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Geotechnical site classification and Croatian National Annex for Eurocode 8

Predrag Kvasnička[1], Leo Matešić[2] and Krešo Ivandić[3]

[1] University of Zagreb, Faculty of Mining, Geology and Petroleum Engineering

[2] University of Rijeka, Faculty of Civil Engineering, Rijeka, Croatia

[3] University of Zagreb, Faculty of Geotechnical Engineering, Varaždin, Croatia

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"Geotechnical and seismological data are highly complementary, and that neither should be used alone for a seismic soil response microzonation study." (Bard, NATO-Workshop, Dubrovnik, 2007)

One of the challenging tasks for Croatian accession to the European Union is the completion of the National Annex to Eurocode 8 (EC8) that calls for the development of national seismic hazard maps. These maps need to be developed for several return periods (probabilities of exceedance) and should consider both bedrock and soil conditions. The latter is especially challenging as it calls for site characterization at a microzonation level, i.e., site characterization based upon $V_{s,30}$, SPT blowcounts, and undrained shear strength, information available only in the departments of Public Works of major cities. In this paper, the authors discuss several shortcomings associated with the EC8 ground type definitions and propose their revision. The authors also present the ongoing work for preparation of the Croatian National Annex to EC8 and explain the rationale for the improvement of EC8 ground type definitions.

Keywords: site response, ground types, Eurocode 8

1. Introduction

Significant structural damage and loss of human life have been directly attributed to the effect of local site conditions in almost all major earthquakes, including the 1985 Mexico City, the 1989 Loma Prieta, the 1994 Northridge, and the 1995 Kobe earthquakes. This paper is written in accordance with Line no. 3 of the MEETING project: "Geology and large scale site effects". That line outlines a call for the regulatory and engineering communities to develop procedures to assess the geological conditions that influence site response to strong ground shakings. With respect to geotechnical engineering considerations, the procedures should be developed based on soil characterization that results from proper site investigation. The results of the investigation will be presented in zonation maps for seismic-geotechnical hazard, with the zones having approximately equal hazard towards seismic events. The process of making such maps is continual, and the maps should be renewed from time to time.

The scope of this project is to make available to the local administrations an information platform of territorial data, supporting the different stages of management of seismic vulnerability. This goal is pursued through the following objectives:

– To define the expected seismic input, based on potentially active seismic sources and models for regional and local propagation.

– To define the local site effects by employing different numerical and instrumental methodologies, and to determine the microzonation maps, with the reliability level depending on the quality and completion of the database.

– To develop the Geographic Information System (GIS) integrated with all available databases from local administrations and with the implementation of simplified algorithms for the models built in the project.

In Line no. 3, for the Croatian side, the plan is to provide the authorities of two selected urbanized areas with the guidelines for preparatory works for making seismic zonation. Zonation should be carried out according to the instructions given in Eurocode 8 and all the relevant literature that may contribute to a better execution of this assignment. In order to test the procedures and the methodologies implemented in the project, the cities of Zagreb and Dubrovnik were selected. Zagreb was selected as a representative of a major city, and Dubrovnik as a representative of a relatively small, historically significant community in an area of high seismicity.

Table 3.1 in EC8 defines different ground types related to soil characterization. These ground types (like many other issues in EC8) are based on soil characteristics that are similar to the ground types defined in the Uniform Building Code (UBC). The main soil characteristic is the shear wave velocity for the upper 30.0 m of soil, denoted by $V_{s,30}$, in combination with the geotechnical soil parameters derived from in situ tests, such as SPT, and the undrained shear strength. The other characteristic is the depth of soil layers over a hard rock, but the situation is not clear for depths over 30.0 m.

