STRONG-MOTION RECORDS SELECTION FOR FRENCH PARASEISMIC ENGINEERING DATABASE

E. Bertrand[1] J.Dupuis[1] and A.-M. Duval[1]

[1] *LRPC de Nice, CETE Mediterranee, Nice, France*
Email: etienne.bertrand@developement-durable.gouv.fr

ABSTRACT :

For earthquake resistance assessment of existing structures as well as for new constructions design, observed strong motion records are commonly used as input either for laboratories shacking table experiment or for computer modelling. Until the early 1990s, strong-motion data was relatively difficult to obtain and process and, in addition, the amount of, particularly near-source, strong-motion was limited. Therefore using standard records was often the only option. However, since then a number of large well-recorded earthquakes have occurred and thus there are many new strong-motion data sources available.
The purpose of the work presented here is to constitute a database of natural time-histories extract from the European Strong-Motion Database adapted to the French earthquake regulation code. This database will offer to the French engineers a quick and easy access to well adapted real records.
The constitution of the database benefits from the setting up of the new European earthquake regulation EC8 in France. The task has been carried out in the frame of a working group managed by the SETRA (a technical department for transport, roads and bridges engineering and road safety of the French ministry for Ecology, Sustainable Development and Spatial Planning).
For each seismicity level of the French metropolitan zoning (weak, moderate and medium) and each soil type (A, B, C, D, E) we propose up to five 3-component accelerometric records selected by their PGA (Peak ground Acceleration) and spectral shape. Because of the non-completeness of the European database, it has been necessary to apply to certain records an amplification factor to increase the observed PGA in order to better fit the regulation code. Nevertheless, this amplification factor never exceeds the database standard deviation on PGA. Through this simple selection procedure, 61 time-histories have been chosen.

KEYWORDS: strong-motion, earthquake design, database, EC8

1. INTRODUCTION

Ground acceleration is the shaking parameter the most often employed in earthquake engineering as it is directly linked to the strength that applies to the structure foundations during an earthquake. Strong-motion records are for instance frequently used as input to the structural models (Douglas, 2006). These strong motions are either natural recordings or numerically modeled time-histories. However, by using natural time-histories engineers should be able to take into account the real variability and complexity of the ground movement in their structural modeling. These records are rather complicated in shape indeed and depend on the source characteristics, the wave travel path in the crust and the local site effects due to the shallower geological layers or the topography. In order to match the true variability of the ground motion several recordings with similar basic criteria (distance and magnitude for instance) has to be considered to test the importance of ground-motion characteristics on the structure’s behavior. An adequate selection of time-histories would thus enable significant value to be extracted from the structural modeling. To help the engineer and encourage them to use several well-adapted recordings as input of their modeling, it is of interest to built a simple database. In the frame of a working group managed by the SETRA (a technical department for transport, roads and bridges engineering and road safety of the French ministry for Ecology, Sustainable Development and Spatial Planning) it has been asked to constitute such a database extract from the European Strong-Motion Database (Ambraseys et al., 2004) adapted to the French earthquake engineering regulation code. The constitution of the database benefits from the setting up of the new European earthquake regulation EC8 in France. The database will offer to the French engineers a quick and easy access to well adapted real records. The number of records selected

will be representative of the natural variability of strong motions.
This article presents the database we implement. It describes the methodology we use for the selection of the strong-motions as well as the associated criteria and specifies the records finally kept.

2. FRENCH SEISMOLOGICAL SETTINGS

2.1. Earthquake regulation code

The earthquake engineering regulation is about to change in order to implement the Eurocode 8 (EC 8). A new seismic zonation based on a probabilistic approach (GEOTER, 2002) is already available and the associated elastic response spectrum will be specified in the national appendix. The influence of local soil conditions on the seismic action is accounted for by considering the five subsoil classes (A, B, C, D and E) described by the stratigraphic profiles and parameters given in the EC8. The French elastic response spectrum related to these soil classes are shown in figure 1.
The French territory is divided in 5 zones but only 4 of them concern the metropolitan France (figure 2). The lowest zone is characterized by a reference peak ground acceleration on rock (a_{gR}) smaller than 7% of g. For the 3 other zones, a_{gR} is fixed at 0.07g, 0.11g and 0.16g (weak, moderate and medium hazard respectively). The strongest hazard zone corresponds to the French West Indies where the reference peak ground acceleration on rock reaches 30% of g. All these accelerations are associated to a return period of roughly 475 years.

