Assessment of social aspects of seismic hazard

T I Danilova, S A Peretokin, N S Medvedeva, K N Akatova
Schmidt Institute of Physics of the Earth, Russian Academy of Sciences, B. Gruzinskaya St., bld. 10/1, 123242, Moscow, Russia

E-mail: dana-geo@yandex.ru

Abstract. This paper is intended to illustrate the applicability of the results obtained from the investigations of social aspects of seismic hazard of the Russian Federation (RF) through the example of the high-seismicity region – the Far Eastern Federal District (FED). Within the FED the comparison of the areas of various seismic zones as per regulatory maps of General Seismic Zoning dated 2016 (GSZ-2016) has been performed and population estimates for each zone have been obtained. For the first time population estimates for zones with increased seismic hazard – grades A, B and C as per GSZ-2016 – are provided. The data obtained may be used for the evaluation of additional risks for FED’s population.

1. Introduction
In terms of population, Russia ranks ninth in the world with 146.4 million people as of 01.11.2020 [1], while the distribution of the population is quite uneven. In general, RF with the exception of certain regions is not a highly seismic territory. Among the high-seismicity regions are: Northern Caucasus, Southern Siberia and the Far East, while the latest is characterized by the earthquake intensity of points >8-10 at epicenter as per 12-level macroseismic scale MSK-64 [2, 3].

Unfortunately, to date seismologists cannot provide reliable information regarding the exact place and time of occurrence of future earthquakes; therefore, the most effective method to reduce the number of possible human casualties and material damage is to identify areas with varying degrees of seismic hazard and to perform corresponding earthquake-resistant construction in these territories [4-7, 8-10].

2. Data and method
Seismic zoning is an important element of the evaluation of seismic risks and hazard. Maps of General Seismic Zoning (GSZ) are the regulatory documents for performing design and construction in seismically active areas. The main purpose of seismic zoning is to assess the seismic hazard in the study area. Since the development of GSZ-97 map of the general seismic zoning of RF all calculations and schemes are based on the probability analysis of seismic hazard.

In 2016 a research work to create a new set of GSZ-2016 maps replacing GSZ-97 maps for RF has been completed [11-13]. The set of maps has been renewed in accordance with the requirements of its revision each 10 years. This research was being carried out since 2009 by specialists from many academic and industry institutes and organizations of RF. At first stage sets of maps GSZ-2012 [14-16,17] and GSZ-2014 [18] were composed which after discussion by the scientific community and updating with modified linear-domain source database including Crimea region [19] formed a basis for GSZ-2016 maps.
Figure 1. Set of maps of the general seismic zoning of the territory of the Russian Federation GSZ-2016 (GSZ-2016-A).

Figure 2. Set of maps of the general seismic zoning of the territory of the Russian Federation GSZ-2016 (GSZ-2016-B).
Technology of general seismic zoning, considering both GSZ-97 and GSZ-2016, is based on probabilistic analysis of seismic hazard, used in most countries located in seismically active regions, and determining the probability of occurrence and possible excess of the points of the calculated seismic effects within a given time interval.

GSZ-2016 set of maps (Fig. 1-3) makes provisions of implementation of anti-seismic practices during the construction of facilities of various risk ratings. GSZ-2016 maps of grades A, B and C illustrate respectively 10%, 5% and 1% of the exceedance probability of the designated seismic intensity within 50 years (either way, 90%, 95% and 99% of their non-exceedance probability).

3. Result
The social aspect means the awareness of the population about the existing seismic hazard and its adaptation to possible seismic risks [19]. Social aspects of the estimation of seismic hazard are illustrated through the example of the Far Eastern Region of RF characterized by high level of seismicity [20].

The Far Eastern Federal District (FED) after inclusion of Republic of Buryatia and the Trans-Baikal Territory (Decree of the President of the Russian Federation No. 632 dated 03.11.2018) is the largest region of Russia of area 6,952,555 km² which represents 40.6% of the whole RF area. It’s comprised of 11 entities: Amur Region, Republic of Buryatia, Jewish Autonomous Region, Trans-Baikal Territory, Kamchatka Territory, Magadan Region, Primorsky Territory, Republic of Sakha (Yakutia), Sakhalin Region, Khabarovsk Territory and Chukotka Autonomous District.

