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A New Generation Russian Seismic Scale

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Abstract—The paper discusses a draft national standard, Earthquake Intensity Scale. The characteristics of the new scale are described, as well as its difference from other seismic intensity scales. Consideration is given to the continuities between the new scale and previous ones. Comments and suggestions concerning the text of the scale are analyzed.

Keywords: seismic intensity scale, macroseismic scale, instrumental scale, object sensor, statistics
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INTRODUCTION

A new-generation seismic intensity scale, the necessity of which seismologists, geologists, and builders have discussed for a long time (Nazarov and Darbinian, 1975; Nazarov et al., 1975; *Seismicheskaya*..., 1975; Medvedev, 1977, 1978; Onofrash and Roman, 1979; Shumila, 1983; Yershov and Shebalin, 1984; Bottari et. al, 1985, 1986; Shebalin and Aptikaev, 2003; Sandi et al., 2010) has finally been created. A draft of the new scale was submitted to the Technical Committee for Standardization (TC 465 on Construction) for consideration. Before that, the draft scale was sent to various organizations, published in journals (Aptikaev, 2011a–2011c), and presented at a meeting of the Scientific Council on Seismology, Russian Academy of Sciences, as well as at domestic and international conferences. Analysis of comments and suggestions concerning the new seismic intensity scale shows that there is a wide variety of opinions about its goals and composition. The most interesting suggestions not accepted by the working group are addressed in this paper.

After the abolition of the Russian National Standard on Measuring the Strength of Earthquakes on a Scale of 6 to 9 Points, GOST 6249-52 (*Shkala*..., 1952), in 1995, the State Construction Committee placed the problem of creating a new seismic scale on its agenda for the first time in 2004. A new scale was developed at the Institute of Physics of the Earth by a group of scientists under the supervision of F.F. Aptikaev: Ya.M. Aizenberg, I.V. Anan'in, Yu.A. Berzhinski, M.A. Klyachko, V.A. Pavlenov, E.A. Rogozhin, S.Y. Sherman, G.S. Shestoperov, and O.O. Erteleva (*Razrabotka*..., 2004). The scale was accepted but not ratified because the State Construction Committee was liquidated. Certainly, the submitted materials were subsequently used.

The development of the new macroseismic scale was resumed after the Federal Program on Stability Enhancement of Residential Buildings and Critical Infrastructure Objects and Facilities in Seismic Regions of the Russian Federation for 2009 to 2013 was approved by the Government of the Russian Federation (Decree No. 365 dated April 23, 2009). The program stipulated the development, implementation, and maintenance of the Russian Uniform Information System on Seismic Safety. Under this program, in 2009, the Institute of Physics of the Earth launched a scientific investigation into the efficiency of different seismic intensity scales used worldwide for seismic hazard assessment. It was also planned to develop and test a new macroseismic scale that would take into account the geological effects of earthquakes, as well as develop application requirements for new scale in the design and construction of buildings. The working group included F.F. Aptikaev (head), Y.A. Berzhinsky, M.A. Klyachko, A.L. Strom, G.S. Shestoperov, and O.O. Erteleva. Although the report of the working group was accepted, no normative document was created, although a draft national standard (Aptikaev, 2010) was prepared. It was only in 2014 that the Institute of Physics of the Earth submitted the seismic scale as a new standard (GOST) to Rosstandart and initiated the first reading of this document.

M.I. Bogdanov, I.L. Kriventsova, and S.G. Shestoperov took an active part in the preparation and discussion of the first version of the seismic scale. The draft national standard named Earthquakes: Seismic Intensity Scale (first version) has attracted the interest of seismologists and engineers. It received over a hundred comments and suggestions from various organizations and leading experts. Most of the comments were accepted.

