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SEISMIC REPORT
NATIONAL HISTORICAL MUSEUM

TABLE OF CONTENTS

1. INTRODUCTION

This report presents the seismic risk study for the building of the National Historical Museum in Tirana. The procedure followed to prepare this seismic report is divided into these two stages:
a) determining the category of land and finding the resonance frequency for each object to be built (based on EC 8) by geophysical methods (passive or active).
To determine the category of the plot as well as to find the resonance frequency of the plot were used:
1) Nakamura o spectral ratio method (HVSR).
2) Active seismic method MASW (Multichannel Analysis of Surface Waves)
b) As well as dynamic ground response (RDT)

2. SITE LOCATION

The building of the National Historical Museum is located in the center of Tirana, in the southern part of "Skënderbej" square. The object under study is located in Ded Gjo Luli Street, Tirana.

Fig. 1. View of the position of the National Historical Museum building
(taken from Asig geoportal).

3. ACTIVITY AND SEISMIC HAZARD FOR TIRANA CITY

- According to seismotectonic data, the area of the city of Tirana from a geological point of view occupies the molasses syncline of Tirana, as part of the Pre-Adriatic Lowlands. It is part of the Ionian-Adriatic seismogenic zone, whose terrains are strongly captured by post-Pliocene compressive movements with complicated tectonic structure and which has generated and may generate in the future earthquakes with maximum magnitude of M_{max} = 5.3–5.6 (Aliaj, et al., 1996) (Fig. 2).

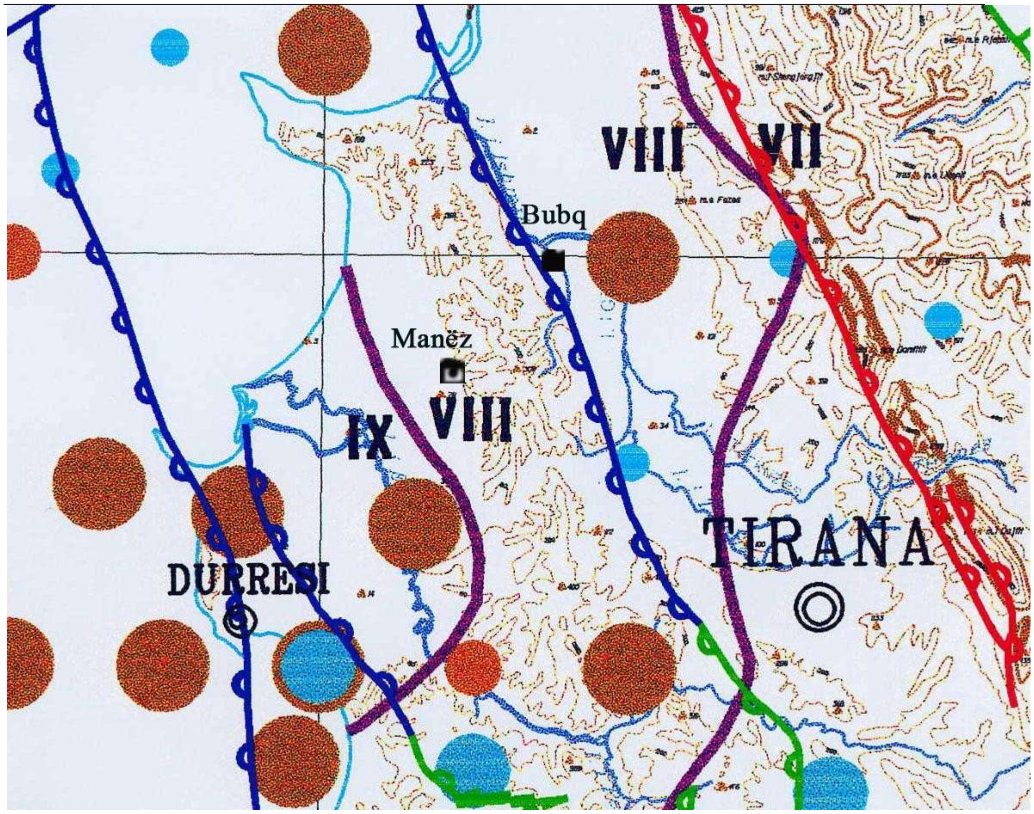


Fig. 2. Fragments of the Neotectonic Map, scl. 1: 200 000 for the area of Tirana (Aliaj 2010)

