Uniform Hazard Spectra and Design Spectra in Northern Algeria

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Abstract
A new probabilistic seismic hazard assessment for Northern Algeria has been carried out. To do it, the used seismic catalog mainly consists of those published by the Spanish IGN, supplemented for the Algeria zone with data published by the CRAAG, and initially updated to 2002. Taking into account the particularity of the seismicity in northern Algeria, the spatially smoothed seismicity approach was used to the computation of seismic hazard. Seismic hazard map in term of PGA with 10% probability of exceedance in 50 years are obtained for rock, which correspond with a seismic hazard map for a return period of 475 years. Afterward, we have derived SA values for rock (V_S > 750 m/s), corresponding to soil types A in the Eurocode 8 and S1 in the Algerian building code, damped at 5%, for different periods. The obtained results were plotted as contour maps as well. In addition to the seismic hazard assessment at different periods, we have computed the UHS at different locations. The used attenuation model allows us a high definition in the computation of the spectra.
Finally, from the computed uniform hazard spectra for different type of soils, and estimated specifically for the most important cities, those obtained for a return period of 475 years and a 5% of damping are proposed as design spectra. 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 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 most recent International Building Code.

Keywords: probabilistic seismic hazard, PGA, SA, UHS, design spectra

Introduction

In the last years, a new probabilistic seismic hazard assessment for Northern Algeria has been carried out. To do it, the used catalog for this study mainly consists of those published by the Spanish IGN, supplemented for the Algeria zone with data published by the CRAAG, and initially updated to 2002. The data published for the 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. The non poissonian events identified via EPRI methodology have been removed. Four complete and Poissonian seismic models were established and used, considering the seismic characteristics of the catalog: those with a seismicity of a) M ≥ Ms 2.5 after 1960; b) M ≥ Ms 3.5 after 1920; c) M ≥ Ms 5.5 after 1850; and d) M ≥ Ms 6.5 after 1700. The spatially smoothed seismicity approach was used for the computation of the seismic hazard. The reason is that this methodology combines both parametric and non-parametric probabilistic methods. Besides, it is well adapted to model disperse or background seismicity, *i.e.*, the seismicity that cannot be assigned to specific geologic structures. Initially, this approach was proposed and developed by Frankel (1995). Seismic hazard map in term of PGA with 10% probability of exceedance in 50 years is obtained for rock, which correspond to a seismic hazard map for a return period of 475 years. Afterward, we have derived SA values for rock (Vs > 750 m/s), corresponding to soil types A in the Eurocode 8 and S1 in the Algerian building code, damped at 5%, for different periods. The obtained results were plotted as contour maps as well. In addition to the seismic hazard assessment at different periods, we have computed the UHS at different locations. The used attenuation model allows us a high definition in the computation of the spectra.
Finally, from the computed uniform hazard spectra for different type of soils, and estimated specifically for the most important cities, those obtained for a return period of 475 years and a 5% of damping are used to propose design spectra. 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 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 most recent International Building Code.
Obtained results have been published in terms of PGA (Peláez *et al*., 2003 & 2005), SA and UHS (Peláez *et al*., 2006) and response elastic spectra (Peláez *et al*., 2007).

Data and methodology outline

As has been pointed out before, the used catalog for this study mainly consists of those published by the Spanish IGN, supplemented for the Algeria zone with data published by the CRAAG, and initially updated to 2002. Data from the EMSC and the USGS have also been incorporated in the catalog. Afterwards, it was updated to June 2003, including the 21 May 2003, M 6.8, Algiers earthquake (Hamdache *et al.*, 2004) and the reappraisal of significant earthquakes which occurred in the 19th century, mainly in northeastern Algeria (Harbi *et al*., 2003). All the magnitudes and intensities were converted to Ms 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. Finally, four complete and Poissonian seismic models were established and used, considering the seismic characteristics of the catalog: those with a seismicity of *a)* M ≥ Ms 2.5 after 1960; *b)* M ≥ Ms 3.5 after 1920; *c)* M ≥ Ms 5.5 after 1850; and *d)* M ≥ Ms 6.5 after 1700. The final result was obtained by weighting the partial results derived from each of the models.

Results

Among obtained results, initially we detail mean PGA values with 10% probability of exceedance in 50 years, *i.e.*, for a return period of 475 years, for rock (Vs > 750 m/s) (figure 1). The greatest values of the seismic hazard appear in the central area of the Tell Atlas. In particular, in the province of Chlef, including the city of El Asnam, and the western part of the provinces of Tipaza and Ain Defla, the mean PGA values are above 0.24g, and reaches 0.48g in the epicentral areas of the 1954 and 1980 El Asnam earthquakes. We can observe in the seismic hazard map another lobe, with a lower value, around 125 km to the east of the previous one. It includes the provinces of Blida and mostly Algiers, including the city of Algiers. Values above 0.24g are also reached in this area.

