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APPLICATION OF MICROSEISMIC AND CALCULATIONAL TECHNIQUES IN ENGINEERING-GEOLOGICAL ZONATION

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ABSTRACT: Data on engineering-geological conditions is the basis for seismic microzonation (SMZ). It is usually based on different data of field geological works in the investigated area, including drilling data, ground-penetrating radar (GPR) sensing, etc. At the same time seismic properties of soils (mainly velocities of p- and s-waves) are obtained by seismic exploration. This technique is used for typical sites. While the quality of initial engineering-geological map strongly affects selection of such "typical" sites. Practice of seismic microzonation has shown that such maps must be refined before usage of the main SMZ techniques (earthquakes and explosions recording, etc.) which are relatively labor-intensive. For practical realization of SMZ in the Republic of the North Ossetia-Alania we had to use combined microseismic technique to refine engineering-geological-data, especially in instrumental "gaps" regions. As a result new statistical method for different site type allocation was developed. It is based on histograms of different site parameters, obtained from microseisms processing. Mobile seismic stations was used to investigate large areas in a short terms, exploration grid size was from 100 up to 500 meters in some places. H/V technique was used for predominant period estimation. Numerical models were used for data control in reference sites. As a result new refined engineering-geological maps of Vladikavkaz, Beslan, Alagir, Ardon and other cities were obtained in a short time.

Keywords: Engineering-geological Conditions, Soils, Site, Microseisms, H/V Technique

1. INTRODUCTION

Geophysical Institute of VSC RAS carries out purposeful works on construction of engineering-geological zoning maps of settlements of the Republic of North Ossetia-Alania, as a basis for seismic microzonation. Engineering-geological zoning maps of Vladikavkaz, Beslan Ardon, Alagir, Digora, Mozdok and settlement Chikola were constructed.

The set of engineering-geological cross-sections and maps that show different engineering-geological aspects of zonated territories has been compiled in the result of work on collection and systematization of the investigation data for the past years [1].

The completeness of materials characterizing rocks when driving mines of various assignments do not always meet modern requirements for creation of seismic microzonation maps since all the collected and further processed information, which became the basis for construction engineering-geological zoning maps was carried out by different authors and in different years [2]–[4], and this information was not designed for the task of seismic microzonation. This results in a corresponding inaccuracy. Thus, the engineering-geological zoning maps of Vladikavkaz and Beslan, composed according to archival materials are presented in Fig. 1.

The lack of detail in the data for construction of engineering-geological zoning map was revealed in the process of work. In particular, the content of sand and clay filler for macrofragmental soils was indicated only for a number of wells.

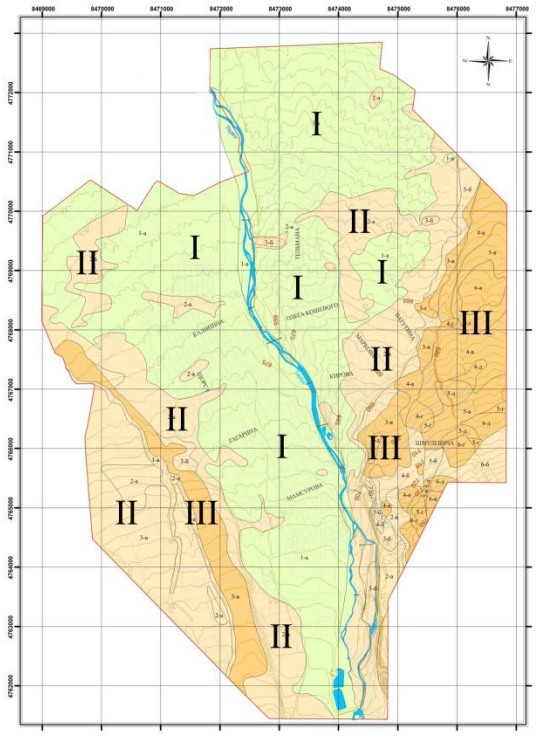

Fig. 1 Engineering geological zoning map of Vladikavkaz, soil types are marked by Roman numbers

From 2009 to 2013 we have carried out active work to refine the engineering-geological conditions

of the territory of a number of cities of the republic with modern geophysical methods: seismic refraction (seismic-refraction method and correlation refraction method) and spectral H/V-relations through microseism records.

From the existing instrumental tools the tool of microseisms that allows promptly examine the significant areas can be selected.

