Appendix A

Ground motions

A.1 Triangular accelerogram

The first load is self-created, so it does not represent the real seismic excitations that are expected to act at the foundations of the structures. It is a triangular accelerogram, with a peak ground acceleration equal to 1m/s^2, lasting 0.50 s. and the period is 0.08 s., as shown in figure A.1.

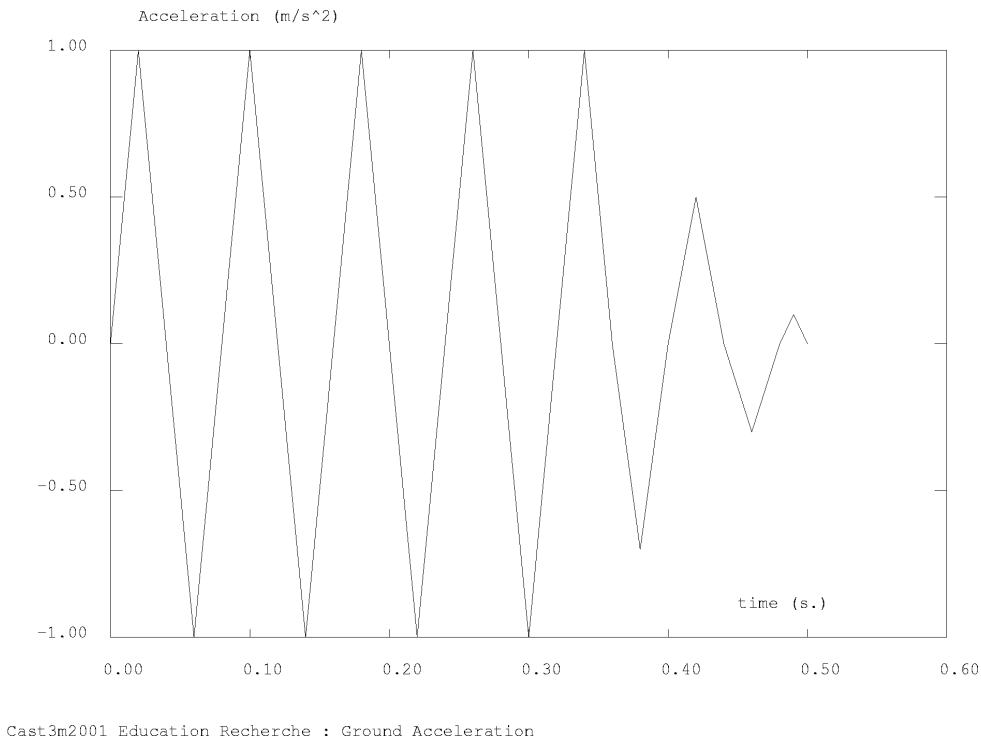

Figure A.1 Triangular accelerogram

In order to work with this acceleration as an input for the response spectrum analysis, it is required to transform it into a response spectrum giving S_a as a function of

the frequency and damping ratio. This response is evaluated for the range of frequencies 1 to 50 Hz and for different damping coefficients of the structure: 2, 5, 10, 15 and 20%. The final set of curves is shown in figure A.2.

Figure A.2 is also useful to observe that the main frequency in the ground acceleration is equal to the inverse of the triangular signal period (0.08^{-1} s = 12.5 Hz), as it was expected. It can also be seen that f_2 = 37.5 Hz = 3·12.5 Hz has an important contribution into the original signal.

