Evaluation of seismic analysis procedures for seismic actions: A Comparative study between Eurocode 8 and KTP-89

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ABSTRACT

The objective of this paper is to address the seismic design considerations for a case study building by using Eurocode 8 and the Albanian seismic code KTP-89 regulations. The parameter which is taken into account in this study is the design spectrum defined in each of the two codes. Basic differences exist between the two design spectra, such as the site coefficients, the spectral shape of the spectrum and also the integration by Eurocode 8 of the near and far field concept. The effects of these differences are studied by considering the different types of soils on a case study building. The obtained results on the base shear are compared and important differences between the two codes approach are discussed.

Keywords: *Seismic analysis, design spectrum, modelling, Eurocode 8, KTP-89.*

1. INTRODUCTION

During last two decades, seismic codes in many European countries have been revised and updated, especially after some destructive earthquakes. Albanian seismic code [KTP-89] [1] is expected to undergo a revision in a near future after the implementation of the adoption to Eurocode norms.

The earthquake resistance consideration for building design in Albania has a history of nearly five decades. The first version of Albanian code has started as a legal provision (KTP – 63) in 1963. It, than was modified in KTP – 78 in 1978 and the last development made to these codes was in 1989 with KTP – 89 which is still in force.

Both Eurocode 8 (EC8) [2] and KTP – 89 codes take into account site effects by introducing different categories of sites. The Eurocode 8 defines five main types of soil and two special types with a soil factor "S" for each type, whereas KTP-89 considers three types without soil factor. It is known that the site classification system is based on definitions of mean shear waves velocity, standard penetration test, unconfined compression test, and relative density. Shear wave velocity V_S–30 was suggested as a tool of classifying sites for building codes [3]. Table 1 shows the different soil types in both codes with shear wave velocity and the values of site factor "S" for spectra type 1 and type 2 of EC8.

Table 1. Ground types defined in Eurocode 8 and KTP-89

Eurocode 8				KTP-89
Soil Type		Type 1	Type 2	Soil Type
Rock (A)	Vs,30>800 m/s	S=1	S=1	Rock (I)
Firm (B)	360<Vs,30<800 m/s	S=1.2	S=1.35	Stiff (II)
Soft (C)	180<Vs,30<360 m/s	S=1.15	S=1.5	Soft (III)
Very soft (D)	Vs,30< 180 m/s	S=1.35	S=1.8	

2. COMPARISON OF DESIGN SPECTRA

The design spectrum is an important parameter in the seismic codes. Most of the seismic design is based on representing the earthquake induced actions in the form of an equivalent static force exerted on building structures. These forces are specified from the maximum acceleration response of the structure which is represented by acceleration response spectrum or displacement spectrum. Soil condition, epicentral distance, magnitude, duration, and source characteristics influence the shape and amplitudes of response spectra. The purpose of representing earthquake forces in seismic codes such as EC8 is to circumvent the necessity of carrying out a site-specific seismic hazard analysis for various engineering projects in earthquake prone regions [4]. While the effects of some parameters may be studied independently, the influences of several factors are interrelated and cannot be discussed individually. Damping ratio and structural vibration period can be counted as the other parameters affecting the response spectra.

Both design codes present zonation maps and response spectra for seismic design. In EC8 two types of spectra are defined: Type 1 for the far field and Type 2 for the near field. If the earthquakes that contribute most to the seismic hazard defined for the site for the purpose of probabilistic hazard assessment have a surface-wave magnitude, M_s not greater than 5.5, it is recommended that the Type 2 spectrum is adopted, if not, Type 1 is recommended [2]. KTP-89 defines only one type of spectra depending on seismic zone and some other factors.

The ordinates of elastic design spectra for both codes are illustrated by their expressions in Table 2. In this table, β shows lower bound factor for the horizontal design spectrum, recommended value for β is 0.2. Seismic hazard is expressed in EC8 by a parameter namely reference peak ground acceleration at the rock surface for a reference return period. The reference return period recommended for the non-collapse performance level is the 475 year, corresponding to 10% probability of exceedance in 50 years. In EC8 the design ground acceleration (a_g) is equal to times the importance factor γI. The Albanian seismic code subdivides the territory into zones of increasing seismicity according to the seismic intensity scale (MSK-64). For seismic design purposes only the zones with seismic intensities between VII and IX are considered as: Intensity VII zone: low seismicity, Intensity VIII zone: moderate seismicity, Intensity IX zone: high seismicity. It defines a coefficient of zone acceleration “ranging from 0.08 to 0.42” according to the seismic zone and soil category.

In Table 2, S is the soil factor defined in EC8 depending on ground types and η is the damping correction factor with a reference value of $\eta = 1$ for 5% viscous damping. Elastic design spectra are drawn as shown in Fig.1 using the expressions shown in table 2 for the soil types defined in the respective codes. Since the studied building is located in a moderate seismicity zone according to the Albanian seismic zonation map, response spectra is given only for moderate seismicity for KTP-89.