Summarizing the data from the depth values of earthquakes, it results that the seism active layer in this area has the floor at a depth of about 20-25 km (Ormeni, 2010). The depth of earthquake generation is of interest for seismotectonic studies, especially in the assessment of seismic hazard. A shallow earthquake with less energy causes greater damage than a deep earthquake with higher energy. Many earthquakes have been generated from the area of active detachments of Tirana, among the most powerful are: year 1617 with I_o = 8 degrees (MSK-64) in Kruja, 26/08/1852 with I_o = 8 points (MSK-64) in Cape of Rodon, 16/05/1860 with I_o = 8 points (MSK-64) in Ura e Beshirit, 04/02/1934 with MS = 5.6 in Ndroq, 19/08/1970 with MS = 5.5 and I_o = 7 points (MSK-64) in the area of Vrap, 16/09/1975 with MS = 5.3 in Cape of Rodon, 22/11/1985 with MS = 5.5 in Gjiu of Drini, 09/01/1988 with MS = 5.4 in Tirana, 21.09.2019 with MS 5.7 in Durres and the strong earthquake of 26 November 2019 in Durres with MS =6.3. Figure 3 presents the map of the epicenters of earthquakes in the region of Tirana and beyond, with magnitude Ms≥4.5, period 0058-2019.

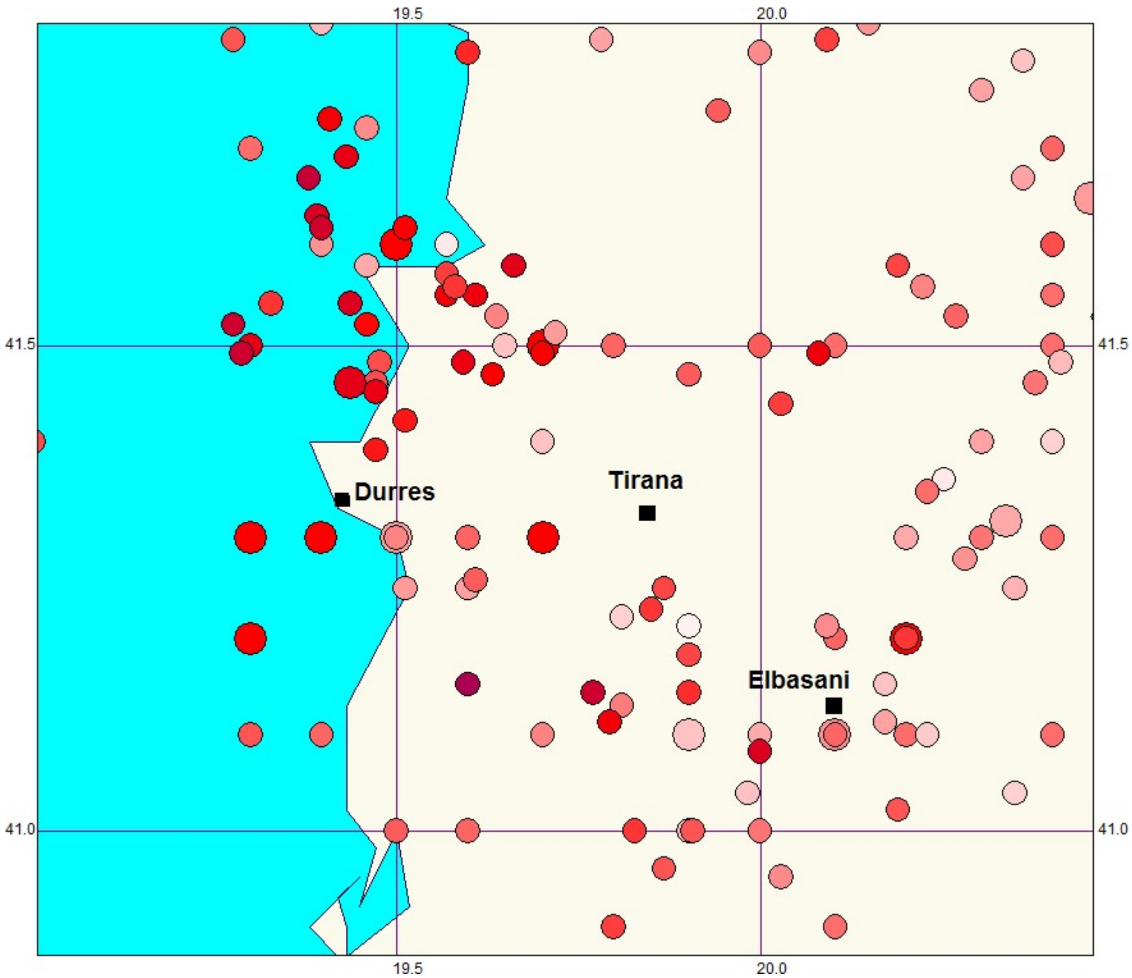


Fig 3. Map of earthquake epicenters for the period 58-2020 (Ormeni 2020), Ms≥4.5

According to the seismic map of Albania at a scale of 1: 500.000 (Fig. 4), Tirana and the surrounding area are included in an area where within the next 100 years can be expected seismic oscillations with intensity (according to MSK-64) of I_o = 7 degrees for average ground conditions and 7.5 degrees for poor ground conditions as shown in the following map of figure 4, taken from the seismic zoning map (Sulstarova et al., 1980).

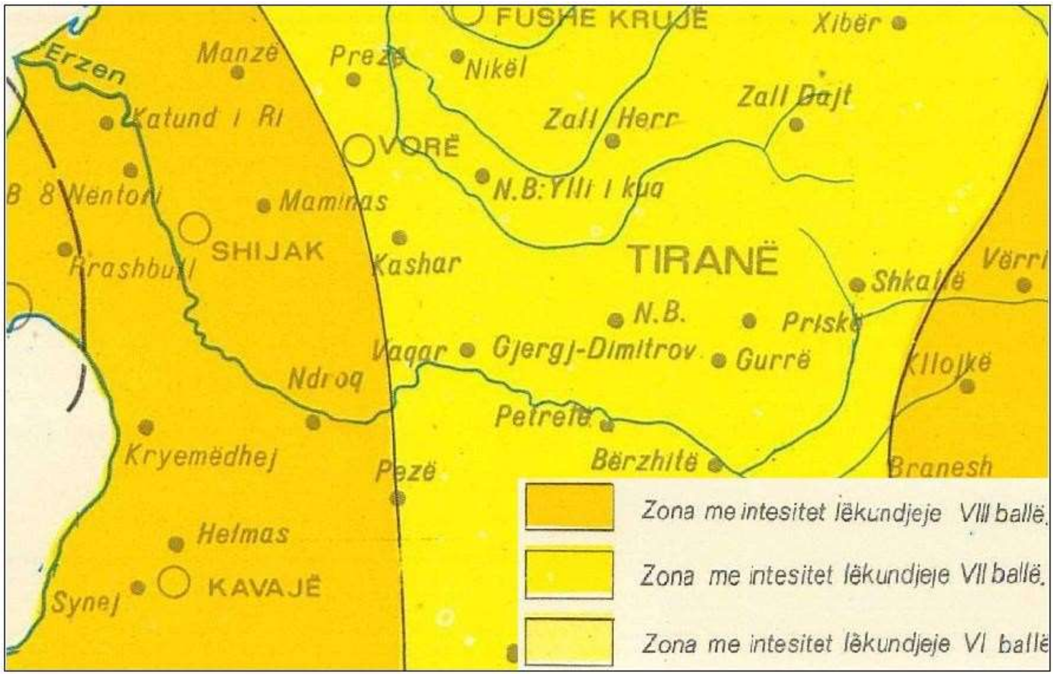


Fig 4. Fragment of the Tirana area from the seismic zoning map (Sulstarova et al., 1980).