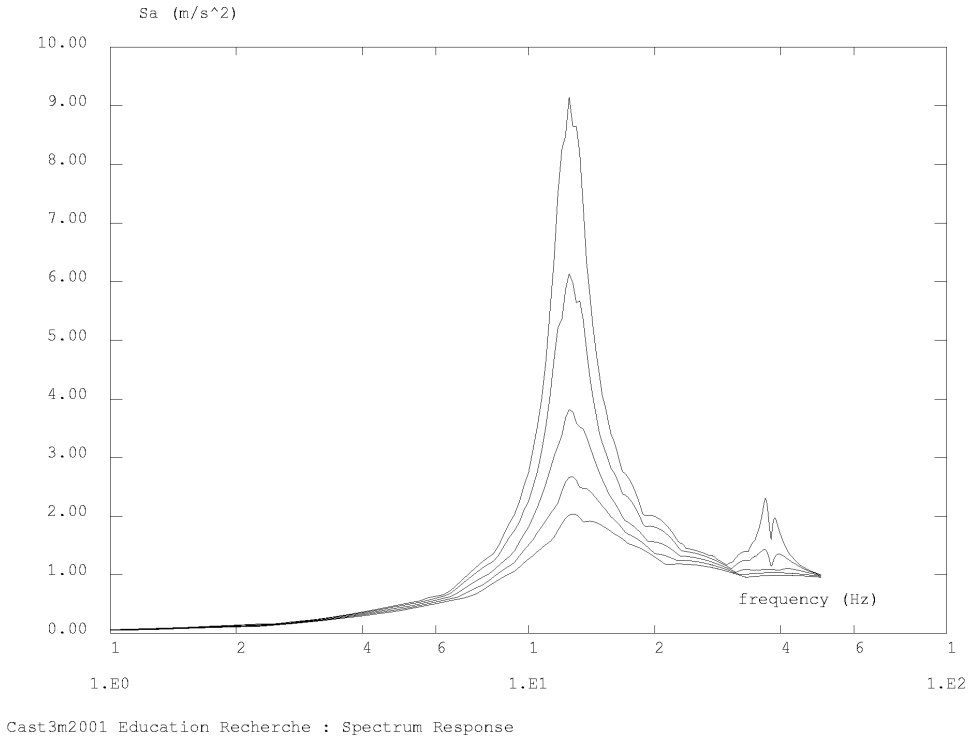

Figure A. 2 Response spectrum evaluated from 1 to 50 Hz and damping ratios 2, 5, 10, 15 and 20%

A.2 Design response spectrum

When performing any structural analysis, the value of the future loads that will be applied are unknown. For this reason, the building codes set the rules to determine a design value for every possible action, and earthquakes are not an exception. The information referring to seismic analysis is found in the Eurocode 8.

The load to be used in the calculations is given as a *Design Response Spectrum*, which depends on various factors:

- Type of analysis. An option is to assume that the seismic load will not originate a non-linear behaviour of the structure, in which it would have zero resistance. The other possible choice is to assume that the structural system will resist the seismic action in the non-linear range, then the load can be reduced and a linear analysis done.

- Soil Conditions: Acting the same earthquake, the ground accelerations on the structure will differ depending on the physic properties of the soil. They are divided in three groups, A, B and C, according to the velocity of a transversal wave through them. Group A corresponds to rock or stiff soil, in consequence it leads to the highest values of $S_{a(\omega)}$ and main frequencies. On the other hand, a C-type soil, i.e. clay, will have lower frequencies and $S_{a(\omega)}$.

- Peak Ground Acceleration (a_g): This parameter depends on the location of the structure, since it refers to the risk of earthquakes in the area. Furthermore, a probability of exceedence for a certain number of years have to be decided in order to obtain the value of a_g.

Once all the previous parameters are chosen and if the damping ratio of the structure equals 5%, the design response spectrum curve is fully defined by four equations. For any different ratio, an amplification factor, also given in Eurocode 8, has to be considered.

In this thesis work an acceleration of 4.8 m/s^2 will be used, which corresponds to a probability of 10% in 50 years in some areas of Turkey and Greece, as shown in figure A.3. The soil will be assumed to be of class A, and the structure with zero resistance in the non-linear range. The obtained design response spectrum is shown in figure, which has been calculated for 2, 5, 10 and 20% damping ratios.

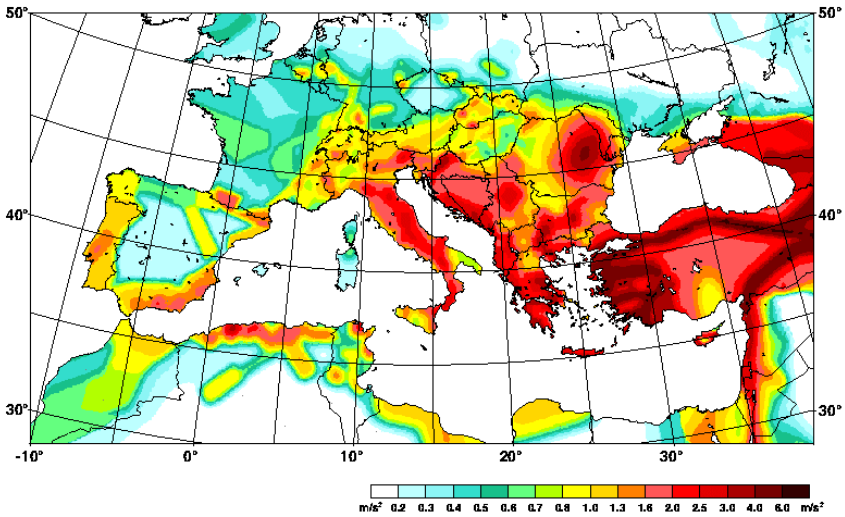

Figure A. 3 Horizontal peak ground acceleration in Europe, 10% probability of exceedance in 50 years, GSHAP (1999)