CONTINUITY BETWEEN THE NEW SEISMIC SCALE AND OTHER SCALES FOR MEASURING EARTHQUAKES

The seismic intensity scale is a successor to the MSK-64 scale (Medvedev–Sponheuer–Karnik scale, 1964 version), the MCS scale (the Mercalli–Cancanni–Sieberg scale), the MM scale (modified Mercalli scale), as well as the EMS-98 scale (European Macroseismic Scale, version 1998) (European..., 1999), and the ESI-2007 scale (European Seismic Intensity Scale 2007 version) (Michetti et al., 2007). The new and the above-listed scales provide intensity estimates for earthquakes within the determination accuracy. It is notable that the EMS-98 scale and the proposed scale provide almost the same intensity estimates.

The discussed seismic scales are also similar in terms of terminology. For example, the new scale's section on buildings and structures uses the concept of "degree of damage to buildings."

The proposed seismic intensity scale is based on a variety of works by domestic and foreign scientists (e.g., *Seismicheskaya* ..., 1975; Aptikaev, 1977; Dolgopolov and Pletnev, 1978; Medvedev, 1978; Aptikaev, 1981; Yershov, 1982; Martemyanov and Shirin, 1982; Chernov and Sokolov, 1983; Yershov and Shebalin, 1984; Shestoperov, 1984, 1988; Shestoperov et al., 1984, 1987; Gekhman, 1985; *Shkala* ..., 1986; Aptikaev and Shebalin, 1988; Aptikaev et al, 1991, 1992, 1999, 2000; Aptikaev, 1999; Sherman et al., 2000, 2003; Kuzin, 2002; Shebalin and Aptikaev, 2003; *Razrabotka*..., 2004; Aptikaev et al, 2006), etc.).

Some reviewers require that the new scale be approved after testing. However, it should be borne in mind that the new scale is not a theoretical product but a result of analyzing many earthquakes that occurred in Russia and abroad. For example, a version of the new scale (MMSK-92) (Shebalin and Aptikaev, 1993) is based on the results of seismic impact assessment of the earthquakes in Dagestan and Spitak in 1970 and 1988, respectively. Even the experts who produced different a priori estimates arrived at the same results when using the new scale.

METHODOLOGICAL SHORTCOMINGS OF PREVIOUS SCALES

The difference between the new scale and GOST 6249-52 (*Shkala*...., 1952) is considered below. Note that a seismic scale, like any standard, should be updated every 10–15 years. This is due to accumulation of data on earthquake effects and the appearance of new building materials, engineering designs, building technologies, and engineering calculation techniques. Since the adoption of GOST 6249-52, bearing-wall constructions, high-rise buildings with new mechanical properties, as well as earthquake-resistant buildings and structures, have come into use; moreover, the global database of strong earthquake ground motions has increased manifold.

The international scale MSK-64, which appeared later than GOST 6249-52, is actually our GOST adapted the Western conditions and therefore less suitable for Russia. Moreover, due to the fact that there were no many strong motion records, the MSK-64 scale was based on a number of unreasonable assumptions that were not confirmed later empirically. The most erroneous is the assumption that a twofold increase in the magnitude of accelerations corresponds to a 1-point increase in seismic intensity. Also, the assumption that acceleration magnitude continuously grows until the seismic intensity is 12 points turned out to be wrong, although the macroseismic sections of all seismic intensity scales state that seismicity above 9 points are related to residual deformations. Also, erroneous is the assumption that the acceleration step and velocity step of instrumental scales have the same size. There is nothing about ground displacements in the MSK-64 scale, although this parameter has to be taken into account in many cases.

However, the MSK-64 scale became outdated, too; it was replaced by the EMS-98 scale (European..., 1998). The latter is obviously inferior to the MSK-64 scale in terms of methodology, although it took the achievements of building science of that time into account. While the MSK-64 scale allows buildings to be unambiguously, albeit roughly, classified by the extent of potential damage due to earthquakes, the EMS-98 scale intervals overlap, which under certain conditions could lead to an additional error of 1.5 points. The EMS-98 scale does not reflect a "no-damage" effect of an earthquake, which excludes statistical data analysis. Finally, this scale contains no instrumental section.

