

Response of the building with a stiffening core during an earthquake of February 02, 2018 in the territory of a metropolis

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Abstract. Earthquakes give rise to a significant number of problems that affect environmental, seismic, and economic risks for the local construction sites. For the first time in the last 40 years, another local zero depth earthquake was registered in the territory of the city of Almaty. In terms of intensity, this was a 3-4-point earthquake. At 100 meters from the tectonic fault, there is a 16-storey building with a stiffening core and an engineering seismometric service station. With the use of AT 1105 sensors and a PCM-8 recorder, instrumental records of accelerations in the basement and on the roof of the building were recorded, and spectral β curves were constructed. The effective duration of the seismic impact in the basement of the building was quite significant, 47-56 seconds. There is undoubtedly an increase in the intensity of local earthquakes compared to 2007-2014. It was found that at the basement level the value of the vertical component is significantly less than the horizontal one. It is assumed that the abnormally high values of acceleration in the horizontal plane are a consequence of the presence of a tectonic fault near the building. Instrumental records of acceleration (accelerograms) can be used in calculations of both the seismic resistance of an object and the assessment of environmental, social, economic, and non-economic risks.

1 Introduction

Earthquakes drastically affect the environment. The entire territory of the Almaty region is prone to earthquakes, which can pose a danger to buildings and structures on the territory of the city. The Almaty region has a rich seismic history. The megalopolis is located on the territory of one of the most highly seismic zones in Central Asia. For a little more than a century, there have been two earthquakes with an intensity of 9-10 points, one earthquake with an intensity of 8-9, one with an intensity of 7-8, and over 100 with an intensity of 6 or less. Almaty today is a megalopolis with a population of 2 million people with the prospect of growth by 2050 to 5 million people. But this is also the city where in 1911 there was an

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earthquake of the class of seismic disasters - the Kemin earthquake on January 4, 1911 with a magnitude of 8.2.

Therefore, instrumental observations are carried out for a significant number of buildings.

In [1] it is noted that, based on the materials of seismic observations, the possibility of earthquakes in the southern and southeastern parts of Almaty has been reliably established. Faults were identified in the city, which are associated with earthquake foci. From January 1, 2005 to December 4, 2014, 1293 earthquakes with energy classes $K = 2.7-9.7$ were registered in the city and its immediate vicinity. According to earlier data [2], from April 1, 1972 to December 31, 1982, 983 seismic events with an energy class of $K = 5.0-13.0$ were registered in Almaty. However, the stations of the engineering and seismometric service on buildings did not register noticeable seismic events in the city.

The Engineering and Seismometric Service (hereinafter - ESS) in the Republic of Kazakhstan is currently represented by 12 stations, including in the city of Taraz (1 station) and the city of Kapshagai (1 station), located at buildings of various designs. 4 stations have both digital and analogue equipment.

Most of the stations have old analog devices. These are VBP sensors that measure velocities and displacements, and OSP sensors that record accelerations and velocities. There are also SM-4 sensors that record displacements. Currently, various measuring systems and instruments have been developed [3-7]. Therefore, the modernization of the stations can potentially be carried out.

A complex of instrumental studies on the behavior of a 16-storey building with a stiffening core, located 100 meters away from the tectonic fault, continues. The building houses seismic station No. 17 "New Square". Earlier, this station obtained instrumental records of the earthquake on September 8, 2017, the source of which was located in the Xinjiang province of the Uygur region of China [8]. There are instrumental records of a weak earthquake on June 3, 2017 with a source also in the city [9].

Thus, experimental research methods (instrumental records of accelerations) and theoretical methods based on the use of computer mathematics systems, such as MATLAB, SCILAB, MAPLE, are combined.

The following objectives were set:

- To investigate the reaction of a high-rise building near a tectonic fault.
- To assess the influence of a tectonic fault on the instrumental characteristics of the basement of the building.
- To identify the possibility of resonance phenomena in such buildings during earthquakes in the city.
- To use the instrumental records of a real earthquake obtained with the station of the engineering and seismometric service No. 17 "Novaya Ploschad" to accomplish these objectives.

2 Method

According to the operational data of the Data Center of the Institute of Geophysical Research, an earthquake occurred in Almaty on February 02, 2018 at 15:20 Astana time (09:20 GMT). The coordinates of the epicenter: 43.15 degrees north latitude, 76.88 degrees east longitude. Magnesium there $m_b = 3.6$. Energy class $K = 7.5$. The earthquake was felt in Almaty with an intensity of 3-4 points. The earthquake source, according to seismologists, was located in the city.

