The Peculiarities of Newest Russian Seismic Standard

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Summary: *Introduction into practice of engineering-seismological researches of the description of seismic impacts by instrumental characteristics demands use of site coefficients for the account of influence of structure features and characteristics of the top part of a geological section. The article shows that the site coefficients, at least in the field of linear representations, can be uniquely describe through a single parameter of the soils – the average seismic rigidity of the 30-meter thickness composing the upper part of the cut. Simple relations allowing determining the response spectrum of soil by parameters of the soil model are deriving. By means of site coefficients, it is possible to construct a response spectrum of a soil model and to calculate necessary characteristics of seismic impacts. In the field of nonlinear coupling of soil model properties and seismic effects parameters, it is proposing to use reduction coefficients.*

Keywords: *seismic microzonation, seismic impacts, response spectrum, seismic rigidity, site coefficient, modeling, continuity, nonlinearity, reduction coefficient.*

INTRODUCTION

The leading role of standards of seismic zoning of the USA in the modern world is generally accepted. This point of view is confirmed by the fact that a large number of countries are aware of the USA norms that emerged at the end of the last century and, mainly, continued to be used in engineering research for two decades. These are European countries that use Eurocodes and countries such as Canada, China, India, Kazakhstan and many others.

The last Russian norms in the field of seismic microzoning (SMR) [SP 283.1325800.2016] appeared at the end of 2016. This document contains many new and original ideas. In this article, attention is focused on the consideration of a number of provisions that significantly distinguish Russian norms from American analogues.

1. REFUSAL OF SITE CLASS CONCEPT

The influence of soil conditions on the parameters of seismic effects for their characterization with the help of the physical quantities is taken into account a multiplicative way by soil coefficients. The "zero" macroseismic additive of the intensity scale corresponds to the coefficient is equal to unit. In other words, to take into account the properties of soils, the acceleration value characterizing the initial seismicity related to the reference soils is multiplied by the soil coefficient depending on the properties of the soil, expressed in terms of soil categories - from A to E. In domestic norms, as in the USA norms, two types of soil coefficients are adopted for short-period and long-period parts of the spectrum corresponding to the regions of the seismic vibration spectrum in which the constancy of accelerations or velocities of vibration are observed.

Note that in this way the properties of the soil are determined discretely, and the transition from one category to another is accompanied by a jump. In this case, the discrete form of representation using the concepts of soil categories contradicts the nature of the properties of soils, continuous in nature.

The use of permanent soil coefficients corresponding to a certain soil category causes abrupt changes at the boundaries of the categories and generates the corresponding inaccuracies.

The constancy of the soil coefficient values for the entire range of properties characterized by the soil category determines the load that is inadequate to the properties of the soil. Let us explain the meaning of the above in the example shown in figure 1.

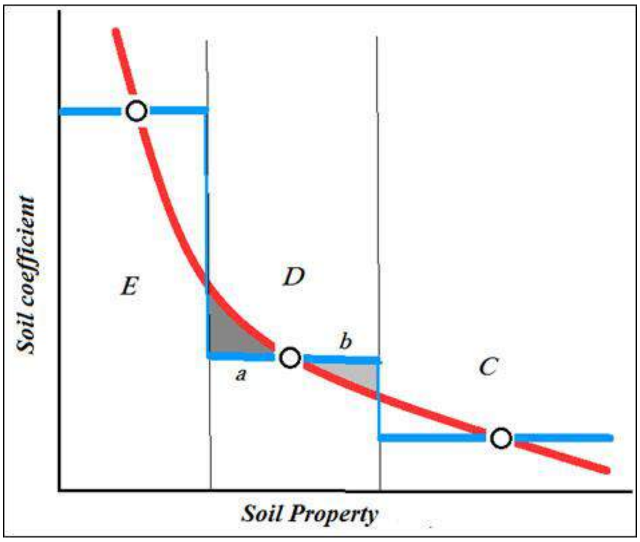

Fig. 1 *Approximation of a continuous curve by a step graph*

The continuous load curve, shown in red, is based on the experimental data highlighted by the empty circles. Taking into account the boundaries of soil categories (indicated by vertical lines), in USA norms the continuous curve is approximated by a step graph highlighted in blue. It is obvious that the soil area of category D? for example) consists of two parts - **a** and **b**. On site **a** the actual seismic effects are greater than the values on the step graph, and for site **b** the values of actual soil coefficient are smaller of the step graph. Similar comments may be made for other categories. Such definition of soil coefficients by the step law, certainly, is insufficient and inadequate.

