fluctuations	Maximum oscillation amplitude		
				Offset, cm	Speed, cm/sec	Acceleration, cm/sec2
1	2	3	4	5	6	7
Station 1 "Institute" 4-storey, frame building. Precast reinforced concrete	LDV+GBIII	Basement-X	0,73	0.016		
		Basement-Y	0.5	0.0625		

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Tx = 0,5 sec Boulders		Roof-X	0,6	0.29		
		Roof-Y	0.61	0.42		
	EMD+GBIII	Basement-X	0,37			12.96
		Basement-У	0.65			13.39
		Roof-X	0.5			46.66
		Roof-Y	0.6			53.22
Station 3 "SCHOOL" 4-storey, frame reinforced concrete Tx = 0,5 sec Ty = 0,18 sec Pebbles with layers of sand and loam.	LDV+M012	Basement-Y	0,7	0,2		
		Roof-X	0,5	0,53		
		Roof-Y	0.68	0.57		
	OSP+M005	Basement-У	0.68			17.71
		Roof-X	0.4			88.46
		Roof-X	0,68			81.89
Station 7 “Tulebayev” 9-storey, frame reinforced concrete series SZHKU T1 =0,48; T2 =0,15 T3 =0,08 Boulders	LDV+M012	1st floor-X	0,72		1.6	
		9th floor-X	0.78		6.97	
		9th floor-Y	0,78		5.24	
	OSP+M005	1st floor-Y	0,47			19.35
Station 11 “Abai ave.” 11-storey, steel frame Tx =0,9 sec Ty =0,3 sec Boulders	LDV+M012	Basement-X	1.28	1.56		
		Basement-У	0.97	0.5		
		12th floor-X	1.12	5.3		
		12th floor-Y	1.3	6.25		
	OSP+M005	Basement-X	0.4			10.89
		Basement-У	0.82			13.53
		12th floor-X	1			30.3
		12th floor-Y	1.15			29.73
Station 15 “Kapshagai HPP” 1-storey frame industrial building, steel. The dam is bulk. Fractured rocky ground.	OSP+M005	Rock-Y	0.6			9.25
		Workshop-Y	0.3			4.87
		Dam-X	0.32			11.53
Station 17 «New Square» 16-storey residential building. A building with well-developed traverses and a rigid core in the form of a space-core structure.	LDV+M012	Basement-X	0,8	0,1		
		Basement-У	0,77	0,093		
		17th floor-Y	1.3	0.33		
	OSP+M005	17th floor-y	0.75			25.08

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Station 20 “Analog House” 9-storey large-panel reinforced concrete series 158. single-storey block section. Ribbon foundation	LDV+M012	9th floor-X	0.4	0.213	
		9th floor-Y	0.48	0.279	
	OSP+M005	Basement-Y	1		11.25
		4th floor-X	0.45		31.08
		4th floor-Y	0.43		25.28
		7th floor-X	0.45		54.22
		7th floor-Y	0.43		36.47
		9th floor-X	0.45		70.0
		9th floor-Y	0.4		48.46
Station 21 “House of CF” 9-storey, large-panel reinforced concrete series 158. single-entrance block section with seismic insulation. The foundation is in the form of kinematic supports.	LDV+M012	Basement-X	1	0,32	
		Basement-	0,9	0,15	
		1st floor-X	1	0.3	
		1st floor-Y	0.86	0.25	
		9th floor-X	0.95	0.418	
		9th floor-X	0.68	0.351	
		9th floor-Y	0.9	0.258	
		9th floor-Y	0.51	0.218	
	OSP+M005	Basement-Y	1		8.01
		1st floor-Y	0.48		15.48
		4th floor-Y	0.53		19.64
		7th floor-Y	0.53		33.89
		9th floor-X	0.5		55.74
		9th floor-Y	0.48		35.27
Station 22 “House of FT” A 9-storey large-panel apartment building. Series 158. Single-entrance block section with earthquake-insulating foundation. Sliding supports with fluoroplast gaskets	LDV+M012	Basement-X	0,78(1.7))	0.11(1.01)	
		Basement-Y	0,7	0,117	
		1st floor-X	0.95(1.7)	0.11(0.68)	
		1st floor-Y	0.45	0.065	
		9th floor-X	0.4	0.27	
		9th floor-Y	0.45	0.32	
	OSP+M005	Basement-y	0.66		13.41
		1st floor-X	0.66		11.63
		4th floor-Y	0.43		28.57
		9th floor-X	0.43		79.78
		9th floor-y	0.45		54.62
Station 24 “Mynbayev” 3-storey building, reinforced concrete frame Boulders	OSP+M005	Basement-У	0.38		14.6
		Roof-X	0.33		69.58
		Roof-Y	0.35		67.19

It is interesting to compare the results of registration of kinematic parameters at stations of the engineering seismometric service on buildings during earthquakes of the same intensity.