2. METHODS

According to "RSN 65-87" microseism tool is subsidiary for seismic microzonation [5]. Indeed, the amplitude level of microseismic vibrations is largely determined by proximity to the source of vibrations and recording time. Analysis of the variation of the maximum amplitudes of microseisms at seismic stations of network "Vladikavkaz" shows daily fluctuations in the level of seismic noise: the greatest amplitude are observed at noon, the minimum for the period from midnight to six in the morning. Especially clearly the mentioned is indicated on the vertical component in the form of lower levels of microseisms at the weekend.

At the same time, a tool based on the microseisms records and construction of spectral H/V relationships [6]–[7] are now widely used in many works to determine the natural frequencies of a ground stratum.

The records of microseismic vibrations in various parts of the Vladikavkaz were obtained during the work on seismic microzonation. Registration of microseisms was performed using three mobile seismic stations that included: recorders of seismic signal (RSS) "Delta Geon-02M" geophones SK-1P and power supplies BP-9/12). Geophones were oriented to the cardinal points: X-component was directed to the north, and the Y-component - to the east.

Recording parameters were determined in accordance with [8]. Examples of the spectral H/V relationships are shown in Fig. 2. X-component is indicated by a solid line, Y-component - dotted line.

According to results of seismic prospering work in some areas computational models were built and the spectral curves of vibration amplification by upper stratum of cross-section with respect to the underlying stratum of dense gravels (for the upper part of the cross-section) were calculated. The relationship between the instrumental and the calculated values of the resonance frequencies is given in Fig. 3. In general, the correspondence of frequency values is observed, the ratio may be interpolated by the relation:

$$f_{calc} = 0.89 \cdot f_{instr} \quad (1)$$

with the value $R^2 = 0.60$

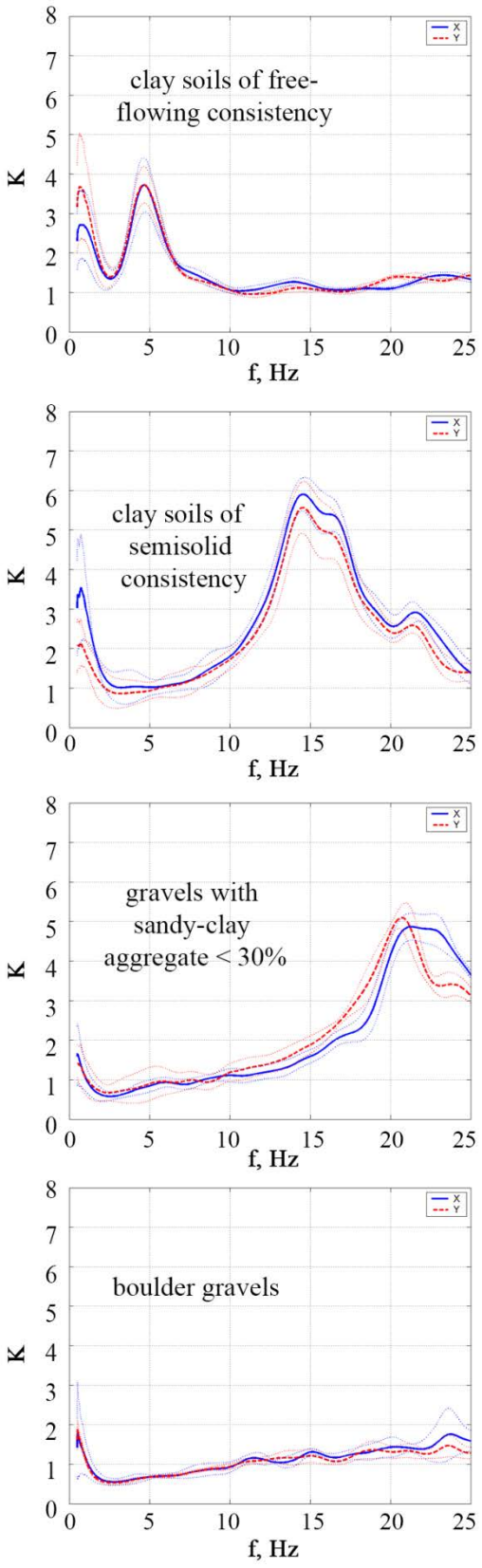

Fig. 2 Typical forms of spectral H/V relationship in areas with different engineering-geological conditions on the territory of Vladikavkaz