2. THE SEISMIC RIGIDITY INSTEAD SHEAR WAVE VELOCITY

We also note another drawback of American norms regarding the determination of soil coefficients - the velocity of shear waves is considered as the only characteristic of soil properties. It should be noted that the velocity of shear waves, although it is the most important characteristic of the seismic properties of the soil mass, but it is not the only value that determines the seismic properties of the soil. The reaction of the soil to seismic effects is also determined by the density, or more correctly by seismic rigidity - the product of density on the velocity of shear waves. And although the range of variations the density of different soils is small compared to the range variations of velocity Vs, it would be unwise not to take it into account at all. It should be noted that the value of seismic rigidity is the main quantitative characteristic of soil properties in table 1 of the Russian standard [SP 14.13330, 2014].

3. STRUCTURAL FACTOR ACCOUNTING

In the USA standards, the influence of the properties of the soil layer on the parameters of seismic oscillations is taken into account by the value of the shear wave velocity, the average for the 30-meter upper layer. There is, however, one circumstance that has not been taken into account. And it plays, as we will see, a very important role. This is the internal structure of the 30-meter layer of soil. Speaking about the internal structure of the soil mass, we mean the order of alternation of layers in the array, which can be arbitrary, although the average values of velocities and densities are preserved. For example, consider two simple models that include two layers with high and low velocities and densities. Model parameters are given in table 1.

Table 1. *The parameters of the models soil massif*

Number of lay	Density, g/cm³	Velocity Vs, м/с	Depth, м
Model C+15			
1	2,0	667	15
2	1,8	400	15
3	2,2	1000	∞
Model C – 15			
1	1,8	400	15
2	2,0	667	15
3	2,2	1000	∞

Calculations were carried out using the NERA program. A short pulse is applied to the input of the layer system. The amplitude of the input pulse was equal to 0.1 g, that determine the linearity of the response to the input action. As already noted, the response spectrum of the system to this effect is a frequency response of the layer system. As the output data in this case, we use the response spectrum, because it displays both frequency and amplitude features of the spectrum. The obtained spectra are presented for comparison in one figure 2.

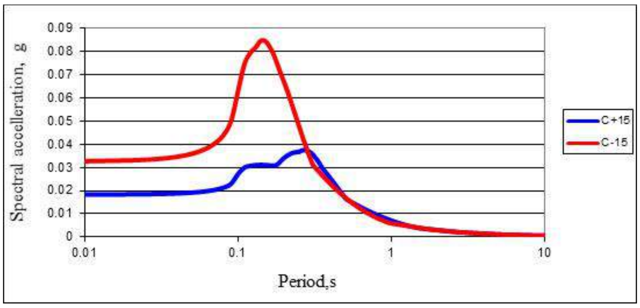

Fig.2 *Responses spectra of models C + 15 and C-15*

It is obvious that models C+15 and C-15 differ as the form of the spectral curve, and, most clearly, the level of spectra. For the model C + 15 it is about 1.5 times lower, which is explained by the structure of the soil layer: in the structure of the model C+15 there is an inverse low-velocity layer, and besides, the upper part of the section in the model C+15 is represented by a layer with increased seismic rigidity. Thus, the seismic wave, suitable from the hard half-space, is weakened due to two factors. First, on the inverse boundary - the roof layer with reduced rigidity - part of the energy is thrown back into the lower half-space. Secondly, on the roof of the upper layer oscillations will be lower precisely because of the increased rigidity.

4. THE THICKNESS OF THE STUDIED SOIL MASSIF

It has already been noted above that in the USA norms the influence of the properties of the soil layer on the parameters of seismic oscillations is taken into account by the value of the transverse wave velocity, the average for the 30-meter upper layer. This value determines the soil category, according to which the soil coefficients and other parameters of seismic effects are determined.

This classification is bases on studies conducted in the United States, where soil properties have been studied up to several hundred meters, but have not yet reached the level of sufficiently hard rock soils. This means that the classification proposed in the United States cannot be directly applied to other regions, especially those with shallow rock foundations. In [*Anbazhagan et al*., 2013] the influence of the depth of the rock Foundation on the properties of soil classes of 30-meter thickness was investigated. In this work, a study of the seismic properties of soil massifs located in different parts of Australia, China, and India was carried out on the basis of recommendations [BSSC, 2003] in a wide range of average velocities of transverse waves (or standard penetration tests). The velocities of transverse waves were studied at depths ranging from several meters to 180 m. It is shown that in the classification system based on the properties of the upper 30-meter thickness of the soil, in cases of shallow occurrence of a rigid engineering Foundation (on velocity Vs > 700 m/s), the average properties of the soil layer are more stringent than provided by the norms. A new classification system based on the properties of average soil thickness to the engineering rigid Foundation was proposed, which seems to be more preferable for sites of soil conditions of shallow Foundation of a number of studied regions. It was also noted that the response spectra, soil coefficients, periods estimated by modeling one-dimensional shear wave processes taking into account the properties of the soil to the depth of the engineering foundation, differ from those obtained taking into account the properties of the 30-meter thickness of the soil, and more adequately characterize the seismic properties of the soils.

