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SEISMIC REPORT
HAMMAM OF DURRES

ATELIER 4
ARCHITECTURE • ENGINEERING • CONSULTING

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1. INTRODUCTION

The framework of the project "Conservation Plan, Reinforcement and Restoration Interventions in 8 objects of cultural heritage and museums in the Municipality of Durrës (Hammam of Durrës; Archaeological Museum; Banesa e "A. Moisiu"; The Castle of Durrës (C-Tower and Fortification Walls); Amphitheatre, Durrës; Castle of Ishmi and banesa pranë mureve të Kalasë; Porto Romano; Kalaja e Rodonit and Kisha e Shna Ndout në Kepin e Rodonit)", Geo-Eng l.t.d. carried out the engineering-seismological study in order to assess the seismic hazards that may pose a threat to these facilities and to recommend the necessary parameters for the projects of structural interventions for their reinforcement. Geo-Eng l.t.d. was contracted by the Ministry of Culture of Albania. The design team of Atelier4 Studio on the other hand, had the tasks of reviewing, modifying and revision of the original report drafted by Geo-Eng l.t.d.

For these purposes, seismic profiles were drafted in each of the above-mentioned objects with the method of Surface Wave Spectral Analysis (MASW) through which the velocity profile of transverse seismic waves (VS) is studied, which enables us to estimate the V_{S30} parameter. Using this parameter is realized the classification of the soil where objects rest on and which has a direct impact on the magnitude of the seismic hazard that threatens these structures.

The V_S velocity represents the strength of the material that composes the subsoil. To enable the full identification of the ground layers using the velocity of these waves, the velocity profiles are modeled in 3-4 layers, from where the depth of each of the layers can be distinguished.

In the first paragraph is presented the position of the seismic measurement scheme where the study was performed, while in the second paragraph is presented the velocity profile according to transverse waves in both directions and the values of the parameter V_{S30}. In the third paragraph is presented the seismic hazard that threatens the objects, expressed in terms of Seismic Intensity and PGA (maximum ground acceleration) and SA (spectral acceleration). In the last paragraph, based on the results of studies on seismic hazards of the project area in terms of horizontal acceleration according to the Eurocode 8 standard (PGA) and Seismic Intensity assessment according to the MSK-64 scale, are presented conclusions and recommendations for each of the objects taken into analysis.

2. LOCATION OF THE SEISMIC MEASUREMENTS SCHEMES

The "passive" surface wave spectral analysis (MASW) method was used to estimate the transverse wave propagation velocity in the nine project objects. This is an essential feature of these waves and is about changing the phase velocity depending on the frequency. The transverse wave velocity (V_s) can be calculated through the mathematical inversion of the phase velocity of the surface waves. The dispersion of these waves is very stressed in stratified geological environments, especially in the near-surface environment.

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Figure. 1. Position of the measurement scheme (with red line) according to the "passive" method spectral analysis of surface waves in the Hammam of Durrës.

3. RESULTS OF THE SEISMIC MEASUREMENTS AND VALUES OF THE V_{S30} PARAMETER

In accordance with the definitions of EC8 (EC8, 2004), the impact of local soil conditions on seismic action can be taken into account by considering seven soil types A, B, C, D, E, S1 and S2. In accordance with these requirements for soil classification according to EC8 and based on the value of V_{S30} it is estimated that:

- In the Hammam of Durrës, V_{S30} value is: V_{S30} = 238.1 m/sec. Based on this assessment, the soil where the Hammam of Durrës rests-on is classified as Type C according to EC8.

All figures show the values of longitudinal wave velocities V_P (green curves) and the number of blow count of the Standard Penetrometer Test (SPT) (red curves) calculated according to the relations $V_P = f(V_S)$ and $N(SPT) = f(V_S)$ implemented in the software SeisImager SW.

