Detailed Seismological Studies the Junction of Different landscapes in South Yakutia

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Abstract. Research objective - determination of the quantitative indicators of seismic wave attenuation on the area of geotechnical landscapes with contrasting properties and the forecast of the seismic intensity impact within the area of study of the linear engineering structure in conditions of permafrost zone. During the research tasks were performed: study of the geotechnical structure of the area, registration of the microseismic disturbance, acceleration graph of the industrial explosions and powerful man-caused sources of the seismic waves. Main hypothesis of the study - contrast saving of the seismic properties of formation from geotechnical landscapes of rooted slopes and above floodplain river terraces in conditions of the permafrost zone. During the research complex of geophysical and seismological researches was performed, drawing of the geotechnical section confirmed by the drilling data. Results of the study confirmed main hypothesis - major difference of seismic properties of frost soils foundations for joint landscapes has been established.

1. Introduction

Years 1909, 1959 and 1985. Those are the years, which left a black mark on history of the great city of Mexico City. Those are the years of devastating earthquakes. The 19th of July 1985 7:18 PM stands out – timestamp that will never be forgotten by the eyewitnesses. “Terremoto de Mexico de 1985” – earthquake in Mexico City 1985, one of the most destructive earthquakes in the history of America.

One of the major questions the answer to which has a significant impact on future expectations of seismic hazards in Mexico City is, was the great 19 September 1985 Michoacán earthquake anomalous in some aspect of source behavior, location or radiation characteristics to concentrate so much damage in Mexico City? [1.2.]. The key point of explaining the cause of catastrophic destruction is the city’s placement in the “intermountain basin”.

Cause of the disaster - sites effects. Earthquake with the surface acceleration in the epicentre 1,5 m/s² turns into destructive impact with surface acceleration 1,7 m/s² 350-400 km away from the epicentre. [3].
Authors note, that the phenomena were well known before the earthquake in 1985, but in case with Mexico City it manifested with especial contrast. «Amplification of ground motion due to local soil conditions is a well-known phenomenon. In the Val-ley of Mexico, spectral amplification for subduction earthquakes (i.e., with epicentral distances greater than 300 km) at soft-soil sites range from 10 to 50 at frequencies between 0.2 and 0.7 Hz with respect to hard-rock sites [4], [5]. However, the hard-rock sites also experience large amplifications of about 10 due to regional site effects (quantified from attenuation relationships) associated with the volcanic arc deposits where the valley is embedded. This means that absolute spectral amplifications in the lake-bed zone of the Valley of Mexico may reach values from 100 to 500, which are probably the largest ever reported worldwide» [3].

Based on the topographic location of Mexico City, authors of the article created a model of the studied area, using non-structured tetrahedral net (fig. 3). Simulation of the passage of seismic waves in the model allowed to obtain apparent confirmation of nature of the phenomenon studied (fig. 4). Research of Cruz-Atienza V.M. and co-authors [3] are fascinating cause of visibility of results obtained. A set of researches [1], [4]-[7], [7]-[15] draws attention on the necessity of the individual evaluation of local ground conditions and composition of specific response spectrum of the ground stratum for the comprehensive evaluation of possible seismic hazard.

2. The studies of the South Yakutia

Researches completed in South Yakutia allowed to estimate the influence of sites effects in conditions of frozen grounds.

The site of research was allocated on the joint of geotechnical landscapes of root-ed slopes and above floodplain river terraces. There is a linear object allocated on the border of landscapes – a single-way train track. The fact that during the research was to establish the fact of presence or absence of sites effects on the area under study.

A seismic survey method of refraction correlation has been carried out to complete this task. The seismic rigidity of 30 m thick stratum, lying in the base of the structure was defined using the data obtained by the seismic survey. Profiles of geophysical researches were paved in parallel to the train tracks – to the west and to the east from the linear structure. Let’s note, that calculated according to the data of seismic survey average seismic rigidity of slope landscape and of landscape of the river terrace did not differ much: average seismic rigidity of 30 m thick layer of slope landscape is 3808 t/m*s², of river terrace – 3086 t/m*s². According to these indices grounds of both landscapes belong to the grounds of 1st category by seismic properties (table 1 SP 14.13330.2012 “Construction in seismic areas” [16]).

![Electromotography and velocity sections, geotechnical landscapes of above floodplain river terraces](image-url)
Electromagnetic researches were completed on the same profiles. Results of the electrotomography confirmed complete spreading of frozen grounds within the section under study, which explain high rates of seismic rigidity of stratum. The train track is allo-cated along the borderline of landscapes made this research practically important. The most valuable data has been obtained during the seismological researches. Placement scheme of three-component accelerographs is displayed on figure 1. Points of observation were chosen according to the objective – ensure the maximum contrast of ground conditions. Station 001 is located on a rooted slope, station 002 – on the above floodplain river terrace.

High amplitude seismic signals from two types of sources were registered during the research – from the passing by freight train and from the industrial explosion in Neryungri mine.

1. Primary accelerograms and three-component response spectres, which display ground motion when the freight train is passing by, are shown on figure 2. Obviously, large amplitudes of soil motions were recorded by station 002, located on the floodplain river terrace. Of particular interest are the spectra of the response of the soil stratum. The response spectra of the horizontal components differ substantially in the amplitude of the signal, with the relative safety of the spectrum. The response spectra of vertical components differ substantially in spectral characteristics - the response spectrum of station 002 is essentially shifted to low frequencies. Given that the amplitude of the signal of the 002 station's response spectrum is higher than the amplitude of station 001, one can make a cautious assumption about the presence of the site effects factor on the area under study. We also note good convergence of the results with seismic data - according to the seismic rigidity calculations, the average resonance frequency of the investigated soil stratum is 9.39 Hz.

