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Prospects of transition to European standards — features of Eurocode-8

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This paper analyzes the features of Eurocode-8, the European standard for earthquake-resistant construction, regarding seismic microzonation and seismic hazard assessment. The standard is compared to the methodology of similar studies in Ukraine. There is a significant difference in approaches to considering local near-surface geological conditions

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of survey sites. The study shows the critical role of shear-wave velocity in the uppermost subsurface as a primary indicator of a site's seismic response. It explores innovative approaches to obtaining velocity characteristics based on multichannel analysis of surface waves and modeling regional near-surface velocity based on Shuttle Radar Topography Mission data. The key issue of implementing Eurocode-8 requirements in Ukrainian conditions is discussed, with a particular focus on making seismic hazard map based on peak ground acceleration.

Key words: DBN V.1.1.12-2014, Eurocode-8, seismic microzonation, shear-wave velocities, peak ground acceleration.

Introduction. One of the most important conditions for successfully integrating Ukraine into the global political and economic space is the transition to international standards. This fully applies to seismic microzonation. In the practice of engineering seismology, the seismic hazard (calculated seismicity) of the territory is determined by background (normative) seismicity and an increase in seismicity due to the influence of local soil conditions, which are expressed in seismic intensity scale (Ukrainian studies) and seismic amplification factors (international studies).

Near-surface physical and geological conditions affect the amplitudes of seismic shaking, which can be greatly amplified and increase the seismic hazard of the territory, as well as the frequency content of the seismic waves.

Seismic microzonation is the procedure of accounting for local site conditions (site response analysis) to refine seismic data for the study area, considering its physical and geological conditions. This process involves estimating peak ground acceleration (PGA), calculating synthetic accelerograms, and generating response spectra at the ground surface. These studies are among the key tasks of engineering seismology and form an integral part of further seismic resistance calculations.

Currently, the main regulatory document governing seismic microzonation in Ukraine is DBN V.1.1.12-2014 «Construction in Seismic Regions of Ukraine» [DBN V.1.1.12:2014, 2014]. In EU countries, the applicable standard is Eurocode-8 [Eurocode 8 …, 2004]. The main provisions regarding seismic microzonation outlined in these regulatory documents differ significantly. Ukraine's transition to European standards requires an understanding and adaptation of the requirements of international regulations.

A comparative analysis of the requirements of DBN V.1.1.12-2014 and Eurocode-8 in the context of seismic microzonation. In Ukrainian seismic microzonation practice, according to DBN V.1.1.12-2014, which refers to Soviet-era standards, the following methods are utilized:

– the method of engineering-geological analogies (EGA);

– the seismic rigidity method (SRM);

– the method of recording earthquakes, explosions, and microseisms;

– computational methods.

Using this combination of methods, the increase in seismic intensity is determined in terms of the MSK-64 scale. These methods are well-known to Ukrainian engineering seismologists and have been successfully used for over 50 years; hence, they do not need further elaboration. Ukrainian seismic hazard maps are constructed in terms of seismic intensity [DBN V.1.1.12:2014, 2014]. These maps enable the evaluation of the background (normative) seismicity for any area within Ukraine.

The seismicity of the survey site is determined by simply adding the intensity increase obtained during seismic microzonation to the values of background (normative) seismicity according to the Ukrainian seismic hazard maps and the construction building and structures of higher-importance classes.

In recent decades, there has been a significant shift towards using advanced computational technologies and numerical modeling methods. This trend also extends to calculations for the seismic resistance of buildings and structures during their design and reconstruction. According to the requirements of DBN V.1.1.12:2014, for the design of buildings and structures of the higher-importance classes, calculations for seismic effects are performed using the direct dynamic method with the representation of seismic action in the form of digital accelerograms.

A fundamental drawback of the approach to seismic hazard assessment applied in Ukraine is that it is based on seismic intensity (in MSK-64 scale points) rather than ground motion parameters such as PGA, velocities, displacements in the geological environment during earthquakes, or response spectra. This necessitates a transition from seismic intensity MSK-64 scale to physical ground motion parameters during earthquakes. While this transition is performed, it is not entirely transparent from a physical perspective. The seismic intensity MSK-64 scale represents the perceived effects of an earthquake, not a physical quantity. Intensity-based hazard assessments, followed by their conversion to ground motion parameters, raise concerns among foreign experts who act as international reviewers for projects involving foreign investments. This issue may become even more relevant during the post-war reconstruction of Ukraine, as funds from other countries will likely be used for redevelopment.

Let us now focus in more detail on the approaches for assessing the impact of local physical and geological conditions of seismic hazards according to Eurocode-8.

A key feature of this approach is assessing the seismicity of a site in terms of predicted ground motion acceleration parameters, specifically the response spectra of single oscillators with different oscillation frequencies subjected to seismic impacts, expressed in terms of surface acceleration within near-surface layers. The response spectrum can serve as input data for calculating the seismic impacts on buildings and structures using spectral methods and as a basis for obtaining synthetic accelerograms for subsequent calculations using the direct dynamic method [Newmark, Rosenblueth, 1971].