Obviously, some reviewers idealize the EMS-98 scale; they mistakenly believe that all of our compatriots participating in the Working Group of the European Seismological Commission (ESC) have supported the EMS-98 scale. However, e.g., seismologist N.V. Shebalin argued that in terms of methodology, the EMS-98 scale is a step backwards compared to the MSK-64 scale. M.A. Klyachko, Director of the Scientific and Technical Center for Earthquake Engineering and Natural Disaster Protection, proposed that the instrumental section be ignored until the Geophysical Service of the Russian Academy of Sciences accumulates a representative database of strong ground motions. Unfortunately, the network of strong motion stations is being deployed extremely slowly in Russia, but even in Europe, where such networks have been in operation for 17 years, instrumental additions to the EMS-98 scale have not yet been created.

FUNDAMENTAL PRINCIPLES OF THE NEW SCALE

The design principles of macroseismic scales were proposed and developed in detail in numerous publications (see, e.g., Suppes and Zines, 1963; Aptikaev, 1972, 1975; Shebalin, 1975; Pfanzagl, 1968; Yershov, 1982; Yershov and Shebalin, 1984; Aptikaev and Shebalin, 1988; Aptikaev, 1999; Shebalin and Aptikaev, 2003; Sherman et al., 2003, etc.). We cannot review them all in detail within the constraints of this paper. Here we just list the basic design principles of the new scale:

(1) the new seismic intensity scale should be an interval scale;

(2) seismic intensity should be directly assessed using statistical data on the responses of different structures to seismic events, with no corrections for local conditions to be introduced, etc.;

(3) the intervals of the new scale should be in strict compliance with the MSK-64, EMS-98, and MMSK-92 scales;

(4) the class of objects whose responses to earthquakes should be assessed in the form available for statistical analysis should be the largest possible;

(5) objects (buildings and structures) should be classified by the degree of their probable response to earthquakes (instead of using limited statistics on those objects that demonstrate the greatest degree of response as in the MSK-64 scale), and the average degree of the response of each type of objects should be subsequently used;

(6) a susceptibility threshold and response saturation threshold should be established to translate the average response into the degree of seismic intensity;

(7) priorities of objects should be established depending on seismic intensity;

(8) strict rules of averaging noncoincident estimates of seismic intensity should be established for each type of objects;

(9) the scale should provide capabilities to study and update the correlation relationships between the level of a macroseismic effect and quantitative parameters of ground motions, including the parameters of residual displacements;

(10) the scale should provide rational approximate earthquake intensity estimation from remote seismological data;

(11) the correlation of the new scale with other scales should be clarified;

(12) the new scale should be concise and simple in structure.

FEATURES OF THE NEW SCALE

The most important characteristic of any scale, e.g., the scale of mineral hardness or the artistry rating scale in figure skating, is its type. According to measurement theory (Suppes and Zinnes, 1963; Pfanzagl, 1968), all scales are divided into five types: nominal, categorical, ordinal, interval, and ratio. These scales are listed in increasing order of complexity. Namely, the nominal scale distinguishes phenomena from each other but does not compare them, whereas the ratio scale allows any arithmetic operations with measurable parameters. Clearly, ratio scales are the most ideal because they reflect relationships between empirical objects most completely (Suppes and Zinnes, 1963; Pfanzagl, 1968).