According to the study "Seismic micro zonation of the city of Tirana" (Koçiaj, S., et al., 1988), the city of Tirana is included in an area where within the next 100 years can be expected earthquakes with intensity I_o max = VII-VIII degrees as per MSK-64 for average soil conditions. The region of Tirana was affected by the earthquake of November 26 in Durres (with a magnitude of Mw.6.4) which reached in Tirana the intensity VII-VIII degrees and in some areas up to VIII degrees. So, the region of Tirana has been affected by historical earthquakes with I_o = 8 degrees (MSK-64) and during the last century by earthquakes with M = 5.3 - 5.6.

4. GEOLOGY-ENGINEERING CONDITIONS OF TIRANA CITY

The city of Tirana lies to the west of Mount Dajti and is surrounded on the East, South and West by hills composed mainly of sandstone deposits mixed with Upper Miocene clays. The main part of the city lies on the good deposits of the second terrace of the Tirana River, composed mainly of red clay. Adjacent to this terrace, in its southern part lies the first terrace of the river Lana, which consists mainly of yellow clays with buffing properties. The first terraces of the Tirana and Lana rivers join in the western part of the city, thus creating the former marshy area of Yzberisht, where mainly weak or very weak soils such as low and plasticity clays and silts and peats predominate.

5. DYNAMIC REACTION OF THE GEOTECHNICAL MODEL OF THE CONSTRUCTION SQUARE.

Based on the studies performed for each object, a 1D one-dimensional sizmostratigraphic model was constructed consisting of piano parallel layers with reciprocal rigidity. In general, a numerical analysis of the dynamic ground response, regardless of the calculation code used, consists of the

following parts:
・determination of the reference geological model to which the dynamic response should be evaluated. Based on the situation, the numerical model that is closer to the real situation is chosen.
・defining the seismic model as input to apply to the model

Assessment of the local effects of amplification or deamplification that the seismic input model undergoes and the effects on existing or future constructions. There are many methods for numerically estimating the dynamic ground response. One of the first and most reliable one-dimensional is the code developed by SEED (1972) SCHNABEL, based on the theory of transverse wave propagation in stratified environments of Kanai (1951), Roesset and Housner (1969) and Tsai and Housner (1970). This code, called Shake, was perfected by SUN (1992) IDRISS with the definitive version called Shake 91. STRATA software (Kottke & Rathje, 2008) distributed by Pacific Earthquake Engineering (https://nees.org/resources/strata). was used to evaluate the dynamic response of the land under consideration. This software enables the calculation of the dynamic ground response by means of one-dimensional (1D) analysis of the equivalent linear method in both the time field and the vibrational method (Random Vibration Theory). In our case we used the method in the time domain, ie with information on the phase and frequency of incoming seismic oscillations and the conventional use of incoming seismograms. STRATA software uses (implement) an improved version of the SHAKE91 calculation code (Idriss & Sun, 1992) and enables the elaboration of a comprehensive statistical treatment of the problem which is very useful in the initial stage of selecting the initial conditions for the plot model for final calculation. STRATA, to describe the nonlinear behavior of the ground uses an equivalent linear model and studies the behavior of stresses (total) - deformations, based on the rheological model of Kelvin - Voight, and using a one-dimensional stratigraphic system with parallel layers, unlimited, in which the total stresses and displacements, provoked by the passage of the transverse seismic wave, are harmonic functions of time. By iteratively improving the oscillation parameters and elastic constants (elastic modulus, quenching coefficient, etc.) by iteratively improving the deformations over time, and solving the differential equations by integration, the seismic oscillation applied to a layer of refractory rigid, is transmitted to the above layers by defining a transfer function containing the spectral changes of the incoming seismic oscillation towards the surface. The Fourier spectrum of the surface-transmitted seismic signal behaves in the time domain (Fourier inverse transformation) by producing a time history (in acceleration, velocity, displacement, stress, and deformation) calculated at operator-selected stratigraphic column points. One of the strengths of STRATA is the rigor of the calculations and its simplicity.