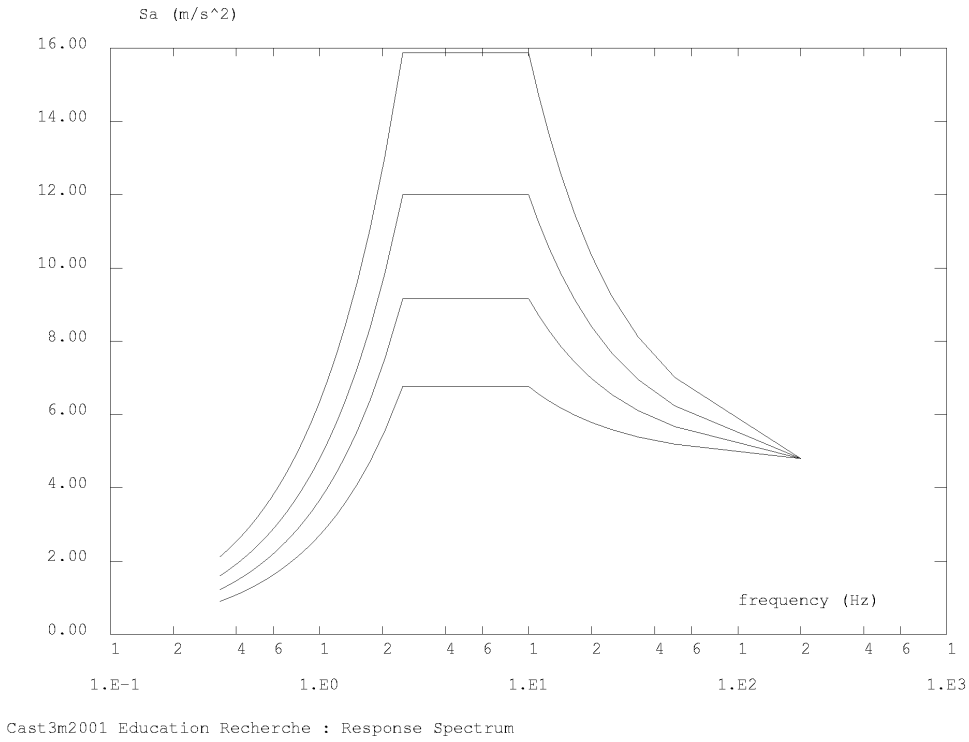

Figure A. 4 Design response spectrum for 2, 5, 10 and 20% damping ratios

A.3 Realistic seismogram: Ardal earthquake

In addition to the analysis of the structure with design response spectrums or other created accelerograms, it is also interesting for the designer to evaluate the structural behaviour with real earthquakes applied on the structure. In this appendix we present the data recorded during an earthquake which will be used in the calculations and was obtained from the Internet-Site for European Strong-Motion Data (2001).

Characteristics :	*Location:*	Ardal (Iran)
	Date:	6/4/1977
	Magnitude:	6.0 Mw
	Local Geology:	Rock
	Epicentral distance:	5 Km
	Fault distance:	4 Km

