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SEISMIC HAZARD ASSESSMENT AND STRONG MOTION MONITORING OF DAMS IN ALBANIA.

LL. Duni[1], N. Kuka[2], I. Hoxha[3] and SH. Kuka[4]

[1]*Associated Professor, Dept. of Seismology and Seismic Engineering, Institute of Geosciences, Tirana, Albania*
[2]*Professor, Dept. of Geoinformation Technologies, Institute of Geosciences, Tirana, Albania*
[3]*Professor, Dept. of Geoinformation Technologies, Institute of Geosciences, Tirana, Albania*
[4]*Doctor, Dept. of Mathematics, Faculty of Basic Knowledge, Polytechnic University, Tirana, Albania*
Email: llduni@hotmail.com, nekikuka@hotmail.com, i_hoxha@yahoo.com, sh.kuka@gmail.com

ABSTRACT

The paper deals with the situation of strong motion monitoring of large dams in Albania. Five HPP-s of the Drin and Mati Cascades are the largest of the country and among them, the Fierza and Komani dams are 170 m and 100 m, respectively. The seismic hazard was performed following the smoothed seismicity approach that reveal PGA values of the order of 0.416 g, 0.448 g and 0.478 g for MCE and 0.156 g, 0.175 g and 0.190 g for OBE earthquakes for Fierza, Komani and Vau Dejes dams, respectively. Some data of the project prepared for the instrumentation of these dams are presented.

KEYWORDS: large dams, strong motion monitoring, seismic hazard.

1. INTRODUCTION

Albania is a high seismicity prone country that has been hit many times by destructive earthquakes. It results that from the period of III–II centuries B.C till in our days, Albania has been stricken from about 55 strong earthquakes with intensities I_o≥VIII degree (MSK-64), from which at least 15 of them have had the intensity I_o≥IX degree (MSK-64). From these 55 earthquakes for a period more than 2000 years, 36 of them belong to 19-th century which make us to believe that the number of disastrous earthquakes we report is underestimated. The strongest earthquake that has stricken Albania during the XX-th century is that of April 15, 1979 (M_w=6.9). The epicenter of this earthquake was located in the coastal area, near Petrovac (Montenegro), very close to the location of the three of the most important Albanian hydro power plants: Vau Dejes, Komani and Fierza with 46 m, 100 m and 170 m dam height, respectively. Komani dam is composed by rocks with a concrete screen, while the Fierza one is composed by rocks with clay core. The Vau Dejes HPP has 3 rocks+clay core dams, while the main Qyrsaqi dam is composed by a concrete part of 120 m length and an rock material part of 355 m length. The reservoir capacity of Fierza power plant is $2.3x10^9$ m^3 and the water shield 70 km^2. These three HPP on the Drini River that cover almost the 95% of the total electricity production in Albania were build in the period 1967-1971 (Vau Dejes HPP), 1971-1978 (Fierza HPP) and 1980-1985 (Komani HPP). The other two important dams of the country are those located in the Ulza and Shkopeti HPP-s as part of the Mat River cascade. These two dams are smaller than those of Drini River cascade and are built as 64 m high concrete gravity dam (Ulza) and 52 m high concrete earth dam (Shkopeti). Ulza HPP was built in 1952-1958 while Shkopeti HPP in the period 1958-1963. In the Figure 1 presented is the location of the five HPP-s and the seismological monitoring stations around them.

The establishment for the first time in Albania of the strong motion monitoring network (ASMN) in the 1985 was followed with the design and installation of the SMA-1 accelerographs on the high dams of Drini and Mati Rivers Cascades. This network operated normally up to the end of 80-s, enabling the record of the Tirana earthquake of January 9, 1988 (M_L = 5.4). After that, due to various reasons, the monitoring was stopped. The ASMN started the operation in 2002 (Duni et al. 2002), but still the high dams are lacking this kind of monitoring. Nevertheless, the installation of a state-of-the-art control and strong motion monitoring system, meeting the requirements of the National Committee on the large Dams and international standards is of great importance and must be carried out as soon as possible. It is impossible to check the current state of the dams without collecting information from their inside and without scientific interpretation by modern tools to discover the safety-relevant phenomena.