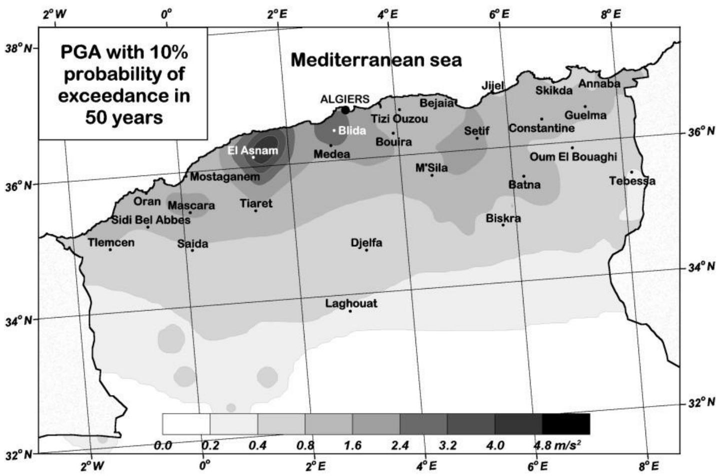

Figure1. Seismic hazard map in terms of PGA for a return period of 475 years

Afterwards, we have derived SA values for rock, corresponding to soil types A in the Eurocode 8 and S1 in the Algerian building code, damped at 5%, for different periods. The obtained 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 Ms 7.0), and to the more important recent instrumental earthquakes of September 9, 1954 (Ms 6.8), and October 10,

1980 (Ms 7.3). The maximum SA value in this region, for a return period of 475 years, is 0.95g at 0.2-sec and 0.4-sec, and 1.07g at 0.3-sec. This region appears clearly as the seismic source generating the higher seismic hazard level, independently of the return period being considered. As example, obtained results for periods of 0.2 and 1.0-sec are shown in figures 2 and 3. All the calculations are done for rock, 5% damping and a return period of 475 years.
In both cases, although with different level of hazard, the maximum spectral acceleration values are observed in the central region of the Tell, in particular, in the region of the Chleff (El Asnam). As has been pointed before, this is the epicentral area of the 1954 (Ms 6.8) and 1980 (Ms 7.3) earthquakes. In the city of El Asnam, for return periods of 100 and 475 years, values of spectral acceleration of the order of 0.4g and 1.0g are obtained, respectively, in the range of periods 0.2-0.3-sec.
The uniform hazard spectra (UHS) have been also derived at different locations. To use the Ambraseys *et al*. (1996) attenuation relationship allows us to compute spectra with a high resolution. An example, the UHS for Algiers, is showed in the figure 4.

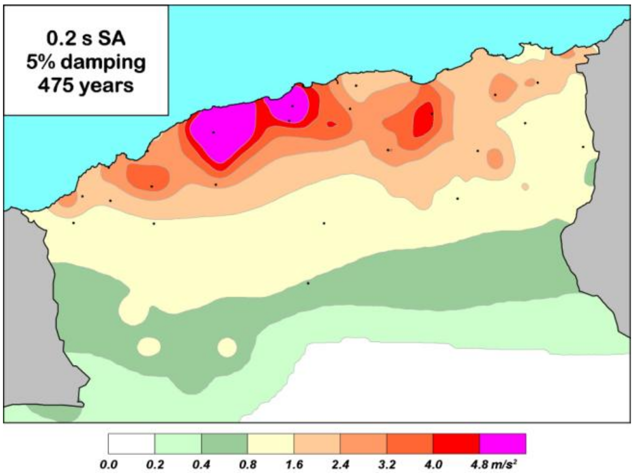

Figure 2. Seismic hazard map in terms of SA for a period of 0.2-sec. It has been computed for rock, 5% damping, and a return period of 475 years

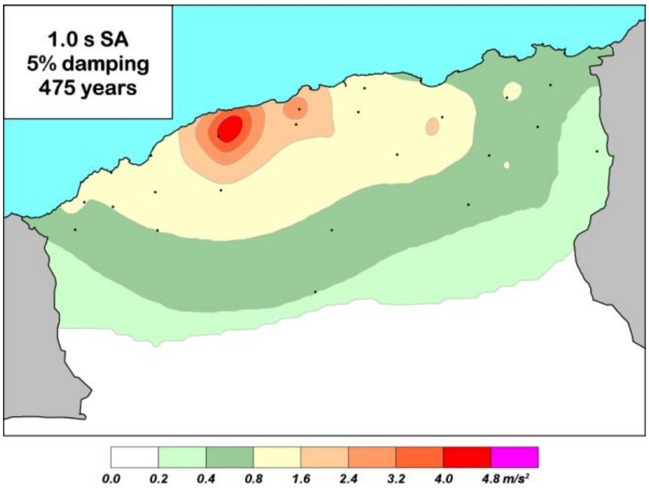

Figure 3. Seismic hazard map in terms of SA for a period of 1.0-sec. It has been computed for rock, 5% damping, and a return period of 475 years.