In this paper, we present the ground types defined in EC8 with a discussion of and comments regarding the types at the Athens ETC-12 (Workshop on the Evaluation and applications of Seismic Eurocode, EC8, Bouckovalas, 2006). Additionally, a new ground-type characterization suggested by Rodriguez-Marek et al. (2001) is described. That characterization was developed from UBC, but it takes into consideration the depth of soil deposits, and it is based predominantly on geotechnical and geological soil characteristics, which makes it more acceptable to geotechnical engineers. Finally, the paper ends with comments and conclusions by which the authors suggest that the Croatian engineering community organize preparatory works for seismic-geotechnical zonation for Croatia in a way that they could be the basis not only for the ground types of the temporary version of EC8 but also for any other rationally based ground-type characterization.

2. Seismic hazard and ground types according to Eurocode 8

Earthquakes produce effects that can cause damage and loss of life. These effects, called hazards, include ground shaking, landslide, rock fall, and ground rupture (surface faulting). In general, the hazard that produces the most widespread damage and loss of life is ground shaking because it can cause building failures and collapses at distances of tens to hundreds of kilometres from the earthquake fault rupture. Recent research has focused on producing national and regional maps of probabilistic earthquake ground shaking. These maps integrate the results of research in the fields of historical seismicity, paleoseismology, strong motion seismology, and site response. The maps take into account all the possible locations and magnitudes of future hypothetical earthquakes (http://earthquake.usgs.gov).

Seismic hazard is expressed in Eurocode 8 (EC8) by a single parameter, namely, the reference peak ground acceleration, a_{gR}, for a reference mean return period. The reference return period recommended for the non-collapse performance level is 475 years, corresponding to 10% probability of exceedance in 50 years in a Poisson occurrence process. In EC8, the design ground acceleration (a_g) is equal to a_{gR} times the importance factor, γ_λ. It is worth noting that the design ground acceleration is related to the so-called base rock or firm soil, rather than to a ground surface, where it could be significantly increased due to possible local amplifications.

A single parameter is not sufficient to characterize ground motion hazard because the hazard is governed not only by a peak value of input ground motion but also by its frequency content and, for geotechnical evaluations, by the duration of strong shaking. While the duration of strong shaking is not explicitly included in EC8, the frequency content is encompassed by the acceleration response spectra (5% damping). Two influences on the frequency content are recognized in EC8, namely:

– the magnitude of the earthquake and

– the geotechnical and geologic conditions of the deposits underlying the civil engineering structures (site conditions).

The site conditions have been classified into different categories in the earthquake codes. These categories are named ground types. Table 1 presents the ground types and the shear wave velocities given in the codes for EC8. Other relevant codes, such as the Uniform Building Code, the International

Building Code and the Turkish Earthquake Code give more information about ground types depending

Table 1. Ground types (according to Table 3.1 from EC8).

Ground type	Description of stratigrafic profile
A	Rock or rock-like geological formation including, at most, 5 m of weaker material at the surface, $V_{s,30}$ > 800 m/s
B	Deposits of very dense sand, gravel or very stiff clay, at least several tens of meters in thickness, characterized by a gradual increase of mechanical properties with depth, $V_{s,30} \approx$ 360–800 m/s, $N_{SPT,30}$ > 50 in granular materials, $c_{u,30}$ > 250 kN/m^2 in cohesive materials
C	Deep deposits of dense or medium-dense sand, gravel or stiff clay with thickness from several tens to many hundreds of meters, $V_{s,30} \approx$ 180–360 m/s, 15 < $N_{SPT,30}$ < 50 in granular materials and 70 < $c_{u,30}$ < 250 kN/m^2 in cohesive materials
D	Deposits of loose-to-medium cohesionless soil (with or without some soft cohesive layers) or of predominantly soft-to-firm cohesive soil. $V_{s,30}$ < 180, $N_{SPT,30}$ < 15 in granular materials, $c_{u,30}$ < 70 kN/m^2 in cohesive materials
E	Soil profile consisting of a surface alluvium layer with $V_{s,30}$ values of class C or D and thickness varying between approximately 5–20 m, underlain by stiffer materials with $V_{s,30}$ > 800 m/s
S_1	Deposits consisting or containing a layer, at least 10 m thick, of soft clays/silts with a high plasticity index (PI > 40) and a height water content, $V_{s,30}$ < 100 m/s, 10 < $c_{u,30}$ < 30 kN/m^2 in cohesive materials
S_2	Deposits of liquefiable soils, sensitive clays, or any other soil profile not included in types A–E or S1