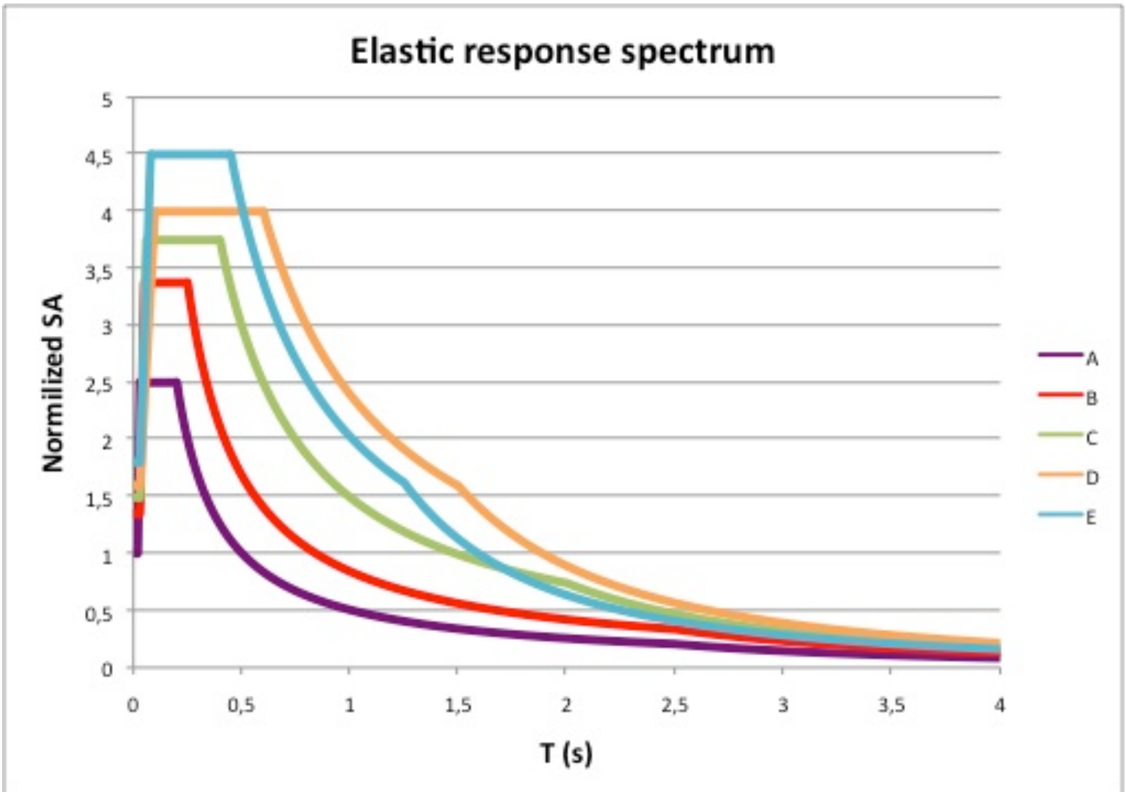

Figure 1: French elastic response spectrum for each soil class defined in EC8.

The accelerometric database we present in this paper is only adapted to the 4 zones describing the metropolitan France.