All seismic scales currently in use can purport to be ordinal scales, which means that the higher the seismic intensity estimate, the stronger the seismic effect. That's it. Note that when correlating different scales, the creators consider their scale uniform and the spacing of someone else's scale variable (Gorshkov and Shenkareva, 1958). Whose is right? Generally, all scales are ordinal scales if special efforts are not taken. No arithmetic operations can be performed with data measured on an ordinal level: you cannot extrapolate estimates of intensity increments for strong earthquakes from the intensity estimates for weak earthquakes. In other words, items measured on the ordinal scale cannot be quantified. The interval scale has a higher rank. In interval scales, intervals between the values of the interval variable are equally spaced. You can perform some arithmetic operations with interval variables. For example, the difference between the second and third numbers on the scale equals the difference between the eighth and ninth. Macroseismic information measured on the interval level can be processed to obtain its median, its arithmetic mean, and standard deviation. Therefore, seismic intensity can be labeled as a fractional numeral as well, which is extremely important for probabilistic estimates and scale correction. The type of scale can be determined if there are mathematically operable characteristics of the phenomenon under study. Analysis of macroseismic evidence (Medvedev, 1953; Kuliev and Shebalin, 1970; *Seismicheskaya*..., 1975; Onofrash and Roman, 1979) shows that some seismic intensity characteristics are normally distributed. To determine the type of a scale, it is compared with another scale of a known type. For example, a seismic scale can be compared with the scales of distances, focal depths, and earthquake magnitudes (macroseismic field equation). All these parameters are measurable. Since the macroseismic field equation is linear, the scale can be considered uniform, at least until an intensity of $I = 10$. We can determine the type of scale by comparing its instrumental and macroseismic sections. Also, we can compare the measured radii of neighboring isoseismal lines (correlation coefficient $k = 0.995$). Such operations were first carried out in (Aptikaev et al., 2008). So, the Mercalli scale is an interval scale. However, the Japan Meteorological Agency (JMA) seismic intensity scale has uneven intervals. The instrumental section clearly demonstrates this. Currently, the Japanese scale is being upgraded, and the intervals of 5 and 6 points are halved.

The objective of the proposed scale is to overcome the disadvantages of the MSK-64 and EMS-98 scales. Thus, this scale comprises the entire range of seismic intensities, since the scale should be used not only to estimate the response of buildings and structures to earthquakes, but also to assess seismic hazard, including in regions with low seismic activity. In the scale are average estimates of the responses of object sensors, not the most intense parts of such distributions.

In addition to accelerations, the instrumental section of the new seismic intensity scale (F.F. Aptikaev and O.O. Erteleva) analyzes the relationships of the responses of object sensors, ground velocities, ground displacements, IRIS energy, and wave power. The contribution of the duration of oscillations to the seismic effect is evaluated. It is shown that accelerations do not characterize the seismic effect better than other parameters. Empirical data show that the best characteristic of the seismic effect is wave energy. However, since there are no sufficient data or method for measuring the duration of oscillations, the new scale has no "wave energy" parameter. In all macroseismic scales currently in use, a seismic intensity of 10 or more is associated with residual deformations rather than ground oscillations. Therefore, extrapolation of accelerations from low intensities to higher intensities makes no sense. Based on empirical data, the maximum average acceleration is close to 1.4 *g*, which corresponds to 9.5 points.

For 1-point seismic intensities, the responses of people and household items (O.O. Erteleva) are also observed on the upper floors of four- to five-story buildings. Such estimates are important when studying seismicity in low-activity regions.

A number of experts (F.F. Aptikaev, Yu.A. Berzhinsky, M.A. Klyachko, and G.S. Shestoperov) have studied the response of buildings and other engineering structures to seismic events. Apparently, this is why there are many conflicting views on this section of the new scale even among the members of the working group.

The new scale defines transport facilities (G.S. Shestoperov and S.G. Shestoperov) and pipelines (Yu.A. Berzhinsky) as separate types.