on the thickness of the topmost layer of soil (h_1) (Dogangun and Livaoglu, 2006). It should be noted that in the 1998 edition of EC8, only three ground types, A, B and C, were defined. However, five main ground types, A, B, C, D and E, and two special ground types, S_1 and S_2, have been described in the final version of EC8.

The site classification system is based on the definitions of site classes in terms of a representative average shear wave velocity ($V_{s,30}$), SPT blow-count, unconfined compression strength, and relative density, among others. Based on the empirical studies by Borcherdt (1994), selection of a shear wave velocity, $V_{s,30}$, is recommended as a means of classifying the sites for building codes, and similar site categories were selected for the Federal Emergency Management Agency seismic design provisions for new buildings (Dobry et al., 2000).

For the two ground types, S_1 and S_2, special studies for the definition of the seismic action are required. Such soils typically have low $V_{s,30}$ values and low material damping and can therefore produce anomalous seismic site amplification and soil-structure interaction. In this case, a special study to define the seismic action should be carried out.

According to EC8 EN 1998-1:2004, 3.2.1 (2), the reference peak ground acceleration on type A ground, a_{gR}, to use in the country or parts of the country may be derived from the zonation maps found in its National Annex. In addition, national territories shall be subdivided by the National Authorities into seismic zones, depending on the local hazard (taking ground conditions into consideration). By definition, the hazard within each zone is assumed to be constant.

Although the subdivision of ground types in Table 1 is an improved version (with more soil subgroups) of the subdivision offered in the ENV version of EC8, the authors of this paper think that there is neither a clear explanation by the authors of the EC8 nor a sound intuitive physical meaning of this subdivision. It will be shown later that the different geotechnical site categories suggested by Rodriguez-Marek et al. 2001 are physically and intuitively more acceptable.

Ground conditions and seismic actions were commented on at the Athens ETC-12 Workshop on the Evaluation and applications of EC8 (Bouckovalas, 2006). A diagram was plotted according to Table 3.1 from EC8 showing an approximate relationship between the ground depth H and V_s or $V_{s,30}$ (Fig. 1). The diagram shows that there is a gap in the EC8 definition of ground types; for instance, it is not clear how to categorize the soil profiles with $V_{s,30}$ > 360 m/s and H = 5–20 m. It was also proposed by some contributors to the Athens Workshop that $V_{s,30}$ should be replaced by V_s. The logic behind this change is explained in detail in the papers from the Workshop. In brief, $V_{s,30}$ may be an overrated indicator of soil stiffness in the case of soft but shallow soil profiles (H < 30 m) and an underrated indicator for deep profiles (H > 30 m) or for profiles with an abrupt stiffness change between 30.0 m of depth and the deeper laying bedrock. However, during the discussion of this topic, it was pointed out that the geotechnical investigation of depths greater than 30.0 m may face objective difficulties and will be often abandoned in practice. Hence,

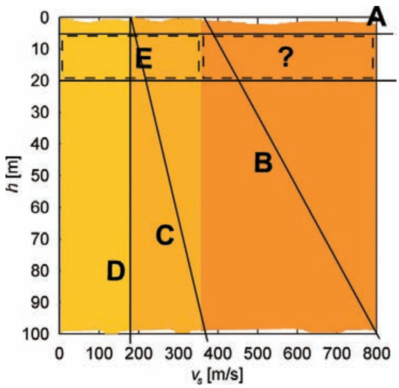

Figure 1. Definition of ground types according to EC8 (approximation).

in a sort of compromise, it was suggested that V_s be used when the depth to bedrock is 30.0 m or less and that $V_{s,30}$ be used for deeper soil profiles. Finally, it was concluded that using the average shear wave velocity over a set of 30.0 m depth to classify a site has the advantage of uniformity.