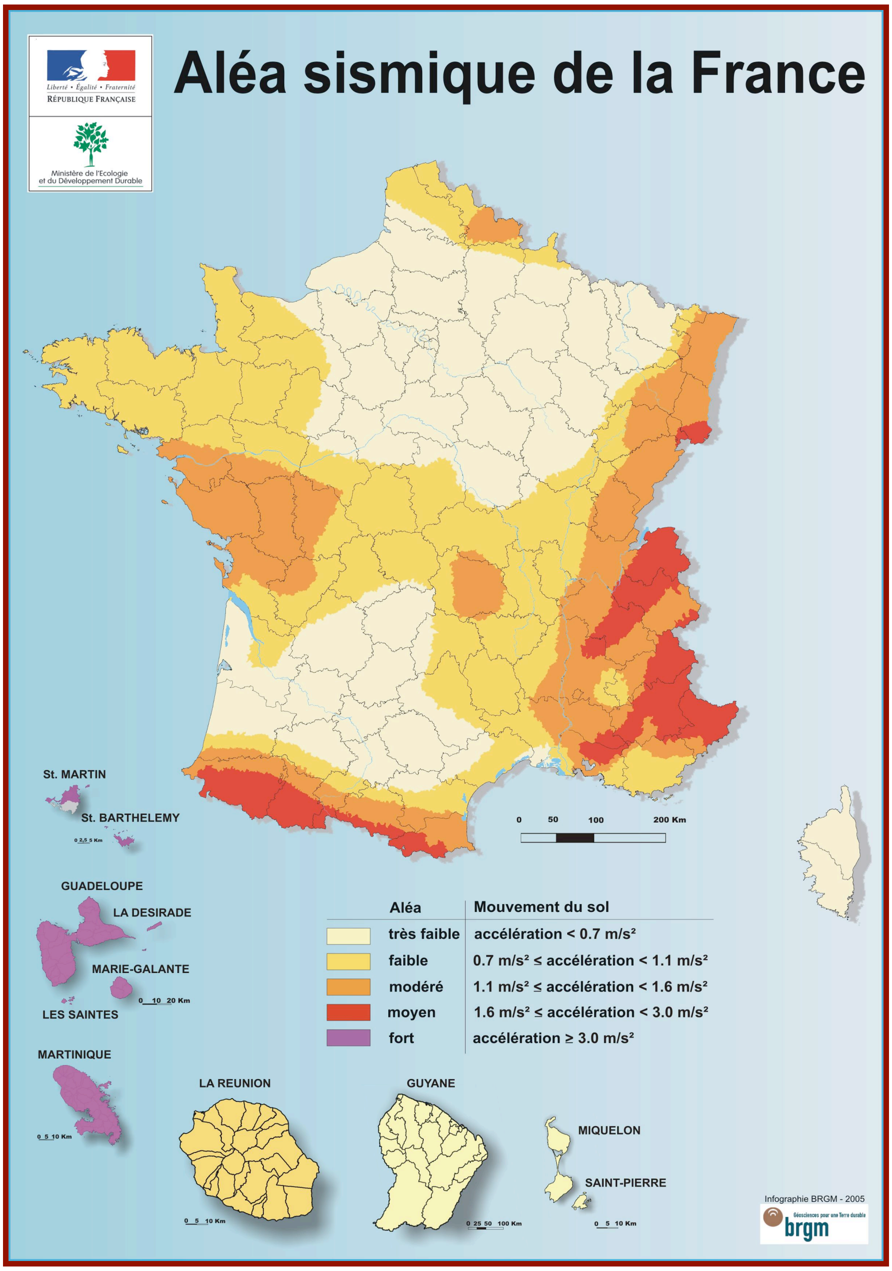

Figure 2 : French new seismic zonation (MEEDDAT, 2005)

2.2. Available data

Metropolitan France is characterized by a moderate seismicity. The last major earthquake of estimated magnitude close to 6.0 that stroke the French territory occurred in 1909 in Provence in southeastern France (according to SISFRANCE database, BRGM, EDF and IRSN). The maximum magnitudes estimated from historical seismicity are of the order of 6.1 to 6.3 (Ligurian sea, 23 February 1887; Pyrenees, 2 February 1428 respectively) (Marin et al., 2004). As the epicenter of these events are both located out of France, the associated ground motion on the French territory wasn't such critical. In the French context, only few things are known about stronger events. These events have never been recorded, never been historically described, but are deduced from geological investigations and observations on a few large faults (Marin et al., 2004). Magnitudes inferred from paleoseismic observations are of the order of 6 to 7. Despite these uncertainties, such events cannot be completely ignored.

