PROBABILISTIC SEISMIC HAZARD ASSESSMENT FOR NORTHERN ALGERIA IN TERMS OF PGA, SA, UHS, AND DEAGGREGATION

by J.A Peláez[1*], M. Hamdache[2], C. López Casado[3], and A. Talbi[2]

In the last few years, a new probabilistic seismic hazard assessment for Northern Algeria has been carried out. The approach used was spatially smoothed seismicity since this methodology combines both the parametric and non-parametric probabilistic methods. Moreover, it is well suited to model the so-called disperse or background seismicity, that is, the seismicity that cannot be assigned to specific geologic structures. Initially, this approach was proposed and developed in works by *Frankel (1995) and Frankel et al. (1996)*.

These new seismic hazard values have been published in terms of mean **peak ground acceleration (PGA)** *(Peláez et al., 2003, 2005)*, **spectral acceleration (SA)**, and **uniform hazard spectra (UHS)** *(Peláez et al., 2006)*. In addition, recently we conducted studies yet unpublished in order to compute seismic hazard deaggregation in terms of magnitude and distance.

Data and methodology

The seismic catalog used for our study mainly consisted of data published by the Spanish IGN, supplemented for the Algerian zone with data published by the CRAAG, and initially updated to 2002. The published data for the study region by the EMSC and by the USGS have also been incorporated into the data file. Afterwards, the catalog was updated to June 2003, including the 21 May 2003, M 6.8, Algiers earthquake *(Hamdache et al., 2004)* and also the reappraisal of significant earthquakes from the 19th century, mainly in northeastern Algeria *(Harbi et al., 2003)*. All the magnitudes and maximum intensities were converted and unified to M_S magnitudes, and all the non-Poissonian earthquakes identified via the methodology proposed by EPRI (1986) were removed. The attenuation relationship developed by *Ambraseys et al. (1996)* was employed in our study as we consider it to be the most reliable one for Algeria, since these authors have considered acceleration data from several earthquakes (e.g., 29 October 1989, M_S 5.7, Tipaza earthquake) recorded in this region.

From our compiled catalog, four complete and Poissonian seismic models were established and used to compute seismic hazard: that with a seismicity of

a) $M \geq M_S$ 2.5 after 1960;
b) $M \geq M_S$ 3.5 after 1920;
c) $M \geq M_S$ 5.5 after 1850; and
d) $M \geq M_S$ 6.5 after 1700.

The final seismic hazard values are obtained by weighing the partial results derived from each of the models. From the smoothed earthquake number included in each model, the seismic hazard is computed from the well-known total probability theorem in terms of the rate of exceedance of different levels of ground motion.

Results

Among the results obtained, initially we consider mean PGA values with a 10% probability of exceedance in 50 years, that is for a return period of 475 years, for rock conditions (Fig. 1).

The highest values for the seismic hazard appear in the central area of the Tell Atlas. In particular, in the wilaya of Chlef, including the city of El Asnam, and the western part of the wilayas of Tipaza and Ain Defla, the mean PGA is above 0.24 g, and reaches 0.48 g in the epicentral area of the 1954 and 1980 El Asnam earthquakes. The seismic hazard map shows another lobe, with a lower value, around 125 km east of the previous one. It includes the wilayas of Blida and most of Algiers, including the city of Algiers. Values above 0.24 g are also reached in this area.

Afterwards, we derived SA values for rock (v_S > 750 m/s), corresponding to soil types A in the Eurocode 8 (*EC 8, 1998*) and S1 in the Algerian building code (*RPA-99, 2000*), damped at 5%, for different periods.

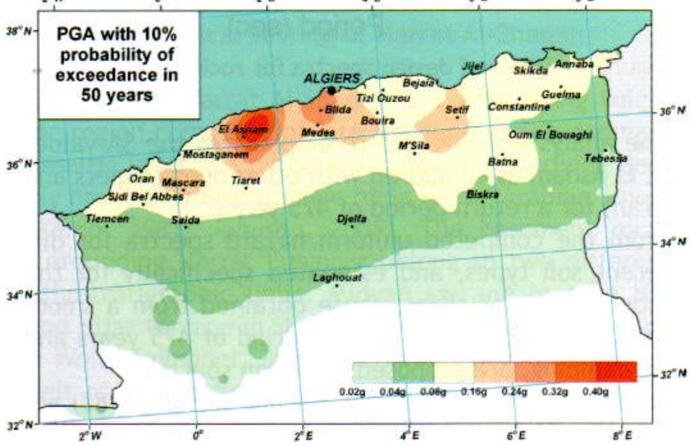

Figure 1 - Probabilistic mean PGA values for rock and a return period of 475 years.