It is widely recognized that the site response is strongly dependent on the soil depth, as will be shown here (see for instance Fig. 2), and the reduction of a site to only the upper 30 m is not necessary. Ignoring the soil depth may introduce an undesirable level of uncertainty in calculating the influence of local soil conditions on ground motion prediction. In addition to ground motion prediction, the site effects have also been introduced into the most current attenuation relationships, which account for site effects only through a broad site classification that divides sites into either "rock" or "soil". Data from recent earthquakes suggest that further refinement in this classification system is warranted to achieve improved predictions of ground motions (see Rodriguez-Marek et al., 2001).

Nevertheless, following the instructions from EC8, the member states of the EU are making efforts to prepare seismic zonation maps for their national annexes. For instance, Rošer and Gosar (2010) published their $V_{s,30}$ distribution map for the City of Ljubljana. Their position was that, although $V_{s,30}$ was not the most suitable parameter to define seismic site response, its spatial distribution provided valuable information to integrate and supplement existing seismic microzonation of Ljubljana. In the other part of the world, Canada, Motazedian et al. (2011) published their $V_{s,30}$ distribution map for the City of Ottawa in conjunction with the National Building Code of Canada. Along with $V_{s,30}$, they also provided a fundamental frequency map, which is not required by EC8.

3. Comments on use $V_{s,30}$ as a representative parameter for ground conditions

The concept of $V_{s,30}$ was introduced by Borcherdt (1994), who developed intensity-dependent, short period and long period amplification factors based on the average shear wave velocity measured over the upper 100 feet (30.0 m) of a site. However, a $V_{s,30}$-based classification system has two important limitations:

(a) It requires a relatively extensive field investigation, and

(b) It overlooks the potential importance of depth to the bedrock as a factor in site response and, consequently, a cause of building damage.

An important factor in predicting earthquake damage is the relationship between the fundamental period of a building and the period of the ground on which the building is constructed. If the building's period equals the fundamental period of the material on which it is built, or if it equals some whole-number multiple of the material's fundamental period, then the seismic shaking will create a resonance with the building that can greatly increase the stresses on the structure. Tall buildings tend to sustain more damage on deep, soft soils because of their similar vibrational period. Small, rigid buildings perform poorly on short-period materials such as bedrock.

This relationship between the building's period and the period of the material on which it is built is illustrated in the following example: Seed et al. (1972) determined the correlation between site effects and building damage for the 1967 Caracas earthquake (Fig. 2). As soils in the Caracas region are relatively uniform in stiffness, the variations of natural periods of the ground were linear functions of the variations in soil depths. Deep deposits (for depths over 150 m) influenced buildings differently, depending on the number of stories N, i.e., on their natural period. Obviously, the upper 30 m soil characteristics alone would not be enough for determining the relationship between the building damage and the soil characteristics.

These observations indicate that the quantification of the site effects is a necessary component of a comprehensive assessment of seismic hazard.

Extensive studies of seismic site response have been carried out over the last thirty years. During that time Seed et al. (1991) developed a geotechnical site classification system based on shear wave velocity, depth to bedrock, and general geotechnical descriptions of the soil deposits at a site. They then developed intensity-dependent site amplification factors to modify the baseline "rock" peak ground acceleration (PGA) to account for the site effects. With this site PGA value and the site-dependent normalized acceleration response spectra, the site-dependent design spectra can be developed. Their work, which has been incorporated into the 1997 Uniform Building Code (UBC), is based primarily on the site classification system and amplification factors developed by Borcherdt (1994), whose site amplification factors are based primarily on the observations from the 1989 Loma Prieta Earthquake. This earthquake

