Building response to two local earthquakes

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Abstract. Instrumental records of two earthquakes with foci in the Almaty territory were obtained, recorded during one month on February 02, 2018, and February 15, 2018. The local seismic events registered in February 2018 in the Almaty territory are analyzed. These are 2 – 4 magnitude earthquakes with foci on the city's territory. Using the AT 1105 sensors and the RSM-8 recorder, station No. 1 "Institute" recorded instrumental readings of accelerations in the basement and the four-story frame-brick building roof. For the first time, an instrumental recording was obtained, on which two groups of waves were identified. Spectral curves β are plotted. Effective duration is insignificant 0.12 – 1.74 sec. New results have been obtained regarding the behavior of a building under the influence of two earthquakes of different intensities. The absence of significant values of the spectral curves of the two earthquakes was noted. There is an increase in the intensity and number of local earthquakes in 2018 compared to 2007 – 2014. The results can be used to design earthquake-resistant buildings, taking into account the requirements of Eurocode 8.

1 Introduction

The city of Almaty is the largest metropolis in Kazakhstan. Its population exceeds 2.5 million people (2024 census). It is known that the city is located in a highly seismic region of Kazakhstan. It was destroyed twice by the following strongest earthquakes: Vernenskiy in 1887 with a magnitude of 7.2 and Kemin in 1911 with a magnitude of 8.2 (according to some new data, the magnitude of this earthquake is 7.9 [1]. The city has repeatedly experienced less severe impacts. The most recent such events include the Zhalanash-Tyup earthquake of 1978 (magnitude 6.9) and the Suusamyr earthquake of 1992 (magnitude 7.3). In different areas of Almaty city, they were felt with an intensity of 5 and 6 MSK.

Since 1968, the seismic engineering service on buildings has been functioning on the territory of Almaty. Currently, 10 buildings of the city are equipped with seismic stations [1-4]. Digital systems and analog devices are installed at the stations.

The seismic danger of the city is usually associated with the seismogenic areas of the Northern Tien Shan. The main of these area, located closest to the city, are Almaty, Zaili and Chiliko-Kemin. Earthquakes with magnitudes from 7.5 to 8.5 strongest earthquakes and their origins in these areas are possible, and the intensity of earthquakes in the city can

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reach 8 to 10 MSK. Extension of areas coincides with the extension of Zaili and Kungey Alatau ridges, Chilico-Kemin fault area [5-8].

In the last 15 years in the territory of Almaty there were observed local earthquakes, the seismic effect of which is about 2-3 MSK.

In order to improve the quality of instrumental recordings, an upgrade of the station network with the latest instruments and systems is planned [9-13].

The purpose of the study is to use instrumental recordings (accelerograms) recorded by seismic station instruments in 2018 to obtain information about the spectral characteristics of soil vibrations, as well as the dynamic characteristics of a four-story frame building.

2 Method and subject of research

A series of weak local earthquakes continue, which are recorded by the network of stations of the engineering and seismometric service of KazRDICA JSC directly on the territory of Almaty.

According to the operational data of the Data Center of the Institute of Geophysical Research, on February 02, 2018, at 15:20 Astana time (at 09:20 GMT), an earthquake occurred in Almaty. The coordinates of the epicenter: 43.15 degrees north latitude, 76.88 degrees east longitude. Magnitude mb = 3.6. Energy class K = 7.5. The earthquake was felt in Almaty with an intensity of 3 – 4 points. The source of the earthquake was in the Nauryzbai district of the city. The results of the analysis of building behavior are given in [4].

Another local earthquake in the territory of Almaty was recorded on June 03, 2017, at 23 hours 57 minutes Astana time (17 hours 57 minutes GMT), 14 km to the north. Epicenter coordinates: 43.30° north latitude, 76.98° east longitude. Magnitude mb = 2.4. Energy class K = 5.7. The earthquake was felt in Almaty with an intensity of 2 points. According to the data of the Seismological Expedition, the source depth is zero.

The focal coordinates of the two earthquakes are very close. The depth of the focus is insignificant.

Thus, the local earthquake on February 2, 2018, was more intense. It was felt by residents of almost all parts of the city. Earthquakes with such parameters were predicted earlier and can be dangerous for the population and housing stock of the city [4-5].

An earthquake was registered by the network of seismic stations of the Seismological Expedition on February 15, 2018, at 23.38 Almaty time. The earthquake epicenter is located 3 km from Almaty, on the Almaty territory.