The Natural Object Responses to Earthquakes section has been significantly broadened in the new scale (A.L. Strom) compared with the previous version. This section is extremely important for Russia because, unlike Western countries, we have extensive sparsely populated regions where there are nothing but natural objects. Also, the Earthquake Environmental Effects section is larger in the new scale. High seismic intensities are described by changes in the relief, i.e., residual deformations. Residual deformations are maximum when (1) a fault outcrops and (2) a large-magnitude earthquake occurs. Clearly, residual deformations are proportional to displacements, but they are not described by accelerations and velocities. Therefore, seismic hazard maps should be based on fault lines maps instead of "averaged" isoseists. Construction in fault zones is prohibited in many countries, though. Many reviewers require that secondary effects of earthquakes should be excluded from the scale because rock falls, landslides, avalanches, and mud flows are likely to occur in the absence of earthquakes. Such a suggestion is understandable as far as Western European countries are concerned. However, in Russia, there are vast sparsely populated areas where only geological effects of earthquakes are available for study. Therefore, the above-mentioned phenomena are included in the scale provided that they occur on a large scale. These effects are taken into account with a small weight.

The new scale does not consider damage to historic buildings. Seismologists often ask why this is. Indeed, ESC and UNESCO began to gather information on this problem. An appropriate section may appear in the scale in the future. However, the problems of seismoarchaeological studies are wider. The results of seismoarchaeological surveys allow the intensity, magnitude, and even the occurrence frequency of earthquakes to be specified. The above-mentioned problems are the tasks of detailed seismic zoning (DSZ). Incidentally, new building rules describing the goals and methods of detailed seismic zoning are being prepared.

INSTRUMENTAL SECTION OF THE NEW SCALE

It is the contents of the new scale that seismologists and engineers strongly disagree about. In Russia, seismic hazard has been traditionally evaluated using the seismic intensity scale. This is due to the fact that only macroseismic information can be used for seismic hazard assessment; there are no instrumental data for many regions of Russia. Estimates of seismic intensity can not be directly used in engineering calculations. Therefore, after the repeal of GOST 6249-52 (*Shkala*..., 1952), new GOSTs began to spring up like mushrooms after a rain; they relate the estimates of seismic effects to peak ground accelerations. Examples are GOST 51371-99 (*Metody*..., 1999); GOST R ISO 8568-2010 (*Stendy*..., 2011); GOST R 53166-2008 (*Vozdeistviya*..., 2009); draft GOST R IEC 60980-2012 (*Rekomenduemyi*..., 2012). All of these standards used the abolished scale (*Shkala*..., 1952) adapted to West European conditions (MSK-64). Some GOSTs use the MCS scale, too; their authors confuse the MCS scale with the old version of the MM scale. In 1999, the instrumental section of the MM scale was significantly changed in the United States (Wald et al., 1999), but the authors of domestic GOSTs preferred to use a half-century-old version of it. The question is: why did they have to void our GOST, the macroseismic assessment of which is still valid now? Why did they have to bring the wrong instrumental section back?

S.V. Medvedev noted in the draft MSK-78 scale that “accelerations are understated by a factor of 1.5 in the MSK-64 scale” (Medvedev, 1978). But nobody heard the creator of the scale; Construction Regulations SP 14.13330 (*Stroitel’stvo*..., 2014) still uses the understated estimates of fifty years ago. This brings up the most commonly asked question: what can we do when macroseismic and instrumental estimates differ widely? The answer is simple: the new scale’s macroseismic and instrumental estimates agree on average, but peak acceleration estimates based on empirical data, as S.V. Medvedev expected, are higher by a factor of 1.5 for 9-point seismicity. The second cause of possible differences is the ambiguous translation of the seismicity index to accelerations depending on distance (Neumann, 1954; Murphy and O’Brien, 1978). Explanation for this phenomenon is given in (Aptikaev, 2012). It is shown that the seismic intensity index is strongly dependent on the duration of oscillations; this factor is usually disregarded. If we take the average ratio of *PGA* to intensity, then we should take the fixed average duration as well. The use of fixed duration eliminates the ambiguity of the relationship between the seismic intensity index and acceleration, but increases the standard deviation from 0.35 points to 0.6 points for 9-point intensity. Construction Regulations SP 14.13330 (*Stroitel’stvo* ..., 2014) only refers to the necessity to take seismic and geological conditions into account when determining design seismic loads. In fact, neither magnitude nor type of movement at an earthquake focus nor focal depth nor epicentral distance is taken into account. Therefore, it is impossible to estimate both the duration and the dominant period of oscillations. That is why some building engineers require that the seismic intensity scale should contain a method for determining the natural period of vibration of structures. This is tantamount to saying that oscillations emitted by an earthquake source are governed by the characteristics of structures. Certainly, the authors of the scale are aware that the response of a building to an earthquake depends on the relationship between the emitted spectrum of the earthquake source and the frequency characteristics of the building. When studying the effects of earthquakes, this factor is taken into account, as well as the effect of ground conditions.

