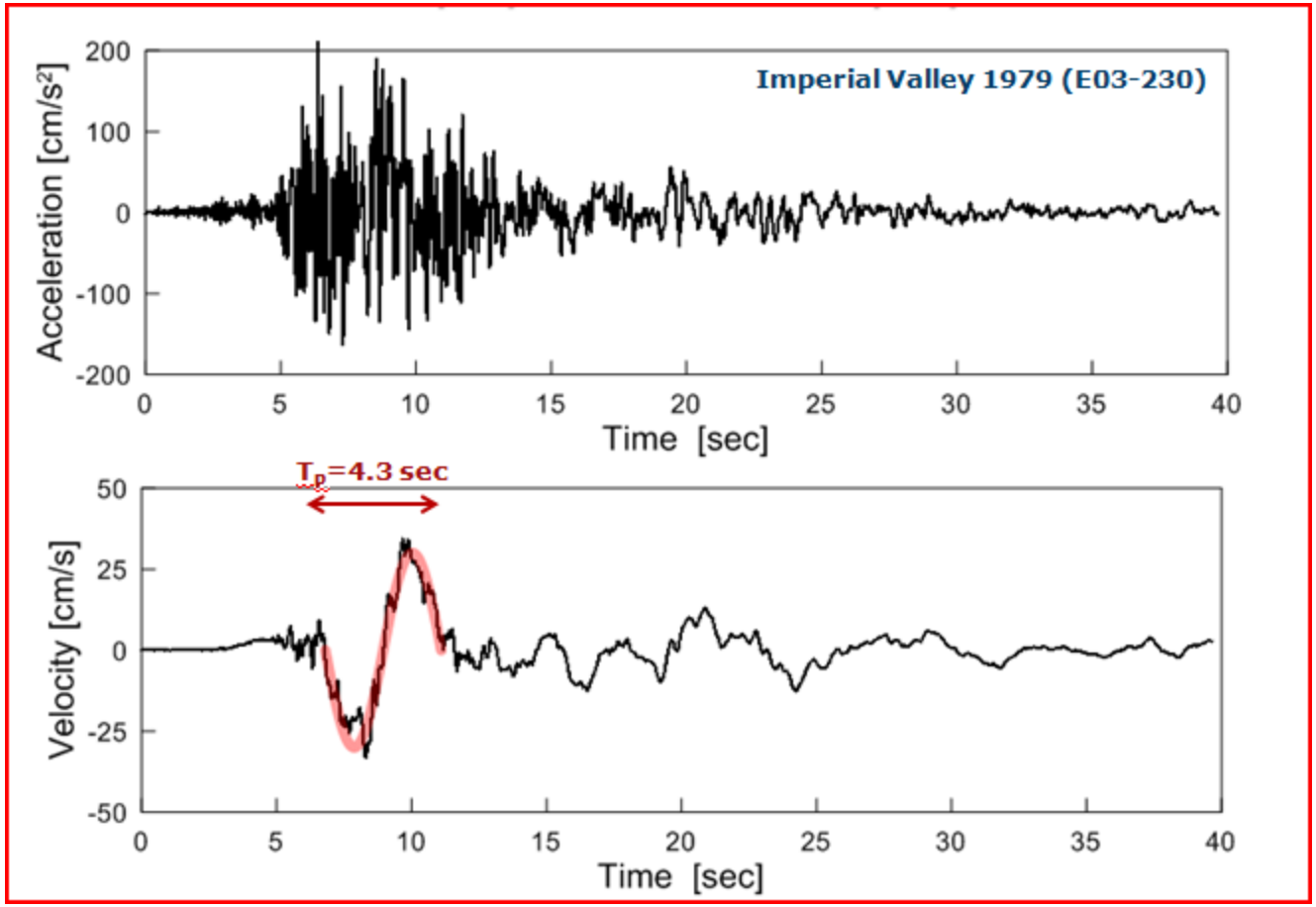
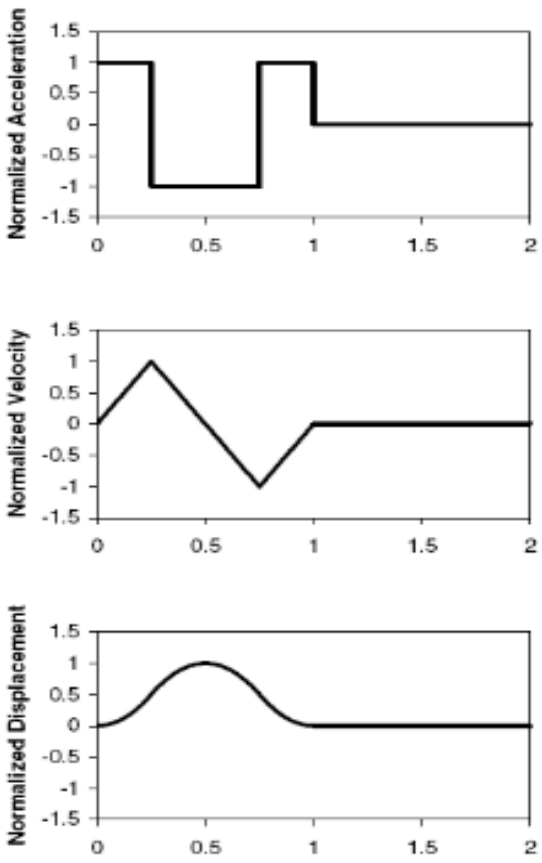
ARTIFICIAL ACCELEROGRAMS