Sensibility information (on the MSK-64 scale): Almaty 2 – 3 points; energy class of the earthquake – 7.2; magnitude MPV – 3.8; epicenter coordinates 43.23° north latitude, 76.88° east longitude; depth – 5 km.

It can be considered that this is practically the second earthquake in February 2018, with a focus located in Almaty.

In [7], based on seismic observations, the possibility of earthquakes in the territory of Almaty in the southern and southeastern parts has been reliably established. Faults were identified on the city's territory, which is associated with earthquake foci. For January 01, 2005 – December 12, 2014, 1293 earthquakes with energy class K = 2.7 – 9.7 were registered on the city's territory and in the immediate vicinity. According to earlier data for April 01, 1972 – December 31, 1982, 983 seismic events with energy class K = 5.0 – 13.0 were registered in the Almaty area.

Station № 1 "Institute" is equipped with an eight-channel digital instrumentation system.The station underwent modernization in 2016. Russian acceleration sensors AT 1105 with high sensitivity have been installed.

Consequently, the research methods are based on experimental data from seismic stations. Instrumental records are analyzed using computer mathematics programs.

3 Results

Instrumental records of accelerations – accelerograms were obtained (Figures 1 – 2). There are two groups of waves along the horizontal axes on the instrumental recordings in the building's basement, differing in amplitude. That is a rather rare instrumental record of an earthquake recorded by stations in Almaty.

Table 1 shows the maximum acceleration values for each of the instrumental recording components. Lines 1 – 3 correspond to accelerations on the roof of the building, 4 – 6 – to the foundation of the building (more precisely, the basement). Spectral coefficients for all three axes on the foundation and roof differ by approximately 1.2 – 2.1 times. In this case, the greatest differences in the values of the spectral coefficients take place for the vertical axis OZ.

Acceleration along the vertical axis at the basement level does not exceed the acceleration value in the horizontal plane along the OX axis. Still, it exceeds the acceleration value along the OY axis. At the roof level, the values of horizontal accelerations are 10% higher than the vertical value.

The accelerations in the azimuthal plane at the level of the roof are approximately the same. The values of the spectral coefficient differ by 20%.

The effective duration of exposure is minimal – at the basement level, the values are 0.05 – 1.74 sec, at the roof level – 0.85 – 2.30 sec.

The frequency composition is stable at the basement level – the prevailing period is 0.08 – 0.14 sec.

The analysis of the graphs in Figures 1-2 shows that the seismic impact has the character of an impulse. The intensity of the earthquake here does not exceed three points.

In another local earthquake on June 3, 2017, the absolute acceleration values on the roof are -2.84 cm/s ^{2} , and on the foundation of the building – 1.59 cm/s ^{2}. Consequently, during the earthquake of February 15, 2018, the acceleration values are 2 times higher.

Table 1. Maximum acceleration values and accelerograms parameters.

No.	Component	Acceleration cm/s^2	Effective duration, s	Spectral coefficient	Spectrum maximum period, s
1	02/15/18-1-u1 (OX)	7.16	0.85	3.87	0.14
2	02/15/18-1-u2 (OY)	4.84	1.66	4.71	0.15
3	02/15/18-1-u3 (OZ)	6.40	2,30	4.33	0.08
4	02/15/18-1-u6 (OX)	3.53	0.12	3.19	0.11
5	02/15/18-1-u7 (OY)	2.03	1.74	2.83 (2.56)	0.08 (0.14)
6	02/15/18-1-u8 (OZ)	2.48	0.05	1.99	0.07

The earthquake spectral curves of February 15, 2015 are shown in Figure 3. It should be noted that the acceleration peaks of the accelerogram at the foundation level correspond to the maximum period of the spectrum 0.07-0.14. The period of maximum spectrum on the

roof of the building is about the same. The spectrum along the OV axis of the basement part has 2 maxima.

For comparison, Table 2 shows the results of processing the instrumental records of the earthquake on February 02, 2018, from [4].

Based on Tables 1 and 2, it is easy to see that, despite the different amplitudes of instrumental recordings, the building behaves in about the same way. There are no resonant vibrations. Effective durations are approximately the same.

According to the values of the recorded accelerations, the earthquake of 02.02.18 was the most intense in 2018.