Quite often, we encounter the requirement that a seismic design procedure should be included in the seismic scale. The answer to such requests is unequivocal: the scale describes the parameters of expected seismic oscillations and seismic effects. It is building science that shows how to use information provided by the scale.

Many reviewers argue that the frequency contents of oscillations should be specified as the following ratios: seismicity index/acceleration, seismicity index/velocity, and seismicity index/displacement. In the proposed seismic intensity scale, peak ground accelerations are considered independent of the dominant period. The dominant period is estimated separately. It must be borne in mind that, unlike the MSK-64 scale, prevailing periods are not fixed in the new scale, the more so because these periods are significantly different for accelerations, velocities, and displacements. In the GOST 6249-52 and MSK-64 scales, the dominant period of acceleration $T = 0.25$ s was fixed in accordance with the fact that four-to-five-story buildings predominated then.

There are objections to changes in ground acceleration levels, contrary to the current regulations. We cannot agree with this because in such a case, the regulations will cease to evolve. Some regulations already meet the proposed instrumental scale, e.g. the General Seismic Zoning Map-97 (*Komplekt*..., 1999) and draft GOST R EN-81-72-2013 on the seismic resistance of elevators (*Lifty*..., 2014). Incidentally, the current regulations do not state that 9-point seismic events cause ground accelerations of 0.4 *g*. They just read: “ground accelerations no less than 0.4 *g*.”

CONSISTENCY OF MACROSEISMIC AND INSTRUMENTAL SECTIONS OF THE SCALE

Some reviewers recommend that macroseismic and instrumental data should be considered separately (similar to the EMS-98 scale (European ..., 1998)). The essence of this recommendation is as follows: it is assumed that the macroseismic scale is more universal due to the comprehensive database of earthquake surveys all over the world, but the instrumental scale is rather has a local character.

Moreover, it is well known that seismic intensity estimates based on the MSK-64 scale are significantly overestimated as far as high intensities are concerned. So, it was concluded that there is disagreement between the macroseismic and instrumental estimates; it was suggested that instrumental and macroseismic scales should be developed separately.

However, a large number of instrumental records made in various regions of the world have been accumulated to date, comprising various seismotectonic environments and a wide range of parameters of earthquake sources and geological settings. Seismic scales have been created, the instrumental and macroseismic estimates of which agree on average. Unfortunately, the Russian database of strong ground motions is not large. However, now the global strong ground motion database is rich enough to develop a reliable instrumental scale of seismic intensity. Thus, in developing the new scale, no less than a hundred strong motion recordings for each intensity index were used to enhance the accuracy of the instrumental estimates.

Only macroseismic data make it possible to cover long periods of time and examine the effects of earthquakes throughout the area. The wider the seismic intensity interval, the more reliable the seismic hazard assessment. Certainly, the maximum effect is achieved by combining macroseismic and instrumental observations. Representative samples of empirical data on macroseismic and instrumental observations make it possible to correlate macroseismic estimates with various parameters of seismic ground motions and assess the accuracy of such correlations. These estimates are required for the design of earthquake-resistant buildings and other engineering structures.