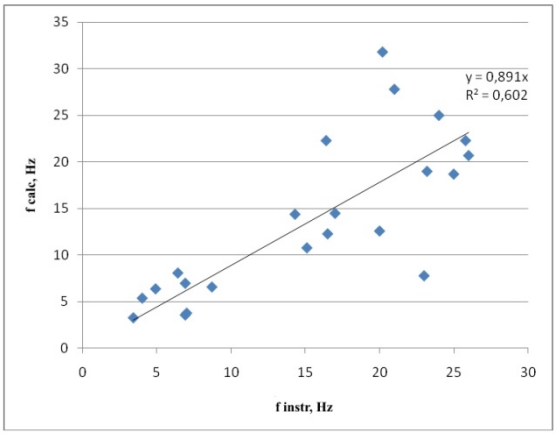

Fig. 3 The relationship between instrumental and the calculated values of the resonance frequencies

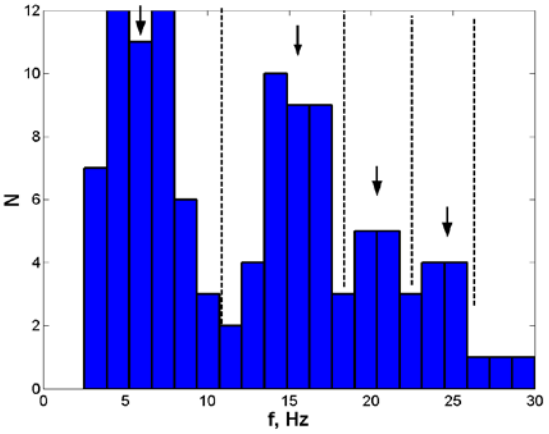

Fig. 4 Distribution histogram of predominant vibration frequencies, according to microseism records in the territory of Vladikavkaz

Despite some observed differences quite general laws can be identified. For sites composed by stratum of clay soils of free-flowing consistency the maximum amplification of the vibration amplitudes and reduced frequencies is observed in the range of 1.7–6 Hz. At the site, composed by clay soils of semisolid consistency amplification of vibrations in general is twice less, and the resonant frequencies will be 6–7 Hz. For the top gravel stratum with filler amount more than 30% the spectral amplitudes are slightly less than basic spectral peak at a frequency of 10–12 Hz; for gravel with filler amount less than 30% the spectral peak corresponds to the 19 Hz and higher.

Compliance of spectral characteristics of sites obtained by different methods, rightly allowed to use the microseism records to improve the differentiation quality of the results of instrumental technique and refine the boundaries of engineering-geological zoning map.

The concept of “average ground conditions” SNiP contains a statistical sense, that is to select the most common types of soils in the investigated area, in other words, soils with a larger area of distribution. It should be noted that is considered not only the territory in which works are carried out directly, but also a more vast area. Therefore, although the investigated site is a sample of the totality, which reflects the general nature of the distribution of the investigated parameters on a more general territory correspondence to the “greater area of distribution” will not be carried out always.

With a sufficiently large number of measurements and uniformity of distribution of the observation points it becomes possible to carry out statistical analysis of the data on the basis of the predominant frequencies. The distribution can be assumed close to normal.

Fig. 4 shows a distribution histogram of the predominant vibration frequencies on which there are several peaks (indicated by arrows). We assume these values mean (mathematical expectations) of each category, whose boundaries are defined by the minimums of the histogram (indicated by the dotted line).

3. RESULTS AND DISCUSSION

Interpolation of obtained data was carried out. According to the results of this interpolation the limit value of 5.8 Hz have also been allocated, what allowed differentiating the distribution area of subsidence soils that are located in the right-bank part of the city, on the engineering-geological zoning map are marked by hatching (Fig. 5).

The sites for which ground conditions require refinement using seismic prospering methods were allocated based on the obtained results. The works were carried out using correlation refraction method. A weight of 400 kg falling from a height of 3.5-4.0 meters was the main source of primary waves in the registration of the vertical component. When registering the horizontal component the multiple (up to 10 strikes) vibrations of medium were recorded when generating elastic shear waves by horizontal impacts on the wall with a sledgehammer slowpoke weighing 8 kg or tamper. For reliable correlations of the first arrivals of the bow wave, the velocities in the soil are quite confidently determined by the field seismograms. For the identification of primary and shear waves the phenomenon of phase inversion and other signs were used [9].

According to results of these works the engineering geological zoning map has been modified (Fig. 6).