6. GEOTECHNIC CONDITIONS OF THE SITE

Based on the performed studies, a one-dimensional 1D sizmostratigraphic model consisting of piano-parallel layers with reciprocal rigidity was constructed. From the geological-engineering point of view, we distinguish 4 layers with different physical-mechanical properties (Seismic microzonation of the City of Tirana (Konomi et al., 1988; Koçiaj et al., 1988).
Layer No. 1 0 -2 m filling material with Vs 190m / s
Layer No. 2 2 -4 m light sand with a combination of suras with Vs 290m / s
Layer No. 3 4 -8 m medium sandstone gravel mixture with Vs 430m / s
Layer No. 4 8 -21 m gravel with Vs 500m / s

The geotechnical model of the construction site was compiled based on the geological-engineering data and the seismic wave velocity values Determined for the construction site formations. The geotechnical model of this construction site was defined as a 4-layer model in accordance with the geological-engineering data and our estimates for transverse seismic wave velocities. The depth of the seismic base is accepted at a depth of over 21 m, based on the measured values of transverse wave velocity. The amplifying environment of seismic oscillations are surface layers with a total thickness of 21 m.

7. PROBABILISTIC ASSESSMENT OF SEISMIC HAZARD OF THE CONSTRUCTION SITE IN ROCKY TERRAIN CONDITIONS

The seismic hazard assessment of the construction site was performed with the Cornell-McGuire probability method. Maximum ground acceleration values - PGA are calculated for rocky terrain with $V_{s,\,30}$ = 760 m / sec, for two levels of probability: 10% probability of exceeding in 10 years and 10% probability of exceeding in 50 years (exposure time or longevity economic), which correspond to two periods of earthquake recurrence: 95 years and 475 years, calculated with the extinction relations of Sadigh et al., 1997 and Spudich et al., 1999 (Aliaj et al., 2010), in full compliance with Eurocode 8 Thus, from the seismic risk calculations for the area of the city of Tirana, where the construction site is under consideration, the values of PGA are about 0.25 g for rocky soil conditions and for a probability of 10% in 50 years. The results of the seismic risk for the construction site of the building " National Historical Museum" is located in the center of Tirana, in the southern part of the square "Skënderbej" in Tirana, for probability 10% in 10 years and 10% in 50 years in rocky soil conditions are summarized in Table 1.

Table 1: Calculated values of the main seismic hazard parameters of the construction site for a return period of 475 years, on rocky terrain.

PP	PGA	Sa (0.2 s)	Sa (0.5 s)	Sa (1.0 s)	Sa (2.0 s)
95years	0.126 g	0.311 g	0.165 g	0.083 g	0.036 g
475years	0.248 g	0.595 g	0.341 g	0.173 g	0.077 g

Maximum ground acceleration values - PGA and spectral acceleration $S_{a.}$ For periods 0.2- 0.5 seconds correspond to short-term energy, which will have the greatest effect on short-term structures, in buildings up to 7 floors high, the most common constructions today in the World. Long-period spectral acceleration values: 1.0 sec., 2.0 sec. etc. represent the level of ground vibration that will have the greatest effect on long-period structures, constructions 10 floors and above, bridges, etc.

8. SOIL CLASSIFICATION ACCORDING TO ALBANIAN DESIGN CODE KTP-N2-89

The classification of soils used in the Albanian Design Code KTP-N.2-89 for the seismic hazard assessment is based on the study for seismic mapping of Albania, for average soil conditions (Sulstarova et al., 1980). Quaternary lands with a large thickness are considered to be areas with medium conditions, for which no increase in macrosmic intensity has been observed and which are compacted and with great depth of groundwater (Tab. 2). According to the Albanian Code KTP-N.2-89, this construction site soil is classified as Second Category, type c Soils.

Table. 2: Classification of soil types in the Technical Design Conditions KTP-N.2-89

Soil category	*Lithological description of soils*
I	*a. Strong igneous and sedimentary rock formations unaffected by tectonics, karst and alteration processes.* *b. Medium-strength flysch formations unaffected by tectonics and alteration; sandstones with gypsum and clay-sandy clay cementation.*
II	*a. Rock formations with highly developed cleavages and alterations.* *b. Compacted or moderately compacted sandy loam formations, regardless of moisture.* *c. Loamy formations* *1. Low plasticity sandy silt, sandy clay with or without the content of granular material, in a strong plastic and elastic state with moisture.* *2. Dense and moderately dense wet gravel sand.*
III	*a. Loamy formations* *1. Coarse, medium-grained and coarse sands, silty sand with water level near the surface.* *2. Soft to very soft (flowing) plastic clays and clays.*