Table 2. Ordinates of spectra for EC8 and KTP-89

Eurocode 8

$0 \leq T \leq T_B$

$$Se = a_g \cdot S\left[1 + \frac{T}{T_B}(2.5 \cdot \eta - 1)\right]$$

$T_B \leq T \leq T_C$

$$Se = a_g \cdot S \cdot 2.5 \cdot \eta$$

$T_C \leq T \leq T_D$

$$Se = a_g \cdot 2.5 \cdot \eta \cdot S\left[\frac{T_C}{T}\right]$$

$T_D \leq T \leq 4s$

$$Se = a_g \cdot 2.5 \cdot \eta \cdot S\left[\frac{T_C T_D}{T^2}\right]$$

Corner Periods of design spectra defined in EC8

Soil type A
Type 1: $T_B = 0.15$, $T_C = 0.4$, $T_D = 2$
Type 2: $T_B = 0.05$, $T_C = 0.25$, $T_D = 1.2$

Soil type B
Type 1: $T_B = 0.15$, $T_C = 0.5$, $T_D = 2$
Type 2: $T_B = 0.05$, $T_C = 0.25$, $T_D = 1.2$

Soil type C
Type 1: $T_B = 0.2$, $T_C = 0.6$, $T_D = 2$
Type 2: $T_B = 0.1$, $T_C = 0.25$, $T_D = 1.2$

Soil type D
Type 1: $T_B = 0.2$, $T_C = 0.8$, $T_D = 2$
Type 2: $T_B = 0.1$, $T_C = 0.3$, $T_D = 1.2$

Soil type E
Type 1: $T_B = 0.15$, $T_C = 0.5$, $T_D = 2$
Type 2: $T_B = 0.05$, $T_C = 0.25$, $T_D = 1.2$

KTP-89

$$S_a = k_E \cdot k_r \cdot \psi \cdot \beta \cdot g$$

k_r – building importance coefficient (Table 5 of KTP)

ψ – structural coefficient (Table 4 of KTP-89)

g – gravitational constant

- Soil category I

$$0.65 \leq \beta_i = \frac{0.7}{T_i} \leq 2.3$$

- Soil category II

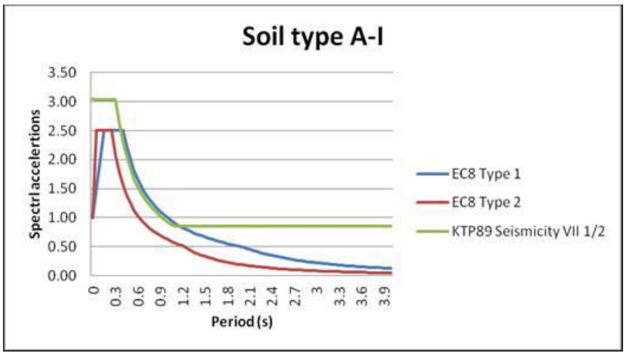
$$0.65 \leq \beta_i = \frac{0.8}{T_i} \leq 2.0$$

- Soil category III

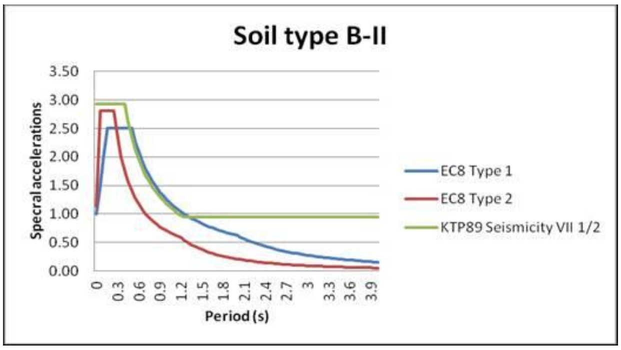
$$0.65 \leq \beta_i = \frac{1.1}{T_i} \leq 1.7$$

k_e table	Seismic Intensity (MSK-64)		
Soil type	VII	VIII	IX
I	0.08	0.16	0.27
II	0.11	0.22	0.36
III	0.14	0.26	0.42

Fig.1 shows the design spectra proposed respectively by the Eurocode 8 and the KTP-89. As mentioned previously, there are some differences as well on the spectral form as on the spectral amplitude. The KTP-89 neglect the soil factor and considers the same spectral amplitude peak values for the three soil types, while the EC8 gives different spectral amplitudes taking account the soil factor and the near and far fields.