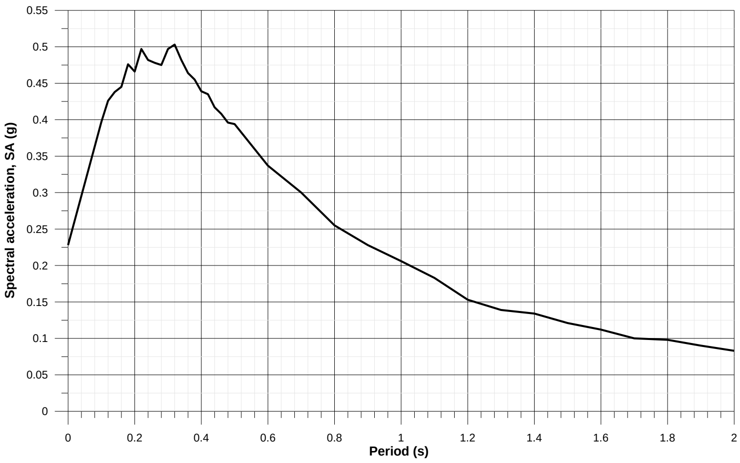

Figure 4. Uniform hazard spectrum for Algiers. It has been computed for rock, 5% damping and a return period of 475 years (Peláez *et al*., 2006).

Design spectra. Preliminary results

The method used here in order to know the design spectra for a certain return period and damping coefficient, need as input only values of the spectral acceleration for two periods, 0.2 and 1.0-sec (Malhotra, 2005). Initially it must be computed the value

$$T_s = 1s\,\frac{SA(1s)}{SA(0.2s)}$$

Next, the design spectrum is defined as

$$SA(T) = \begin{cases} 0.4SA(0.2s) + 3SA(0.2s)\dfrac{T}{T_s} & T < 0.2T_s \\ SA(0.2s) & 0.2T_s < T < T_s \\ SA(1s)\dfrac{1s}{T} & T > T_s \end{cases}$$

The final result is a simplified design spectrum in where, strictly speaking, only the spectral accelerations for 0.2 and 1.0-sec correspond to the return period for which this spectrum has been computed.
In the following table (table 1), the values that define the design spectrum for some of the most important cities in the north of Algeria, for different soil types, and for a return period of 475 years, are shown.

Cities	***rock***		***soft***		***stiff***	
	SA (0.2 s)	***SA (1.0 s)***	***SA (0.2 s)***	***SA (1.0 s)***	***SA (0.2 s)***	***SA (1.0 s)***
Oran	0.289	0.111	0.394	0.149	0.400	0.161
Mostaganem	0.270	0.126	0.368	0.169	0.374	0.208
Medea	0.493	0.218	0.683	0.360	0.672	0.293
Mascara	0.369	0.150	0.504	0.201	0.512	0.248
El Asnam	0.865	0.441	1.180	0.593	1.200	0.731
Tiaret	0.262	0.145	0.358	0.194	0.364	0.239
Argel	0.466	0.206	0.636	0.760	0.646	0.340
M’Sila	0.309	0.113	0.421	0.151	0.428	0.186
Tizi-Ouzou	0.211	0.103	0.287	0.138	0.291	0.170

Blida	0.638	0.264	0.871	0.355	0.885	0.437

Table 1. SA (g) for a return period of 475 years, periods of 0.2 and 1.0-sec, and 5% damping. Soil types are according to the classification by Ambraseys *et al*. (1996).

In the figure 5 some results are shown. We can see for the cities of the El Asnam, Algiers and Oran the design spectra for rock (Vs > 750 m/s, corresponding with the soil type A of EC 8) and soft soils (180 < Vs < 360 m/s, corresponding with the soil type C of EC 8).
Finally, in figure 6 we show the clear relationship among SA(0.2 s) values and the PGA value obtained at the same location, the same return period, and the same soil type. We can observe that, independently of the return period, the spectral acceleration value for a period of 0.2-sec is the double of the PGA value for rock, and of the order of 2.6 for other types of soils. This dependency implies that we can use as parameters to define the proposed design spectra the pair (SA(0.2 s), SA(1.0 s)) or the pair (PGA, SA(1.0 s)) with the same reliability.