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For example, [15,16] shows the results of station registration of the 5-6 magnitude earthquake of the Sarakamysh earthquake in Kyrgyzstan on June 5, 1970. The magnitude of the earthquake is 6.5, the energy class is 15, the intensity at the epicenter is 8 points, and the distance from Almaty city is 150 km. Compared to the earthquake on January 23, 2024, the magnitude is lower, but the earthquake is 110 km closer. The shaking of the ground in the buildings of Almaty city was felt for 1 min., and the most intense part was 10-15 sec.

The earthquake was recorded by 6 seismic stations [15] No. 1 “Institute”, No. 2 “4th floor KPD”, No. 3 “School”, No. 4 “Residential building”, No. 8 “Rahat”, equipped with analog equipment and located in the central part of Almaty city. Stations 1, 2, 3, 4, and 8 are on buildings whose bases are composed of hard boulder-pebble rocks, and station 8 “Rahat” is on soft loamy soils. Stations No. 3 and No. 8 were located near tectonic faults.

Of the six mentioned stations, only station No. 1 “Institute” and No. 3 “School” are currently preserved. At station No. 1, along with analog devices, there are also digital devices. Therefore, in a separate table 5, we will present the results of the registration of the Sarakamysh earthquake by station No. 1 and in Table 6, the magnitude of displacements and accelerations at station No. 3. No data was provided on the OY axis for the “SCHOOL” station.

Table 5 - “INSTITUTE” station acceleration PGA, cm/s^2 [Author's material]

Direction	Basement	Roof
OX	10.0	30.0
OY	-	40.0

Table 6 - Acceleration and displacement at the “SCHOOL” station, cm/s^2 [Author's material]

Direction	Basement, cm - movement	Roof, cm/s^2 -accelerations
OX	0.088	30.5
OY	-	

The peak values of displacements and accelerations during the earthquake 05.06.70 in the basement and roof levels are lower than during the earthquake 23.01.24. This does not apply to the “Rakhat” station, located at the corner of Rayymbek and Nazarbayev avenues near a powerful tectonic fault. The acceleration at the basement level is quite anomalous, 25 cm/s^2. No such acceleration was recorded during the earthquake on 23.01.24. Apparently, the most reasonable explanation here is the effect of a tectonic fault on the reaction of the building.

It should be noted that during the 5-6-point Zhalanash-Tyup earthquake of 1978, the acceleration on the free soil surface reached 35 cm/s^2 [17].

3.3 Engineering analysis of the consequences of the earthquake on January 23, 2024

A total of 118 budget-owned facilities and 70 commercial facilities were surveyed.

No earthquake damage was detected in the load-bearing structures of the surveyed facilities, and according to the Code of Rules of the Republic of Kazakhstan, 1.04-110-2017* [18], it can be assessed as serviceable structures.

The following damage was detected in the curtain structures of the surveyed facilities as a result of the earthquake:

– cracks in the sealing of antiseismic seams;

– vertical and horizontal cracks at the junctions of the partitions with the load-bearing structures;

– inclined and vertical cracks with an opening width of up to 0,3 mm from the corners of the doorways and in the “blind” sections of individual partitions;

– peeling of plaster layers.

Cracks in the sealing of antiseismic seams, cracks along the perimeter of partitions correspond to the operation of independent dynamic compartments of the surveyed objects during seismic

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impacts, and their occurrence does not contradict the requirements of the Code of Rules of the Republic of Kazakhstan 2.03-30-2017* [19].

Damage in the form of cracks in the sealing of antiseismic seams and along the perimeter of partitions is classified according to the MSK-64 (K) seismic scale [1] as damage of the 1st degree, and requires routine repairs. Even with this degree of damage, cosmetic repairs are required. According to the existing damage scales for construction projects, the cost of repairs can reach up to 7.5% of the original estimated cost of the building.