Since 1995, France is equipped with a permanent accelerometric network (RAP). It is composed of stations located in the most seismic zones of France (mainly southeaster, Alps, Pyrenees and northeaster). According to the French national seismic survey database (ReNaSS), the maximum magnitudes of event having their epicenter in metropolitan France recorded by this network are equal to Ml 5.6-5.4 (Pyrenees, 18 February 1996; Brittany, 30 September 2002; Vosges, 22 February 2003).
The reference peak ground acceleration on rock (a_{gR}) for each zone of the French seismic zonation corresponds approximately to a returning period of 475 years and to a probability of exceedance of 10% in 50 years. Thus, for the moment, it does not exist any strong-motion recording that could fit the French earthquake regulation requirements in the French database. In order to supply this lack of data, we have to look for time-histories in databases from countries with stronger seismicity. In order to be coherent with the seismological and the geological settings of France, we choose to consider the European strong-motion database (Ambraseys et al., 2004).
Even if some authors have already shown that the consistency of ground motion prediction equations (GMPE) derived in European countries are of limited consistency with the French data recently available (e.g. Marin et al. 2004), it seems that this database is the most adapted one. Indeed, Douglas (2004) considers ground motions from five regions of Europe and by applying analysis of variance to data binned into similar magnitude and distance intervals concludes that there is little evidence for inter-regional variations in ground motions within Europe. Moreover, Campbell (2003) shows that ground motion in stable continent regions are richer in high-frequency motions than those in more seismically active region and hence an analysis made for a structure in such a region should ideally use input accelerograms in accordance.
The data provided by Ambraseys et al. (2004) has also been thoroughly validated within various projects leading up to the publication of the CD ROM and consequently it provides a reliable source of data. Finally, the strong-motion records contained on the CD ROM have been individually processed using bandpass filters based on the signal-to-noise ratio of the record and therefore the acceleration, velocity and displacement time-histories should be free of noise within the passband of the filters used.

3. SELECTION CRITERIA

Due to the high sensitivity of results from structural modeling to the set of input acceleration time-histories used (e.g. Kwon and Elnashai, 2004) it is important that a reasonably large set of accelerograms is employed so that the uncertainty in the results can be assessed (Douglas, 2006). However, structural testing is a time-consuming and expensive exercise therefore the number of input time-histories used should be kept to a minimum.
As most modeling of the structures response to earthquakes is conducted using one-dimensional horizontal excitation, only horizontal components are considered in this paper. Moreover, the two horizontal components from the same triaxial strong-motion record are considered independently.
The first selection criterion we take into account is a magnitude-distance filter to exclude records from magnitudes and distances that are not possible by considering the seismogenic sources of France. According to Marin et al. (2004) metropolitan France has a seismic hazard that is thought to be characterized by earthquakes of magnitudes (Ml) less than or equal to 6.3. Therefore accelerograms from small and moderate earthquake with magnitudes les than about 6.3 are most appropriate for our database. Because some seismogenic sources are located outside the border of the country, we consider epicentral distance up to 100 km and we enlarge the research including magnitude (Mw) up to 6.7. In addition, Marin et al. (2004) consider that the average focal depths in France are less than or equal to 12km. As this parameter is often miss-evaluated in epicentre localisation, the upper bound in our selection is pushed to 30 km. Search criteria of 5.0 $<Mw<6.7$, $de<100$km and $h<30$km returned 247 horizontal component.
To reduce the number of selected time-histories, we consider in a second step the French earthquake regulation code by taking into account the specific peak ground acceleration ($S.a_{gR}$) by zone as well as the appropriate elastic spectrum shape for each EC8 soil type (figure 1). The following table gives the peak ground acceleration taken into account for each of the seismic zone and the soil type.

