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SEISMIC REPORT
KURCAJ BRIDGE

ATELIER 4
ARCHITECTURE • ENGINEERING • CONSULTING

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1. INTRODUCTION

In the framework of the project "Conservation Plan, Reinforcement and Restoration Interventions in 9 objects of cultural heritage" (Kurcaj Bridge in the River of Zeze, Kruja; Bashtova Castle, Rrogozhina; Preza Castle (Clock Tower and Northeast Tower) Preza; Castle of Lezha - Archaeological Park; Kruja Castle (Clock Tower and fortification walls), Kruja; Ruins of the Church of St. Mary, Mamurras, Kurbin; Church of the Rubik Monastery, Mirdita; Former Archbishopric of Durrës in Delbnisht, Kurbin, Lezha; Tekke of Dollma in the Castle of Kruja)", Geo-Eng sh.p.k. 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.

For this purpose, 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 (V_S) 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.

As can be seen from the transverse wave velocity distribution profiles, the V_S velocity also 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 the positions of seismic measurement schemes in all sites where the study was performed are presented, while in the second paragraph the velocity profiles according to transverse waves in each of them and the values of the parameter V_{S30} are presented. In the third paragraph the seismic hazard that threatens the objects, is 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, conclusions and recommendations for each of the objects taken into analysis are presented. In the Annex of this report are presented photos with aspects from the work with the seismic method MASW.

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. The MASW method is based on the study of surface wave dispersion. This is an essential feature of these waves and is about changing the phase velocity depending on the frequency. The transverse wave velocity (Vs) 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. Figures 1 shows the positions of the measurement schemes according to this method.

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Fig. 1. Position of the measurement scheme (with red line) according to the "passive" method spectral analysis of surface waves in the Bridge of Kurcaj in the River of Zeze, Kruja

3. RESULTS OF THE SEISMIC MEASUREMENTS AND VALUES OF THE VS30 PARAMETER

From the results of seismic measurements presented in Fig. 9-16 result the values of the parameter V_{S30} (transverse wave velocity in the first 30 meters of the cut) in all 8 profiles realized within the project.

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 site where is located the Bridge of Kurcaj in River Zeze, V_{S30} value is: V_{S30} = 568.4 m/sek. Based on this assessment, the soil where the Bridge of Kurcaj in River Zeze rests-on is classified as Type B 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.

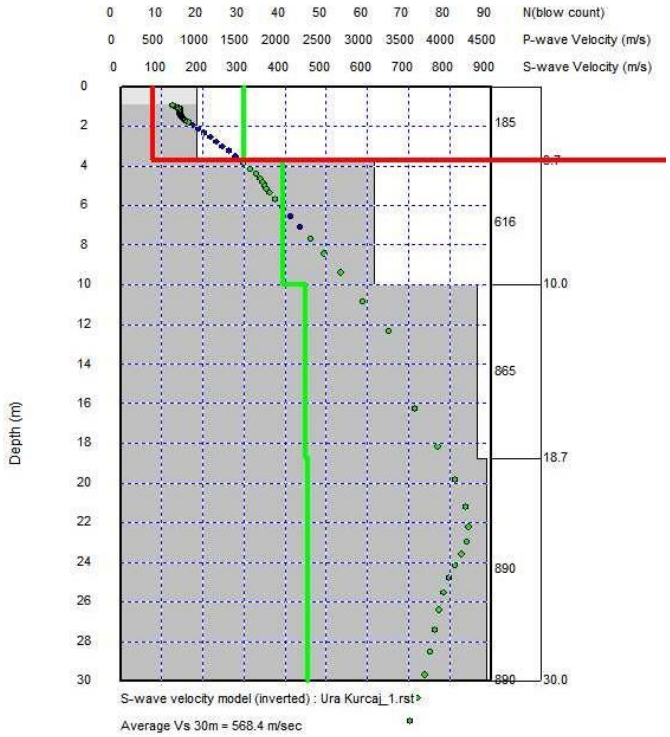

Fig. 2. The curve of variation of V_S in the soils where the Kurcaj Bridge in River Zeze, rests-on

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 hazard assessment in terms of Seismic Intensity for the cultural heritage object (Kurcaj Bridge in Zeze River, Kruja), we are based on the Seismic Microzoning Map of Albania of 1980 (Sulstarova et al., 1980). According to this map, Kruja Castle, Preza Castle, St. Mary's Church and Kurcaj Bridge in Zeze River are located in an area with expected seismic intensity VII degree according to MSK-64 scale.

But, observations of the consequences of the earthquake of November 26, 2019 have shown that the seismic intensity in the area near the epicenter, which according to the 1980 map is estimated with intensity VII degree, is actually determined with a higher value, VIII degree according to this scale. The case of Thumana is evident and in these conditions, the assessment with intensity VII degree according to the 1980 assessment is controversial. In these conditions, for the Kurcaj Bridge in the Zeze River, which according to the 1980 Map are located in the VII degree area, we are obliged to evaluate hazard with a seismic intensity of VIII degree according to the MSK-64 scale.