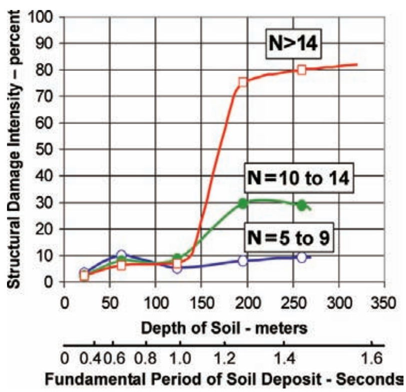

Figure 2. Building damage in the 1967 Caracas Earthquake, with N being the number of stories (Seed et al., 1972).

shows significant nonlinear site response effects, whereas the observations from the 1994 Northridge Earthquake indicate that the site amplification factors should not decrease as significantly with an increasing ground motion intensity (Rodriguez-Marek et al., 2001). Hence, the current UBC site factors may be unconservative.

4. Geotechnical seismic site response procedure by Rodriguez-Marek et al. (2001)

Recent work completed at the University of California at Berkeley based on the results from the 1994 M_w = 6.7 Northridge and 1989 M_w = 6.9 Loma Prieta, California earthquakes made use of introducing a measure of depth in a site classification system (Chang and Bray, 1995; Chang et al., 1997). On the basis of their work, Rodriguez-Marek et al. (2001) developed a new procedure for determining site amplification factors that were both intensity and frequency dependent. The procedure determines the site amplification factors that are estimated based on a site classification system that includes soil stiffness and soil depth as its key parameters. The uncertainty levels resulting from the proposed classification system are compared with those resulting from a simplified “rock vs. soil” classification system and a code-based system, which uses the average shear wave velocity $V_{s,30}$ measured over the upper 30.0 m of a site.

This method for developing the site-dependent amplification factors is based on the following:

(1) The proposed scheme utilizes only general geological and geotechnical information, including depth to bedrock or to a significant impedance contrast. More elaborate measurements, such as average shear wave velocity (V_s), are utilized only as a guideline and are not essential to the classification system.

(2) Two major recent earthquakes, the Loma Prieta Earthquake and the Northridge Earthquake, were considered. The distance-dependent attenuation relationships for 5% damped elastic acceleration response spectra were developed for each earthquake and for each site condition. For simplicity, any reference to response spectral values implies linear elastic acceleration response spectra at 5% damping.

(3) These attenuation relationships were utilized to develop site-dependent amplification factors with respect to the baseline site condition, Site Class B, “California Rock”. The site-dependent amplification factors are a function of both spectral period and intensity of motion. Amplification factors estimated for the Northridge and Loma Prieta earthquakes were combined to develop recommendations that can be generalized to other events.

Classification Scheme: The amplification of ground motions at a nearly level site is significantly affected by the natural period of the site ($T_n = 4 \cdot H / V_s$; where T_n = natural period, H = soil depth, and V_s = shear wave velocity; i.e., both the dynamic stiffness and the depth are important). The natural period of soil deposit is included in Tab. 2. Other important seismic site response factors are the impedance ratio between the surficial and the underlying deposits, the material damping of the surficial deposits, and how these seismic site response characteristics vary as a function of the intensity of the ground motion, as well as other factors. To account partially for these factors, a site classification system should include a measure of the dynamic stiffness of the site and a measure of the depth of the deposit. Although earlier codes made use of natural period as a means to classify site conditions (e.g., 1976 UBC), recent codes, such as the 1997 UBC, disregard the depth of the soil deposit and use mean shear wave velocity, $V_{s,30}$, over the upper 30.0 m as the primary parameter for site classification. Both analytical studies and observation of previous earthquakes indicate that depth is indeed an important parameter affecting the seismic site response. Fig. 2 shows a measure of building damage as a function of site depth in the 1967 Caracas Earthquake. The damage is concentrated in the buildings whose natural period matches the natural period of the soil deposit.