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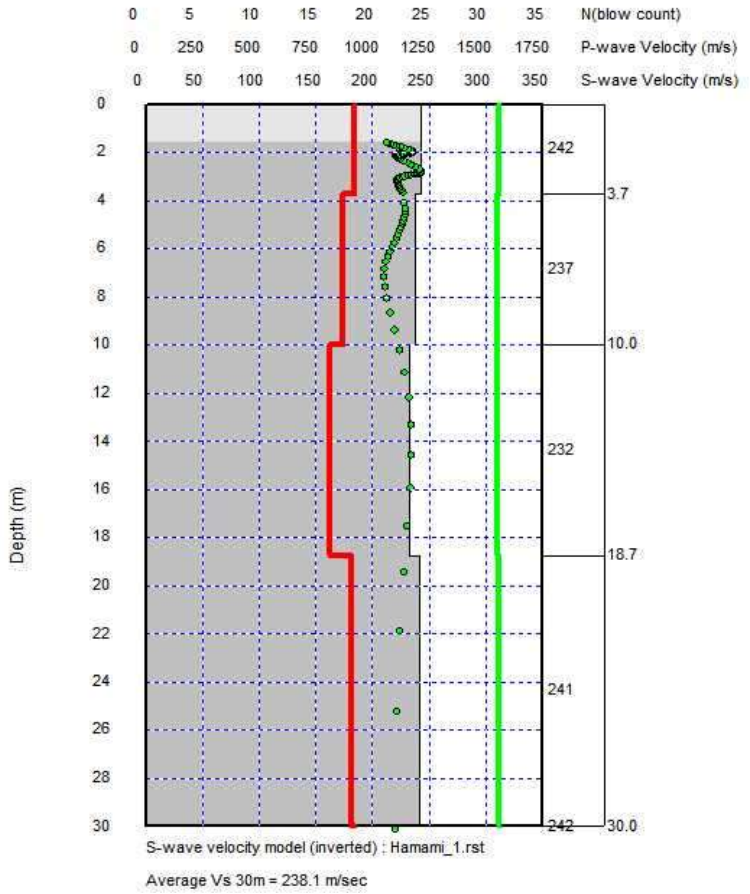

Figure. 2. The curve of variation of V_S in the soils where the Hammam of Durrës rests-on.

4. SEISMIC HAZARD OF THE SITES OF THE PROJECTS

4.1 SEISMIC HAZARD IN TERMS OF SEISMIC INTENSITY ACCORDING TO MSK-64 SCALE

For the seismic risk assessment in terms of Seismic Intensity for the Hammam of Durrës we are based on the Seismic Microzoning Map of the city of Durrës. According to this assessment, Hammam of Durrës is rated with an expected Seismic Intensity of VIII-IX degrees (8.5 degrees) according to MSK-64 scale.

Figure 4 shows the Seismic Map of Albania according to Sulstarova et al. 1980, and Figure 5 shows the seismic intensity distribution map according to the MSK-64 scale observed by the earthquake of November 26, 2019 with M = 6.4, prepared by IGJEUM and published in the framework of the special report of EERI (Earthquake Engineering Research Institute).

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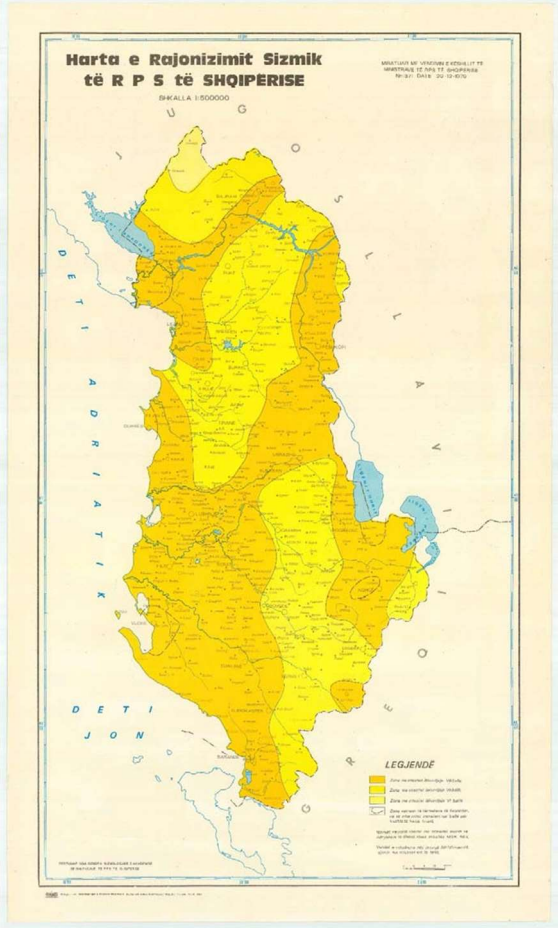

