Up to now we have discussed the subject of near field records and their characteristics as well as the subject of the evaluation of appropriate acceleration spectra for different scenarios of earthquake events. The present lecture deals with the subject of the evaluation of artificial accelerograms compatible with either non pulse or pulse like records. The evaluation of artificial accelerograms is useful in what regards elastic and inelastic time history analyses of structural models when appropriate real records are not available. In aseismic regulations for structures of special interest it is acceptable to perform time history analyses with artificial accelerograms.

Before dealing with the procedures that permit the evaluation of artificial accelerograms we can discuss the models of mathematical approximation of directivity pulses. As we have already noted the records characterized by forward directivity contain, especially in the ground velocity time-history, a characteristic pulse directly associated with the directivity phenomenon. These pulses are found in records normal to the fault plane. It has been observed that the mathematical approximation of near field pulses through simple functions is adequate in what regards the evaluation of structural response to directivity pulses. Accordingly, different mathematical models have been presented, ranging from the simplest possible up to more complicated approximations. We have also seen that the most significant parameters affecting the mathematical simulation of the directivity pulses are the pulse period, the pulse amplitude and the number of significant half-cycles of the model.

$$v(t) = \begin{cases} A\,\frac{1}{2}\left[1 + \cos\left(\frac{2\pi f_P}{\gamma}(t - t_0)\right)\right]\cos[2\pi f_P(t - t_0) + v], \\ 0, \quad \text{otherwise} \end{cases} \tag{3}$$

$$t_0 - \frac{\gamma}{2f_P} \le t \le t_0 + \frac{\gamma}{2f_P} \quad \text{with } \gamma > 1.$$

$$a(t) = \begin{cases} -\frac{A\pi f_P}{\gamma}\left[\begin{array}{l} \sin\left(\frac{2\pi f_P}{\gamma}(t - t_0)\right)\cos[2\pi f_P(t - t_0) + v] \\ + \gamma\sin[2\pi f_P(t - t_0) + v]\left[1 + \cos\left(\frac{2\pi f_P}{\gamma}(t - t_0)\right)\right]\end{array}\right], & t_0 - \frac{\gamma}{2f_P} \le t \le t_0 + \frac{\gamma}{2f_P} \text{ with } \gamma > 1, \\ 0, \quad \text{otherwise} \end{cases}$$

$$d(t) = \begin{cases} \frac{A}{4\pi f_P}\left[\begin{array}{l} \sin[2\pi f_P(t - t_0) + v] + \frac{1}{2}\frac{\gamma}{\gamma - 1}\sin\left[\frac{2\pi f_P(\gamma - 1)}{\gamma}(t - t_0) + v\right] \\ + \frac{1}{2}\frac{\gamma}{\gamma + 1}\sin\left[\frac{2\pi f_P(\gamma + 1)}{\gamma}(t - t_0) + v\right]\end{array}\right] + C, & t_0 - \frac{\gamma}{2f_P} \le t \le t_0 + \frac{\gamma}{2f_P} \\ \frac{A}{4\pi f_P}\frac{1}{(1 - \gamma^2)}\sin(v - \pi\gamma) + C, \quad t < t_0 - \frac{\gamma}{2f_p} & \gamma > 1 \\ \frac{A}{4\pi f_P}\frac{1}{(1 - \gamma^2)}\sin(v + \pi\gamma) + C, \quad t > t_0 + \frac{\gamma}{2f_p} \end{cases}.$$