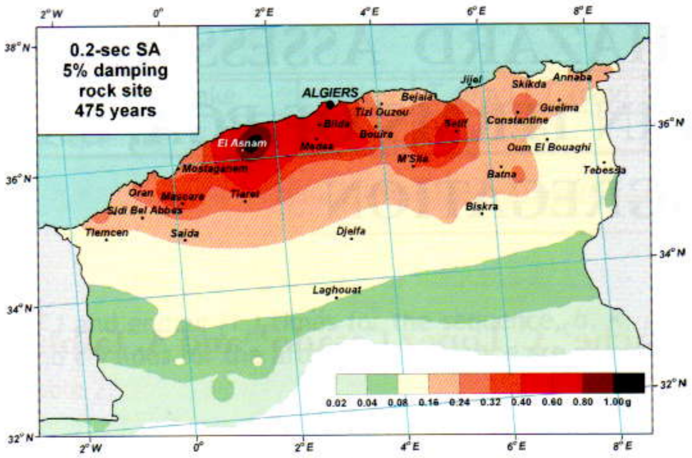

Figure 2 - Probabilistic SA values for rock, 0.2-sec, damped at 5% and a return period of 475 years.

The results were plotted as contour maps as well. These plots commonly show that maximum values occur again in the central part of the Tell Atlas, close to the location of the historical earthquake of January 15, 1891 (macroseismic magnitude M_S 7.0), and close to the more important recent instrumental earthquakes of September 9, 1954 (M_S 6.8), and October 10, 1980 (M_S 7.3). The maximum SA value in this region, for a return period of 475 years, is 0.95 g at 0.2-sec and 0.4-sec, and 1.07 g at 0.3-sec (Fig. 2). This region appears clearly as the seismic focus generating the higher seismic hazard level, independently of the return period being considered.In addition to the seismic hazard assessment at different periods, we have computed the UHS at different locations. The attenuation model used allows high definition in the computation of the spectra.

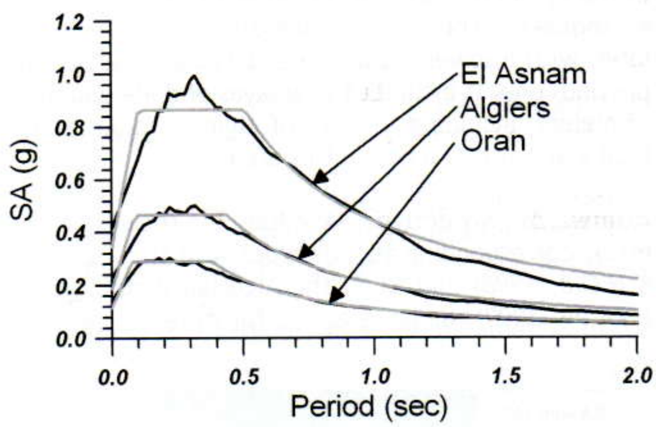

Figure 3 - UHS and design spectra for rock damped at 5%.

The analysis of Figure 3 re-emphasizes the SA values at El Asnam as compared with other ones (Algiers and Oran) for a return period of 475 years.
From the computed uniform hazard spectra for different soil types, and estimated specifically for the most important cities, those obtained from a smoothing approach, for a return period of 475 years and 5% damping, are proposed as design spectra.
To do so, we have used the *Newmark-Hall (1982)* approach with certain modifications. The spectral acceleration for 0.2-sec is used to establish the spectral region for lower periods (region controlled by the acceleration), while a spectral acceleration value for 1.0-sec is used to establish the spectral region for intermediate periods (region controlled by the velocity), as such it is proposed in the recent International Building Codes.

Finally, a deaggregation study of the mean PGA in terms of magnitude and distance was performed. Based on these results, we can compute the so-called control earthquake *(Bernreuter, 1992)*, that is, the earthquake contributing most to the seismic hazard in a certain location from a probabilistic point of view. To define this value, the average values or the modal values of the magnitude and distance can be used; it is the so-called 2D hazard deaggregation technique.
The modal values are more representative when applied to the seismoresistant design or the calculation of the safe shutdown earthquake.