SCALE OF SEISMIC RISK AS AN ALTERNATIVE SEISMIC SCALE

Let us to cite one of the comments made at a meeting of the Scientific and Technical Council on Earthquake Engineering and Natural Disaster Protection (Scientific and Technical Center for Earthquake Engineering and Natural Disaster Protection): "In fact, the approach used in the macroseismic section of the seismic intensity scale reproduces most shortcomings of the MSK scale, which are rightly criticized in the explanatory note to the seismic intensity scale. The main drawback of the new scale is that its engineering part does not contain an assessment of structural vulnerability. But this is the most important characteristic. It is this characteristic that yielded substantial progress in the development of the European Macroseismic Scale (test version from 1992). This was partly owing to the fact that 17 seismologists and engineers from the former Soviet Union took part in the activities of the European Seismological Commission. The main, absolutely unacceptable drawback of the proposed seismic intensity scale is that it disregards all the achievements of the current European Macroseismic Scale EMS-98. The nonconformance to international standards makes the seismic intensity scale unacceptably outdated; the scale has not been harmonized with European standards and is unfit for use."

This statement is the rationale for the creation of an alternative new seismic scale. What is the alternative scale? What is it based on? What tasks does it focus on? We will try to answer these questions.

Indeed, accelerations as per the MSK-64 scale at high intensities are significantly underestimated; it was therefore concluded that there is disagreement between the macroseismic and instrumental estimates. In many countries, seismic intensity scales have been created; the instrumental and macroseismic estimates on these scales agree on average.

The above objections to the principles of the new Russian seismic intensity scale reflect the wish of users to rank the effects of earthquakes by damage, not strength. During development of the EMS-98 scale, G. Tiedemann, who represented the Swiss Reinsurance Company, Zurich, proposed that the strength of an earthquake should be evaluated in terms of loss of functionality of structures (Tiedemann, 1982, 1984, 1988). From this viewpoint, if a building suffers third-degree damage and it is decided to demolish it, then this is considered to entail bigger costs than the total collapse of the building (fifth-degree damage). In the latter case, merely dump trucks have to be hired to remove debris, while third-degree damage implies additional costs to demolish the damaged building. However, from an administrative viewpoint (rescue operations, obstruction removal, repair and construction of new buildings, and infrastructure repair), as well as from the viewpoint of insurance companies (payments on insurance policies), such an approach is quite reasonable.

M.A. Klyachko, a member of the working group on the new seismic scale, proposed that the term vulnerability be used to characterize the seismic stability of buildings and engineering structures; he developed a seismic vulnerability scale (Klyachko, 1996a, 1996b; 2007; Klyachko, 2003). He also prepared an alternative version of the scale (Klyachko et al., 2012), which focuses on the assessment of postearthquake damage to buildings rather than the strength of earthquakes. The main difference between the two versions of the scale is that, within the engineering range from 7 to 9 points, the basic version's measure of seismic intensity is the level of destruction of buildings, while the alternative version's measure is the loss caused by an earthquake. In the opinion of the working group and a group of experts who examined both versions, Klyachko's scale can be used to assess earthquake losses and help make earthquake mitigation decisions, rather than estimate the strength of earthquakes. Klyachko's version is recommended for use as a seismic risk scale.

CONCLUSIONS

It is shown that the new seismic scale, which is discussed as a draft of the Russian National Standard (GOST), has been harmonized with other modern seismic scales; in contrast to the latter, it assesses the sizes of earthquakes with a higher accuracy using a statistical approach. It is shown (Aptikaev et al., 2008) that the discussed scale can be attributed to the type of interval scales as far as the range from 1 to 9.5 points is concerned. In other words, this scale can be considered an internally uniform one; all arithmetic operations are allowed within the scale (including calculations of the arithmetic mean and standard deviations and extrapolation of earthquake intensity increments into the high-intensity region.

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