Comparative analysis of dynamic solutions using Albanian Seismic Code KTP-89 and Eurocode 8

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ABSTRACT

The scope of this presentation is to compare some of principal characteristics of structural dynamic responses computed using Earthquake Resistant Design Regulations KTP-N.2-89, (Albanian Seismic Code) and Eurocode 8 (prEN 1998-1). In this paper are mentioned some of the principal differences between two codes, comprising mainly: Seismic Intensity Classification according to Seismic Zonation Map of Albania, Identification of Ground Types, Reference Peak Ground Acceleration, Elastic and Design Response Spectrum used to present earthquake motion at a given point on the surface. Spectrum Analysis (horizontal and vertical direction), Analysis Methods, etc.

The comparative results of two codes issued by dynamic analysis of reinforced concrete dual system structure chosen are presented along with respective conclusions.

Keywords: *seismic, spectrum, shear, displacement, acceleration*

INTRODUCTION

The Balkan region is one of the world’s most active seismic zones and one in which earthquakes caused heavy losses of life and property throughout history.

In 1970, the countries of the region (except Albania) undertook projects REM/70/172 and REM/74/09 under assistance of UNDP and UNESCO, a survey of seismicity of the region, as a result of which observatory networks and detailed studies of seismicity are improved. Albania took part not formally in some of these activities.

After catastrophic earthquake of 15.04.1979 in Montenegro and northern Albania, the immediate request in developing further earthquake studies was finalized through Project Document RER/79/014/C/01/13 signed by UNDP and UNESCO, where Albania officially joined in November 1981. The project defined the primary long-term and immediate objectives in development of scientific methods for earthquake-resistant design of buildings.

As it is known the most important natural hazard in Albania is earthquake. Thus, the ways and means of reducing consequences from earthquakes is of vital importance.

As result the first seismic code in Albania officially known as Earthquake Resistant Design Regulations KTP-N.2-89, (Albanian Seismic Code) was prepared by Seismic Center, Academy of Science of Albania, Department of Design, Ministry of Construction, Tirana, Albania 1989.

The european standards approved by CEN (European Committee for Standardization) establish a set of harmonised technical rules for the design of buildings. Through standards approved, Eurocode 8 consists of technical rules applied to the design and construction of buildings in seismic regions.

Their overall goal is to make such structures more resistant to earthquakes. Seismic design codes help structural engineers to design structures that will not be damaged in minor shaking and will avoid serious damage or collapse in a major earthquake.

The philosophy of earthquake design for structures other than essential facilities has been well established and proposed as follows:

- to prevent non- structural damage in frequent minor ground shaking
- to prevent structural damage and minimize non- structural damage in occasional moderate ground shaking.
- To avoid collapse or serious damage in rare major ground shaking

The design seismic action is expressed in terms of:

a) the reference seismic action $\mathbf{a_{gR}}$, associated with a reference probability of exceedance, P_{NCR}, in 50 years or a reference return period, T_{NCR}, and

b) the importance factor $\boldsymbol{\gamma_I}$, to take into account reliability differentiation. An importance factor γ_I is assigned to each importance class.

The scope of this paper is to compare Earthquake Resistant Design Regulations KTP-N.2-89, (Albanian Seismic Code) with Eurocode 8 (EC-8).

In advance, there are some of the principal difference between two codes:

- Classification of Seismic Intensity and division of Albanian Seismic Zone
- Classification of Soil Category
- Spectrum Analysis, (horizontal and vertical direction)
- Classification of structures for importance coefficient.
- Methods of analysis
- Load combination
- Design of Foundation
- Classification of Ductility
- Seismic control joints
- Detailing rules