8.1 DESIGN SPECTRUM AS FOR ALBANIAN TECHNICAL CONDITION KTP-N2-89

The calculation of seismic hazard for buildings and sites according to the Albanian Code KTP N2-89 is performed with the method of elastic response spectrum of maximum horizontal acceleration. In the case of horizontal seismic action, the design values of the spectral acceleration response spectrum S_a is calculated from the expression:

$$S_a = k_E \cdot k_r \cdot \psi \cdot \beta \cdot g \quad (1)$$

where: k_E –seismicity coefficient, the values of which are given in Table 3;

k_r –the coefficient of importance of the construction object, the values of which are given in Tables 4-a, 4-b and 4-c;

ψ –the response coefficient of the structure under seismic action, the values of which are given in Table 5;

β –the dynamic coefficient, the values of which depend on the vibration period T of the ground and are taken as shown in Table 4 and Fig. 5;

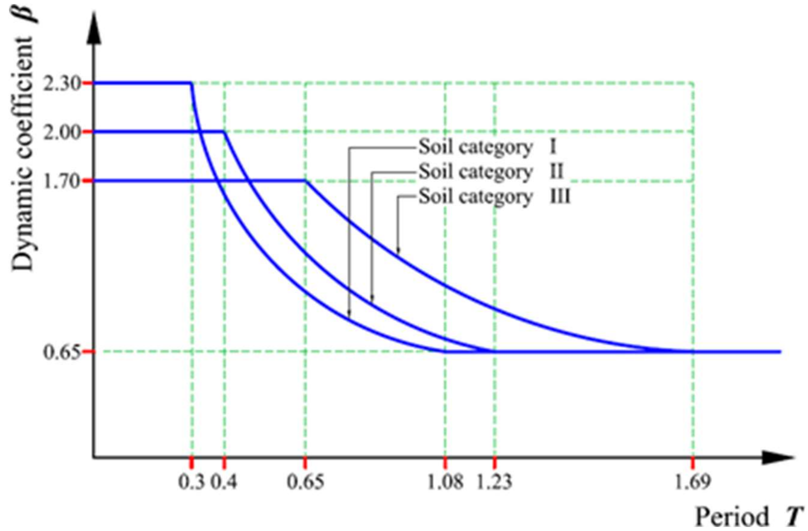


Fig. 5: Dynamic coefficient β for different soil categories

g - gravity acceleration, which expresses the spectral acceleration calculated by formula (1). For the case of vertical seismic action, the calculated values of the spectral response are obtained by multiplying those defined by the horizontal seismic action by the coefficient of 2/3. Both k_E and β(T) depend on the local conditions of the soils on the construction site, which are classified into three categories. Seismicity coefficient values k_E are given in Table 3, depending on the category of soil and seismic intensity at the construction site.

Table 3: Seismicity coefficient values -kE

Soil category	Seismic intensity VII degrees	Seismic intensity VIII degrees	Seismic intensity IX degrees
I	0.08	0.16	0.27
II	0.11	0.22	0.36
III	0.14	0.26	0.42

For seismic intensity VII ½ and VIII ½ points defined in seismic microzoning maps, seismicity coefficient values - kE are determined by interpolation. For seismicity VI ½ front the value of kE is taken to be 2/3 of the intensity VII front.

The dynamic coefficient - β is determined by the following formulas depending on the natural period T_i and the category of land on the construction site, as follows:

- For soil category I $0.65 < \beta = 0.7 / T_i < 2.3$ (2)

- For soil category II $0.65 < \beta = 0.8 / T_i < 2.0$ (3)

- For soil category III $0.65 < \beta = 0.1.1 / T_i < 1.7$ (4)

The dynamic coefficient - β is determined depending on the natural period Ti and the category of land on the construction site (see Table 4).