Table 3.1: Peak ground acceleration criteria for each seismic zone and soil type.

		Weak	Moderate	Medium
A	a_{gR} (g)	0,07	0,1	0,16
	Interval (g)	0,05 – 0,085	0,085 – 0,13	0,13 – 0,18
B	$S.a_{gR}$ (g)	0,0945	0,135	0,216
	Interval (g)	0,069 – 0,11	0,11 – 0,17	0,17 – 0,25
C	$S.a_{gR}$ (g)	0,105	0,15	0,24
	Interval (g)	0,07 – 0,125	0,125 – 0,19	0,19 – 0,28
D	$S.a_{gR}$ (g)	0,112	0,16	0,256
	Interval (g)	0,07 – 0,137	0,137 – 0,2	0,2 – 0,29
E	$S.a_{gR}$ (g)	0,126	0,18	0,288
	Interval (g)	0,09 – 0,15	0,15 – 0,23	0,23 – 0,31

We do not take into account the soil type specified in the European database since we are interested in fitting the spectral shape given in the regulation (figure 3). Furthermore, it has been necessary for some cases to apply a correction factor to the selected traces in order for the mean to better fit the wished peak ground acceleration. This is already done in previous study (e.g. Boomer et al., 2004). According to Krinitsky and Chang (1977) such a correction factor should not be greater than 4 whereas Vanmarcke (1979) allows it to be in the range 0.5-2. In this study, this factor is always smaller than the standard deviation of the selected traces and is included between 1.1 and 1.4.

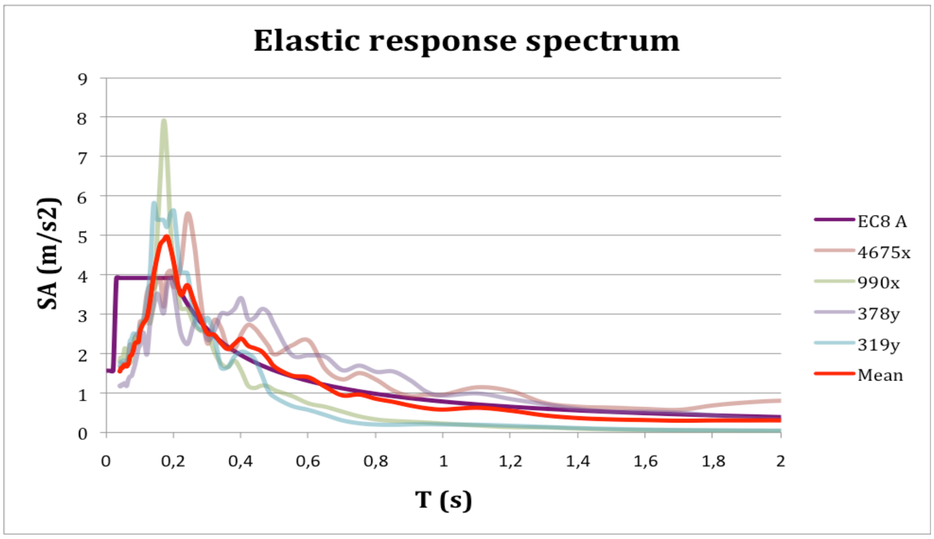

Figure 2 : Example of response spectrum fit for medium zone, soil A.

4. DATABASE DESCRIPTION

The strong-motion database we've build is composed of 61 time-histories (table 4.1). Some of them are common to several zones and soil types. Most of the selected traces have been recorded in Italy or Greece.
The three graphics presented in figure 3 give the distribution of the selected traces in function of the peak ground acceleration (PGA), the epicentral distance and the magnitude respectively. As already mentioned, we select data recorded at distance smaller than 100 km from event with a magnitude ranging between 5 and 6.7. The distribution of data in this range is rather homogenous. The PGA is varying from 0.04 g to 0.61 but most of the accelerograms selected are characterized with a PGA between 0.08g and 0.3g, in good agreement with the French seismic hazard specified in the regulation.