1. SOME PRINCIPAL RULES ACCORDING TO EC- 8 AND KTP-89

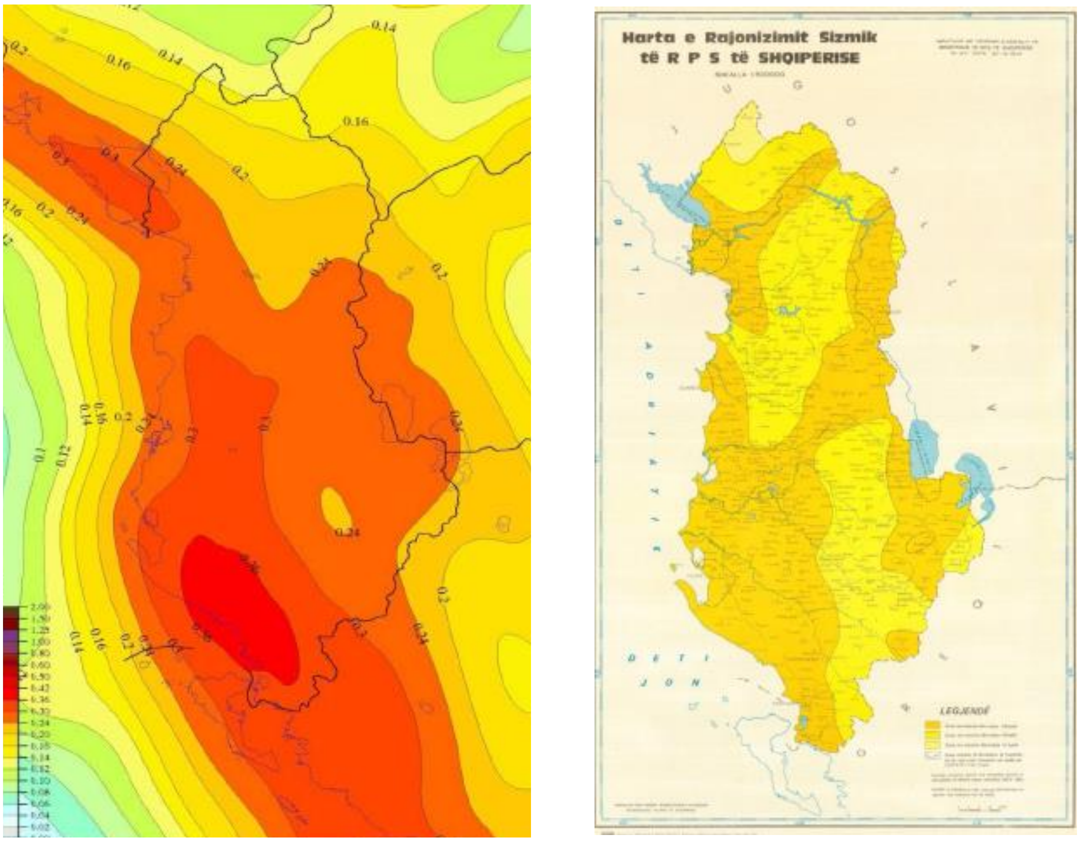
1.1 Classification of Seismic Intensity and division of Albanian seismic Zone

For the purpose of EN 1998, national territories shall be subdivided by the National Authorities into seismic zones, depending on the local hazard. By definition, the hazard within each zone is assumed to be constant.

For most of the applications of EN 1998, the hazard is described in terms of a single parameter, i.e. the value of the reference peak ground acceleration on type A ground, a_{gR}.

The reference peak ground acceleration, chosen by the National Authorities for each seismic zone, corresponds to the reference return period T_{NCR} of the seismic action for the no-collapse requirement (or equivalently the reference probability of exceedance in 50 years, P_{NCR}) chosen by the National Authorities. An importance factor γ_I equal to 1,0 is assigned to this reference return period. For return periods other than the reference, the design ground acceleration on type A ground a_g is equal to a_{gR} times the importance factor γ_I ($a_g = \gamma_I . a_{gR}$).