For comparison, it should be noted that earlier on the territory of Almaty city, a very weak earthquake was recorded on June 3, 2017 at 23.57 Astana time (17.57 GMT), 14 km to the north. The coordinates of the epicenter are 43.30 degrees north latitude, 76.98

degrees east longitude. Magnitude $m_b = 2.4$. Energy class $K = 5.7$. The earthquake was felt in Almaty with an intensity of 2 points. The focal coordinates of the two earthquakes are very close. The depth of the focus is insignificant.



Fig. 1. View of the building.

Thus, the last local earthquake on 02/02/2018 is more intense. It was felt by residents of almost all areas of the city. Earthquakes with such parameters were predicted earlier and can be dangerous for the population and housing stock of the city [1-2].

Station No. 17 "New Square" is located on a 16-storey residential building with a stiffening core (Fig. 1). It should be noted that this station began operating in 1987. In 2008, the station was modernized - a digital instrumental measuring system RSM-8 with ADXL sensors was installed.

The structural basis of the building is a braced frame, inside of which there is a lattice stiffening core in the form of a space framework. The size of the core in the plan is 6800-6790 mm. The core of stiffness is developed in two levels by traverses. The spatial stability of the building is ensured by the joint work of single-span frames and a lattice stiffening core. A braced frame rests on columns with a section of 740x740 mm. The columns are made of M400 heavy concrete.

The foundation of the building is made of precast and monolithic reinforced concrete. The soil consists of coarse gravel.

3 Results

Instrumental records of accelerations – accelerograms – were obtained (Figures 2-4).

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). Accelerations in the basement level in the horizontal plane approximately coincide 25.44-26.41 cm / s². In terms of magnitude, this is a 5-6-point earthquake. The vertical acceleration at the basement level is less than that recorded in the horizontal plane. Acceleration in the level of the last tier is less than in the basement level. It can be noted that the first form is not realized here in its pure form. At the roof level, the value of the horizontal acceleration is 3 times less than the vertical value.

The spectral coefficients on all three axes on the foundation and the roof differ by about 1.4-2.7 times. At the same time, the greatest differences in the values of the spectral coefficients take place in the vertical axis OZ.

At the basement, accelerations are of a pronounced impulsive type (Figure 4).

The values of the accelerations in the azimuthal plane at the basement level approximately coincide. The values of the spectral coefficient differ by 7-8%.

At the basement level, the frequency content is stable - the prevailing period is 0.10-0.14 sec.

In general, even visually, the nature of the seismic impact is impulsive. Therefore, although the acceleration values are significant at the basement level, the macroseismic effect does not exceed the intensity of 3-4 points.

It should be noted that during the local earthquake on June 3, 2017, the absolute values of acceleration did not exceed the acceleration values of 2.84 cm / s² on the roof, and 1.59 cm / s² on the foundation. In the case of the earthquake of 02.02.2018, the accelerations are about an order of magnitude higher.

It is worth noting that on the digital instrumental records of the local earthquake on June 3, 2017, there was an incomprehensible shift of zero lines on the horizontal components on the roof of the building. In the event of an earthquake on 02.02.2018, the indicated displacement did not take place.

Table 1. Maximum values of accelerations and parameters of accelerograms.

№	Element	Acceleration, cm/s ²	Effective duration, S	Spectral ratio	Spectral peak period, s
1	98-17-17y OY	14.36	1.66	3.93	0.10
2	98-17-17z OZ	40.39	2.20	3.98(3.79)	0.24(0.10)
3	98-17-10x OX	16.89	0.64	3.60	0.14
4	98-17-10y OY	18.81	0.76	3.99	0.13
5	98-17- xpod OY	26.41	47.12	2.20	0.14
6	98-17- ypod OY	25.44	56.44	2.36	0.10
7	98-17- zpod OZ	5.84	1.61	5.43	0.11

Figures 5,6,7 show the spectral curves of seismic events on February 2, 2018. Acceleration peaks at the basement level correspond to an oscillation period of 0.10-0.14

sec. On the roof of the building, the period of the spectrum maximum along the horizontal and vertical axes logically increases.

It should be noted that, despite the low intensity of the earthquake, the spectrum along the OZ axis on the roof of the building has two maxima. At the basement, all spectral curves have at least 2 local maxima.