Table 4.1: Strong-motion data list.

Zone	Soil Type	Time-history id	Comp.	Region	Magnitude (Mw)	Epic. Dist. (km)	PGA (g)	Corr. Factor
Weak	A	94	y	Friouli	5,23	16	0,0512	1
		366	y	Lazio Abruzzo	5,93	36	0,065	
		5824	x	Strofades	5,02	26	0,042	
		615	y	Umbria Marche	6,04	55	0,066	
	B	114	y	Friuli	5,33	15	0,107	1
		120	x	Friuli	5,6	15	0,097	
		160	x	Friouli	5,43	7	0,086	
		1711	y	Ano Liosia	6,04	20	0,079	
		980	y	Campano Lucano	5,29	4	0,08	
	C	322	y	Campano Lucano	5,29	8	0,109	1,2
		602	x	Umbria Marche	6,04	27	0,106	
		5826	x	Strofades	6,64	90	0,073	
		1314	x	Ano Liosia	6,04	17	0,11	
		1713	x	Ano Liosia	6,04	18	0,062	
	D	1911	x	Komilion	5,42	15	0,134	1,1
		5850	x	Strofades	6,64	38	0,12	
		5826	x	Strofades	6,64	90	0,073	
	E	322	y	Campano Lucano	5,29	8	0,109	1
		1911	x	Komilion	5,42	15	0,134	
		5850	x	Strofades	6,64	38	0,118	
Moderate	A	128	x	Friuli	6,04	28	0,064	1
		160	x	Friuli	5,43	7	0,088	
		602	x	Umbria Marche	6,04	27	0,11	
	B	138	x	Friuli	6,08	37	0,099	1
		318	y	Campano Lucano	5,29	5	0,153	
		1713	x	Ano Liosia	6,04	18	0,062	
		1710	y	Ano Liosia	6,04	19	0,124	
		1312	x	Ano Liosia	6,04	20	0,16	
	C	170	y	Basso Tirreno	6,1	18	0,159	1
		175	y	Volvi	6,29	29	0,146	
		1911	y	Komilion	5,42	15	0,134	
		624	x	Umbria Marche	5,58	15	0,187	
		378	y	Lazio Abruzzo	5,93	16	0,114	
	D	170	y	Basso Tirreno	6,1	18	0,159	1,2
		175	y	Volvi	6,29	29	0,146	
		378	x	Lazio Abruzzo	5,93	16	0,114	
		1911	y	Komilion	5,42	15	0,134	
	E	581	x	Komilion	5,42	16	0,201	1,3
		4675	x	South Iceland	6,57	13	0,163	
		624	y	Umbria Marche	5,58	15	0,184	
		822	y	Umbria Marche	5,33	5	0,18	
		982	x	Friouli	5,43	9	0,183	
Medium	A	319	y	Campano Lucano	5,29	6	0,149	1
		378	y	Lazio Abruzzo	5,93	16	0,114	
		990	x	Lazio Abruzzo	5,53	15	0,081	
		4675	x	South Iceland	6,57	13	0,163	
	B	147	y	Friuli	6,08	14	0,233	1
		159	y	Friuli	5,43	7	0,192	
		288	y	Campano Lucano	6,93	43	0,219	

	C	123	y	Friuli	5,6	15	0,235	1
		147	y	Friuli	6,08	14	0,233	
		159	x	Friuli	5,43	7	0,192	
		581	x	Komilion	5,42	16	0,2	
		6093	y	Kozani	5,25	16	0,188	
	D	122	x	Friuli	5,6	9	0,23	1,4
		413	x	Kalamata	5,99	10	0,285	
		581	x	Komilion	5,42	16	0,2	
		6093	y	Kozani	5,25	16	0,188	
	E	123	y	Friuli	5,6	15	0,235	1,3
		413	x	Kalamata	5,99	10	0,285	
		6093	x	Kozani	5,25	16	0,188	