Table 2. Maximum acceleration values and accelerograms parameters.

No.	Component	Acceleration cm/s^2	Effective duration, s	Spectral coefficient	Spectrum maximum period, s
1	98-1-xkro (OX)	36.29	0.19	3.93	0.14
2	98-1-ykro (OY)	36.54	0.58	3.34	0.17
3	98-1-zkro (OZ)	29-18.	1.86	4.84	0.11
4	98-1-xpod (OX)	17,44	0.15	2.82	0.06
5	98-1-ypod (OY)	9,09	1.45	2.50	0.05
6	98-1-zpod (OZ)	20,44	0.09	1.76	0.05

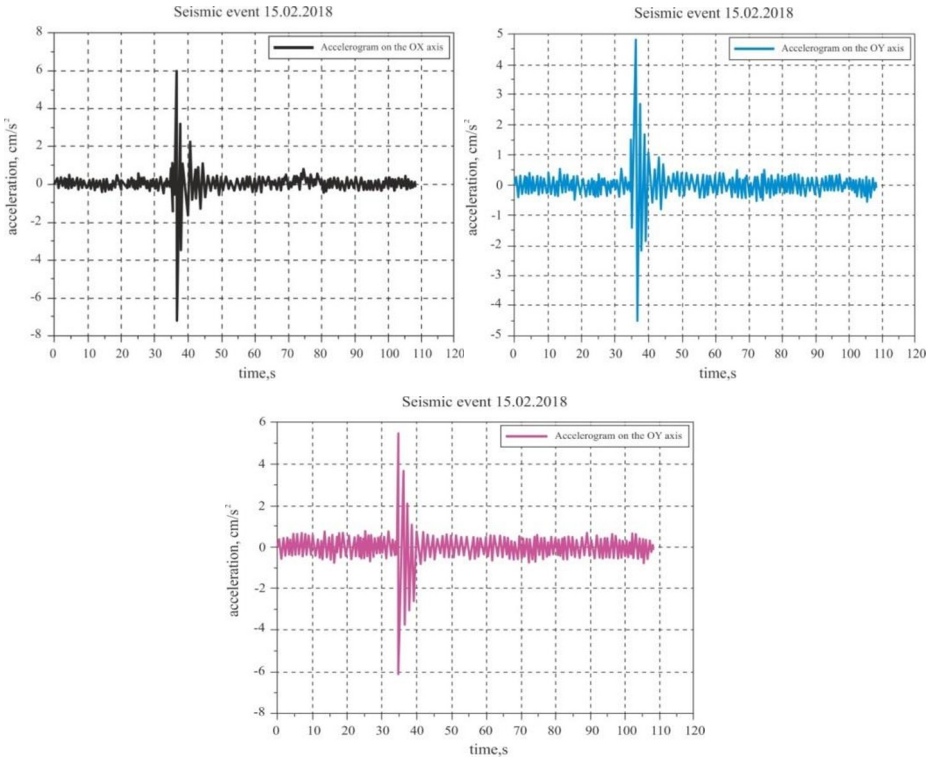

Fig. 1. Accelerograms of the February 15, 2018 earthquake (station no. 1 “Institute”, roof).