Thus, in addition, shallow-focus earthquakes with sources in the western part of the city of Almaty are possible.

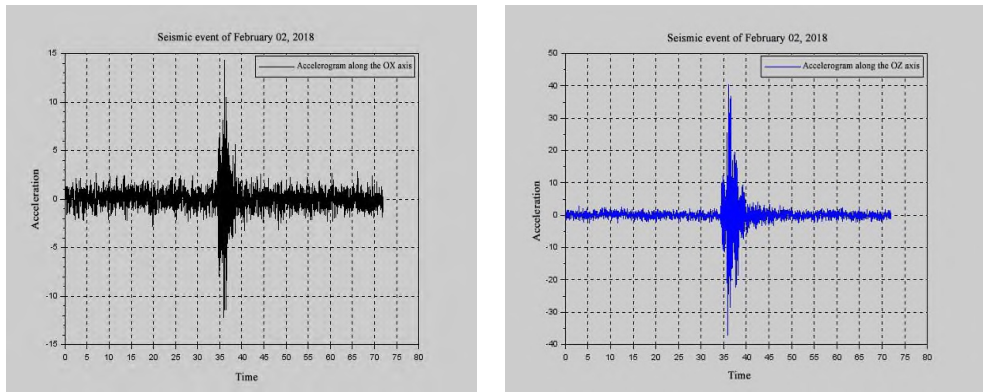


Fig. 2. Accelerograms of the earthquake of February 2, 2018 (Station number 17 "New square", roof).

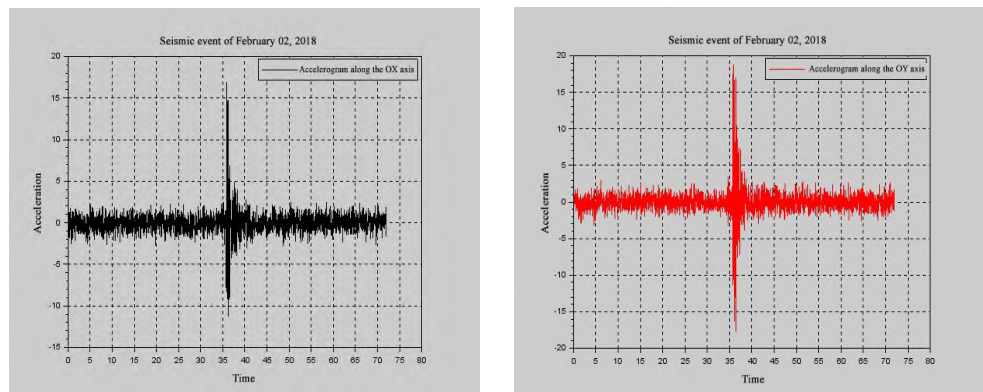


Fig. 3. Accelerograms of the seismic event on February 2, 2018 (station No. 17 "New Square", 10th floor).

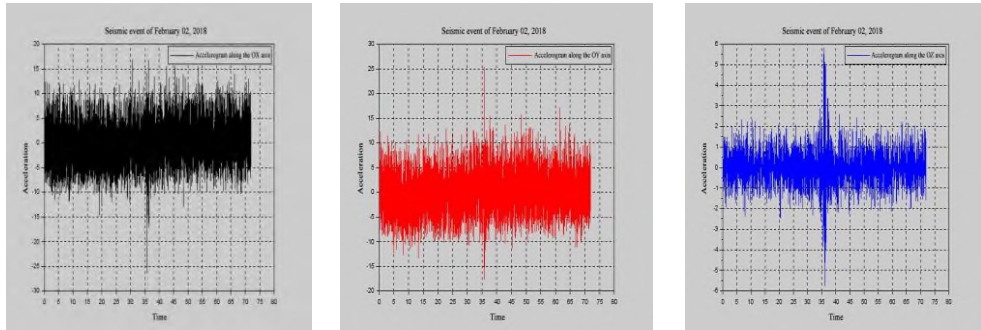


Fig. 4. Accelerograms of the seismic event on February 2, 2018 (station No. 17 "New Square", basement).