(a)



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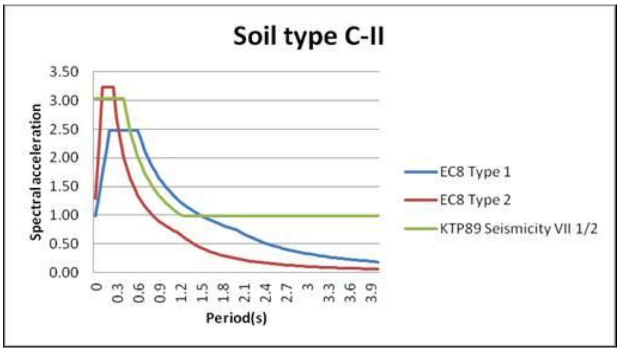

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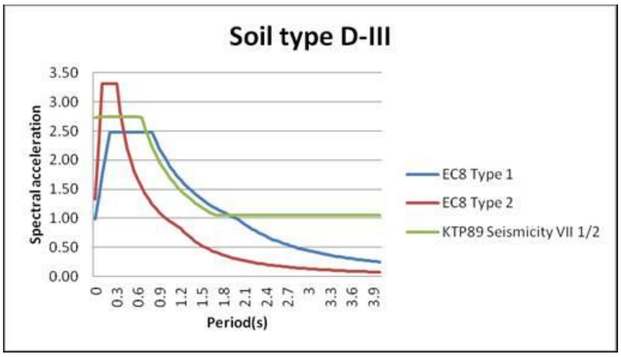

(d)

Figure 1 (a, b, c, d). Elastic design spectra defined in EC8 and KTP-89

3. DESCRIPTION OF CASE STUDY STRUCTURE AND FINITE ELEMENT MODELLING

The building taken in consideration in this study is an 8 story frame-shear wall structure. The total height of the building is 25.2 m and the stories have an elevation of 3.15 m. The building has dimensions of 13.85 m and 27.85 m in plan.

To evaluate the seismic response of the building, elastic analyses were performed by the response spectrum method using the software ETABS [5]. The seismic analyses of the building are carried out separately in the longitudinal and the transverse directions. Sample finite element model is shown in Fig.2.

The beams and columns were modelled using frame elements while the walls were modelled using shell elements. Slabs were considered as rigid diaphragms at each story elevation. The unit weight of concrete is taken as 25 KN/m^2, and the Young's modulus 28000 MPa. The damping ratio is assumed as 5% in all modes. The building is sited in a moderate seismicity zone according the KTP-89 code's seismicity map and also according to the definitions given in the building's technical report. Reference peak ground acceleration is taken to be 0.25g that is recommended [6], and the same value is taken for EC8 to make the comparison.

4. SEISMIC ANALYSIS OF THE CASE STUDY BUILDING

The mode numbers taken into account for this building is 12. Modes with the corresponding periods and participating mass ratios of the building are presented in Table 3. First and third modes of the building vibrate respectively in the *y* and *x* direction. The second mode takes place as torsion mode.