Eurocode-8 recommends two types of spectra: 1) for events with $M \geq 5.5$; 2) for events with $M < 5.5$. When calculating the response spectrum, the following parameters are considered: PGA at the site, based on the general seismic hazard map and adjusted by the building and structures importance coefficient; a coefficient accounting for damping (with 5 % damping being the most commonly used); a coefficient taking into account the soil factor (amplification coefficient for different soil conditions); characteristic period boundaries of the response spectrum which define its shape. The last two parameters are determined by the local soil conditions. At the same time, the primary characteristic defining soil conditions is the average shear-wave velocity in the upper 30-meter layer of the geological profile (V_s^{30}). It is calculated using the formula:

$$V_s^{30} = \frac{30}{\sum_{i=1}^{n} \frac{h_i}{V_{s_i}}},$$

where h_i is the thickness of the i-th layer and V_{s_i} is its shear wave velocity (for layers up to 30-meter depth). Despite discussions regarding the suitability of V_s^{30} [Castellaro et al., 2008; Mazanec et al., 2024], it remains the most commonly applied soil classification parameter.

The values of shear-waves' velocity V_{s_i} in a layered Earth's subsurface are determined during field or borehole seismic surveys. Among the advantages of the approach is its simplicity and transparency in implementation.

However, a significant limitation is the inability to account for resonance effects in the case of the presence of boundaries with a sharp change in velocity in the section. This issue, however, can be resolved through computational methods without requiring additional field investigations. Over the past decades, integrating powerful computational tools into research practice has made computational methods effective for considering local seismic conditions. Currently, the methodology for accounting for resonance effects is well-developed and successfully applied in international and domestic engineering seismology practices [Kendzera, Semenova, 2021].

The influence of the sedimentary rock soil of the exploration site on the transformation of the seismic signal (site response analysis) is assessed by calculating the amplitude-frequency characteristics of the medium for the case of normal incidence of a plane shear wave on a horizontally layered rock model. The spectrum of seismic waves at the surface of the soil is determined by multiplying the spectrum arriving from the «rock» (crystalline basement, limestone roof, etc.) by the corresponding amplitude-frequency characteristics of the horizontally layered rock model. This recalculation makes it possible to consider the site's resonance properties caused by the shallow geological structure, velocity, and density characteristics.

Innovative methods for obtaining the V_s^{30} parameter. The V_s^{30} parameter can be determined using field or borehole seismic survey data. Most commonly, investigations are conducted using either the shear-wave refraction method or through vertical seismic profiling in boreholes. The methodology, data processing techniques and interpretation approaches are well-established and are not discussed in detail in this study.

In the last decades, the field seismic survey method based on surface waves analysis (especially using MASW, multichannel analysis of surface waves) [Park et al., 1999] has gained increasing popularity for solving engineering seismological problems [Mazanec, Valenta, 2023]. The standard MASW process using the vertical component of Rayleigh waves consists of acquiring multichannel records and performing dispersion and inversion analysis. These procedures enable the derivation of a shear-waves velocity model as a function of depth. In the active MASW method, surface waves are generated using an impact source (typically a sledgehammer). In the passive MASW approach, surface waves originate from natural environmental vibrations [Socco et al., 2010]. MASW is one of the straightforward and cost-effective seismic methods, making it a powerful tool for mapping V_s^{30}.

Regardless of the method used, dense networks of seismic survey measurements are rarely available, even for seismically active regions. Constructing regional-scale V_s^{30} schemes solely based on seismic survey-measured V_s^{30} values is practically impossible. The availability of high-resolution, unified satellite topographic data worldwide, obtained as part of the Shuttle Radar Topography Mission (SRTM), has led to the development of an alternative methodology for constructing V_s^{30} schemes [Wald, Allen, 2007]. Digital V_s^{30} distribution models based on the SRTM database can be computed online on the official USGS website: https://earthquake.usgs.gov/data/vs30/. For Ukraine, the results of the construction V_s^{30} scheme based on SRTM data are discussed in [Dovbnich, Viktosenko, 2023].

Conclusions. The full implementation of Eurocode-8 requirements in Ukraine is feasible only with the availability of a Ukrainian seismic hazard map not in terms of seismic intensity (in MSK-64 scale points) but in terms of PGA for different return periods (typically, once in 475 years in international practice). Developing such maps is a priority task for engineering seismology in Ukraine, ensuring a meaningful transition to international standards. Addressing this issue and utilizing the existing experience and results of seismic microzonation studies can serve as a key element in choosing strategies for earthquake-resistant design of buildings and structures, including during Ukraine's post-war reconstruction.

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Перспективи переходу на європейські нормативи — особливості Eurocode-8

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Проаналізовано особливості європейського нормативу з сейсмостійкого будівництва Eurocode-8 у частині сейсмічного мікрорайонування й оцінювання сейсмічної небезпеки. Показано суттєву відмінність підходів щодо врахування локальних приповерхневих фізико-геологічних умов майданчиків вишукувань порівняно з методологією аналогічних досліджень в Україні. Показано ключову роль вивчення швидкостей поширення поперечних хвиль у верхньої частині розрізу — головного показника відгуку майданчика на сейсмічні впливи. Розглянуто інноваційні підходи щодо отримання швидкісних характеристик за даними багатоканального аналізу поверхневих хвиль і побудови регіональних приповерхневих швидкісних моделей за даними супутникової топографії.

Обговорено ключове питання реалізація вимог Eurocode-8 в умовах України — побудова карт загального сейсмічного районування в прогнозних рухах ґрунту (пікових прискореннях).

Ключові слова: ДБН В.1.1.12-2014, Eurocode-8, сейсмічне мікрорайонування, швидкості поширення поперечних хвиль, прогнозні рухи ґрунту.