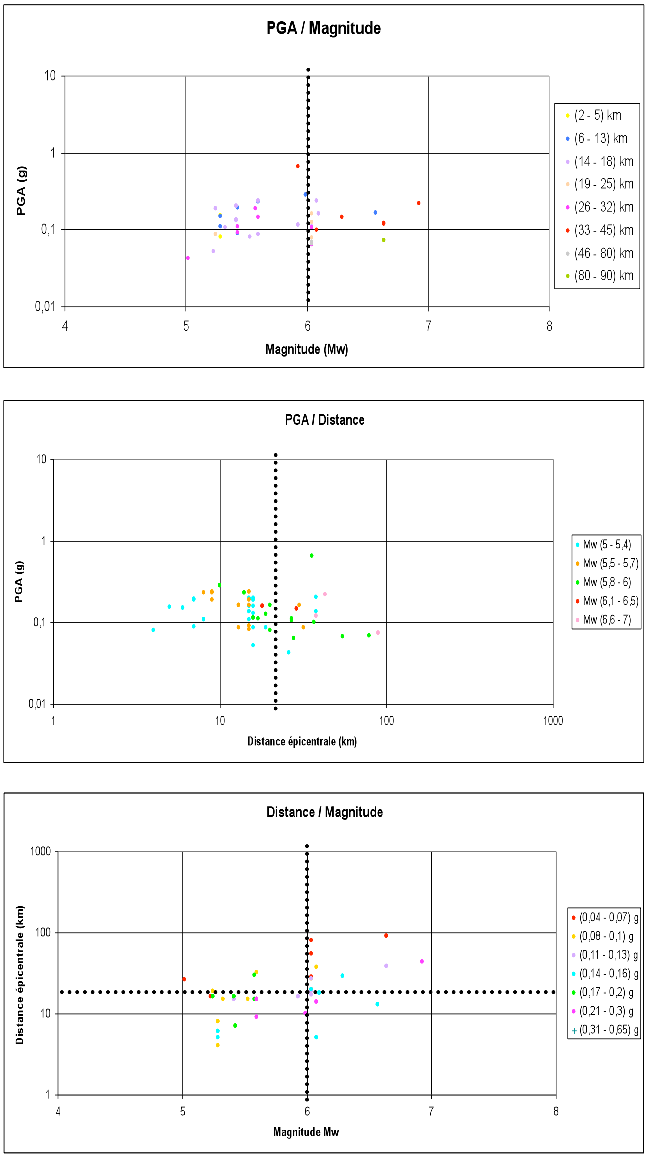

Figure 4: Data distribution in function of PGA, epicentral distance and Magnitude.

Figure 4 allows separating the data into several categories. In term of magnitude, below a magnitude of 6 the

PGA are more dispersed than above but the mean is quite similar for both part. Regarding the epicentral distance, it is above 20 km that the PGA seem more dispersed. Finally, data are mainly distributed in two groups. The first one is composed with the records from earthquake of magnitude smaller than 6 and epicentral distance smaller than 20 km, whereas the second is characterized with distance greater than 20 km and magnitude greater than 6.

5. CONCLUSION

This article presents a selection of natural accelerograms for use as input to structural testing. This database is a subset of the European strong-motion database (Ambraseys et al., 2004) and is suited for the new French earthquake engineering regulation code.
Through a simple selection procedure, 61 time-histories have been chosen by considering the French seismotectonic settings as well as the reference peak ground acceleration on rock for each zone of the French seismic zonation, the local soil condition amplification factor for the EC 8 soil classes and the associated elastic response spectrum.
As the return period associated to the peak ground acceleration we are referring to is close to 475 years, the strong-motion can be directly used for structures belonging to the class II of the EC8. For the others, an importance factor has to be taken into account as specified in the European regulation code.
The time-histories are available in a simple folder classification and an identification sheet is associated to each time-history referenced by the earthquake name. It is subdivided in three principal information fields respectively relating to the corresponding event, the recording site and the time history main parameters.

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