To illustrate the effect of soil profile depth on surface ground motions, Rodriguez-Marek et al. (2001) used a synthetic motion for an earthquake of moment magnitude 8.0 (M_w = 8.0) on the San Andreas Fault in the San Francisco Bay as an input outcropping rock motion for a soil profile with varying thickness. The input rock motion was modified to match the Abrahamson and Silva (1997) attenuation relationship for an earthquake of moment magnitude 7.5 (M_w = 7.5) at a distance of 30 km. The soil profile represents a generic stiff clay site. The upper 30.0 m of the profile was kept constant, whereas the depth of the profile was varied between 30.0–150.0 m. A one-dimensional wave propagation analysis was performed using the equivalent-linear program SHAKE91 (Idriss and Sun, 1992). The effect of nonlinearity was a function of soil type (e.g., Vucetic and Dobry, 1991). The result was:

– An increase in depth shifts the fundamental period, where the amplification is toward higher values. This results in significantly different surface motions as a function of the depth to bedrock.

– An increase in depth also results in a longer travel path for the waves through the soil deposit.

This result accentuates the effect of soil material damping, resulting in greater attenuation of high frequency motion. However, the significantly higher response at longer periods for deep soil deposits is an important expected result that should be accommodated in a seismic site response evaluation. The effect of soil nonlinearity is two-fold:

(a) The site period shifts toward longer values, and

(b) The material damping levels in the soils at a site increase. The increased damping levels result in lower spectral amplifications for all periods.

The effect of damping, however, is more pronounced for high frequency motion. Hence, PGA is more significantly affected by soil damping. The consequences of the shift toward longer site periods depend on the soil type and the input motion. For some sites, the site period may be shifted toward periods containing high-energy input motion, resulting in large spectral amplification factors with an associated increase in PGA. Conversely, the site period may be shifted to periods where the energy of the input motion is low, resulting in large spectral amplification at long periods associated with a decrease of amplification for short periods. This may result in lower levels of PGA, and possibly even in attenuation of PGA.

The site classification system proposed by Rodriguez-Marek et al. (2001) is an attempt to encompass the factors affecting seismic site response while minimizing the amount of data required for site characterization. The site classification system is based on two main parameters and two secondary parameters. The primary parameters are the following:

(1) Type of deposit, e.g., hard rock, competent rock, weathered rock, stiff soil, soft soil, and potentially liquefiable sand. These general divisions introduce a measure of stiffness, i.e., average shear wave velocity, to the classification system. However, a generic description of a site is sufficient for classification, without the need for measuring shear wave velocity over the upper 30.0 m, $V_{s,30}$.

(2) Depth to bedrock or depth to a significant impedance contrast.

The secondary parameters are depositional age and soil type. The former divides soil sites into Holocene or Pleistocene groups, the latter into primarily cohesive or cohesionless soils. These subdivisions are introduced to capture the anticipated different nonlinear responses of these soils. Tab. 2 summarizes the site classification scheme.

Rodriguez-Marek et al. (2001) concluded that the proposed classification system is based on a general geotechnical characterization of the site, including the depth to bedrock. They found that the proposed classification system resulted in a reduction in standard deviation when compared with a simpler "rock vs. soil" classification system. Their results showed that the sites previously grouped as "rock" can be subdivided into rock sites and weathered soft rock/shallow stiff soil sites, resulting in an improved site categorization system for defining site-dependent ground motion. They also showed that the development of an attenuation relationship based on the proposed site classification scheme is necessary. With this new relationship, they found that the spectral acceleration values for a site could be estimated directly without the use of amplification factors.

Table 2. Geotechnical site categories by Rodriguez-Marek et al. (2001).

