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CORRECTING OF MAPS OF GENERAL SEISMIC ZONING ON THE BASIS OF ENGINEERING-SEISMOMETRIC OBSERVATIONS

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SUMMARY

In January 2000, according to the resolution of the Ministry of State Building of Russia, a new paragraph was included in the Building Code for seismically resistant constructions. It outlines the necessity for the provision of engineering-seismometric service (ESS) in the enterprises of hazardous and environmentally harmful production. The paper considers the possibilities of ESS in specifying the initial seismic hazard of the territories and reducing aftereffects of the man-made disasters, using the cities of Irkutsk and Angarsk as an example.

INTRODUCTION

The relations between accelerations of ground motion and energy class of earthquakes were obtained due to the processing of the data on real earthquakes recorded by engineering-seismometric stations in Irkutsk and Angarsk cities. This made it possible to specify the initial seismic hazard for these cities if an earthquake with M = 7.5 occurs in one of the most hazardous zones of Probable Earthquake Foci (PEF).

The new maps of seismic hazard (GSZ-97 A, B, C) were approved for the Russia territory in January 2001. They are created on the new methodological basis and involve three levels of seismic hazard for constructions with various category of responsibility and various service life: 10% probability of exceeding of design intensity for 50 years (10% at T=500 years) for the main mass construction, 5% probability of exceeding of design intensity for 50 years (5% at T = 1000 years) for buildings of higher importance, 1% probability of exceeding of design intensity for 50 years (1% at T = 5000 years) for buildings of particular importance. The earlier map GSZ-78 used 50% probability of exceeding of design intensity within the next 50 years, that corresponds to the recurrence interval of maximum (for the given region) shakings one in 100 years and 0.5% probability of exceeding of design intensity that

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corresponds to the recurrence interval one in 10000 years. These assessments are excluded from the new maps of GSZ-97 A, B, C: the first one because of unjustifiably high risk and the second one because of the incorrect statistical estimations.

According to the new maps of GSZ-97 A, B, C the initial seismic hazard for industrial cities of the Irkutsk region is as follows: Irkutsk - 8, 8, 9 (in accordance with the category of buildings - mass construction, of higher importance and of particular importance), Baikalsk - 9, 9, 10, Shelekhov - 8, 9, 10, Angarsk - 8, 8, 9, Usolje-Sibirskoe -7, 8, 9, Sayansk - 7, 7, 8. If these estimates are true and industrial enterprises in these cities can be referred to the category of higher importance and particular importance, it means that they were constructed and designed for seismic hazard which is 1-2 units below that of real hazard. According to G.L. Koff and I.V. Chesnokova [1], well-known experts in the area of earthquake damage insurance, Irkutsk region is one of the most unfavorable areas of Russia in terms of seismic risk.

In January 2000, according to the resolution the Ministry of State Building of Russia, a new paragraph was included in the Building Code for seismically resistant constructions. It outlines the necessity for the provision of engineering-seismometric service (ESS) in the enterprises of hazardous and environmentally harmful production. The paper considers the possibilities of ESS in specifying the initial seismic hazard of the territories and reducing aftereffects of the man-made disasters, using the cities of Irkutsk and Angarsk as an example.

In Pribaikalye there is a number of industrial works, where because of seismic hazard of the region the engineering-seismometric observations are to be carried out to meet federal and industrial safety requirements.

In Irkutsk region Baikalsk, Angarsk, Shelekhov and Usolje-Sibirskoe are the cities with the most environmentally dangerous productions in seismically active regions. In these cities in addition to ESS service in residence houses, it is necessary to set up ESS in enterprises of productions dangerous to people health and environment.

These enterprises are:

1. Baikalsk - the Baikal pulp and paper mill (seismicity is 9-10 according to the Building Code).
2. Shelekhov - Aluminium and cable plants (seismicity 9-11).
3. Angarsk - the Angarsk electrolysis-chemical plant and the Angarsk petrochemical plant (seismicity 8-9).
4. Usolje-Sibirskoe - Chemical plant and storage of dangerous substances (seismicity 8-9).
5. Sayansk - the Sayansk chemical plant (seismicity 7-8).

Besides, transporting of substances harmful to people health and environment by East-Siberian railway and pipelines is dangerous. In southern part of Lake Baikal the railway main line crosses zones with initial seismicity 9-10. Breakdown of trains with environmentally hazardous shipments can happen during a large earthquake. Besides, two runs of petroleum pipeline «Omsk-Angara», ethylene pipeline «Angarsk-Sayansk», kerosine pipeline «Angarsk-Irkutsk- Airport», which cross the zones with potential seismic hazard of 7, 8 and 9 units, lie through the territory of this region.