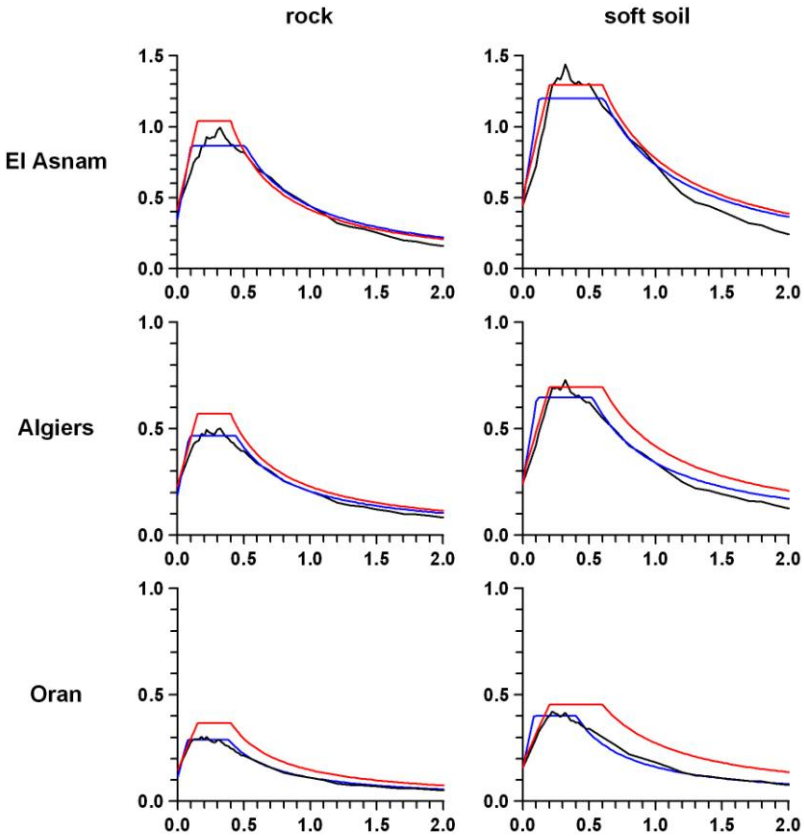

Figure 5. Uniform hazard spectra (pseudo-acceleration (g) *vs.* period (s)) for a return period of 475 years and 5% damping, computed for the cities of the El Asnam, Algiers and Oran. Uniform hazard spectra (in black), elastic design spectra proposed in this work (in blue) and elastic design spectra proposed in the EC-8 (in red).

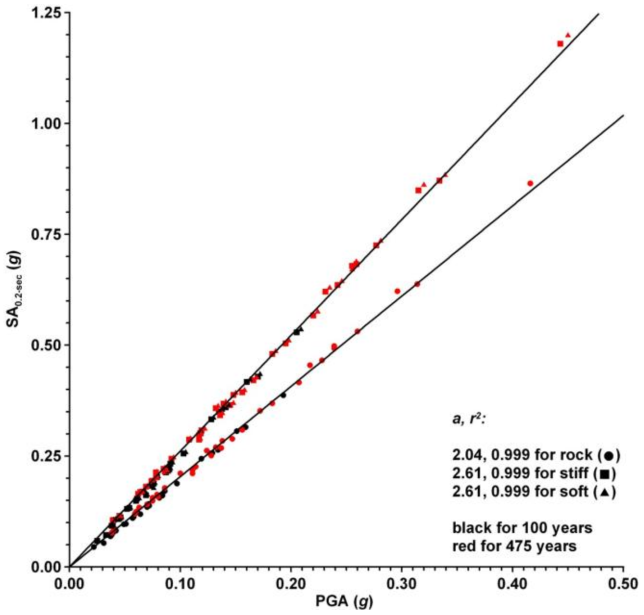

Figure 6. Relationship between SA(0.2 s) and PGA. For each type of soil, slope (a) and coefficient of determination (r^2) values are showed

Conclusions

This study gives a large overview on seismic hazard estimation obtained in northern Algeria. The obtained results are used to propose design spectra in this region. The advantage of the proposed approach is the use of only two parameters obtained for a specific return period, soil type and damping.

In our case, we have used the parameters obtained from the estimation of uniform hazard spectra (UHS) obtained previously at different locations in northern Algeria.

After comparing design spectra, uniform hazard spectra and elastic response spectra according with EC 8, we observed that design spectra obtained using the procedure explained in this study, are easier to define, presenting a high reliability in mostly cases, especially for intermediate and long periods.

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