The inclined and vertical cracks obtained as a result of the earthquake from the corners of the doorways and in the "blind" sections of individual partitions of the surveyed objects show that these partitions were made with a construction defect, without antiseismic measures. These partitions do not meet the requirements of subsection 9.4 of the Code of Rules of the Republic of Kazakhstan according to their design solutions. 2.03-30-2017* [19], and by the nature of the damage, they are treated according to the Code of Rules of the Republic of Kazakhstan. 1.04-110-2017* [18] to the limited-use constructions of the 1st category. These partitions are subject to seismic reinforcement, and the volume of construction work is determined according to defective certificates drawn up by the construction contractor.

According to the results of the operational survey, individual facilities require a detailed examination.

Partitions classified, based on the nature of the damage, as Category 1 structures with limited serviceability in accordance with the Code of Regulations of the Republic of Kazakhstan 1.04-110-2017* [18] must be reinforced in accordance with the following recommendations::

1. Remove the old plaster from the partition surfaces.
2. Clean the horizontal and vertical seams of the masonry walls to a depth of 15 mm.
3. Drill through holes in the partitions for the Z-shaped anchors. The holes should be staggered in increments of no more than 600 mm. The Z-shaped anchors are made of ∅6 mm class A240 reinforcing rods.
4. Install Z-shaped anchors in the drilled holes.
5. Clean the surface of reinforced partitions with compressed air.
6. Install reinforcement grids made of reinforcement rods Ø5 mm of class Bp-I or Ø8 mm of class A400 with mesh sizes of 150x150 mm along the partitions and attach them to the partitions using Z-shaped anchors.
7. Reinforcement grids should be placed at a distance of at least 10 mm from the surface of reinforced structures. In the corners and intersections of the partitions, the nets should be bent and brought around the corner by at least 1,0 m. It is not allowed to dock end-to-end in such places of the grid. Install all vertical and horizontal overlapping grids in the seams (overlap length of at least 150 mm or at least one cell). The rods of adjacent grids should be connected to each other and to Z-shaped anchors with knitting wire.
8. Along the inner perimeter of the door openings in the partitions, install flat reinforcement frames made of two ∅12 mm A400 class rods with ∅10 mm A400 class transverse rods. The pitch of the transverse rods should be 150 mm. Flat reinforcement frames should be fixed to the walls using L-shaped anchors Ø6 mm class A240, installed in pre-drilled holes 250 mm deep in 300 mm increments. Reinforcing mesh reinforcement of partitions should be connected with flat frames of monolithic reinforced concrete framing of doorways using knitting wire. The joints of the reinforcing grids should be removed from the corners of the openings by at least 1,0 m.
9. After installing reinforcement grids, flat frames, L-shaped and Z-shaped anchors, make holes in the partitions with a hard, high-quality mortar.
10. Fill the flat doorway reinforcement frames with concrete of class C20/25 (B25) with a thickness of at least 80,0 mm. Reinforcement grids should be plastered 3-4 times with a cement-sand mortar of at least M150 grade and at least 40 mm thick.

When carrying out work to strengthen the partitions, follow these recommendations and the "Manual on strengthening the load-bearing structures of buildings and structures, reconstructed enterprises located in the II and III zones of Almaty city".

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Construction work must be carried out in strict compliance with safety regulations according to [21].

4 CONCLUSIONS

1. The intensity of the seismic impact of the earthquake on 23.01.24, taking into account the duration, can be estimated as 5-6 points. All instrumental data were obtained on average seismic properties of soils - boulders, pebbles [20].

2. There is no noticeable effect of the presence of tectonic faults on the instrumental characteristics of the seismic impact in the basement of the building (stations No. 17 “New Square” and No. 16 “Hotel”. At station No. 3 “School”, abnormally high accelerations were detected in the coverage level of 88.46 cm/s^2 and 81.89 cm/s^2. These anomalies may indicate the influence of a nearby tectonic fault on the reaction of the building.

3. The vertical component of the seismic impact at all stations in the basement is less than the horizontal ones. Vertical accelerations have a higher spectral frequency than horizontal accelerations.

4. Instrumental recordings of accelerations in the basements of buildings show that the accelerograms are formed by two groups of waves. The former lead to fluctuations in the base with a period of up to 0.4 sec, and the latter - up to 1 sec. This is the first earthquake in the territory of Almaty city, which lead to low-frequency ground vibrations.

5. The instrumental data from the stations of “KazRDICA” JSC and the Data Center of the IGR NNC RK on the acceleration values in the basement and in the ground are almost identical.

6. On the territory of the Kapshagai HPP, the earthquake intensity does not exceed 4 points.

7. The network of stations of the engineering and seismometric service of “KazRDICA” JSC is in working condition. All stations provided instrumental information.