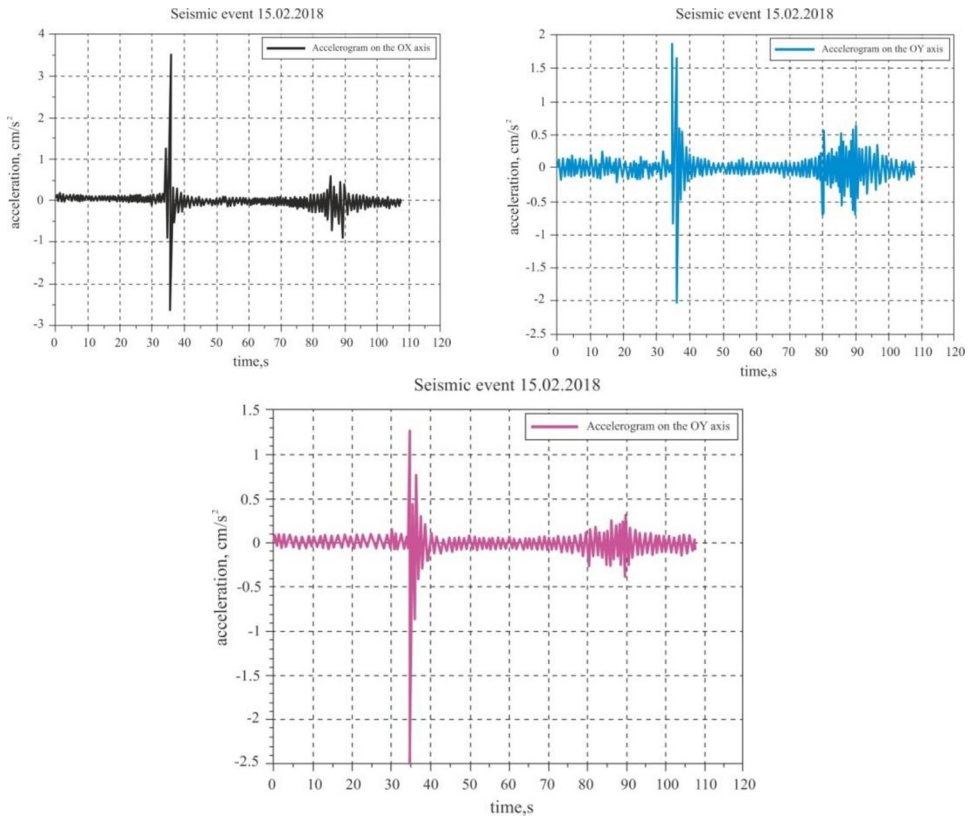

Fig. 2. Accelerograms of the seismic event on February 15, 2018 (station No. 1 "Institute", foundation).

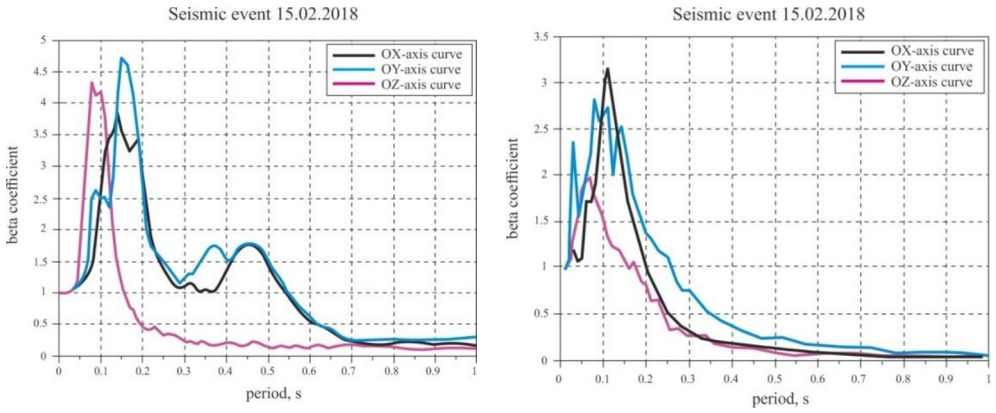

Fig. 3. Spectral curves of seismic events on February 15, 2018 (top picture – roof, bottom one – foundation).

4 Discussion

The maximum acceleration values of strong movements in 2007 – 2014, except for the 2007 earthquake, equal to 0.2 – 1.6 cm/s2, which is less than the acceleration values from Tables 1 and 2. During the earthquake on December 29, 2007, at a distance of 26 km from

the KNDC station, accelerations of 32.1 – 33.9 cm/s2 were recorded, close enough to the values of accelerations from Table 2 [5].

For comparison, the spectral curves were plotted at the basement level in the horizontal plane of the earthquake on February 02, 2018. Figures 4 and 5 show the spectral curves of two earthquakes along the OX and OY axes.

The OY spectral curves are more jagged. No radical differences in the magnitude of the spectrum maximum are observed.

Thus, shallow-focus earthquakes with sources on the territory of Almaty continue to be possible.

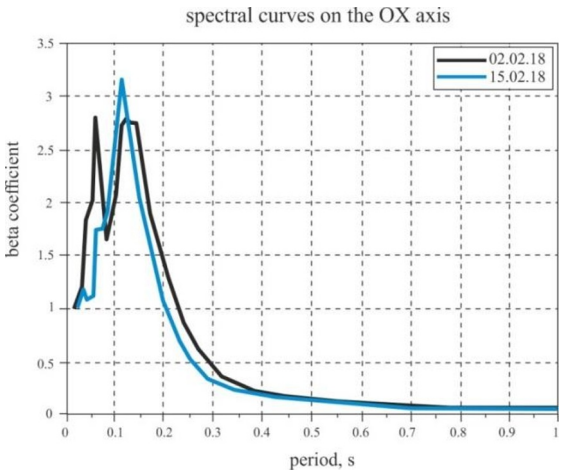

Fig. 4. Spectral curves of seismic events February 2 and February 15, 2018 (basement – OX axis).