In Earthquake Resistant Design Regulations KTP-N.2-89, (Albanian Seismic Code) the division in zone of Albanian map is made by intensity seismic scale MSK-64. There are three seismic intensity category VII, VIII, IX (MSK-1964). (Fig. 1b). A probabilistic seismic hazard map of Albania, (Fig. 1a) is presented by Duni & Kuka in 2010 from Albanian Seismic Center.



a) b)

Figure 1. a) Probabilistic seismic hazard map of Albania (Duni & Kuka 2010)
a_{gR} - reference peak ground acceleration; T_{NCR} =475 years, P_{NCR}=10%
b) Seismic zonation map of Albania (Sulstarova 1980)

1.2. Classification of Soil Category

Ground types A, B, C, D, and E, in Eurocode 8 are described by the stratigraphic profiles and parameters given in Table 3.1 (prEN 1998), may be used to account for the influence of local ground conditions on the seismic action. This may also be done by additionally taking into account the influence of deep geology on the seismic action.
In Earthquake Resistant Design Regulations KTP-N.2-89, (Albanian Seismic Code) the classification of soils is made by 3 category; (I, II, III-d category of soils according to Table 1 KTP-89)

1.3. Spectrum Analysis, (horizontal and vertical direction)

In Eurocode 8 spectrum analysis is divide in Horizontal elastic response spectrum and Vertical elastic response spectrum.
The values of the periods T_B, T_C and T_D and of the soil factor S describing the shape of the elastic response spectrum depend upon the ground type (Table 3.2 prEN 1998).
The vertical component of the seismic action shall be represented by an elastic response spectrum, $S_{ve}(T)$. (Table 3.4 prEN 1998)
In KTP-89 vertical response spectrum is equal to horizontal response spectrum multiply by coefficient 2/3.

1.4. Design ground displacement

According to EC-8, the design ground displacement d_g, corresponding to the design ground acceleration, may be estimated by expression:

$d_g = 0{,}025 \cdot a_g \cdot S \cdot T_C \cdot T_D$ with a_g, S, T_C and T_D as above.

Displacement according to KTP-89 $u_{ki} = k_E \cdot k_r \cdot \psi \cdot \beta_i \cdot \eta_{ki} \cdot g \cdot (T_i/2\pi)^2$

1.5. Classification of structures for importance coefficient.

Buildings are classified in 4 importance classes (prEN-1998), depending on the consequences of collapse for human life, on their importance for public safety and civil protection in the immediate post-earthquake period, and on the social and economic consequences of collapse. The importance classes are characterized by different importance factors $\boldsymbol{\gamma}_I$.
Table 4-a in KTP-89 gives the building importance coefficient $\mathbf{k_r}$, where the buildings are classified in V category.

1.6. Methods of analysis

The seismic effects and the effects of the other actions included in the seismic design situation may be determined on the basis of the linear-elastic behavior of the structure.
- The reference method for determining the seismic effects shall be the modal response spectrum analysis, using a linear-elastic model of the structure and the design spectrum.
- Depending on the structural characteristics of the building one of the following two types of linear-elastic analysis may be used:
a) the “lateral force method of analysis”
b) the “modal response spectrum analysis", which is applicable to all types of buildings
- As an alternative to a linear method, a non-linear method may also be used, such as:
c) non-linear static (pushover) analysis;
d) non-linear time history (dynamic) analysis,
In general the horizontal components of the seismic action shall be taken as acting simultaneously.

a) E_{Edx} "+" $0{,}30E_{Edy}$ b) $0{,}30E_{Edx}$ "+" E_{Edy}

E_{Edx}, E_{Edy} - action effects due to the application of the seismic action along the chosen horizontal axis x, y respectively of the structure;
If the structural system or the regularity classification of the building in elevation is different in different horizontal directions, the value of the behavior factor $\boldsymbol{q}$ may also be different.
The sign of each component in the above combinations shall be taken as being the most unfavorable for the particular action effect under consideration.

1.7. Load combination

In Albanian Seismic Code**,** in combinations of actions for seismic design situations partial factors are defined as follows:
seismic load partial factor is equal to 1,0.
dead load partial factor is equal to 0,9;
live load (long term) partial factor is equal to 0,8;

live load (short term) partial factor is equal to 0,4 (Table 3, KTP-89)

According to EC-8, the inertial effects of the design seismic action shall be evaluated by taking into account the presence of the masses associated with all gravity loads appearing in the following combination of actions:

$\Sigma G_{k,\ j}$ "+" $\Sigma\psi_{E,i} \cdot Q_{k,i}$) where $\psi_{E,i}$ is the combination coefficient for variable action i . (Recommended values of $\psi_{E,i}$ factors for buildings Table A1.1 peEN-1990)

The combination coefficients $\psi_{E,i}$ take into account the likelihood of the loads Q_k,i not being present over the entire structure during the earthquake. These coefficients may also account for a reduced participation of masses in the motion of the structure due to the non-rigid connection between them.