The study is based on GSZ-2016 A, B, C maps used in territorial planning, city zoning, architectural and construction design, construction, overhaul, reconstruction of infrastructure facilities, operation of buildings and structures of various risk ratings. Numbers of population [21] living in the zones of various seismic intensity as per GSZ-2016 A, B, C maps have been compared.
Figure 4. Comparison of population density maps of the Far Eastern Federal District (a) and the GSZ-2016-A map (b).

Figure 5. Comparison of population density maps of the Far Eastern Federal District (a) and the GSZ-2016-B map (b).
Figure 6. Comparison of population density maps of the Far Eastern Federal District (a) and the GSZ-2016-C map (b).

Fig. 4-6 demonstrate distribution of population density in zones of varying seismic intensity according to GSZ-2016 A, B, C maps of the FED comprised of Amur Region, Jewish Autonomous Region, Kamchatka Territory, Magadan Region, Primorsky Territory, Republic of Sakha (Yakutia), Sakhalin Region, Khabarovsk Territory and Chukotka Autonomous District. Numbers in tables 1-3 correspond to FED within the boundaries shown on the maps.

Tables 1-3 contain percentages of population and corresponding zones of probable points of earthquake >7 based on GSZ-2016 A, B, C map set.

Table 1. Values of the areas of zones of different points according to the GSZ-2016-A map and the percentages of FED’s population.

| Points | Areas of the zones of different points | Population of the zones of different points |
|--------|--------------------------------------|-------------------------------------------|
|        | km²                                  | 1/1000 person                              |
|        | %*                                   | %**                                       |
| 7      | 2379.2                               | 749.4                                     |
|        | 38.7                                 | 13.6                                      |
| 8      | 462.3                                | 350.2                                     |
|        | 7.5                                  | 6.4                                       |
| 9      | 103.1                                | 434.7                                     |
|        | 1.8                                  | 7.9                                       |

*Percentage of the total FED’s area, **Percentage of the total FED’s population

Table 2. Values of the areas of zones of different points according to the GSZ-2016-B map and the percentages of FED’s population.

| Points | Areas of the zones of different points | Population of the zones of different points |
|--------|--------------------------------------|-------------------------------------------|
|        | km²                                  | 1/1000 person                              |
|        | %*                                   | %**                                       |
| 7      | 2174.0                               | 1510.9                                    |
|        | 35.4                                 | 27.5                                      |
| 8      | 1164.2                               | 780.0                                     |
|        | 19.0                                 | 14.2                                      |
| 9      | 227.5                                | 720.6                                     |
|        | 3.7                                  | 13.1                                      |

*Percentage of the total FED’s area, **Percentage of the total FED’s population
Table 3. Values of the areas of zones of different points according to the GSZ-2016-C map and the percentages of FED’s population.

| Points | Areas of the zones of different points | Population of the zones of different points |
|--------|----------------------------------------|---------------------------------------------|
|        | km$^2$ | %* | 1/1000 person | %** |
| 7      | 1173.0 | 19.1 | 2704.7 | 49.2 |
| 8      | 2276.0 | 37.1 | 1131.0 | 20.0 |
| 9      | 955.6  | 15.6 | 988.4  | 18.0 |

*Percentage of the total FED’s area, **Percentage of the total FED’s population

Tables 1-3 show that the percentages of the total FED’s population living in the zones of probable earthquake’s points $>$7 comprise: GSZ-2016 A – 28.0%; GSZ-2016 B – 55.1%; GSZ-2016 C – 99.7%. Areas of zones of probable points $>$7 for FED comprise: GSZ-2016 A – 28.0%; GSZ-2016 B – 55.1%; GSZ-2016 C – 75.4%.

4. Conclusion

For the residents of the areas with a high seismic hazard, the risk will always occur, but it must be minimized and made acceptable in certain socio-economic conditions. To ensure the safety of the population during the construction of various structures and facilities with a higher risk level, it is necessary to take social aspects into account.

The data provided in this paper should be taken into account as additional information when planning the construction of certain objects in the region. The presented data make it possible to assess seismic risks and take them into account when ensuring the seismic resistance of specific construction objects. For the first time, the article presents data on the distribution of population density and zones of probable seismic intensity for the territory of the Russian Federation using the example of the Far Eastern Federal District based on GSZ-2016-A, B, C set of maps. Until now, no such assessments have been carried out.

