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Investigation on strong-motion processing procedures

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BACKGROUND OF THE STUDY

The major difficulty in the reliability analysis of earthquake ground accelerations recorded in the near field is that no true signal is available. In order to be able to control and study the transformations and distorsions of current processing procedures, a reference signal has to be defined.

In our study, two signals, of known analytical expression, were designed to simulate possible earthquake ground motions. The first signal (S1), is based on a non-stationary formulation, both in time and frequency. A limited number of frequencies had been retained to facilitate the subsequent analysis. It also contains "difficulties" usually encountered in routine digitisations and a permanent displacement function has been introduced (Menu,1985). The second signal (S2), is based on real ground acceleration in order to resemble a real case as closely as possible in view of a particular processing (Goula an Mohammadioun, 1985). They are represented on figure 1 where it can be seen that signal S2 has a continuous broad-band spectrum whereas signal S1 is governed more by low frequencies. Both of these signals have been input to a computer simulated single pendulum transducer to carry the actual recording instrument effect (f0=20Hz, =0.6). From a computer generated set of time and acceleration points, delta t=0.005sec, an analogue trace was carefully produced by a photoplotter for each signal. The effects of the photoplotter were analysed for all the frequency range of interest (Rinaldis,1985). The analogue traces were sent for processing to all European Strong Motion processing centres for digitization and treatment.

Preliminary results were discussed during a workshop held in Rome in June 1985 (Rinaldis et al.,1985). A synthesis of the first results was presented at the VIII European Conference on Earthquake Engineering held in Lisbon in 1986 (Rinaldis et al.,1986). Final results were presented in the XXII General Assembly of the E.S.C. in Barcelona in 1990 (Goula et al.,1992).

This note summarizes the final analysis.

COMPARISON OF DEDUCED DISPLACEMENT TIME HISTORIES

Displacement time histories have been chosen to compare the different processing techniques because they represent the final result of these processings i. e.: base-line correction (high-pass filtering) and double integration. As we dispose of the actual displacement (analytical signal) we can draw a comparison between the displacements resulting from the different methods.

The displacements calculated by the following organisations, participants in the Rome workshop (Rinaldis et al.,1985) have been analysed:

-E.N.E.A.-Rome
-Imperial College-London
-C.E.A.-Paris
-Bulgarian Academy of Sciences-Sofia
-Russian Academy of Sciences-Moscow
-Earthquake Researh Institute-Ankara
-U.S.G.S.-California

Each team used its own filtering techniques choosing the domain in which the calculations was made, the time and/or the frequency. The methods used, indicating the type of filtering, the cut-off frequency, the domain in which the processing is carried out and the type of digitization are shown in table 1.

Table 1:Processing procedures used by seven agencies (some present several cases) to compute the displacements showed in the figure 4.
(*)Integration performed in frequency domain.

	FILTERING	Fcut(Hz)	DOMAIN	DIGITISATION
1	Half-cosinus	0,10	Frequency	Automatic
2	Half-cosinus	0,15	Frequency	Automatic
3	Butterworth	0,25	Time	Automatic
4	Butterworth(8p)	0,10	Time(*)	Semiautomatic
5	Butterworth(8p)	0,25	Time(*)	Semiautomatic
6	Butterworth(8p)	0,25	Time(*)	Manual
7	Ormsby	0,25	Time	Manual
8	Perm. Displ.		Time	Manual
9	Ormsby	0,60	Time	Manual
10	Ormsby	0,15	Time	Manual

All the displacements obtained by the methods shown in Table 1 applied to the signal S2 are represented in Figure 4. They have been organized in two different graphs to facilitate analysis. Part a) shows the displacement obtained from procedures 1 to 6 next to the analytical displacement. Part b) shows the four remaining ones also accompanied by the analytical displacement.

Initially these results seem to confirm the surprising resemblance to the analytical signal especially of the first six treatments (part a). The one that varies most refers to procedure No.6, which is the same as the No.5, the only difference being that the signal has been digitised manually.

These results show the efficiency of the treatments to eliminate the low frequencies contained in the non-corrected acceleration signals.

It must be pointed out that these good results have been obtained using simple techniques based on different filters, like half-cosinus or Butterworth and they operate either in the time domain or in the frequency domain.

The treatments Nos 7-10 (part b) show more significant variations. The procedures using the Ormsby filter give different results. In fact No.10 corresponds well enough to the analytical signal, the real one. The dispersions are probably due to the wrong assumptions on the selection of the parameters used.

The case of treatment No.8 from which a permanent displacement can be obtained, is not really correct because it has been assumed the existence of a permanent displacement which in fact did not exist. This may indicate that in real cases where the real displacement is not known a priori, it is very difficult to reconstruct it reliably.

CONCLUSION

For analyzed raw data and the corresponding recovered displacement time histories, the frequency range where results are strongly suitable is the same, that is, there is no evidence of added noise because of different processing routines used.

The results show that there is no single better technique to perform the processing of the raw data. Different procedures (1 to 6) have given excellent results using simple methods. Other displacements obtained show a large dispersion (Nos.7 to 9) and a reduced suitable frequency range, that probably is partially due to an unreliable selection of parameters involved in the processing.

For strong-motion data users, the results of this investigation could allow us to recommend wherever possible to use uncorrected data and to control carefully the procedures of correction. Only corrected data obtained from a well established processing tecnique should be used.

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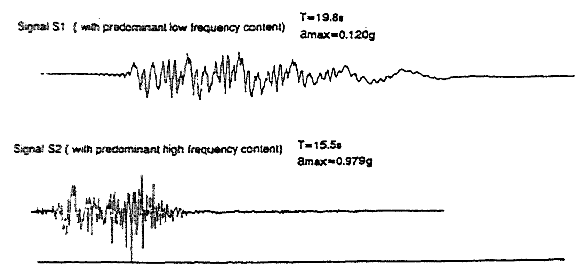

Figure 1. Synthetic signals used in the investigation.

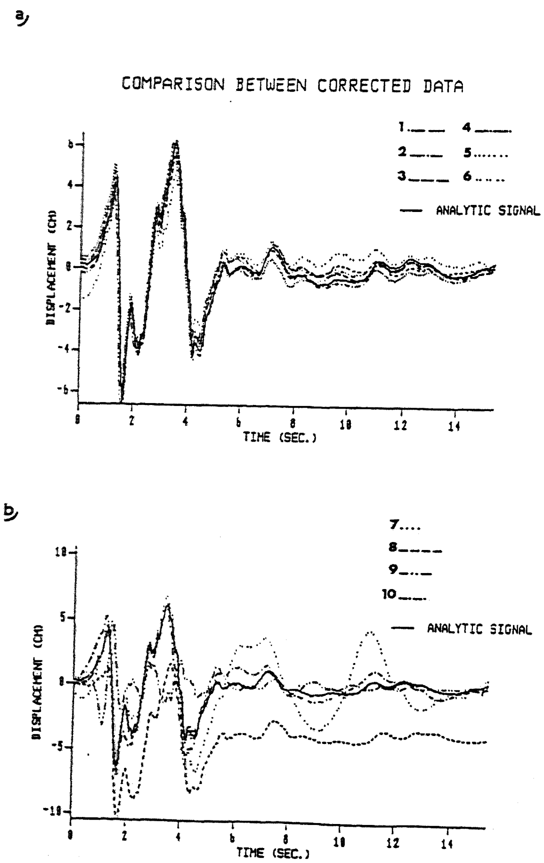

Figure 2 Displacements obtained by processing procedures:
a) 1 to 6 (table 1),
b) 7 to 10 (table 1),
applied to accelerogram S2, compared to analytical displacement.