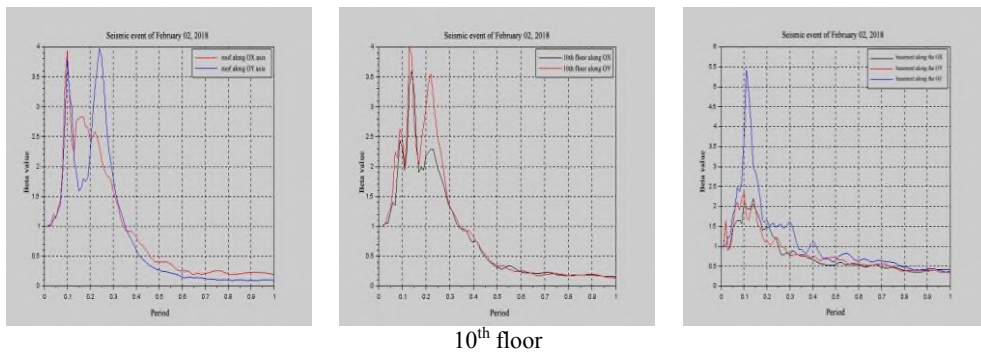


Fig. 5. Spectral curves of seismic events on February 2, 2018 (top picture - roof, in the middle - 10th floor, bottom – foundation).

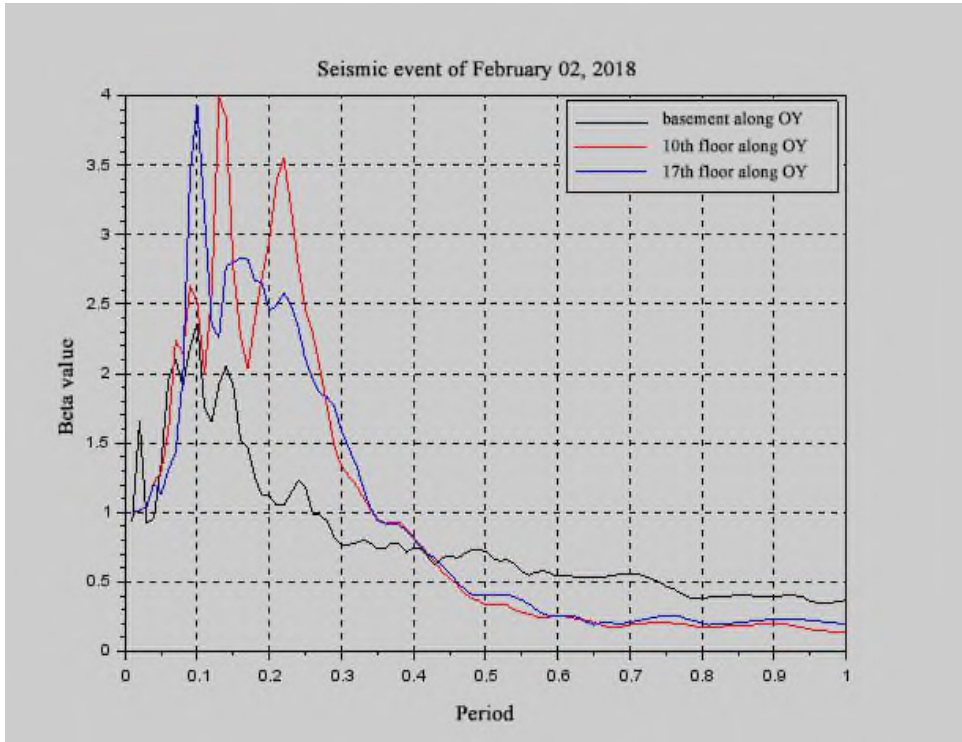


Fig. 6. Spectral curves of seismic events on February 2, 2018 (floor by floor along the OY axis).