Site	Categories
A	Hard rock
B	Rock
C	Weathered/Soft rock or shallow stiff soil
D	Deep stiff soil
E	Soft clay
F	Special, e.g., liquefiable sand

Site	Description	Site period	Comments
A	Hard rock	≤ 0.1 s	Hard, strong, intact rock; $V_s \geq 1500$ m/s
B	Rock	≤ 0.2 s	Most "unweathered" California rock cases; $V_s \geq 760$ m/s or < 6.0 m of soil
C – 1	Weathered/Soft rock	≤ 0.4 s	V_s ~ 360 m/s increasing to more than 700 m/s, 6.0 m < weathered zone < 30.0 m
– 2	Shallow stiff soil	≤ 0.5 s	Soil depth > 6.0 m and < 30.0 m
– 3	Intermediate depth stiff soil	≤ 0.8 s	Soil depth > 30.0 m and < 60.0 m
D – 1	Deep stiff holocene soil, either S (Sand) or C (Clay)	≤ 1.4 s	Soil depth > 60.0 m and < 210.0 m. Sand has low fines content (< 15%) or non-plastic fines (PI < 5). Clay has high fines content (> 15%) and plastic fines (PI > 5)
– 2	Deep stiff pleistocene soil, S (Sand) or C (Clay)	≤ 1.4 s	Soil depth > 60.0 m and < 210.0 m. See D_1 for S or C subcategory
– 3	Very deep stiff soil	≤ 2.0 s	Soil depth > 210.0 m
E – 1	Medium depth soft clay	≤ 0.7 s	Thickness of soft clay layer 3.0–12.0 m
– 2	Deep soft clay layer	≤ 1.4 s	Thickness of soft clay layer > 12.0 m
F	Special, e.g., potentially liquefiable sand or peat	~ 1.0 s	Holocene loose sand with high water table ($z_w \leq 6.0$ m) or organic peats

- Deep stiff soil
  - Depth > 60 m
    - D1 Holocene
    - D2 Pleistocene
    - Dc Mostly cohesive
    - Ds Mostly cohesionless
- C category
  - C1 Weathered bedrock
  - C2 Hallow stiff soil over competent bedrock (6 m < depth < 30 m)
  - C3 Stiff soil (30 m < depth < 60 m)

5. Discussion

Finding the soil deposit depth is not only a matter of philosophy, but also a matter of ground investigation expenses, which may strongly influence every investment budget. When asked "to which depth should be the V_s recorded?", Dr. Neven Matasovic, a consulting engineer practicing in California (Matasovic, 2008), replied: "It depends. If you measure the shear wave velocities by either

Spectral Analysis of Surface Waves (SASW, the preferred method) or REMI, there is no reason to limit the investigation to the top 30 m. Both of these methods can easily reach 100 m or more, provided that there are no special constraints for placement of geophones during measurements. This is important as the site response analysis requires the V_s profile be above the bedrock. What we are talking about are the code requirements that call for the soil type to be established based upon V_s (or SPT N) in the top 100 ft (30 m). The 30 m value has been selected because of practicality – the majority of site exploration is terminated within 30 m (except for major structures), so why bother? Microzonation should be based upon code requirements. That includes the identification of soil type 'F' zones as well (soil type F, in UBC 1997 and IBC 2006 roughly corresponds to EC8 types S1 and S2). 'Refining' within the 'F' zones does not make sense, as whoever builds in these zones has an option to improve the subgrade and/or to recommend pile foundations, deep excavation/basement, etc., so what is the point of refining within the 'F' zones?"

A building code is a compromise between the research knowledge and the professional skills on one hand and the political will on the other. The acceptable local seismic hazard is a political decision regarding the level of protection, which depends on the amount of money that should be devoted to seismic risk mitigation, rather than a technical evaluation prescribed by a building code (Maugeri and Massimo, 2001).