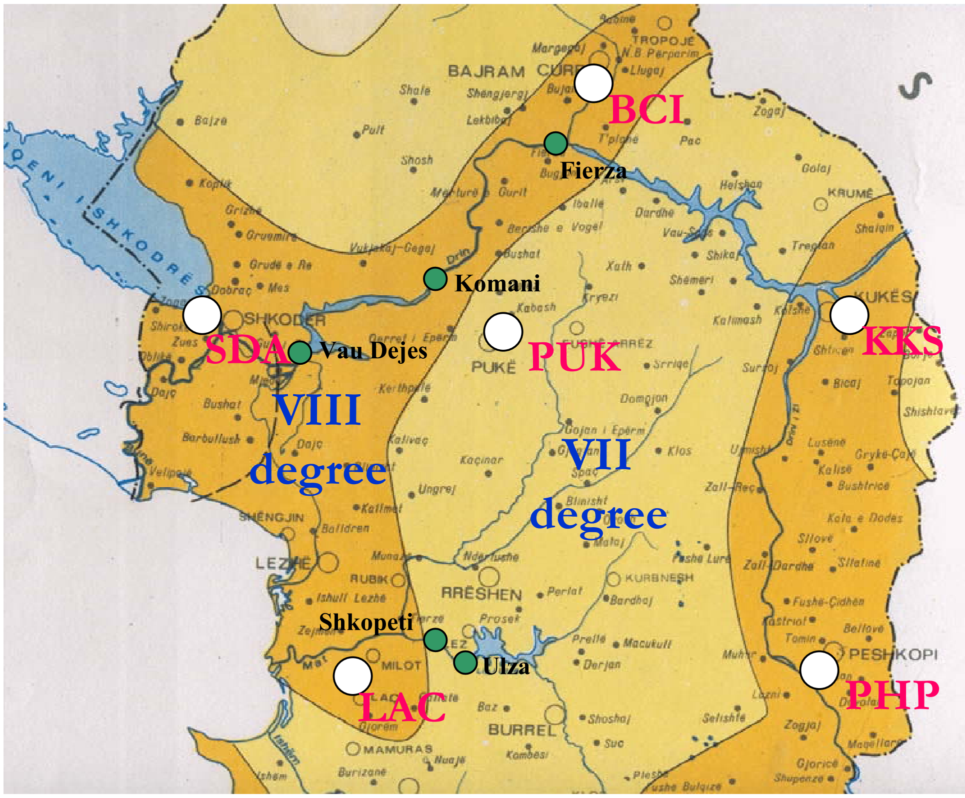

Figure 1. Fragment of Seismic Zonation Map of Albania (Sulstarova et al., 1980) showing the two main areas of VIII and VII degree of expected seismic intensity according to MSK-64 scale. The seismological stations with the respective codes around the HPP-s in the Drin and Mat River Cascades are shown with white circles.

2. SEISMICITY OF ALBANIA AND ASSESSMENT OF SEISMIC HAZARD AT THE DAM SITES

The overall energy released by the Albanian earthquakes during the XX-th century is E=6.448 $\times$ 10^{22} erg that corresponds to the energy released by an earthquake of magnitude M_S=7.34. This energy represents about 7% of the total energy released by all the shallow earthquakes that have occurred in Europe in this period of time (Sulstarova et al., 2003).

Albania is situated in the surrounding zone of Egean, which is the most seismically active zone of European sector of Alpin-Mediterranean seismic belt. The country is part of the contact zone between Adriatic microplate and Albanide's orogen which is part of a wider collision between Eurasian and African. This contact which possibly takes effect through a continental type of collision unceasingly accumulates deformations and propels the longitudinal tectonic faults bordering it as well as transversal tectonic faults cutting it and penetrating to the interior of the peninsula. Are precisely these continuous accumulations of tectonic deformations that through active faults as the earthquake cradles give way to seismic energy release shaping so the seismicity of the country (Muço, 1998; Sulstarova and Aliaj, 2001; Sulstarova et al., 2003). Studying the depth distribution of the earthquakes, the conclusion has been reached that those are mainly shallow, the depth of the majority of them do not exceed 20-25 km (Sulstarova et al., 2003).

A large amount of data for the Albanian earthquake has been collected. These data cover a 2000 years period of time. A comprehensive presentation in given in "The catalogue of Albanian earthquakes" (Sulstarova and

Koçiu, 1975) that shows the data collected up to 1970, "Earthquake Catalogue of the period 1971-1990 with magnitude $M_S \geq 4.0$" (Koçiaj et al., 1993) and " Earthquake Catalogue of the period 1976-1995 with $M_L \geq 3.0$" (Muço, 1998).