Figure. 3. Seismic Map of Albania (Sulstarova et al., 1980)

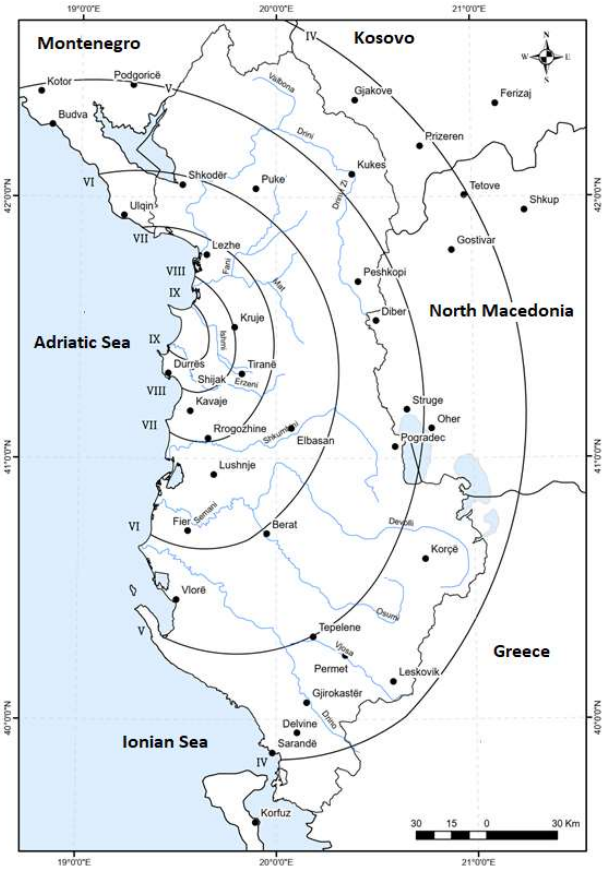

Figure. 4. Map of the distribution of intensities observed during the earthquake of November 26, 2019 in Albania.

4.2 SEISMIC HAZARD IN TERMS OF PEAK HORIZONTAL ACCELERATION AND SPECTRAL ACCELERATION (PGA AND SA)

For the seismic risk assessment according to the probability methodology recommended by Eurocode 8 (EC8, 2004), the well-known and widely accepted model of Boore et al., 1997 was used, which is formulated for shallow earthquakes and uses the same magnitude scale and metric distances such as that of Ambraseys et al. (2005).

All calculations were performed for the conditions of "hard rock", with a transverse wave propagation speed of 800 m / sec in the upper 30 meters of the ground and corresponding to class A of Eurocode 8. The results of the calculations are summarized in Tables 1-6.

Table 1. Maximum values of horizontal acceleration and spectral values in Type A ground in the site area

Period Ses	Spectral acceleration, g			
	Return period 95 years	Return period 475 years	Return period 975 years	Return period 2475 years
PGA	0.189	0.286	0.333	0.404
0.10	0.271	0.459	0.563	0.72
0.20	0.358	0.593	0.722	0.916
0.30	0.316	0.528	0.653	0.832
0.50	0.203	0.352	0.44	0.578
1.00	0.083	0.151	0.193	0.261
2.00	0.044	0.080	0.102	0.138

The values presented in Table 1 represent the seismic hazard parameters (maximum horizontal acceleration and spectral values) of the soil where the bases of the construction sites rest on of all project sites. The values presented represent return periods from 95 years to 2475 years. The values recommended for this project represent a probability level of 10% probability of exceeding 50 years (repetition period 475 years). Further, the safety factor of the structure is taken into account in this assessment.