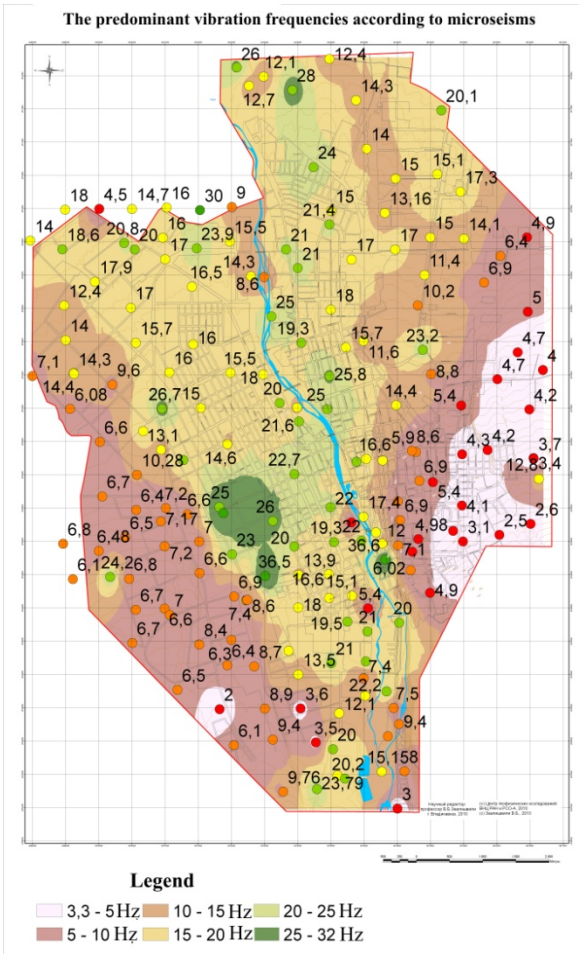

Fig. 5 The predominant vibration frequencies on the territory of Vladikavkaz according to instrumental data

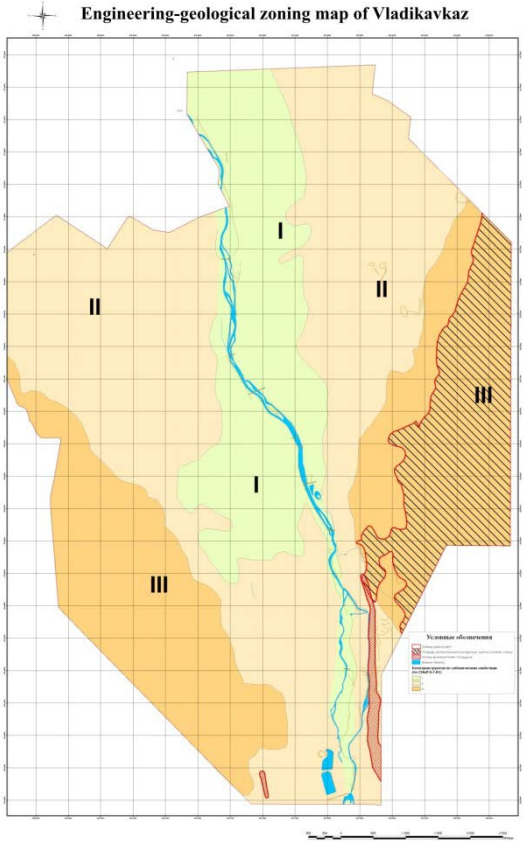

Fig. 6 Refined engineering-geological zoning map of Vladikavkaz, soil types are marked by Roman numbers, subsiding soils are located in dashed zone

In the territory of Vladikavkaz according to results of field work, both the right and the left bank of the vast territory, including primordial soils of category II were transferred to category III (Table 1 SNiP Russia [10]) (Figure 6). The spread area of subsidence soils is marked by shading. The main difference is in allocation of a large zone of category III soils in the west part and it was later justified by drilling results.

4. CONCLUSION

A method for refining engineering-geological zoning maps, which consists in carrying out instrumental research in two phases is developed.

In the first stage the research of territory using microseisms is performed. The map of predominant vibration frequencies is constructed. Allocation of various ground complexes on the basis of the predominant frequencies is carried out. A comparison of the obtained data with the engineering-geological zoning map that is being refined is performed.

In the second stage the areas whose boundaries do not coincide with the data of engineering geological zoning map are allocated and, if necessary refinement of soil conditions in given and global sites where soil conditions are confirmed by the data on the geological structure is performed.

The proposed method makes it possible to replace traditional labor-intensive and costly field research by microseismic survey of a wide area. The method is characterized by high speed and low cost.

The examples of engineering-geological zoning maps of Vladikavkaz and Beslan territories are given.

The obtained data were compared with the results of calculations of seismic vibration amplification by ground stratum on mathematical models.

The problems that arise in solving some problems of differentiation of ground complexes using spectral method and areas for further research are identified.

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