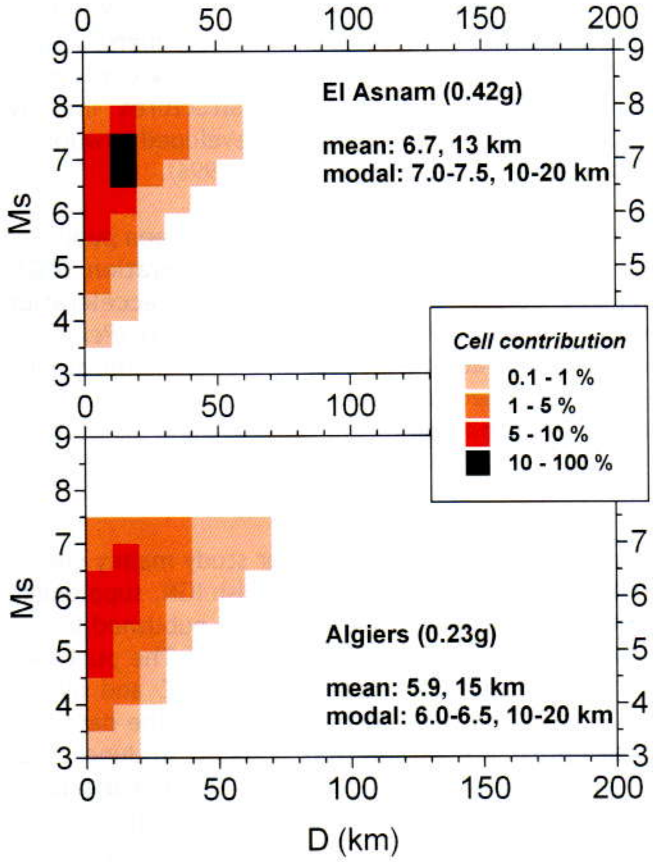

Figure 4 - Probabilistic seismic hazard deaggregation in terms of magnitude and distance for a return period of 475 years.

As an example, some unpublished results are showed in Figure 4. A typical morphology can be observed with a single nearby lobe both in El Asnam and Algiers, where hazard is due exclusively to a single local seismic focus, more or less extensive, surrounding the city. As can be seen, using the average or modal values to calculate the control earthquake provides values that nearly coincide. The dominant event in these locations is an earthquake hosted less than 20 km away, with a magnitude of M_S 6.0-6.5 in the case of Algiers and of M_S 7.0-7.5 in the case of El Asnam.
As indicated by different authors, and as is already taken into account by different American regulations (e.g., *USNRC, 1997*), this type of study is essential in

order to be able to completely analyze the results obtained in any study of seismic hazard.

References

Ambraseys, N.N., Simpson, K.A., and Bommer, J.J. (1996). Prediction of horizontal response spectra in Europe. Earthquake Eng. Struct. Dyn. 25, 371-400.

Bernreuter, D. L. (1992). Determining the controlling earthquake from probabilistic hazards for the proposed Appendix B. Lawrence Livermore National Laboratory Report UCRL-JC-111964. Livermore, California.

EC 8 (Eurocode 8) (1998). Design provisions for earthquake resistance of structures - Part 1-1: General rules. Seismic actions and general requirements for structures. European Prestandard ENV 1998-1-1. Comité Européen de Normalisation, Brussels.

EPRI (Electric Power Research Institute) (1986). Seismic hazard methodology for the Central and Eastern United States. EPRI Report NP-4726, Palo Alto, California.

Frankel, A. (1995). Mapping seismic hazard in the central and eastern United States. Seismol. Res. Lett. 66, 8-21.

Frankel, A., Mueller, Ch., Barnhard, T., Perkins, D., Leyendecker, E.V., Dickman, N., Hanson, S., and Hopper, M. (1996). National seismic-hazard maps: Documentation June 1996. U.S.G.S. Open-File Report 96-532.

Hamdache, M., Peláez, J.A., and Yelles Chauche, A.K. (2004). The Algiers, Algeria earthquake (MW 6.8) of 21 May 2003: preliminary report. Seism. Res. Lett. 75, 360-367.