The seismic hazard, evaluated as design ground acceleration at the bedrock, is usually prescribed by the national codes, such as the Italian Code (D. M. 16 January, 1996) and the French Code (AFPS, 1990) for Europe. However, the new trends are that the design ground acceleration be prescribed by the local authorities (D. L. 13 March, 1998), such as the Sicilian Region in Italy, which must promote a local code for seismic zonation of Sicily, according to the acceptable local seismic hazard chosen by the Sicilian community. Moreover, the design ground acceleration could be prescribed by the local special codes for the rehabilitation of historical monuments and cultural heritage, such as in the case of the seismic improvement of the Noto cultural heritage and monuments damaged by the 1990 Sicilian earthquake (Sicilian Region, 1999). The monuments need a special code because a seismic retrofitting to resist a design ground acceleration given by the national building codes is not possible; however, when the old technologies are used, only rehabilitation linked to an acceptable acceleration is possible.

The design spectrum acceleration at the bedrock given by national, local or special codes is affected by many uncertainties; so, the possibility of a more careful alternative evaluation must be considered in the new trends in the codes. The statistical evaluation of design spectrum is based on historical seismicity and seismic catalogues. Historical seismicity data are numerous in Italy because of the historical documents dating back to the Greek and Roman civilizations. The historical data can allow the mapping of the isoseismic lines of the most destructive earthquakes.

6. Conclusion

On its way to joining the European Union, the Republic of Croatia is required to accept the Eurocodes and to provide relevant National Annexes. Probably the most challenging (and expensive) task will be to prepare the National Annex for Eurocode 8 because it calls for the inclusion of seismic hazard maps based upon peak ground acceleration for defined return periods (in large scale) and maps of this peak ground acceleration influenced by the local site conditions, or microzonation (in small scale). The local site conditions are represented by the ground types, which depend on $V_{s,30}$ and some other geotechnical characteristics.

In the paper, the authors list some drawbacks to EC8, such as the ground types, and give their arguments for reconsidering the parameters that define soil characterization. The authors suggest that the Croatian engineering community organize preparatory works for seismic-geotechnical zonation for Croatia in a way that they could be the basis not only for the ground types of the temporary version of EC8 but also for any other rationally based ground-type characterization.

Ignoring the soil depth may introduce an undesirable level of uncertainty in the influence of local soil conditions on ground motion prediction. In addition to ground motion prediction, using the average shear wave velocity $V_{s,30}$ over a set of 30 m depth, as recommended in EC8, to classify a site has the advantage of uniformity. However, the seismic site response is also a function of the soil depth, as shown in Figure 2. Thus, ignoring the soil depth may introduce an undesirable level of uncertainty in ground motion prediction (Rodriguez-Marek et al., 2001).

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SAŽETAK

Geotehnička klasifikacija tla i hrvatski Nacionalni dodatak Eurokodu 8

Predrag Kvasnička, Leo Matešić i Krešo Ivandić

U postupku pristupanja Europskoj uniji, jedna od obaveza Republike Hrvatske je da, u sklopu Nacionalnog dodatka za Eurokod 8, izradi karte seizmičkog hazarda. Te karte treba izraditi za nekoliko povratnih razdoblja (perioda) i to, za potresnu pobudu na osnovnoj stijeni i na površini tla. Ovo drugo uključuje i definiranje osobina slojeva tala na određenoj lokaciji, tzv. mikrozonaciju, i to na temelju brzina posmičnih elastičnih valova, $V_{s,30}$, broja udaraca standardnog penetracijskog pokusa, *SPT* i nedrenirane čvrstoće tla, podataka koji se mogu naći u arhivama gradskih uprava. U članku autori razmatraju klasifikaciju tipova tala za mikrozonaciju, kako ih definira Eurokod 8, i iznose neke nedostatke takve podjele, te predlažu određene izmjene. Autori također prezentiraju i neke elemente Hrvatskog nacionalnog dodatka za EC8.

Ključne riječi: odziv lokalnog tla, tipovi tala, Eurokod 8

Corresponding author's address: Predrag Kvasnička, University of Zagreb, Faculty of Mining, Geology and Petroleum Engineering, Pierottijeva 6, Zagreb, Croatia, tel: +385 (0)1 5535 882, fax: +385 (0)1 4836 051, e-mail: pkvasnic@rgn.hr