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Seismic ground motion variations resulting from site conditions

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Abstract: Amplification of seismic ground motions in the territory of Almaty city is evaluated by using different methods. The pattern and probable causes of ground motion variations in different engineering-geological conditions are characterized. An expeditious application of these techniques within a complex methodical approach for Almaty city microzonation is considered.

Key words: ground motion variations; spectral ratio; methodical approach

1 Introduction

Evaluation of seismic ground motion amplification and deamplification caused by the effect of subsurface geology is a critical part of seismic microzonation studies. In Almaty city, as in some other world megalopolises, the amplification of strong motions resulting from a layered medium is complicated by the irregular geological structure of a deep sedimentary basin with alluvium-proluvium filling. We studied the soil response within the city territory from accumulated instrumental data recorded by the Almaty strong-motion network. Previous studies[1] were carried out in cooperation with experts from the German Research Center for Geosciences (GFZ).

At present, with renovation of seismic microzonation of the city territory being initiated, upgrading the methodical basis is required. In this connection we analyzed the possibility of applying some simple and commonly used foreign techniques to the conditions of the Almaty sedimentary basin and the advisability of their introduction into a complex methodical approach for city microzonation.

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2 Ground motion variations over the basin territory

Experimental data obtained by the local Almaty strong-motion network during more than a 12-year period[2] and results of engineering-geological studies in Almaty indicate the dependence of ground motion variations on station location over the basin territory. Even if the effects from looser near-surface layers are impossible to separate from those of the dipper basin structure, S waves are considered to be especially affected by loose sedimentary layers up to 100 m thick. This effect can be observed at periods < 1 secondy. By estimating ground motions from 1 to 10 secondy, we can consider the influence of a source and thick sedimentary layers (of up to several kilometers). In Almaty basin, the shaking intensity varies considerably with the increase of sedimentary cover thickness and the steepness of the basement slope. As an example, the accelerograms and Fourier spectra of the February 14, 2005 earthquake ($Ms = 5.9$, Rep = 250 km, $h = 5$ km) recorded during the network operation period are shown in figure 1.

We can see amplification of long-period vibrations resulting from the thick sedimentary cover at all stations with the exception of MDO, which is located on rock. In the higher frequency range, the spectral level is increased at stations located on resonating layered soils