The observed phenomenon of spectral shift and amplification of amplitudes over river valley deposits cannot be explained by the presence of any one factor. M. H. T. Rayhani and colleagues [11] found that the spectra of the response of the earth's strata obtained in full-scale experiments exceed the standard spectra, especially in the high-frequency range. «The observed response spectra are shown to be above the NEHRP building code design requirements, especially at high frequencies» [11]. In their work, the authors indicate that «The influence of local geologic and soil conditions on the intensity of ground shaking and earthquake damage has been recognized for many years. Local site conditions can

![Figure 2. Source - freight train, horizontal longitudinal component.](image-url)

![Figure 3. Ground response spectra acceleration, source - freight train, near zone.](image-url)
profoundly influence all of the important characteristics of strong ground motion: amplitude; frequency content; and duration. The extent of their influence depends on the geometry and material properties of the subsurface materials, on site topography, and on the characteristics of the input motion» [11].

As in many other studies of similar subjects, the authors of the work pay special attention to the response spectrum of the soil base of the structure, which make a significant contribution to sites effects. To clarify the results obtained at these same observation points, the effect of another yet technogenic source of strong seismic signals, industrial explosions on the Neryungri coal mine, was recorded on the studied ground layer. The accelerogram of the effect of the explosion on the strata, registered by station 001 is displayed on figure.

Figures 3 show the response spectra of the earth strata, calculated from station 001 data (upper graphs) and station 002 (lower graphs). Figure represents the response spectrum of soil stratum accelerations, calculated for the entire data array. The obtained numerical indicators: horizontal longitudinal component, station 001 – 0.00001951 g in 28.18 Hz, station 002 – 0.00005667 g in 44.67 Hz; horizontal transverse component, station 001 – 0.00000124 g in 28.18 Hz, station 002 – 0.0006131 g in 37.58 Hz; vertical component, station 001 – 0.00001120 g in 28.18 Hz, station 002 – 0.00008763 g in 31.62 Hz.

From the above data, it can be seen that the spectral accelerations are shifted to high frequencies. To assess the effect of relatively long-period oscillations on the ground base, the original signal was filtered in a band from 0.5 to 20 Hz. The results of calculating the spectral accelerograms of the response of the soil strata for the filtered signal are shown in Fig. 3. Maximum spectral amplitudes shifted to lower frequencies as expected: horizontal longitudinal component, station 001 – 0.00004632 g in 18.84 Hz, station 002 – 0.00002256 g in 15.85 Hz; horizontal transverse component, station 001 – 0.00002490 g in 25.12 Hz, station 002 – 0.00002047 g in 10.0 Hz; vertical component, station 001 – 0.000003728 g in 13.34 Hz, station 002 – 0.00002256 g in 15.85 Hz.

So, the main conclusions obtained from the processing of accelerograms of soil oscillations under the influence of external man-made sources of a strong seismic signal: in the case of finding the source of the signal in the near zone (the passage of a freight train), there is a distinct site effect, expressed in a significant increase in signal amplitude in the thickness of river sediments, With the shift of the maximum spectral acceleration to the low-frequency region; In the case of passage of oscillations from a sufficiently remote source (industrial explosions), a certain increase in the amplitude of the signal is observed in the thickness of the river deposits, the spectral accelerations are shifted to high frequencies. When filtering a signal in the passband of 0.5-20 Hz, the maximum spectral acceleration shifts to a region of relatively low frequencies, especially this effect is expressed for the horizontal longitudinal component, the subparallel axis of the structure, and the river valley.

It should be mentioned that to ensure the reliability of observations, work was done to assess the identity of the work of the accelerometers of seismological stations.

To do this, the accelerometers were placed side by side on a horizontal concrete pad and during 20 minutes the micro seism was recorded. This show on the histograms of the accelerations, constructed from the results of this registration. The horizontal axis of the histogram is acceleration, vertical is the number of counts. The figure illustrates the high degree of convergence of data by two accelerometers.

3. Result and conclusion

As a resultant conclusion on the research topic, it is necessary to note the imperfection of the existing regulatory framework for seismic-resistant construction - both European [17] and Russian [16]. For example, in the updated version of SNIP II-7-81* - SP 14.13330.2011 [16], the seismic stiffness method was adopted as the main instrumental method. But even with one small example, we can see that the data of the seismic rigidity method are not always sufficient for a correct estimation of the seismic hazard, the studies performed indicate the need for an individual assessment of local ground conditions and the construction of specific soil-response spectra for a comprehensive assessment of the possible seismic hazard of any area under study. This statement is confirmed by numerous studies,
as one example - the report of the Greek researchers K. Pitilakis, Z. Roumelioti [18] at the Vienna Congress on Recent Advances in Earthquake Engineering and Structural Dynamics 2013 (VEESD 2013) 28-30 August 2013, Vienna, Austria. In Fig. 4 is an illustration of the report. This illustration combines the normative spectra of the response of the Greek national building code (EAK) and Eurocode 8 (EC8) and the response spectra of real earthquake accelerations. It is obvious that the acceleration of the real spectrum is an order of magnitude more dangerous than those stipulated by the regulations.

Figure 4. Left: Acceleration response spectra of the 2003 earthquake at LEF (town of Lefkas) station. The design spectra of the Greek national building code (EAK) and Eurocode 8 (EC8) are superimposed. Right: Acceleration time histories at LEF. PGA values are noted [18].

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Acknowledgments
This study was supported by the Russian Scientific Fonds ( N 15-17-20000) and the grant of the Government of Sakha(Yakutia) Republic for a comprehensive study of the territory of the Republic in 2016-2020.