The earthquake data of the XX-th century are the most complete while the macroseismic information for the period 1800-1900 might be considered more or less reliable only for the earthquakes with $I_0 \geq$VII degree (MSK-64). For the period before 1800 the seismological data are available only for earthquakes with $I_0 \geq$VIII degree. For the period 1900-1970 the data are complete for earthquakes with $I_0 \geq 6$ degree; in the meantime, many data are available for smaller earthquakes with $I_0 \leq$VI degree, also (Sulstarova et al., 2003).

The most important event related to the HPP-s was the swarm of Nikaj–Merkuri, near the high dam and reservoir of Fierza HPP and the reservoir of Komani HPP. This induced seismicity phenomena has been the subject of several studies (Muço 1982, 1989, 1991). The swarm of Nikaj–Merkuri started abruptly on November 10, 1985, reached its peak by the end of November-beginning of December 1985 and then continued at a much lower level of activity for several months. A total of more than 17,000 micro-earthquakes with local magnitude $M_L > 1.0$ were recorded by Bajram Curri Seismological Station – the nearest station to the swarm zone; the hypocentral coordinates of 1800 events were determined. About 300 events were felt and caused slight damages in the epicentral zone; the cumulative intensity was VI–VII degree of MSK-64 scale. The maximum earthquake magnitude in this swarm was $M_L = 4.6$ and the depth of micro-earthquakes were shallow up to 10–15 km (Muço, 1991).

2.1. Seismic hazard assessment

The study of strong ground motion and the earthquake hazard in large dam projects plays a crucial role in the sustainability and economy of the project. Seismic hazard analysis is commonly performed to provide a quantitative estimation of the earthquake hazard at a dam site, thus providing the necessary design and controlling ground motion parameters.

Up to now, the seismic hazard in Albania has been assessed mostly in terms of macroseismic intensity (Sulstarova et al., 1980). Several attempts have been made to express the seismic hazard in terms of ground acceleration, velocity and displacement following different approaches (Muço et al. 2001, Muço et al. 2002, Peçi et al. 2002).

Depending on the methodology of characterizing the hazard, a seismic hazard analysis is referred to as (i) deterministic (DSHA) or (ii) probabilistic seismic hazard analysis (PSHA).

In the deterministic seismic hazard analysis, the ground motion characteristics are determined by choosing a controlling earthquake scenario and estimating the corresponding ground motion parameters.

The PSHA provides a framework in which the uncertainties in the size, location, and rate of recurrence of earthquakes and the variation of the ground motion characteristics with magnitude size and location can be considered in the evaluation of the seismic hazard by relating the ground motion parameter with average return period. The main benefit of the PSHA is that it allows computation of the mean annual rate of exceedance of a specified level of ground motion parameter at a particular site based on the aggregate risk from potential earthquakes of many different magnitudes occurring at many different source-site distances.

Of various probabilistic methods in use, the spatially smoothed seismicity approach was chosen. This method was developed by Frankel (1995) and further refined by Lapajne et al. (2000), and is widely used today (Frankel et al., 2000, 2002). The method still follows the basic approach established by Cornell in 1968, but no delineation of seismic sources is needed. The observed area is divided into grid cells, and in each cell the activity rate (the number of earthquakes above the threshold magnitude) is calculated and then spatially smoothed with a Gaussian function. The annual rate of exceedance of the specified level for a given ground motion parameter, and finally the relevant value corresponding to a given return period is calculated.

We have applied the spatially smoothed seismicity approach for the assessment of the seismic hazard parameters for the dam sites of Drini and Mati rivers, namely for Fierza, Komani, Vau Dejes, Ulza and Shkopeti HPP-s in terms of Peak Ground Acceleration (PGA) and Spectral Acceleration (SA). The analysis has been performed for the Maximum Credible Earthquake (MCE) as safety level and the Operating Basis Earthquake (OBE) as serviceability level. Both earthquakes are selected according to established international standards described in the ICOLD Bulletin 72 "Selecting Seismic Parameters for Large Dams" (ICOLD, 1989). Under the MCE load some damage to the dam is allowed, but an uncontrolled outflow of the reservoir must be avoided and all safety related equipment has to remain functional. Under the OBE, no structural damage such as tension cracks in concrete dams is allowed and all equipment has to remain functional.