Table 4: The values of the parameters that determine the shape of the dynamic coefficient curves β

Site category	T_C (sec)	T_D (sec)	B ($0<T<T_C$)	B ($T_C<T<T_D$)	B ($T_D<T$)
I	0.30	1.08	2.3	0.7/T	0.65
II	0.40	1.23	2.0	0.8/T	0.65
III	0.65	1.69	1.7	1.1/T	0.65

According to the Albanian Design Code KTP N.2-89 the seismic coefficient, in other words, the acceleration (acceleration) of the ground, expressed as a function of the gravity acceleration - g, is determined based on the category of the soil and its seismic intensity, these taken specifically for the site. According to the Table 2 of the Albanian Seismic Code KTP N.2-89, for 2nd soil category and for a seismic intensity of 8 degrees (MSK-64), the seismic coefficient obtained with interpolation is k_E = 0.22g.

According to the Albanian Design Code in force in our country, the seismic action in a construction site is presented through the elastic response spectrum of the maximum horizontal ground acceleration, which is calculated from the following relation (Duni & Kuka, 2003):

$$Sa\ (T) = k_E\ \beta(T)\ g \quad (5)$$

Where k_E- seismicity coefficient expressed in g, β(T) - dynamic coefficient that depends on the period of ground vibration (seen as a normalized reaction spectrum with 5% of damping). Including in this relation the parameters k_r (coefficient of importance of the object) and η (the coefficient of ductility and damping of the structure) are obtained the design values of the acceleration. Elastic reaction spectra according to the level in the format of the Albanian Code KTP-N2-89:

- From the parameters for the construction site: intensity 8 degrees (MSK-64), soil category II: K_E = 0.22, β (T) = 2.0, the maximum spectral acceleration is: S_a (T) = 0.440 g.
- The elastic response spectrum according to KTP-2-89 results in the value of the maximum spectral acceleration S_a(T) = 0.440 g, T_C = 0.40 sec and T_D = 1.23 sec.

9. CLASSIFICATION OF LAND ACCORDING TO EC8

In accordance with the definitions of EC8 the impact of local soil conditions on seismic action can be considered by considering five soil classes A, B, C, D, and E. In accordance with these requirements for land classification according to EC8 and based on parameters calculated we can estimate that the parameter VS30. By MASW method -> VS30 = 498 m / sec.

-According to EC 18, the geological environment in this construction site is classified as Class B.

Very compacted sand, very hard gravel or clay deposits, characterized by a gradual increase in mechanical properties, with increasing depth and equivalent velocity values between 360m / s and 800m / s

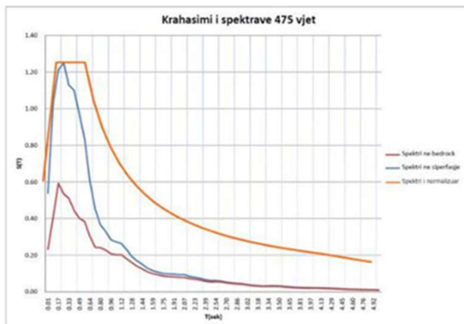
From the seismic noise recordings, the HVSR graph was calculated and analyzed, with the following parameters:

a) distance of time frame 30 s,

b) smoothing with triangular frame with a size of 5% of the central frequency.

We are dealing with a recording in which the peak (H / V> 2) on the frequency is clearly visible f0 = 0.999 Hz and with an amplitude A0 = 2.405 which is confirmed by meeting the SESAME validity criteria. The period of ground vibration is:

T0 = 1 / f0 = 1.001 sec.



10. CONCLUSIONS

Based on the material treated in this engineering-seismological report for the assessment of the seismic risk of the construction site of the building of the "National Historical Museum" located in the center of Tirana, in "Skënderbej" square, the following main conclusions are drawn:

1. The construction site in the study is classified as category II, c according to KTP-N.2-89,

2. The vibration period of the ground is: T_0 = 1 / f0 = 1.001 sec.

a_{max} = 0.466 * g,

$Se(T)_{max}$ = 1.206 * g,

TB (s) = 0.09sec; TC (s) = 0.276 sec; TD (s) = 2.592 sec.

3. This spectral curve satisfactorily covers the amplitude of the spectral reaction according to the accelerograms used in this study to calculate the seismic risk for a wide range of periods of interest to this object. This curve results in an acceptable level for the computational spectrum of accelerations to be used on this construction site.

11. LITERATURE

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