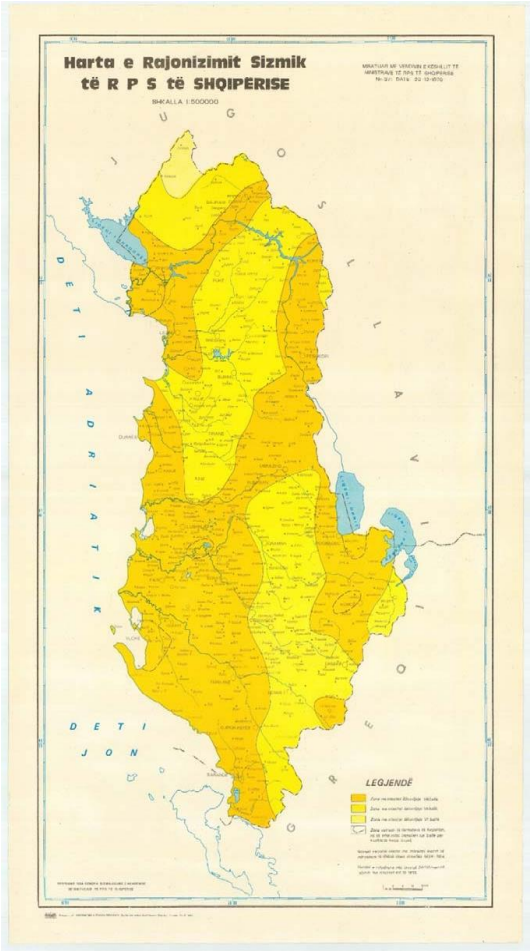

Figure 3. Seismic Map of Albania (Sulstarova et al., 1980)

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 are 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 Table 1.

Table 1. Maximum values of horizontal acceleration and spectral values in Type A

Period Sec.	Spectral acceleration, g			
	PP=95 years	PP=475 years	PP=975 years	PP=2475 years
PGA	0.174	0.263	0.309	0.376
0.10	0.251	0.420	0.513	0.661
0.20	0.335	0.545	0.666	0.838
0.30	0.295	0.486	0.596	0.762
0.50	0.190	0.325	0.404	0.530
1.00	0.080	0.142	0.180	0.242
2.00	0.174	0.263	0.309	0.376

The values presented in Tables 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 facility of Kurcaj Bridge in the Zeze River, Kruja. The values presented represent repetition 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

5.1 CONCLUSIONS AND RECOMMENDATIONS FOR THE SITE 'KURCAJ BRIDGE IN ZEZE RIVER, KRUJA'

1. Soil where rests-on the "Kurcaj Bridge in Zeze River, Kruja", in the framework of the project "Conservation Plan, Reinforcement and Restoration Interventions in 9 objects of cultural heritage", is classified as Type B according to Eurocode 8, having VS_{30} = 568.4 m/sec and, being part of the 2nd cathegory of soils (in the absence of geological data) according to Albanian KTP.N2.1989.

2. Seimic intensity in the area of the "Kurcaj Bridge in Zeza River, Kruja" should be taken VIII degree according to the MSK-64 scale.

3. According to the Albanian design condition KTP-N2-89 taking into account: the Seismic Intensity of VIII degree according to MSK-64; being part of the 2nd cathegory of soils and having an 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) the Seismicity Coefficient results to be k_E = 0.264.

4. Given the seismicity around the area of objektit, with earthquakes of magnitude greater than 5.5, the calculations of horizontal and vertical spectra according to Eurocode 8 are performed taking

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into account Type 1 of the spectrum according to EC8, with parameters (for horizontal spectrum): S=1.20, T_B=0.15 s; T_C= 0.50 s; T_D=2.0 s.

5. We recommend that the Eurocode 8 standard be used for reinforcement and restoration interventions in objekt in "Kurcaj Bridge in Zeze River, Kruja", in the framework of the project "Conservation Plan, Reinforcement and Restoration Interventions in 9 objects of cultural heritage", considering both levels of seismic action for the Ultimate Limit State (ULS) requirement and for the Serviceability Limit State (SLS)requirement. Specifically:

➢ For the Ultimate Limit State (ULS) state for the horizontal elastic design spectrum consider the Significance Factor according to EC8 equal to yI =1.2(Buildings whose seismic resistance is important in terms of the consequences that accompany collapse, eg, schools, conference rooms, cultural institutions, etc.). Under these conditions PGA reference agR in Soil Type A results to be: agR=0.263g (Table 3, PGA for a return period of 475 years), while the design acceleration in Soil Type A: a_g=0.263g*1.2=0.316g.

Considering the Soil Factor for soil Type B, S=1.20, Design Acceleration for the condition of Ultimate Limit State (ULS) for the projects to be designed results: ag*1.20=0.316*1.20=0.379g. Acceleration value 0.379g should be used for structural calculations. The other parameters are as follows: T_B=0.15 s, T_C=0.50 s, T_D=2.0 s

We would like to point out that the above value 0.379g of acceleration recommended for the design of the structure for the condition of Ultimate Limit State (ULS) is the product of acceleration in Soil Type A (a_g=0.316g) with Soil Factor (S=1.20). If the calculation program with which the structural engineer dimensions 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=0.316g dhe S=1.20.