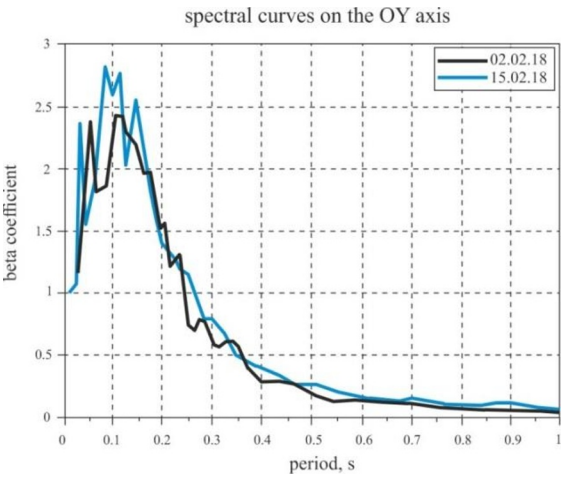

Fig. 5. Spectral curves of seismic events February 2 and February 15, 2018 (basement – OY axis).

The availability of instrumental data on local earthquakes gives rise to an interesting problem of evaluating the dissipative and inertial characteristics of the design model of a building based on instrumental records of earthquakes. That is the inverse problem of the theory of seismic stability, the solution of which is of great theoretical and practical importance.

Estimates of the spectral composition of earthquakes on 15.02.2018 with two pronounced points are very important. Such earthquakes can be dangerous for buildings equipped with seismic isolation systems. The development of mathematical models of such earthquakes is useful for the theory and practice of calculating seismic isolation systems.

According to the values of the maximum period of the spectrum from Table 1, it can be concluded that the seismic impact in this place is of a high-frequency nature. Therefore, the construction of multi-storey flexible buildings is preferable. In such buildings, resonant phenomena will be absent.

5 Conclusion

1. Seismic events that occurred on February 15, 2017, are the local earthquake with an intensity of no more than 3 points in terms of intensity and frequency composition. There are two groups of waves along the horizontal axes on the instrumental recordings in the building's basement, differing in amplitude. Such an instrumental record of an earthquake was obtained for the first time (Figure 2).
2. Spectral curves seismic the events of February 2 and February 15, 2018, are quite close in frequency composition in the basement level. The differences in the values of the spectral maxima are within 5 – 10%.
3. Oscillations of the base of the structure in the basement during both local earthquakes are high-frequency with a maximum spectrum period of 0.05 – 0.1 sec. Such earthquakes are dangerous for low-rise rigid buildings.
4. In [5-7] indicates the possibility of earthquakes with foci in the Almaty territory. Additionally, this article establishes the possibility of local earthquakes with foci in the western (northwestern) part of the city. A more detailed clarification of the modern seismological situation in Almaty is required, for example, for microseismic zoning of the city's territory. The observations continue.
5. Shallow-focus earthquakes of this type are dangerous for low-strength houses with load-bearing brick walls, but they are not hazardous for large-panel dwellings built up in digital neighborhoods in the western part of the city.
6. The increase in the intensity and number of local earthquakes compared to 2007-2014 is no doubt.
7. A sufficient amount of instrumental information is accumulated at the seismic station No. 1 "Institute," based on which it is possible to start solving the inverse problem of the theory of seismic resistance , which will make it possible to clarify the calculation of seismic-resistant structures, taking into account the probabilistic characteristics of the seismic effect and the structure itself [14-17] .
8. It is necessary to continue installing stations of the engineering and seismometric service on buildings with seismic isolation systems[14-18], on buildings on pile foundations [19-20]
9. Instrumental recordings with two groups of waves (two shocks, Figure 2) it can be used in the calculations of buildings on the territory of the city of Almaty to improve the quality of the assessment of seismic resistance of multi-storey buildings of mass construction by the method of nonlinear calculation Pushover Analysis [21-26].

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