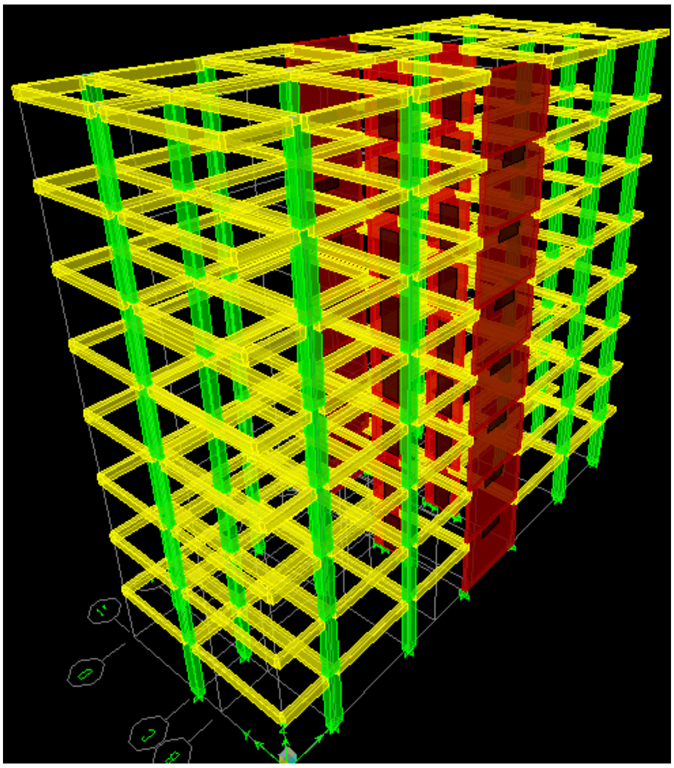

Figure 2. 3D View of three dimensional finite element model of the building

Table 3. First twelve modes and modal participating ratios of the building

		Individual mode (%)			Cumulative sum (%)		
Mode	Period	U_x	U_y	U_z	U_x	U_y	U_z
1	0.984243	0.0256	72.3146	0	0.0256	72.3146	0
2	0.876388	1.081	0.6764	0	1.1066	72.991	0
3	0.633609	68.022	0.005	0	69.1286	72.996	0
4	0.263984	0.0062	13.328	0	69.1348	86.324	0
5	0.221446	0.1016	0.3457	0	69.2364	86.6697	0
6	0.144224	17.7064	0.0005	0	86.9428	86.6702	0
7	0.116628	0.003	5.6607	0	86.9458	92.3309	0
8	0.096600	0.0161	0.2599	0	86.9619	92.5907	0
9	0.064543	0.0004	2.8841	0	86.9623	95.4748	0
10	0.060226	6.7725	0.0012	0	93.7347	95.476	0
11	0.055737	0.0092	0.3495	0	93.7439	95.8254	0

12	0.041753	0.0002	1.2651	0	93.7441	97.0906	0

As shown from Table 3, only seven modes give a cumulative sum of the participating ratios greater than 90% for *y* and ten modes for *x* directions.

The base shears of the building were obtained from seismic analysis using the design spectra corresponding to 5% critical damping and considering fixed base condition. Seismic analyses of building were carried out for each type of soils defined in KTP-89 and their equivalent in EC8. Fig.3 presents the base shears of the building. Horizontal axis represents the soil types in both codes. As it is shown in Table.1, soil classification differs in both codes. Regarding the KTP-89 soil classification, it is decided that Soil type II corresponds to “B” and “C” in EC8, whereas Soil I matches with Soil Type “A” and Soil type III with “D”.

As seen from Fig.3, base shears become more important for soft soils because of the low fundamental frequency of the building. The results show also that EC8 type 1 gives the maximum base shears for all soil types, because the ordinate of spectra of fundamental period of the building which is 0.98s is more important for EC8 type 1, whereas EC8 type 2 gives values of base shear closer to KTP-89 only for very soft soil (soil type D-III), which can be explained by the importance of soil factor defined by EC8 for this soil type which is equal to 1.8. This result shows the importance of taking far field earthquake (Type1) when we deal with flexible structures.

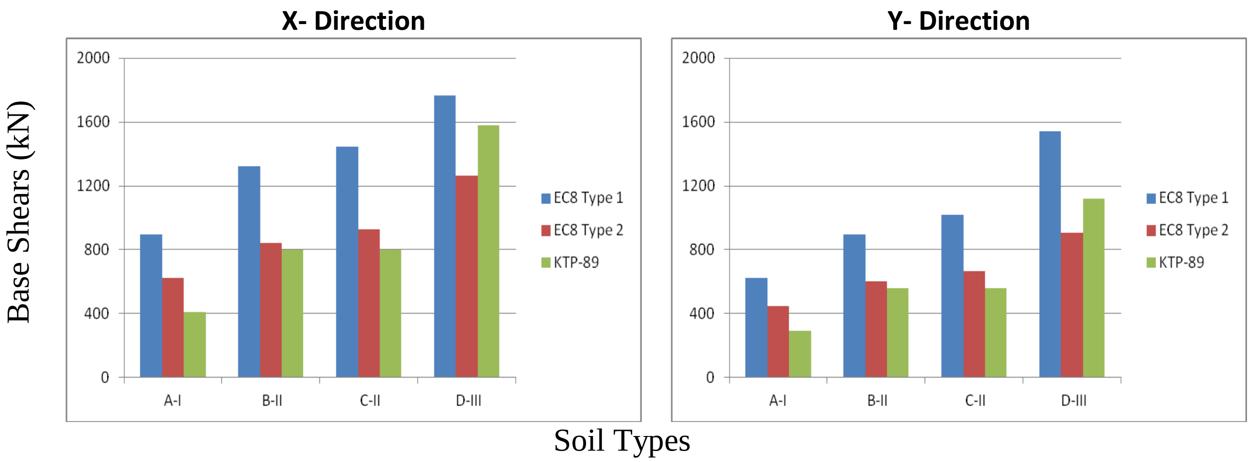

Figure 3. Base shear of the building considering four types of soil

5. CONCLUSIONS

This study evaluates the seismic analysis of a representative case study building which is common in Albanian RC building stock. Design spectrum is considered as a parameter in the seismic analysis. EC8 and KTP-89 design spectra are compared and the differences are discussed. EC8 takes into account two important parameters which is not the case of KTP-89: site effect by introducing site factor *S*, and near and far field.

Base shear demands increase when soil gets softer, so the maximum value is given for soil type D-III (very soft soil). EC8 type 1 gives the maximum base shear values for all ground types. KTP-89 shows base shear values lower than EC8 Type 2 except in the case of D-III, this is because of the importance of k_E factor for this soil type.

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