2. ANALYSIS OF REINFORCED CONCRETE STRUCTURES

In the example below it is shown the dynamic analyses results of dual reinforced concrete system for the building structure.

Dynamic analysis

Active loads that are taken into account are:

- Dead Load DL G
- Live Load LL P
- Seismic Load EL S

Load combinations

In addition to the dead load G and live load P, the structure is subjected to earthquake forces S, and considering that earthquake forces are subject to reversals, the following load combinations might have to be considered:

1.35 DL + 1.50 LL (EC2 2.3.3)

1.0 DL + 1.5·0.3 LL ±1.0 EL (EC2 2.3.3)

These default loading combinations are produced for persistent and transient design situations (EC2 2.2.1.2) by combining load due to dead, live, and earthquake loads according to the simplified formula (EC2 2.3.3.1) for ultimate limit states.

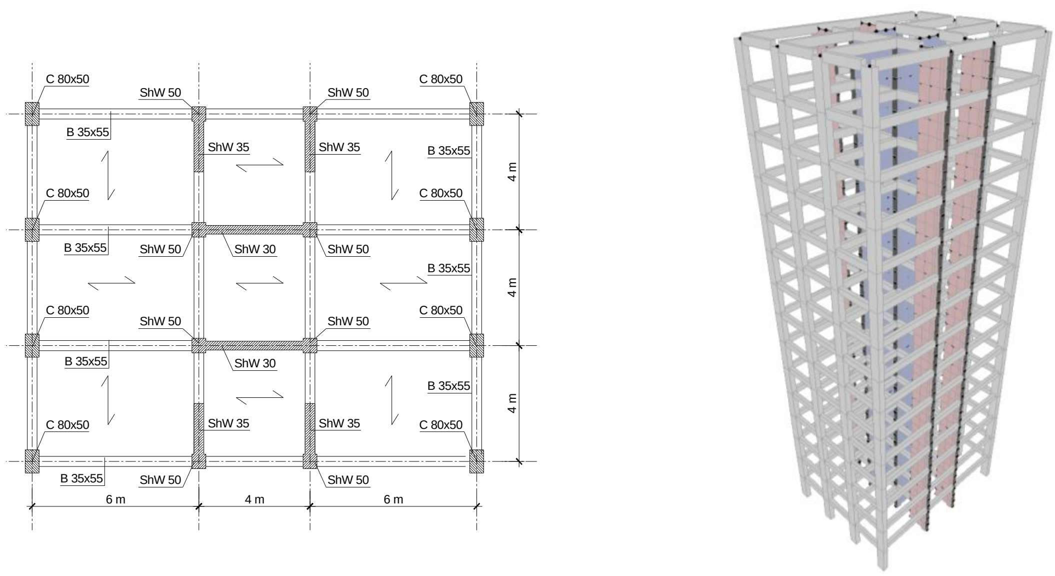


Figure 2. Planimetri and 3D model of reinforced concrete building

Seismic Force according to KTP- N.2-89

Seismic horizontal force in the storey level is defined by formula:

$$E_{ki} = k_E \; k_r \; \psi \; \beta_i \; \eta_{ki} \; Q_k$$

k_E=0.36 - seismic coefficient, (Tab 2, KTP-N.2-89 Albanian Seismic Code) is presented below Table 1.