References

[1] Medvedev S V 1947 On the account of seismic activity of an area during construction Trudy Seysmologicheskogo Instituta AN SSSR 119 83–85
[2] Ulomov V I, Peretokin S A, Medvedeva N S, Akatova K N, Danilova T I 2014 Seismological aspects of general seismic zoning for the territory of the Russian Federation territory (maps OSR-97, OSR-2012, OSR-2014) Problems of Engineering Seismology 41 (4) 5–24
[3] Bender B, Perkins D M 1987 SEISRISK III a computer program for seismic hazard estimation United States Geological Survey Bulletin 1772
[4] Medvedev S V 1962 Engineering seismology (Gostrostyizdat, Moscow) 283
[5] Peretokin S A 2016 Some aspects of probabilistic seismic hazard assessment using empirical dependences Engineering Survey 7 39–47
[6] Riznichenko Yu V 1965 On the activity of earthquakes foci and shaking of the Earth’s surface Izvestiya AN SSSR Fizika Zemli 11 1–12
[7] Ulomov V I 2007 On program / mathematical software of the maps construction of probabilistic seismic mapping by the OSR-97 methods Geophysical Research 7 29–52
[8] Building Seismic Safety Council 2001 National Earthquake Hazards Reduction Program recommended provisions for seismic regulations for new buildings and other structures 2000 edition Part 1 Provisions (FEMA 368) Publishing house of the Building Seismic Safety Council Washington D C USA https://studylib.net/doc/12073269/nehrp-recommended-provisions-for-seismic-regulations-for
[9] Solberg C, Rossetto T, Joffe H 2010 The social psychology of seismic hazard adjustment re-evaluating the international literature Natural Hazards and Earth System Sciences 8 (10) 1663–1677
[10] Danilova T I, Peretokin S A, Medvedeva N S, Akatova K N 2019 Social aspects of seismic hazard in the Russian Federation Prospects for development of engineering survey in Russian Federation Materials of the 15th All-Russian Conference of prospecting organizations Moscow 2019 595–607

[11] Gusev A A, Shumilina L S 1995 Some questions of the methodology of general seismic zoning In collection of scientific papers V I Ulomov (ed.) Seismicity and seismic zoning of Northern Eurasia Publishing house of the Schmidt Joint Institute of Physics of the Earth Russian Academy of Sciences Moscow 2–3 289–299

[12] Ulomov V I 2012 Updating normative seismic zoning in the integrated information system “Seismic safety of Russia” Problems of Engineering Seismology 39 (1) 5–38

[13] Bender B, Perkins D M 1987 SEISRISK III a computer program for seismic hazard estimation United States Geological Survey Bulletin 1772

[14] Ulomov V I 2013 General seismic zoning of the territory of Russia — GSZ-2012 Problems of Engineering Seismology 40 (4) 5–20

[15] Ulomov V I, Bogdanov M I 2013 A new set of the seismic zoning maps of the Russian Federation (GSZ-2012) Engineering Survey 8 30–39

[16] Ulomov V I, Bogdanov M I, Pustovitenko B G, Peretokin S A, Strom A L, Akatova K N, Danilova T I, Medvedeva N S 2015 Analyzing the seismic hazards of the Crimea and North Caucasus and adapting the obtained assessments to the GSZ-2014 set of maps Engineering Survey 13 12–27

[17] Ulomov V I, Shumilina L S 1999 A set of maps of general seismic zoning of the territory of the Russian Federation – GSZ-97 Scale 1:8 000 000 Explanatory note and a list of cities and towns located in earthquake-prone areas Publishing house of the Schmidt Joint Institute of Physics of the Earth Russian Academy of Sciences Moscow

[18] Gusev G S, Imaeva L P 2014 Modern tectonic (geodynamic) activity of the Territory of Russia Prospect and Protection of Mineral Resources 12 23–29

[19] Ulomov V I, Bogdanov M I, Trifonov V G, Gusev A A, Gusev G S, Akatova K N, Aptikaev F F, Danilova T I, Kozhurin A I, Medvedeva N S, Nikonov A A, Peretokin S A, Pustovitenko B G, Strom A L 2016 Explanatory note on the GSZ-2016 maps set of general seismic zoning of the Russian Federation territory Engineering Survey 7 49–121

[20] Information on the socio-economic situation in Russia (January – November 2020) 2020 Publishing house of the Federal State Statistic Service Moscow https://rosstat.gov.ru/storage/mediabank/3fc2fOjo/oper-11-2020.pdf

[21] The official site of the OpenSHA 2020 http://opensha.org