Harbi, A., Benouar, D., and Benhallou, H. (2003). Reappraisal of seismicity and seismotectonics in northeastern Algeria. Part I: Review of historical seismicity. J. Seismol. 7, 115-136.

Newmark, N.M., and Hall, W.J. (1982). Earthquake spectra and design. Earthquake Engineering Research Institute Monograph Series no. 3, Berkeley, California, USA.

Peláez, J.A., Hamdache, M., and López Casado, C. (2003). Seismic hazard in Northern Algeria using spatially smoothed seismicity. Results for peak ground acceleration. Tectonophysics 372, 105-119.

Peláez, J.A., Hamdache, M., and López Casado, C. (2005). Updating the probabilistic seismic hazard values of Northern Algeria with the 21 May 2003 M 6.8 Algiers earthquake included. Pure Appl. Geophys. 162, 2163-2177.

Peláez, J.A., Hamdache, M., and López Casado, C. (2006). Seismic hazard in terms of spectral accelerations and uniform hazard spectra in Northern Algeria. Pure Appl. Geophys. 163, 119-135.

RPA-99 (Règles Parasismiques Algériennes 1999) (2000). Centre National de Recherche Apliquée en Génie Parasismique, Alger.

USNRC (U.S. Nuclear Regulatory Commission) (1997). Identification and characterization of seismic sources and determination of safe shutdown earthquake ground motion. Appendix C: Determination of controlling earthquakes and development of seismic hazard information base. Regulatory Guide 1.165, Office of Nuclear Regulatory Research, Washington, D.C.

1) Department of Physics, University of Jaén, Jaén, Spain
japelaez@ujaen.es

2) C.R.A.A.G., Algiers, Algeria

3) Department of Theoretical Physics, University of Granada, Granada, Spain

* Corresponding author

RECENT VOLCANIC AND SEISMIC ACTIVITIES 2009 AT HARRAT AL-SHAQAH, WESTERN SAUDI ARABIA

by Hani Zahran[1] , Salah El-Hadidy[2]

Introduction

One of the volcanic provinces in western Saudi Arabia, Harrat Al-Shaqah (also known as Harrat Lunayyir), recently suffered from earthquake swarm with numerous small to moderate-size earthquakes in April-July 2009. The most intensive activity occurred on $17-19^{th}$ May when six magnitude 4.6-5.7 earthquakes occurred. Following the events the Saudi Civil Defence Authority evacuated the area and relocated over 20000 people to the neighboring cities of Yanbu and Medinah. The activity continued throughout June with several magnitude 4-5 earthquakes but then quieted down in July. Harrat Lunayyir is a lava field, relatively small (1750 km^2) compared to other lava fields in western Saudi Arabia. It lies 50 km east of the Umm Lojj port (Longitudes 37°45'0" and 37°75'0"E and Latitudes 25°10'0"N and 25.17°N). The oldest lavas of Harrat Lunyyir, most probably Pliocene in age (Fig.1), are easily recognizable in the field, as their surfaces are strongly weathered and affected by erosion that is expressed by a well-developed drainage system.

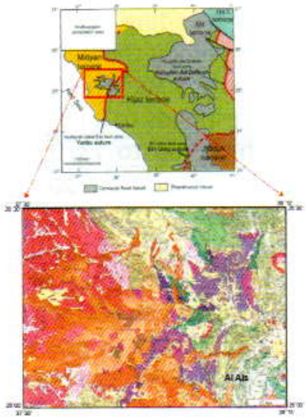

Figure 1 - Location map of Harrat Al-Shaqah, Saudi Arabia

Geological setting of Harrat Al-Shaqah

Geologically Harrat Al-Shaqah is a very young volcanic region composed of late Neogene and Quaternary basaltic lavas and pyroclastics directly overlying deeply eroded Neoproterozoic rocks of the Arabian Shield *(Kemp, 1981; Johnson, 2005)*. The basement rocks surrounding Harrat Lunayyir belong to two different lithostratigraphic units: Midyan terrane located NW and Hijaz terrane in SE *(Johnson, 1998, 2005; Johnson & Woldehaimanot, 2003)*. A complex of fault-bounded belt of ultramafic to mafic ophiolitic rocks known as Jabal Wask ophiolite lay between these two terranes and make the Yanbu suture (the Hudayrah-Jabal Ess fault-zone). Harrat Lunayyir have morphologic characteristics and lava flow stratigraphy indicates its