Table 1. Seismic coefficient according to soil category and seismic intensity (MSK-1964)

Soil category	Seismic coefficient k_E		
	Intensity VII	Intensity VIII	Intensity IX
I	0.08	0.16	0.27
II	0.11	0.22	0.36
III	0.14	0.26	0.42

k_r=1.0 - importance coefficient, Tab 4-a, KTP-N.2-89 Albanian Seismic Code

ψ=0.28 - structure coefficient, Tab 5, KTP-N.2-89 Albanian Seismic Code

βi - dynamic coefficient (Fig.3)

$$1.\; 0.65 \le \beta_i = \frac{0.7}{T_i} \le 2.3 \qquad \textit{for soil category} \quad I$$

$$2.\; 0.65 \le \beta_i = \frac{0.8}{T_i} \le 2.0 \qquad \textit{for soil category} \quad II$$

$$3.\; 0.65 \le \beta_i = \frac{1.1}{T_i} \le 1.7 \qquad \textit{for soil category} \quad III$$

$$\eta_{ki} = \phi_{ki} \frac{\sum_{j=1}^{n} Q_j \phi_{ji}}{\sum_{j=1}^{n} Q_j \phi_{ji}^2}$$ - seismic force distribution coefficient

According to Eurocode 8: for ground type - B, Type 1 elastic response spectra (Tab 3.2 pnEN 1998 we have this values of parameters:

S=1.2, T_B(s)=0.15, T_C(s)=0.5, T_D(s)=2,

for PGA=0.32g, Importance factor γ_I=1, a_g=3.14; Ductility q=3 (Fig.3)