$$\ln(PHV) = a + b\,m + c\,\ln\left(r^2 + d^2\right)$$

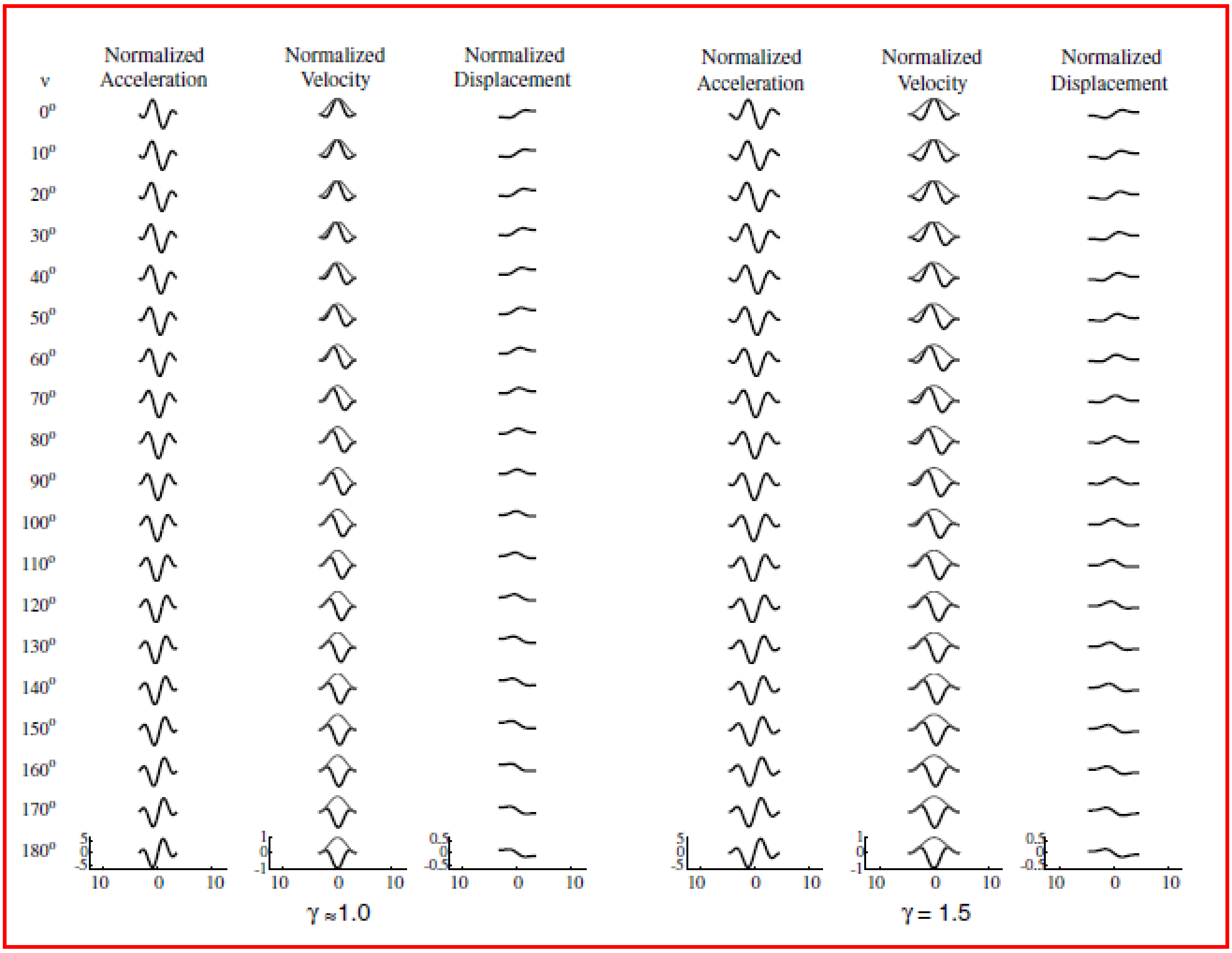
Data Set	*a*	*b*	*c*	*d*
All Motions	2.44	0.50	-0.41	3.93
Rock	1.46	0.61	-0.38	3.93
Soil	3.86	0.30	-0.42	3.93

ΑΡΧΕΙΟ DATA

Δεν χρειάζεται αλλαγή στις δύο πρώτες γραμμές.

3η	I5, 6F10.4, I5	ICASE, TRISE, TLVL, DUR, A0, ALFA0, BETA0, IPOW
4η	3F10.4, 5I5	DELT, AGMX, FIX, NDAMP, NCYCLE, NPA, NKK, NRES
5η	8F10.0	DAMPING
6η	2F10.4	T, SV