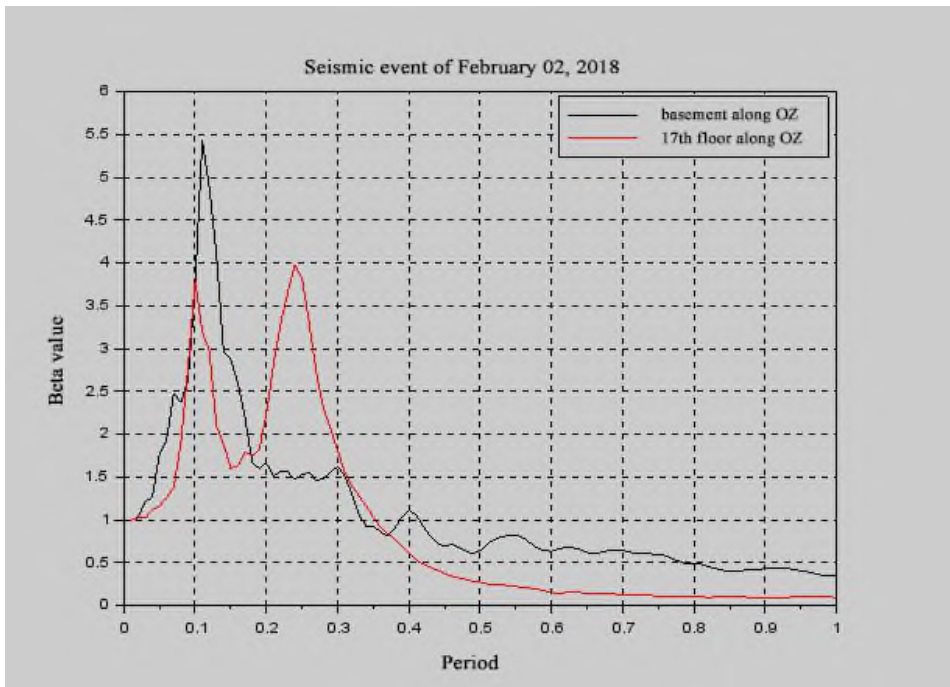


Fig. 7. Spectral curves of seismic events on February 2, 2018 (floor by floor along the OZ axis).

4 Discussion

Attention is drawn to the magnitude of the acceleration in the basement of the building in the horizontal plane ($25\text{-}26\text{ cm/s}^2$). Such accelerations correspond to an earthquake with an intensity of 5-6 points on the MSK 64 scale. Although the general macroseismic effect of the 02.02.2018 earthquake did not exceed 4 points. It can be assumed that significant acceleration values are a consequence of the presence of a tectonic fault located 100 meters from the building, which is a crack in the earth's crust covered with a thick layer of sedimentary rocks.

According to [1], the maximum acceleration values of strong movements in 2007-2014 in the territory of Almaty, except for the 2007 earthquake, are $0.2\text{-}1.6\text{ cm/s}^2$, which is less than the acceleration values from Table 1. During the earthquake on December 29 2007, at a distance of 26 km from the KNDC (Institute of Geophysical Research) station, accelerations of $32.1\text{-}33.9\text{ cm/s}^2$ were recorded.

Once again, it has been confirmed that earthquake sources can be located both on the territory of the city of Almaty and outside it. Therefore, the use of seismic-insulating foundations of various types remains relevant, which will reduce seismic loads by moving the building as a solid body without deformation of the above-foundation part [10-14].

It is necessary to continue monitoring the behavior of a 16-storey building with a stiffening core, equipped with a station of the engineering and seismometric service No. 17 "New Square". It is necessary to continue studying the behavior of the building both during local earthquakes on the territory of the city and at remote ones [9].

It should be noted that in the city of Almaty, on a tectonic fault, there is a building of a 25-storey hotel, also equipped with an engineering and seismometric service station on the buildings [15]. Thus, comprehensive studies of the influence of fault zones on the behavior of high-rise buildings are being carried out.

5 Conclusion

- The seismic event on February 2, 2017 is a local earthquake with an intensity of no more than 4 points in intensity and frequency content.
- It can be assumed that the influence of tectonic fault presence is to increase the peak values of acceleration in the horizontal plane in the basement of the building. Accelerations in MSK-64 seismic scale points increase by 1-2 points. The impact at the basement level is impulsive.
- Acceleration along the vertical axis at the basement level is 4-5 times less than the acceleration value in the horizontal plane.
- In [1-2] the possibility of earthquakes with foci in the territory of Almaty is indicated. Additionally, the possibility of local earthquakes with foci in the western (north-western) part of the city was established. This will make it possible to clarify the current seismological situation in Almaty, for example, for the purpose of seismic microzoning of the city territory.
- A 16-storey building with a stiffness core gets deformed in two modes of vibration. The accelerations in the level of the last tier are less than the accelerations in the basement level.
- Shallow earthquakes of this type are dangerous for low-strength houses with load-bearing brick walls but are not dangerous for flexible buildings with a fundamental tone period of more than 1 second.
- Undoubtedly, there is an increase in the intensity of local earthquakes in the city compared to 2007-2014.

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