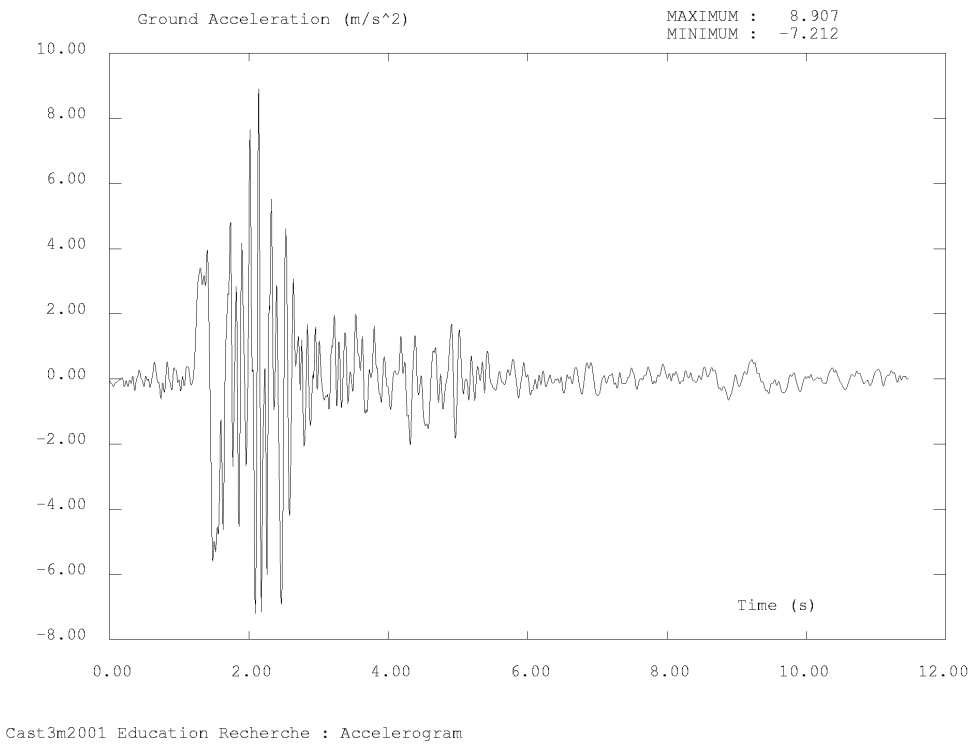

Figure A. 5 Accelerogram registered during the Ardal earthquake (6/4/1977), Internet-Site for European Strong-Motion Data (2001)

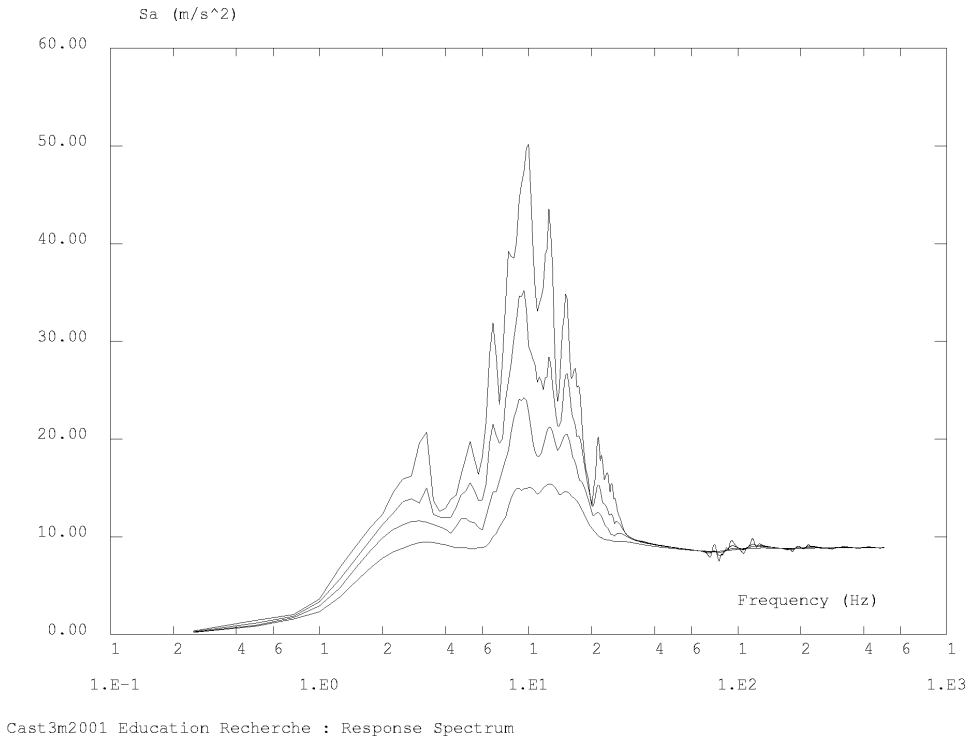

Figure A. 6 Response spectrum for the Ardal earthquake and 2, 5, 10 and 20% damping ratios