Refinement of the seismicity of construction sites for high-rise buildings

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Abstract. The development of the construction of high-rise residential buildings requires a separate approach, depending on the engineering and geological conditions of the site for seismic microzoning. There are not only engineering sectors but also large premises that will serve as business offices and technical centers in the underground part of high-rise buildings. In this regard, the foundation of the building goes to great depth. The influence of soil conditions at the level of abutment of the buildings’ foundation can be determined with seismic microzoning. As a result, the task of clarifying the projected construction site in construction is currently relevant. It includes the refinement of the seismic intensity of the construction site during the construction of high-rise buildings, which are located in different multilayer soil types.

1. Introduction
Seismic microzonation requires specific approach during the construction of the high-rise buildings and depends on engineering and geological conditions of a construction site. High-rise buildings rise upwards and their foundations go down during construction. High-rise buildings are usually multifunctional objects, which means that the underground part of these buildings will serve as the engineering sector, where the engineering, water supply and sewer, heat and gas supply networks are located, and will serve as business offices and technical centers as well. Thus, the foundations of multi-storey buildings go down and can sit on solid soils (depending on the engineering and geological conditions of a particular area). All these factors require a completely new approach and a new interpretation for the seismic microzonation of the construction site. Herewith, the effect of soil conditions in seismic microzonation should be determined for soils at the level of abutment of the building foundation.

At the end of the last century and the beginning of the present, seismic microzonation was performed only for the soil surface layer, because the architectural design of the buildings was focused on typical 5-9 storey buildings. This was a good design decision for the earthquake-resistant construction. Those buildings usually had shallow foundations and sat on the upper soil layers. Engineering communications were located in the building’s foundation. It was enough to determine the seismic characteristics of the upper soil layer for a low-rise building. But, starting from the 1980s, developing the higher-rise buildings in areas with solid and single-layer soil became more common. There was also experience in seismic microzonation on the construction site for chimneys for a heat power station, where the soils were multilayer and the foundations of these structures sat on solid soils. For such structures, the individual seismic microzonation of the site was refined. Considering the previous construction experience, this method can be applied to modern high-rise buildings located in
the multi-layer soils of the construction site as well, therefore, the task of refining the details of construction site in construction at this time is relevant, which includes refining the seismic intensity data of the construction site.

It includes the specification of the seismic intensity of the construction site during the construction of high-rise buildings, which are located in multilayer soils.

The major provisions of the determination methods for calculating the increment of the score depending on the soil conditions were proposed by S.V. Medvedev [1]. The issues of microzonation of urban areas and construction sites, as well as the analysis of scientific works can be also in the publications of M.P. Kamchybekov [2] and others.

2. Initial data and analysis
On December 26, 2020, at 04:28:33.13 PM (local time), an earthquake with a magnitude of $M_{pv} = 5.3$ or $K = 11.9$ was registered in Kadamzhai district, Batken region. The source of the earthquake was located in the northern foothills of the Katantau mountain ridge.

The locals did not panic, although the earthquake was quite strong. Probably, this can be explained by the psychological factor of small town and rural area residents, whose life and work activities are more connected with nature. Residents of large cities work in plants, factories, offices, trade centers and live in high-rise buildings, they are out of touch with nature and the evidence from practice shows, that they are more susceptible to panic [3] if an earthquake occurs with the same strength and the epicenter of the earthquake is approximately at the same distance. The seismicity in the epicentral region is considered in the work [4].

The parameters of the earthquake measured by different seismological services are shown in Table. Its strength was 5 points. The epicenter of an earthquake, determined by different seismological services, is shown in Figure 1.

| Name                        | Date       | Time, UTC | Latitude | Longitude | Depth, km | $M_{pv}$ | $Mag$ | $mb$ | $Ms$ | $K$ |
|-----------------------------|------------|-----------|----------|-----------|-----------|----------|-------|------|------|-----|
| IS NAN KR (KRNET)           | 2020-12-26 | 10:28:33.13 | 40.13°   | 71.43°    | 11        | 5.3      |       |      |      | 11.9|
| KNDC                        | 2020-12-26 | 10:28:25.27 | 39.52°   | 71.19°    | 5         | 5.1      | 5.4   | 11.8 |      |
| Geophysical Service of the RAS | 2020-12-26 | 10:28:35.0  | 40.23°   | 71.62°    | 20        |          |      |      |      | 5.3 |
| CSEM-EMSC                   | 2020-12-26 | 10:28:36.2  | 40.26°   | 71.65°    | 2         | 5.5      |       |      |
| USGS (NEHRP)                | 2020-12-26 | 10:28:35.0  | 40.15°   | 71.66°    | 20        | 5.5      |       |      |