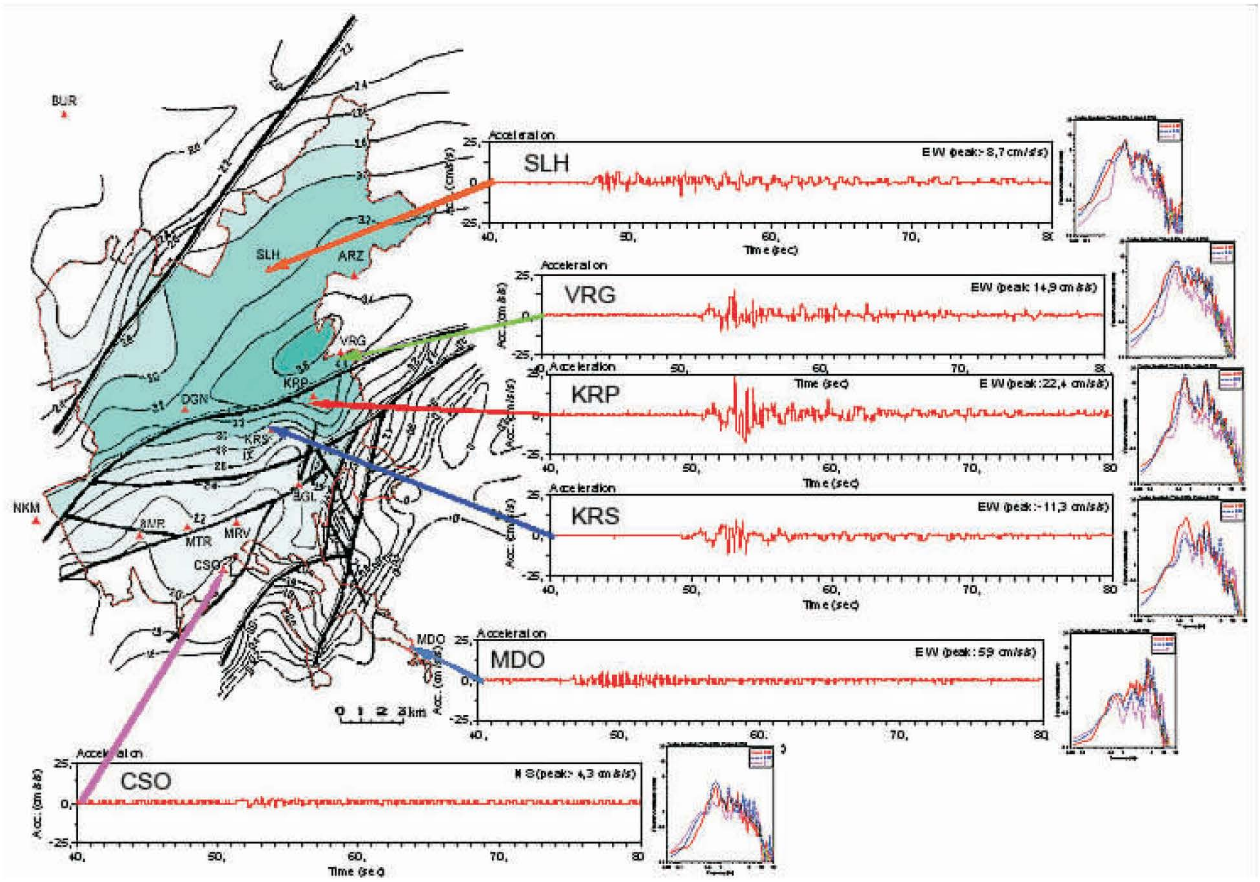

Figure 1 Accelerograms and Fourier spectra obtained in Almaty territory during the February 14, 2005 earthquake

with lower stiffness (KRP, VRG, and SLH) in comparison with stations located on boulder gravel (CSO). On thick boulder gravels amplification is observed in the zone of steep dipping of the basin boundary and lithological substitution of boulder gravel into loam and loamy sand (KRS). This also produces additional amplification at the KRP station. Amplification in a narrow frequency range at the MDO station may be caused by topography, as the station is located on the mounting slope. The other recorded earthquakes display a similar pattern. Figure 2 clearly displays the difference in the response spectra obtained in three types of soil conditions (rock outcrop, debris cone, and piedmont plain) during the May 22,2003 Lugovskoe earthquake (Ms=5.6, h=10 km, Rep≈330 km).

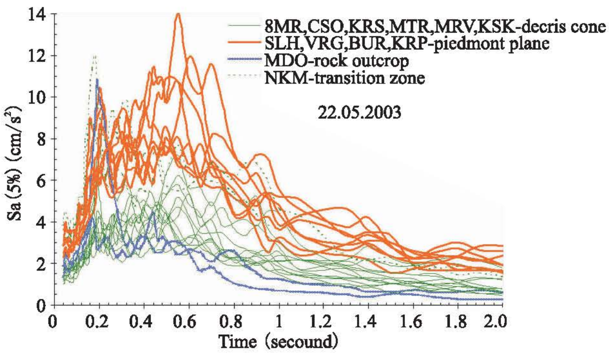

Figure 2 Response spectra of the Lugovskoe May 22, 2003 earthquake at stations located in different soil conditions in Almaty

3 Methodical approach

The microzonation methodical approach commonly used in Kazakhstan and most post-Soviet countries is based on assessment of the macroseismic intensity increment obtained by using different methods (engineering-geological, impedance contrast, seismological, and modeling) with respect to the specified average soils, usually the second category according to Kazakhstan's Building Code. The most usual practice throughout the world is to determine amplification in spectral accelerations (acceleration spectral densities) at high and low frequencies and with respect to soils with good seismic properties (such as class B rocks according to the National Earthquake Hazards Reduction Program classifi-