8. All stations are located on medium-sized seismic soils. This impoverishes the information obtained during earthquakes and distorts intensity estimates. Therefore, it is necessary to install stations on soils of Sh-IV categories according to the Eurocode 8 classification as soon as possible.

There are only 3 stations No. 3 "SCHOOL", No. 17 «New Square» and No. 16 «Hotel» located near tectonic faults. There is a need to create new ISS stations near all identified tectonic faults in the city.

9. Abnormally high accelerations were recorded on the roof of the building at station No. 3 “School”, and in two axes 81-88 cm/s^2. The station is located near a tectonic fault on Rayymbek ave. It seems reasonable to assume that the sides of the fault may move during earthquakes.

10. Instrumental records of accelerations and displacements were obtained at the seismic isolation site of stations No. 20-22. It has been reliably established that the seismic insulation system of the building on kinematic foundations reduced the seismic load by up to 30%. With an increase in the intensity of the seismic impact, the effect of seismic insulation will be higher. It has been scientifically proven that the seismic isolation system reduces the seismic load even in low-frequency earthquakes.

11. No earthquake damage was detected in the load-bearing structures of the surveyed facilities.

12. The load-bearing structures of the surveyed objects can be assessed according to the Code of Rules of the Republic of Kazakhstan 1.04-110-2017* [18], as serviceable structures.

13. Damage to non-load-bearing structures resulting from an earthquake is classified on the MSK-64 (K) scale [1] as minor damage of the 1st degree, and requires routine repairs.

14. To further address the issue of ensuring the seismic safety of the population of Almaty, the following studies-which focus on the specific seismological conditions of the city-may prove useful: local ground conditions [22]; the selection of instrumental earthquake records for assessing the response of buildings [23]; the determination of the dynamic characteristics of buildings of various storeys [24], the effect of frequent ground motions on the response of buildings [25], and methods for reinforcing strip foundations [26].

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REFERENCES

1. **Building regulations of the Republic of Kazakhstan 2.03-28-2004 (2004).** The scale for estimating earthquake intensity is MSK-64(K). Almaty: Publishing House of the Committee for Construction and Housing and Communal Services, Ministry of Industry and Trade of the Republic of Kazakhstan.
2. **Ashimbaev, M.U, Taubaev, A.S., Aldakhov, S.D.,** (2004). Lessons from the Lugovskoe earthquake of May 23, 2003 in Kazakhstan. studies of the Seismic resistance of structures and structures, 23, 23-33.
3. **Abakanov, T.D., Mikhailova N.N, Nysanbaev T.E., Li, A.N., Poleshko, N.N., Aristova, I.L., Silacheva N.V., Kalmykova, N.A.** (2009). Lugovskoe earthquake on May 22, 2003 with mw=5.5, io=7-8 (Southern Kazakhstan). The earthquakes of Northern Eurasia in 2003, 284-293.
4. **Mikhailova, N.N., Poleshko.N.N.** (2013). Kapchagai earthquake on May 1, 2011. Proceedings of the National Nuclear Center of the Republic of Kazakhstan, 1, 102-110.
5. **Akilbekova, Z.E., Dyusembin,E.A. Abdreshov, Sh.A.** (2025). Kapchagai earthquake recorded on May 1, 2011: Earthquake analysis. Bulletin of Science, No. 12(93), part 1, 1133-1149.
6. **Yenidogan, C.** (2026). Seismic performance of SI and conventional healthcare facilities during the February 6, 2023, earthquakes: Validation of SI system response per the TSDC-2018. Engineering Structures, 357, 122167. https://doi.org/10.1016/j.engstruct.2026.122167
7. **Yadim, Y., Yılmaz S., Kaplan H., Corradi M., Castori G.** (2026). Seismic vulnerability of deficient RC buildings: insights from the February 6, 2023, Turkey Earthquake. Procedia Structural Integrity, 78. https://doi.org/10.1016/j.prostr.2025.12.241
8. **Vuran, E, Timurağaoğlu, M.O., Hakan, O.** (2026). Soil-structure interaction analysis of a typical RC wall - frame building collapsed in the February 6, 2023 earthquakes. Structures, 90, 112409. https://doi.org/10.1016/j.istruc.2026.112409
9. **Gani, E, Öztürk, S., Sary, A.** (2025). Examination of the severe impact of the February 6, 2023 earthquakes on Antakya district considering pulse-like ground motions, supershear rupture, and basin effects. Soil Dynamics and Earthquake Engineering,198, 109608. https://doi.org/10.1016/j.soildyn.2025.109608
10. **Dong, Y., Cao, F., Wang, Y., Xie, Y.** (2026). Engineering characteristics of the strong ground motions from the 2023 Kahramanmaraş earthquake sequence in Türkiye. Journal of Seismology, 30(68). https://doi.org/10.1007/s10950-026-10424-1
11. **Ozan, I.** (2024). Structural damage assessment of reinforced concrete buildings in Adıyaman after Kahramanmaraş (Türkiye) Earthquakes on 6 February 2023. Engineering failure analysis, 2024, 156. https://doi.org/10.1016/j.engfailanal.2023.107799
12. **Hanks, T.C. Kanamori, H.A.** (1979). A moment-Magnitude scale. Journal geophysics resource, 84, 2348-2350.
13. **Silacheva, N. V. Stepanenko, N.P., Kurilova, O.K., Kudabayeva, A.D.& Danabayeva, A.T.** (2024). Detailed seismic zoning of the East Kazakhstan region in the Republic of Kazakhstan. Geodesy and Geodynamics, 15(2), 156-165. https://doi.org/10.1016/j.geog.2023.08.005
14. **Aptikaev F. F.** (2012). Instrumental scale of seismic intensity. ASB.
15. **Vypryazhkin Yu. A., Zhunusov T. Zh.** (1970). Ground and building vibrations during five-magnitude earthquakes in Alma-Ata. Studies of earthquake resistance of structures and structures. 3-4 (13-14).
16. **Zhunusov T. Zh., Vypryazhkin Yu. A., Denisov B. E.** (1970). The reaction of buildings during a 5-6 magnitude earthquake in Alma-Ata. Design and construction of earthquake-resistant buildings and structures. 17-36.
17. **Zhunusov T. Zh., Vypryazhkin Yu. A., Denisov B. E.** (1978). The reaction of buildings during a 5-6 magnitude earthquake in Alma-Ata. Studies of earthquake resistance of structures and structures, 10 (20). 206-223.