Note to Table: IS NAS KR (KRNET) - Institute of Seismology of the National Academy of Sciences of the Kyrgyz Republic; KNDC - Kazakhstan National Data Center; Geophysical Survey of the RAS - Geophysical Survey of the Russian Academy of Sciences; CSEM-EMSC - European-Mediterranean Seismological Center; USGS stands for National Earthquake Hazards Reduction Program (NEHRP).
Simultaneous earthquake registration at different levels in the section and in different soil conditions allows us to determine the increment in the intensity of the studied soil. The analysis of the data obtained by this method assumes the formation of a linear dependence in the soils behavior under strong movement. It should be noted that each strong earthquake brings specific unique effect, which depends on many factors, such as the type of tectonic fault, focal mechanism, epicentral distance, magnitude, etc. Thereby it is necessary to accumulate static data and perform monitoring by an instrumental method for calculations. The accumulation of digital instrumental observations will allow us to reasonably predict the soil behavior during a strong earthquake.

An engineering seismology station, seismic sensors installed at different levels depending on the soil conditions in the territory of Osh city, have registered this earthquake. The distance from the epicenter of the earthquake to the studied is about 124 kilometers. SM-3 electrodynamic seismic sensors [5, 6] with a 2 sec natural frequency of the pendulum, was used as a sensor for registering the record of soil vibrations from earthquakes. Three components were mounted at each seismic observation point (Figure 2). The top soil layer is brown loam (reference soil), hard, highly porous, subsiding, related to category III by its seismic properties. The bottom soil layer (the studied soil), - pebble soils with sandy aggregate content up to 25%, with boulder stones content up to 20%, from a depth of 9.5 meter with signs of cementation (conglomerates), related to category II by its seismic properties.
The records of the earthquake vibration velocity for two seismic registration points and amplitude spectrum of earthquake oscillation are shown in Figures 3 and 4. As it is shown on the figures that the vibration amplitude in loam soil is much higher than one in pebble soils.

Figure 2. Geotechnical condition of the projected construction site and the location of the seismic points and their number.

Figure 3. Record of vibration velocity from an earthquake. Indices 1 and 2 show the number of the seismic points.
Figure 4. Amplitude spectrum of earthquake oscillation.

3. Methodology
The increment of the studied soil’s score comparing to the reference soil is performed according to the classical formula [1,7]:

$$\Delta I = 3.3 \cdot \lg \left( \frac{V_2}{V_1} \right),$$

where $V_2$ is the amplitude of the recording of the vibration velocity of the studied soil (pebble soils), and $V_1$ is the amplitude of the recording of the vibration of the reference soil (loamy soils).

The amplitude estimates of calculated increments of the intensity for N-S, E-W and Z components for studied pebble soil (seismic point #2) is 1 point lower at a depth of 6.3 m below the earth's surface than in loamy soils (seismic point #1).

The seismic intensity scales have been constantly improved recently. The relevance of this sphere increases every time when it comes to ensuring the seismic resistance of buildings and structures in earthquake-prone areas. The scope of applying the seismic intensity scales is same as for the other calculation methods. In any case, you can always use the classical category of soils by their seismic properties and the value of scores (intensity); in our case, we used the MSK-64 [8] and the modern EMS-98 [9] scales.

4. Result
The result of the instrumental experiment shows that the increment in the seismicity of the studied soil (pebble soils) for the construction site under design at a depth of 6.3 meters under the ground surface and below that is 1 point lower than the one for the loamy soils.

5. Conclusion
As a result of the experiment, we can conclude that, under difficult engineering and geological conditions of the construction site, we can remove the top soft layer of soil to the level of the hard pebble layer. This will reduce the seismicity of the construction site on which it is planned to build high-rise buildings.
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