The thickness of the soil layer, significant for the purposes of the SMZ is determining by paragraph 6.18of new Russian standard [SP 283.1325800.2016]. "The estimated thickness of the soil should correspond to 30 m or more in the dispersed rocks or thickness to the boundary with R >2000 tm-2s-1 in the case of its presence in the upper 30-meter thickness of the cut".

5. THE DETERMINATION OF SOIL COEFFICIENTS

Consider how the ground factors given in the American standards [BSSC, 2003]. This issue is discussed in detail in [*Power et al.*, 2004], whose materials are used here. This paper presents data obtained mainly from empirical data of the survey of large earthquakes in the West of the United States, as well as the results of computer modeling.

Soil coefficient values for categories E, D and C, obtained by different researchers and marked by blue dots, are given on Fig. 3. Category A and B coefficients of the soil is equal to 1 and 0.8 and is therefore not considered here. As shown in Fig. 3, the values of soil coefficients determined by different authors vary in a fairly wide range, which reflects both the objective factor-the difference between the parameters of earthquakes and soils, and is a consequence of the subjective factor manifested in the difference in data processing methods. But, what is particularly noteworthy, the normative values for category E are the maximum in relation to the rest of the values of this family, and for category C the picture is the opposite – the normative values are the minimum in the family of the corresponding soil coefficients. The values of soil coefficients take as normative based on measurements of soil vibrations from the 1989 earthquake in Loma-Prieta.

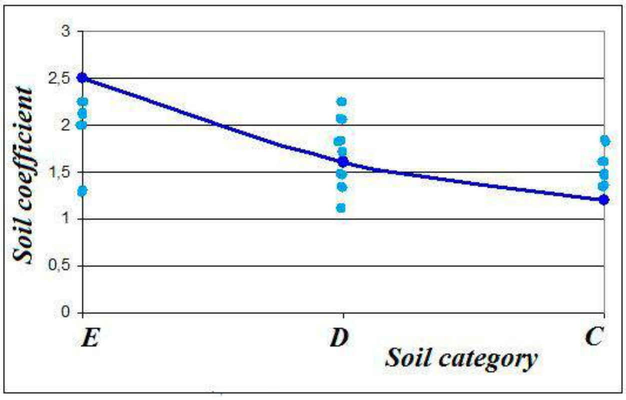

Fig.3 *Dispersion of soil coefficients values relative to standard values*

It is also evident that the representation in NEHRP of soil coefficients based on data from only one earthquake as normative is not convincing enough. In our opinion, in this case, preference should be given to the results based on the data of computer simulation of the connection of soil coefficients with the value of the seismic rigidity of the soil mass, as described in [*Aleshin*, 2018], the resulting graph from which is shown in figure 4.

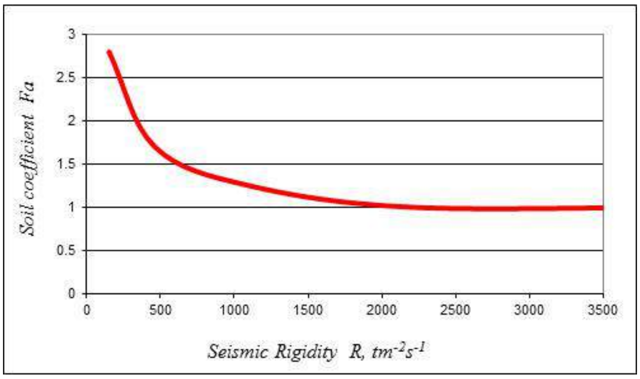

Fig. 4 *The dependence of soil coefficients Fa from seismic rigidity*

Chart data Fig.4 significantly different from the values of soil coefficients of the American standards [BSSC, 2003]. First, the values of Fa on the chart figure

4 exceed tabular values from American norms, and, secondly, the values of soil coefficients remain constant at R > 2000 $tm^{-2}s^{-1}$.

This can be completed illustrative presentation of the distinctive features of domestic standards. We will add two more short remarks of general nature to the article.

6. A STRONG DEFINITION OF THE PARAMETERS OF THE REFERENCE SOIL

In US standards [BSSC, 2003] parameters of the reference soils is determining by reference to category B, which characterize by the range of Vs 760 – 1500 m/s. Although values of soil coefficients changed in this range slightly, still the strong fixing of the parameters of the reference soil, as it is in the Russian standards, increases the accuracy of determining the characteristics of seismic effects.

7. RUSSIAN NORMS ARE MORE UNIVERSAL

In comparison with the American norms, the Russian norms are universal, since they allow the use of both instrumental characteristics of seismic oscillations and their macroseismic analogues in the form of seismically intensity or increments of intensity. This position provides continuity in the use as usual macroseismic characteristics so instrumental ones – maximum accelerations, durations and soil coefficients.

8. CONCLUSION

These considerations reasonably show the advantages of Russian seismic standards in comparison with American analogues, and the main task in the field of domestic seismic microzoning is to disseminate and harmonize their basic provisions with other regulations.

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