➢ For the Serviceability Limit State (SLS)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, eg, schools, conference rooms, cultural institutions, etc.). Under these conditions PGA reference agR in Soil Type A results to be: agR=0.174g (Table 1, PGA for a return period of 95 years), while the design acceleration in Soil Type A: a_g=0.174g*1.2=0.209g.

Considering the Soil Factor for Type B, S=1.20, Design acceleration for the condition of Serviceability Limit State (SLS)for the structural design to be performed results: ag*1.20=0.209g*1.20=0.251g. Acceleration value 0.251g should be used for structural calculations. The other parameters are as follows: T_B=0.15 s, T_C= 0.50 s, T_D=2.0 s.

We would like to point out that the above value 0.251g of acceleration recommended for the design of the structure for the condition of Serviceability Limit State (SLS)is the product of acceleration on Soil Type A (a_g=0.209g) with Soil Factor (S=1.20). If the calculation program with which the

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structural engineer dimensions 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=0.209g and S=1.20.

➢ For the Ultimate Limit State (ULS) for the vertical elastic design spectrum, the design acceleration to be taken avg=0.284g. The other parameters are as follows: T_B=0.05 s, T_C=0.15 s, T_D=1.0 s .

➢ For the of Serviceability Limit State (SLS)for the vertical elastic spectrum of the design the design acceleration to be taken: avg=0.188g. 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 of the elastic design response spectrum for the Ultimate Limit State (ULS) according to EC8 for retrofiting and restoration interventions in object "Kurcaj Bridge in Zeze River, Kruja", results in better protection than the corresponding spectrum according to the technical condition KTP-N2- 89 with seismic intensity VIII degree according to MSK-64 and 2nd cathegory of soil.

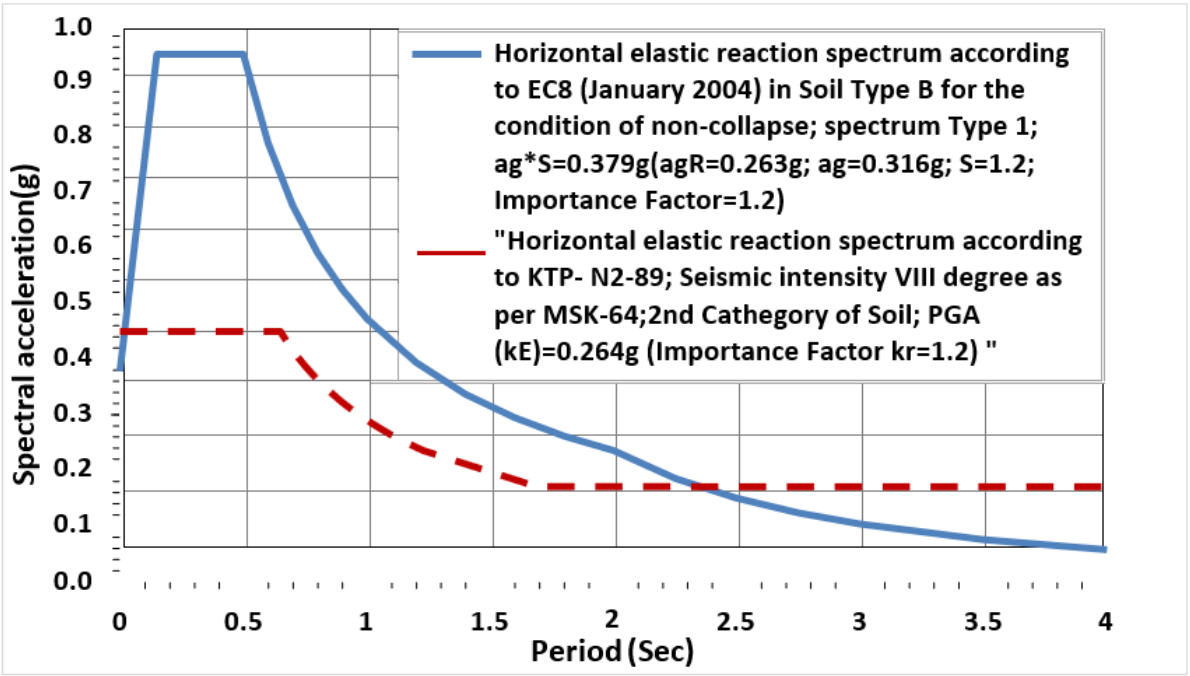

Fig. 4. Comparison of the horizontal elastic response spectrum according to KTP-N2-89 with the horizontal elastic design spectrum for the "non-collapse condition" for reinforcement and restoration interventions in "Kurcaj Bridge in Zeze River, Kruja"

5.2 ASPECTS OF WORK DURING FIELD WORK WITH MASW SEISMIC METHOD

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