ΑΡΧΕΙΟ ΑΠΟΤΕΛΕΣΜΑΤΩΝ ACCRES



A most efficient mathematical representation of directivity pulses is the one proposed by Mavroeides and Papageorgiou. This specific representation results from the combination of two signals, a periodic one with a period equal to the pulse period and a transient envelope with a bell-shaped form and a duration equal to a multiple of the pulse period. The combination of the two signals with the appropriate parameters permits a very close approximation of the original pulse. The function representing the velocity pulse has two terms, the first one approximating the bell-shaped envelope and the second the periodical signal. The main parameters of the approximation are the amplitude of the bell-shaped envelope A, the characteristic frequency fp which is the inverse of the pulse period Tp, the pulse duration given by the ratio γ between the total duration and the pulse period and the phase shift ν affecting the shape of the final pulse representation. In the following we can see the effect of the phase shift parameter on the shape of the final pulse, as well as the effect of the γ factor on the spectral amplification, a subject already discussed. In order to simulate the directivity pulse for a given earthquake scenario, we can use the known relationship between pulse period and moment magnitude. For the estimation of the bell-shaped amplitude A we can use the relationship for the amplitude attenuation where a, b, c, d are constants, m is the moment magnitude and r the distance from the fault. At that point it is interesting to introduce an index of the velocity time history, the energy flux which is the time interval of the squared ground velocity. This index is a measure of the energy contained in the ground motion and in the case of a directivity velocity pulse this measure takes abruptly large values at the beginning of the ground motion duration.

In order to create synthetic artificial accelerograms we have to combine the pulse like ground motion with a usual non pulse like record. In the following slide we can see this combination of a non pulse like record with an artificial directivity pulse.

The artificial non pulse like records can be estimated with two different procedure, with the creation of artificial or semi-artificial records. The artificial records are evaluated with the use of a procedure based on the assumption that the velocity spectrum for zero damping of a record is the envelope of the Fourier spectrum of the record. The Fourier spectrum presents the amplitude with which different frequencies participate in the time function. There is a close relationship between a time history and its Fourier transform. As from a time history the Fourier spectrum can be estimated, accordingly, from the Fourier spectrum with an inverse transform the time history can be evaluated. So, if we have the Fourier spectrum we can evaluate an appropriate time history. In order to do that we estimate the velocity spectrum from the appropriate acceleration spectrum from the well known relationship between SA and SV. From the velocity spectrum we estimate the Fourier spectrum and with an inverse transform we evaluate a random periodic white noise time history. In order to define a realistic ground motion time history we need to define an envelope function for the time history. This envelope will be multiplied with the periodic random white noise in order to define a time history. The envelope time function can have different shapes but we prefer the one with exponential build up to the level amplitude and the exponential decay from the level amplitude. The following slides present the envelopes for different magnitudes for near to the fault recordings. Finally, in the file DATA the appropriate values are given in order to produce an appropriate accelerogram. In the following the accelerogram is produced , and a comparison between the target and the simulated acceleration and velocity spectra are given. Afterwards, a simulated pulse for A=50 cm/sec, Tp=1.78 sec, γ=2, v=90 is produced. The pulse is added to the original artificial motion and a near field ground motion is produced. The ratio between the spectra of the pulse and the non pulse motions is estimated and it is found close to the expected bell-shaped amplification. The spectra are shown for acceleration and velocity. Finally the energy flux for the two ground motions is presented and it can be seen the energy flux is more abrupt and concentrated at the start of the ground motion for the pulse-like ground motion. The inelastic spectra are also shown and it can be seen that there also exists an increase in the ductility demand for periods at about half the pulse period. The problem with this procedure is that the artificial ground motion presents large duration which is not absolutely compatible with the real ground motions next to the fault.

Consequently, another procedure for semi-artificial accelerograms has been developed This procedure is based on the use of an already existing accelerogram and the modification of its frequency content in order to fit to an existing target spectrum. In that case the envelope of the time history is realistic and problems such as those with the artificial accelerograms are avoided. The semi-artificial accelerogram is produced with the use of the program SEISMOMATCH. Accordingly, an original accelerogram is selected, as well as a target spectrum. In this case the original accelerogram was the E04-140 record lready used in a former exercise. The target spectrum was the one developed for the scenario of the last exercise. We see that the accelerogram is modified so that its acceleration response spectrum fits the target spectrum. From the acceleration time histories we see that although the general shape of the time history is the same the ground motion values have changed. In this modified time history we add the pulse time history and we produce a near field record. The relevant acceleration spectra and their ratio is shown, compatible with the bell-shaped amplification. Finally the energy flux is shown.