This outlines the necessity for the provision of ESS on large railway bridges (more than 150 m long), in railway tunnels and transfer stations of pipelines.

When seismic risk of the urbanized territory is considerably high and there is a lack of instrumental seismological information, the engineering-seismological monitoring of seismic events on the basis of engineering-seismometric service is of special importance.

In the recent years the scope of ESS activities has increased due to the development of seismometric data management technology. The following objectives should be undertaken:

1. To provide dynamic passports of buildings and constructions at various dynamic loads: natural and man-made (earthquakes, explosions, microseisms, transport motion and so on).
2. To control the state of constructions (using microseisms of oscillations) during their operation on the basis of the analysis of variation of dynamic passport parameters, which include amplitude-frequency characteristics, periods of free oscillations, attenuation ratio and so on. Seismometric control is of particular importance in the case of observation of constructions and technological lines of environmentally harmful productions.
3. To block or disconnect hazardous technological units and processes in an emergency, at seismic loads exceeding a given level.
4. To provide seismometric bank of data for behavior of various constructions at felt and large earthquakes.
5. To specify the initial seismic risk of the territory.
6. To improve the maps of seismic microzoning of the cities.
7. To correct and specify the existing codes on aseismic building.

In accordance with these objectives of «Seismic safety of Irkutsk» program, Institute of the Earth Crust SB RAS and laser experimental-methodical party of SB RAS created the multichannel engineering-seismometric station (ES) [2]. Nowadays these seismic stations, termed as «Baikal», are installed: in the Angarsk electrolysis chemical plant - 48-channel ES, in the Irkutsk HEPS - 32-channel ES and in the 16-storey residence house of 135 series in Akademgorodok (Irkutsk city) - 16 -channel ES.

Two years of ES operation in Pribaikalye provided the instrumental-seismological data of unique importance. 1999 year was particularly «high-yield» for seismic events. In 1999 the seismic station on the dam of the Irkutsk Hydroelectric Power Station (HEPS) recorded 26 earthquakes with K=11-14.7; seismic station in the 9-storey wall house of 135 series in Akademgorodok recorded more than 100 earthquakes with K=9 -14.7 and seismic station in the Angarsk electrolysis-chemical plant recorded 80 earthquakes with K = 9.5-14.7. A digital record of the February 25, 1999 earthquake of intensity 6 was obtained for the first time in the area of Irkutsk and Angarsk cities throughout the period of instrumental observations in Pribaikalye.

Following the main shock of the February 25, 1999 earthquake, tens of smaller earthquakes-aftershocks were recorded in the same Primorsk PEF zone, which is located 75 km of Irkutsk and 100 km of Angarsk. These earthquake records were used in predicting parameters of the most widespread grounds in the area of Irkutsk city to predict oscillation parameters in the dam foundation of the Irkutsk HEPS at maximum possible earthquake with K= 16.8 and M = 7.5 from this PEF zone and to predict ground motion in the territory of Angarsk electrolysis-chemical plant at maximum possible earthquake from the same zone.

The procedure of improvement of initial seismic hazard can be illustrated by the example of ESS operation at the Irkutsk HEPS and the Angarsk electrolysis-chemical plant.

In 1999 the engineering-seismometric station at the Irkutsk HEPS recorded 26 close and local earthquakes. Twelve earthquakes in the area of southern Baikal: distance R = 67-80 km, energy class 11 - 14.6; eight in the area of northern Baikal: R=547-570 km, K=11.4-14.8; two in the area of Middle Baikal and Selenga river delta: R=220, 161 km, K=11.8 and 11.4; two in Mongolia: R=341, 577 km, K=13.2 and 13.2 and one in the East Sayan: R=211 km, K=12.0. The strongest ground motions were produced by the earthquake of February 25, 18 h, 58 s (Greenwich time), the main shock M =6.1, energy class K=14.6, (February 26, 2 h, 58 s, local time). The maximum amplitude of oscillation displacements of section 4 in the concrete dam at marks 412 and 456 was correspondingly 0.76 mm and 1.12 mm on component Y, visible period 0.67 s, the maximum amplitude of velocity 0.8 cm/s and 1.1 cm/s and the maximum amplitude of accelerations 7.6 cm/s^2 and 10.1 cm/s^2. On MSK-64 scale the intensity of shakings is estimated to be 4 in the dam foundation and 4-5 at the top. It should be noted that from macroseismic evidence the oscillation intensity on February 25, 18 h 58 m is estimated to be 5-6 for Irkutsk.