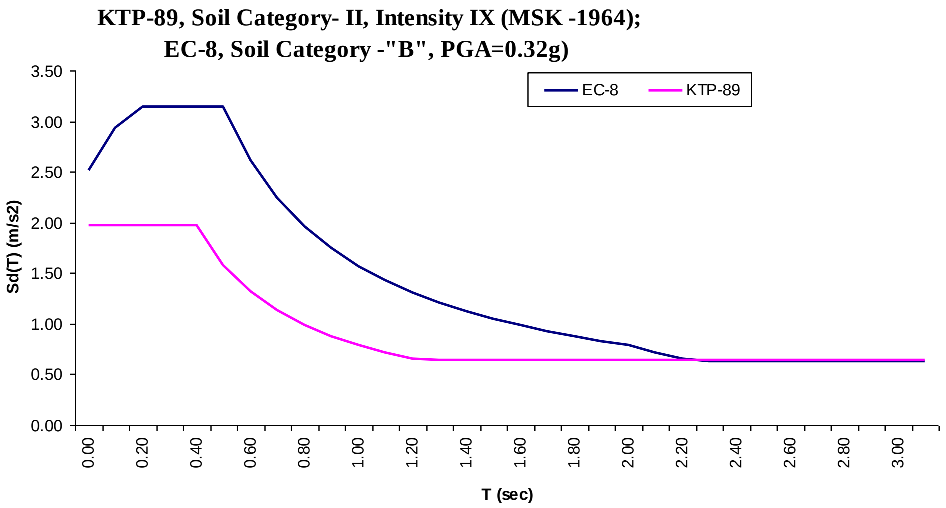


Figure 3. Design response spectrum according KTP-89 & EC-8

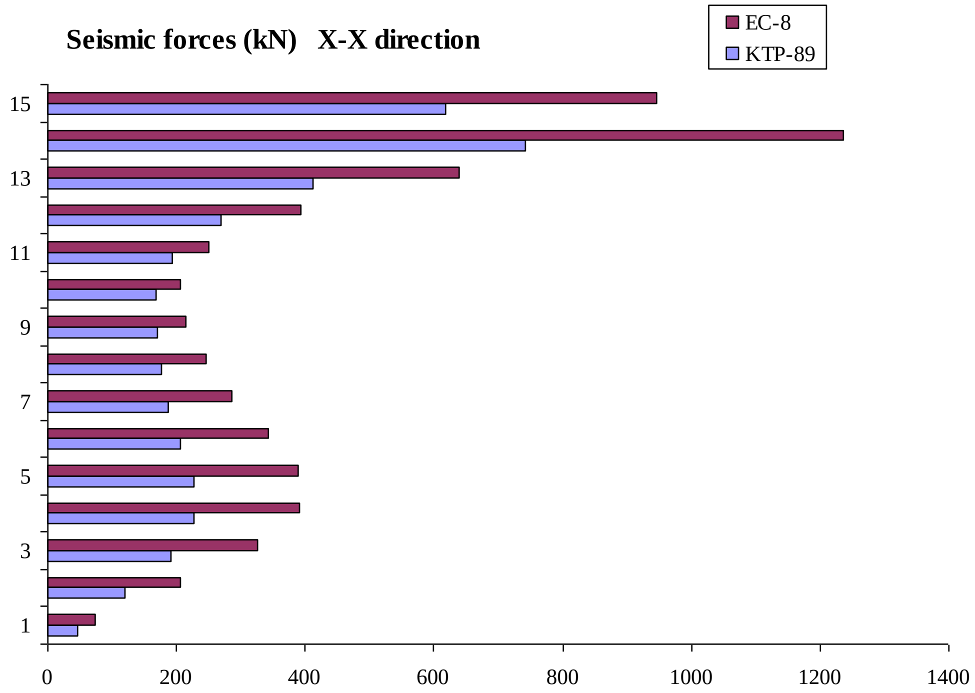


Figure 4. Seismic force in X-X direction according KTP-89 & EC-8

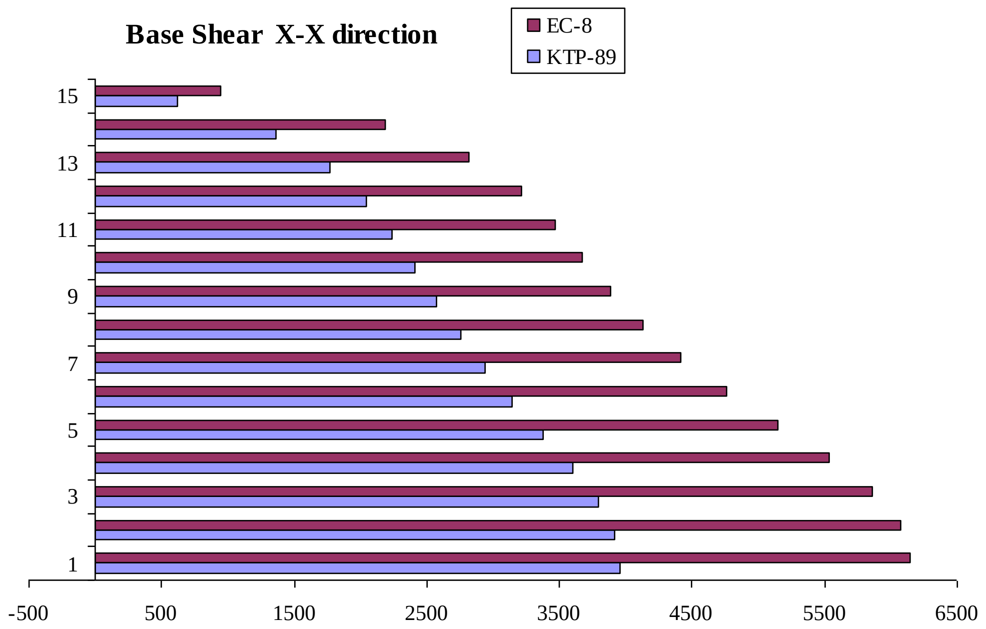


Figure 5. Base shear in X-X direction according KTP-89 & EC-8

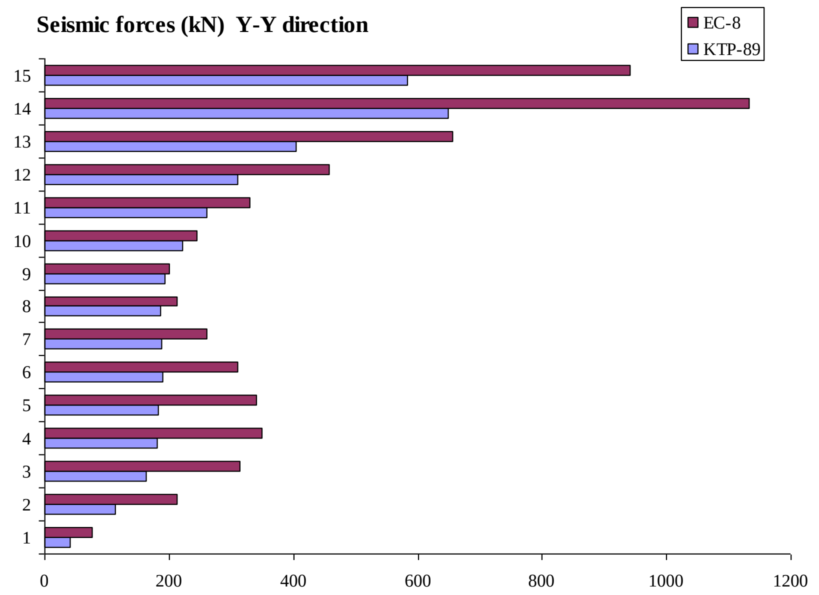


Figure 6. Seismic force in Y-Y direction according KTP-89 & EC-8

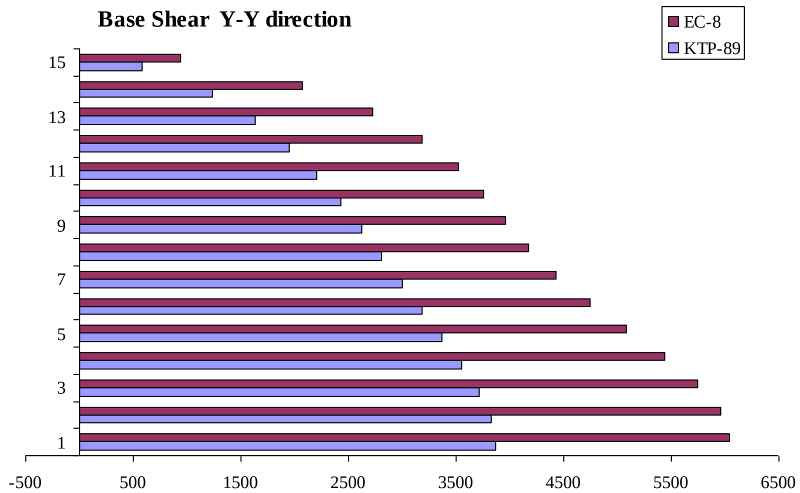


Figure 7. Base shear in Y-Y direction according KTP-89 & EC-8

Table 2. Results for some element in structural model

Elementi 25 (Beam)		
	KTP-89	EC-8
Axial force	0 kN	0 kN
Shear force	21 kN	33 kN
Moment	81 kN×m	123 kN×m

Shear wall		
	KTP-89	EC-8
Axial force	1750 kN	2720 kN
Shear force	2460 kN	3655 kN
Moment	19752 kN·m	30056 kN·m

Elementi 23 (Column)		
	KTP-89	EC-8
Axial force	750 kN	1124 kN
Shear force	31 kN	48 kN
Moment	95 kN·m	146 kN·m

Displacement of the top level		
	KTP-89	EC-8
Joint 1764	6.25 cm	9.36 cm

3. CONCLUSION

- Design response spectrum input values according to Earthquake Resistant Design Regulations KTP-N.2-89, (Albanian Seismic Code), are considerably lower compared to respective values taken of EC-8 formulations. In structures with low values of fundamental frequency this difference is neigligible.
- analyses according to EC-8 presents approximately 30% higher values of seismic loads and base shear in both X,Y horizontal directions compared to respective values based on Earthquake Resistant Design Regulations KTP-N.2-89, (Albanian Seismic Code).
- Generally, structural response under the seismic design situation defined based on EC-8 consists in higher forces and displacements values compared to respective values based on Earthquake Resistant Design Regulations KTP-N.2-89, (Albanian Seismic Code).
- In despite of structural assesement of buildings erected prior to the adaption of Earthquake Resistant Design Regulations KTP-N.2-89, (Albanian Seismic Code), structural examination and reassesement of all buildings according to Eurocode-8 rules must be developed.

Finally, should be mentioned that a properly engineered structure does not necessarily have to be extremely strong or expensive. It has to be properly designed to withstand the seismic effects while sustaining an acceptable level of damage. Basic concepts of the earthquake engineering, implemented in the major building codes, assume that a building should survive a rare, very severe earthquake by sustaining significant damage but without globally collapsing. On the other hand, it should remain operational for more frequent, but less severe seismic events.

4. REFERENCES

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