5. CONCLUSIONS AND RECOMMENDATIONS

1. The soil where rests-on Hammam of Durrës, is classified as Type C according to Eurocode 8 having V_{S30} = 238.1 m/sec and, as 3rd category of soils (in the absence of geological data) according to KTP.N2.1989 (KTP.N2.1989).
2. Seismic intensity in the area of the Hammam of Durrës must be taken VIII-IX (8.5) degrees according to the MSK-64 scale.
3. According to the design condition KTP-N2-89 taking into account: Seismic Intensity of VIII-IX degrees according to MSK-64; 3rd Category of soils and Importance Factor k_r=1.2 (Table 4-a: Group II, Values of the Importance Factor, sites and buildings of special importance, Point d: Sites and monumental buildings of special cultural values) results to be Seismicity Coefficient k_E = 0.408.
4. Given the seismicity around the city of Durrës with earthquakes of magnitude greater than 5.5, the calculations of horizontal and vertical spectra according to Eurocode 8 are performed

taking into account Type 1 of the spectrum according to EC 8, with parameters (for horizontal spectrum): S=1.15, T_B=0.20s, T_C= 0.60s, T_D=2.0s.

5. We recommend that the Eurocode 8 standard be used for reinforcement and restoration interventions in the Hammam of Durrës considering both levels of seismic action for the "non-collapse" requirement and for the "limited damage" requirement.
   Specifically:
   For the "non-collapse" state for the horizontal elastic design spectrum consider the Significance Factor according to EC8 equal to y_I =1.2 (Buildings whose seismic resistance is important in terms of the consequences that accompany collapse, such as schools, conference rooms, cultural institutions, etc.). Under these conditions PGA reference a_{gR} in Soil Type A results to be: a_{gR}=0.286g (Tab. 1, PGA for a return period of 475 years), while the design acceleration in Soil Type A: a_g=0.286g*1.2=0.343g.
   Considering the Soil Factor for soil Type C, S=1.15, **Design Acceleration for the state of "non-collapse" for the projects to be designed results: a_g*1.15=0.343*1.15=0.394g. Acceleration value 0.394g should be used for structural calculations.** The other parameters are as follows: T_B=0.20 s, T_C=0.60 s, T_D=2.0 s (Fig. 24).

   We would like to point out that the above value 0.394g of acceleration recommended for the design of the structure for the condition of "non-collapse" is a product of acceleration in Type A Land (a_g=0.343g) with the Soil Factor (S=1.15). If the calculation program with which the structural engineer designs the structure requires the ground factor S to be calculated (included in the program) separately, then the following parameters must be entered in the program: a_g=0.343g and S=1.15.

   For the "limited damage" condition for the horizontal elastic design spectrum must be considered the Importance Factor according to EC8 equal to yI = 1.2 (Buildings whose seismic resistance is important in terms of the consequences that accompany collapse, i.e. schools, conference rooms, cultural institutions, etc.). Under these conditions PGA reference a_{gR} in Soil Type A results to be: a_{gR}=0.189g (Tab. 1, PGA for a return period of 95 years), while the design acceleration in Soil Type A: a_g=0.189g*1.2=0.227g.

   Considering the Soil Factor for soil Type C for this site, S=1.15, **Design acceleration for the state of "limited damage" for the structural design to be performed results: a_g*1.15=0.227g*1.15=0.261g. The acceleration value of 0.261g should be used for structural calculations.** The other parameters are as follows: T_B=0.20s, T_C= 0.60s, T_D=2.0s.

   We would like to point out that the above value 0.261g of acceleration recommended for the design of the structure for the condition of "limited damage" is the product of acceleration on Soil Type A (a_g=0.227g) with the Soil Factor (S=1.15). If the calculation program with which

the structural engineer designs the structure requires the ground factor S to be calculated (included in the program) separately, then the following parameters must be entered in the program: a_g=0.227g and S=1.15.

- For the "non-collapse" state for the vertical elastic design spectrum, the design acceleration to be taken a_{vg}=0.309 g. The other parameters are as follows: T_B=0.05 s, T_C=0.15 s, T_D=1.0 s
- For the state of "limited damage", for the vertical elastic spectrum of the design, the design acceleration to be taken: a_{vg}=0.204g. The other parameters are as follows: T_B=0.05 s, T_C= 0.15 s,T_D=1.0 s

6. From the comparison it turns out that the elastic design response spectrum for the "non-collapse" state according to EC8 for retrofitting and restoration interventions in Hammam of Durrës, results in better protection than the corresponding spectrum according to the technical condition KTP-N2-89 with seismic intensity VIII-IX degrees according to MSK-64 and 3rd Category of soil.

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5.1 ASPECTS FROM WORKING WITH THE SEISMIC METHOD MASW IN THE HAMMAM OF DURRES

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