The relation between the maximum amplitudes of displacements of the concrete dam top (mark 456) and the amplitudes of the foundation displacements (mark 412) is on the average: on X component - 1.13, σ =0.26; on Y - 1.29, σ =0.17; on Z - 0.91, σ =0.10. Values of visible frequencies of displacements of the foundation and the top of the concrete dam at the 1999 earthquake lie mainly in the range of 0.6 - 2 Hz.

Earthquake records of close earthquakes in southern Baikal are the most important for the assessment of seismic hazard of the Irkutsk HEPS. The results of processing of these records at mark 412 of section 4 of the concrete dam provided the relations between maximum amplitude of displacements (A), velocities (A_v), acceleration (A_a) and energy class:

$lgA = 0.52 \cdot K - 4.85$.
Where A in mkm, correlation coefficient r = 0.96, standard error σ =0.16.

$\lg A_v = 0.53 \cdot K - 7.95$, A_v in cm/s, r = 0.96, $\sigma = 0.17$.

$\lg A_a = 0.51 \cdot K - 6.64$, A_a in cm/s^2, r = 0.95, $\sigma = 0.18$.

From these formulas one can estimate the maximum amplitude oscillations in the dam foundation of the Irkutsk HEPS for a large earthquake, which can occur at a distance of 70-80 km. It can be said with assurance that for the earthquakes with K = 16.8 the values of maximum amplitude of oscillation velocity will average 9 cm/s and with probability P = 0.84 will not exceed 13 cm/s. The maximum amplitude of accelerations will be on the average 85cm/s^2 and with P = 0.84 will not be greater than 122 cm/s^2. It is to be noted that because our relations are obtained for oscillations in linear area, they yield probably too high evaluations for a large earthquake.

Late in 1997 the 48-channel engineering-seismometric digital station of the Angarsk-electrolysis-chemical plant was put in operation and during 5 years it has recorded 129 earthquakes in various focal zones of Pribaikalye, 43 of which are felt earthquakes with intensity 2 and higher. Two earthquakes with intensity 5-6 in the area of Angarsk city are among these felt earthquakes. These data are extremely important to design buildings and constructions for seismic stability.

The relation between lgA and K was derived in the processing of experimental data using orthogonal regression. The results of the processing provided the analytical expressions of relations between logarithm of maximum amplitudes of accelerations on grounds A_x and A_y and energy class, where A are given in cm/s^2:

$LgA_x = 0.39\ K - 4.37$ (1)

$LgA_y = 0.38\ K - 4.20$ (2)

By formula (1) the root-mean-square uncertainty $\sigma = 0.15$ of logarithm unit, by formula (2) $\sigma = 0.12$ of logarithm unit.

The results of calculations of maximum accelerations by formula (2) show that, according to Chipizubov' s data [3], the maximum magnitude from the nearest and the most hazardous PEF zone (the Main Sayan fault) will not exceed M = 7.5 within the next 100-200 years. This magnitude value, from Aptikaev's universal relation between magnitude and energy class, corresponds to K = 16.5 and consequently, the acceleration by formula (2) is Ä = 0.1g, and in terms of root-mean-square Ä = 0.15g.

From these calculations it was concluded that to design antiseismic measures in the territory of the Angarsk electrolysis-chemical plant maximum acceleration can be taken as 0.15g instead of 0.2g, as it follows from the map GSZ-97-B, which is recommended to be used in this enterprise. In addition, the number of the recorded earthquakes increases, and hence we can further improve the maximum values of seismic accelerations using a greater amount of real records just for the area of the Angarsk electrolysis-chemical plant where engineering-seismometric station is installed.

The system of automatic monitoring of the construction condition, emergency blockage and disconnection of hazardous productions consists of three-channel accelerographs, automatic central point of control and automatic device for measurement of dynamic parameter variations. Three-channel accelerographs contain: starters, information-carriers with the analysis system, time markers and control device. Automatic central point of control involves a unified time marker. Automatic device for measurement of dynamic parameter variations consists of a measuring device and a device of comparison.

Therefore, the engineering-seismometric monitoring in the urbanized territories with high seismic risk is of considerable importance in specifying initial seismicity and preventing man-made disasters and reducing losses from large earthquakes as a whole.

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