The selected annual probabilities of exceedance for MCE and OBE are 1/10,000 and 1/150, respectively. These values are compatible with the recommendations of ICOLD (1989) and are commonly used in dam engineering practice. In Table 1 presented are the PGA values for the OBE and MCE at different dam sites.

Table 1. PGA for OBE and MCE for the dam sites

HPP site	MCE (annual probability of exceedance 1/10,000)	OBE (annual probability of exceedance 1/150)
Fierza	0.416	0.156
Komani	0.448	0.175
Vau Dejes	0.478	0.190
Ulza	0.435	0.171
Shkopeti	0.437	0.171

3. STRONG MOTION MONITORING OF DAMS

Significant advance was achieved during the last years towards the development of digital monitoring systems consisting on network recording, data transfer as well as their interpretation. These systems represent significant achievements compared to the analogues instruments. The actual strong motion accelerographs permit (i) high dynamic range recording with resolution up to 24 bit, (ii) large memory capability, up to several hours of recording, (iii) real time data processing, even without their transfer, and (iv) different communication possibilities and data transfer.

Strong motion data related to soil and structure vibration during strong earthquakes are essential for the assessment of seismic hazard, determination of design criteria as well as for the all the dynamic analysis in earthquake engineering. Without this kind of data all the analysis and studies would be based on assumptions. The stochastic character of earthquakes makes it difficult for this kind of data to be collected rapidly. One of the possibilities to resolve the question is the establishment of a network with an appropriate number of instruments for the recording of soil behavior and structures response during strong earthquakes.

Large dams are among the first structures where seismic design criteria have been applied since the 30-s. Until the publication of the ICOLD Bulletin 72 "Selecting Seismic Parameters for Large Dams" (ICOLD, 1989), it was a common practice to use the static method for their design (Martin, 2003). It is already known that earthquakes can generate much larger ground shaking than that accepted at the time of the construction of the majority of the existing dams worldwide. Furthermore, large dams whereas appear as rigid bodies, respond dynamically to earthquake shaking (Martin, 2003).

The main objective of the structural seismic monitoring and, in this context of the dams also, is to facilitate the studies dealing with their behavior during strong earthquakes, thus improving our understanding of their dynamic response and on the same time of their damage potential during the seismic action. As a result of this process, the design practice can be modified in order the earthquake damaging potential to be minimized.

In the Figures 2 and 3 presented are the proposed positions of the strong motion sensors for the Vau Dejes (Qyrsaqi) and Ulza dams in the framework of the project prepared for this purpose (Duni and Kuka, 2004). This instrumentation aims to provide data for the soil vibration (free-field sensor) and for the basement and the dam's body.