https://doi.org/10.51488/1680-080X/2026.3-18

18. **Code of Rules of the Republic of Kazakhstan 1.04-110-2017* (2017).** Inspection, assessment of the technical condition and seismic reinforcement of buildings and structures. Astana: Publishing House of the Committee for Construction and Housing and Communal Services.
19. **Code of Rules of the Republic of Kazakhstan 2.03-30-2017*** (2018). Construction in seismic zones (areas). Astana: Publishing House of the Committee for Construction and Housing and Communal Services, Ministry of Industry and Trade of the Republic of Kazakhstan.
20. **Code of Rules of the Republic of Kazakhstan 2.03-31-2020** (2020). Development of the territory of Almaty city, taking into account seismic microzoning. Publishing House of the Committee for Construction and Housing and Communal Services.
21. **Code of Rules of the Republic of Kazakhstan 1.03-106-2012*** (2020) .Occupational health and safety in construction" (as amended 2020-12-20), Publishing House of the Committee for Construction and Housing and Communal Services.
22. **Surovtseva N.V., Abakanov T., Nigmetov G.M.** (2026). Experimental studies of the seismic vulnerability of a building model on reinforced soils. Bulletin of KazGASA, 99(1), 311–325. https://doi.org/10.51488/1680-080X/2026.1-21
23. **Tuleev A.T., Abakanov T., Begaliev U.T., Lapin V.A.** (2025) .Seismic response of a 22-storey monolithic building based on instrumental acceleration records. Bulletin of KazGASA, 98(4), 311–325. https://doi.org/10.51488/1680-080X/2025.4-15
24. **Tuleyev A.D., Abakanov T.D., Lapin V.A., Begaliev U.T., Seitkazinov O.D., Dzholdasova K.K.** (2024). Effect of the number of storeys on seismic resistance of high-rise monolithic buildings in Almaty. Bulletin of KazGASA, 94(4), 183–192. https://doi.org/10.51488/1680-080X/2024.4-14
25. **Amangeldy A.N., Magzum A.N., Pentaev T.P., Suleimenova D.N.** (2024). A study of the deformation process in multi-storey buildings in the city of Almaty. Bulletin l of KazGASA, 93(3), 100–117. https://doi.org/10.51488/1680-080X/2024.3-04
26. **Aubakirova B.M.** (2024). Methods of injection reinforcement of foundations in construction. Bulletin of KazGASA, 91(1), 50–64. https://doi.org/10.51488/1680-080X/2024.1-04

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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