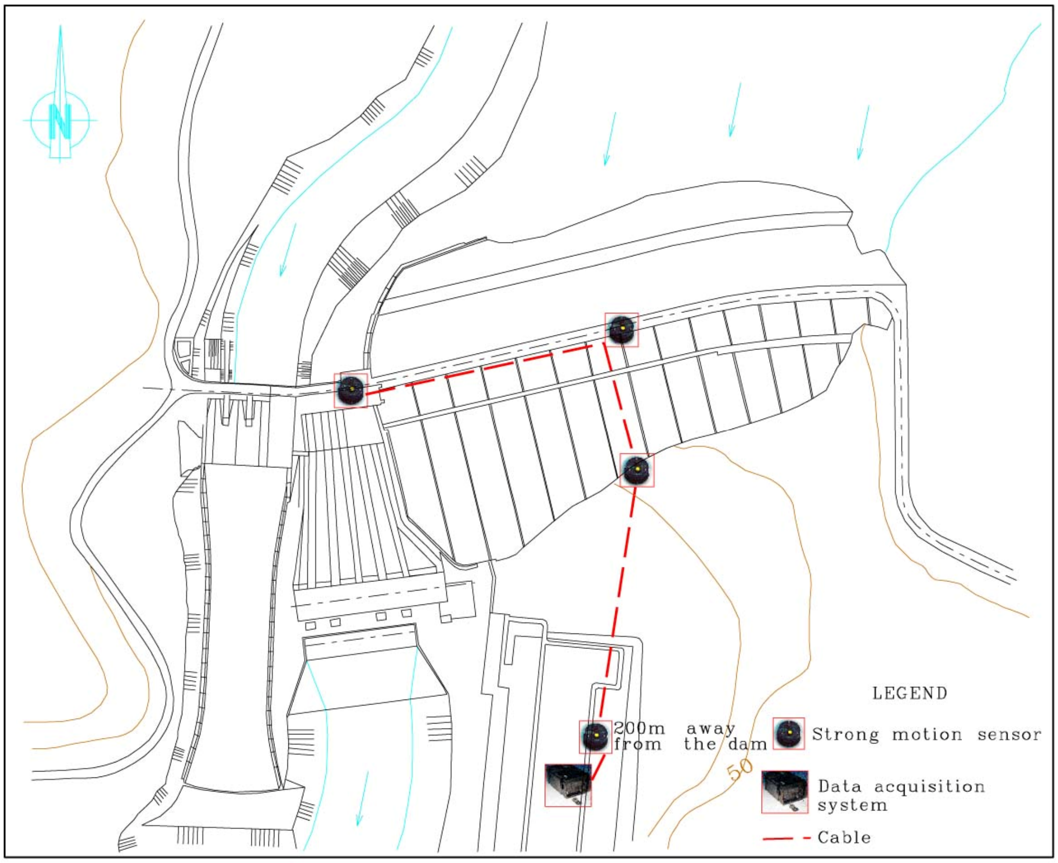

Figure 2. The strong motion monitoring of Qyrsaqi (Vau Dejes) dam

4. CONCLUSIONS

The high dams are an important element for the earthquake risk assessment in the areas where these structures are build and can be affected by their damage. This aspect is emphasized when the dams are built in areas of seismic activity. This is the case of high dams in Northern Albania. In order to provide all the information regarding the behavior of these structures in case of earthquake, for their normal operation as well as safeguard the downstream population, it is necessary to monitor the entire area and the dam itself through the establishment of the (1) local seismographic network, and (2) strong motion network.

The paper presented deals with the second phase of dams monitoring in Albania. Installation of strong motion instruments on the dam body will provide the necessary basic data for the analysis of their response during strong earthquakes, enabling the rapid decisions for the further utilization as well as the measures to be undertaken for the necessary repairs immediately after a strong earthquake.

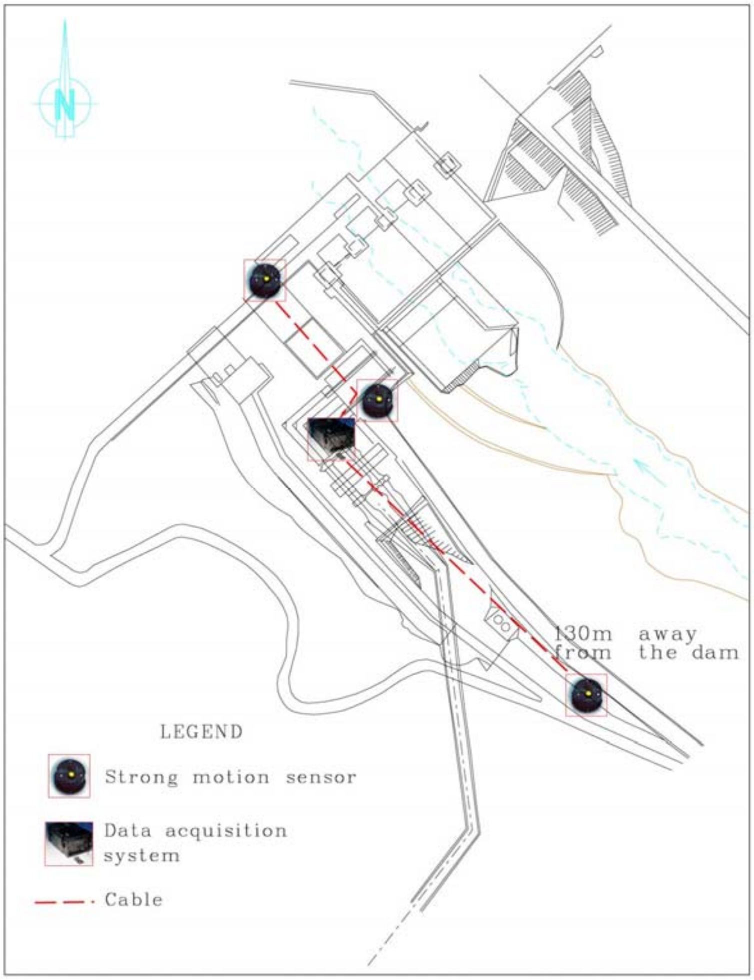

Figure 3. The strong motion monitoring of Ulza dam

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