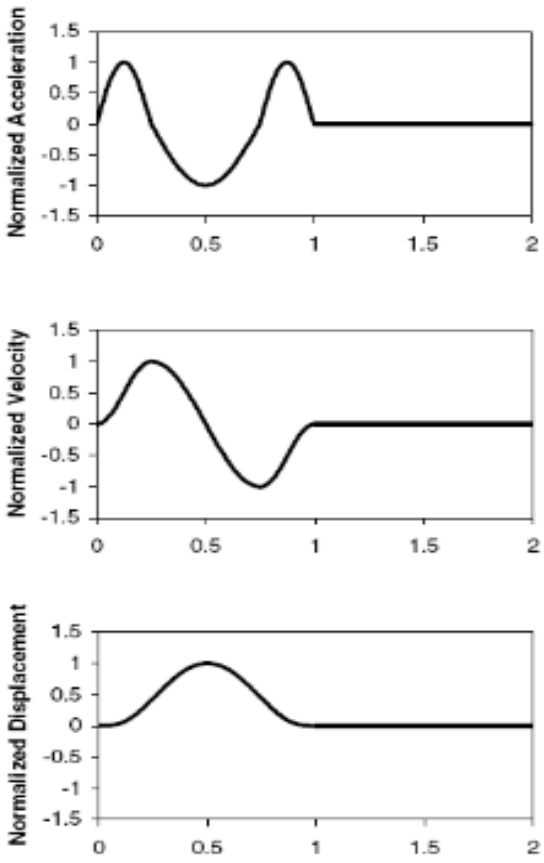
NEAR-FIELD PULSE SIMULATION


Imperial Valley 1979 (E03-230)
Acceleration [cm/s²]
200
100
0
-100
-200
0
5
10
15
20
25
30
35
40
Time [sec]
T_p=4.3 sec
Velocity [cm/s]
50
25
0
-25
-50
0
5
10
15
20
25
30
35
40
Time [sec]

PULSE SIMULATION

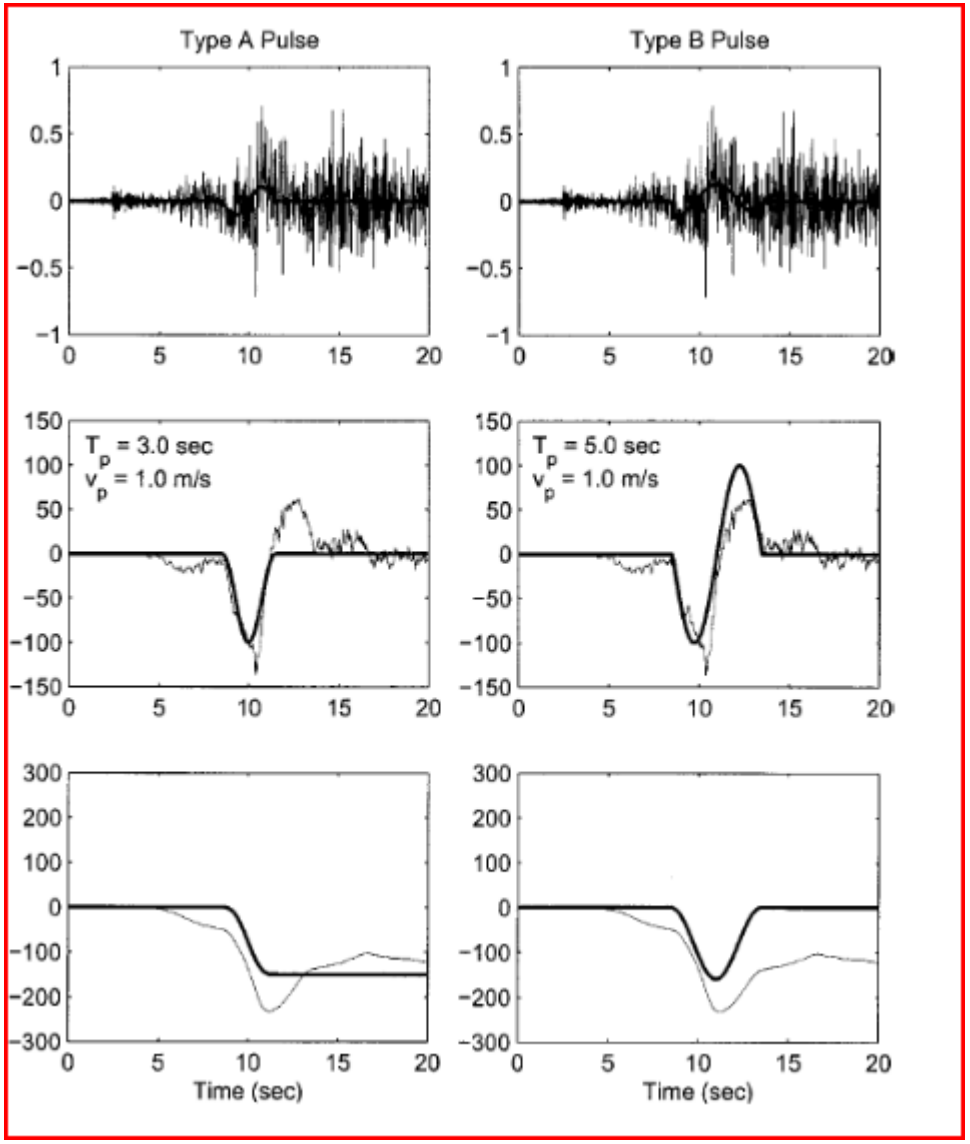


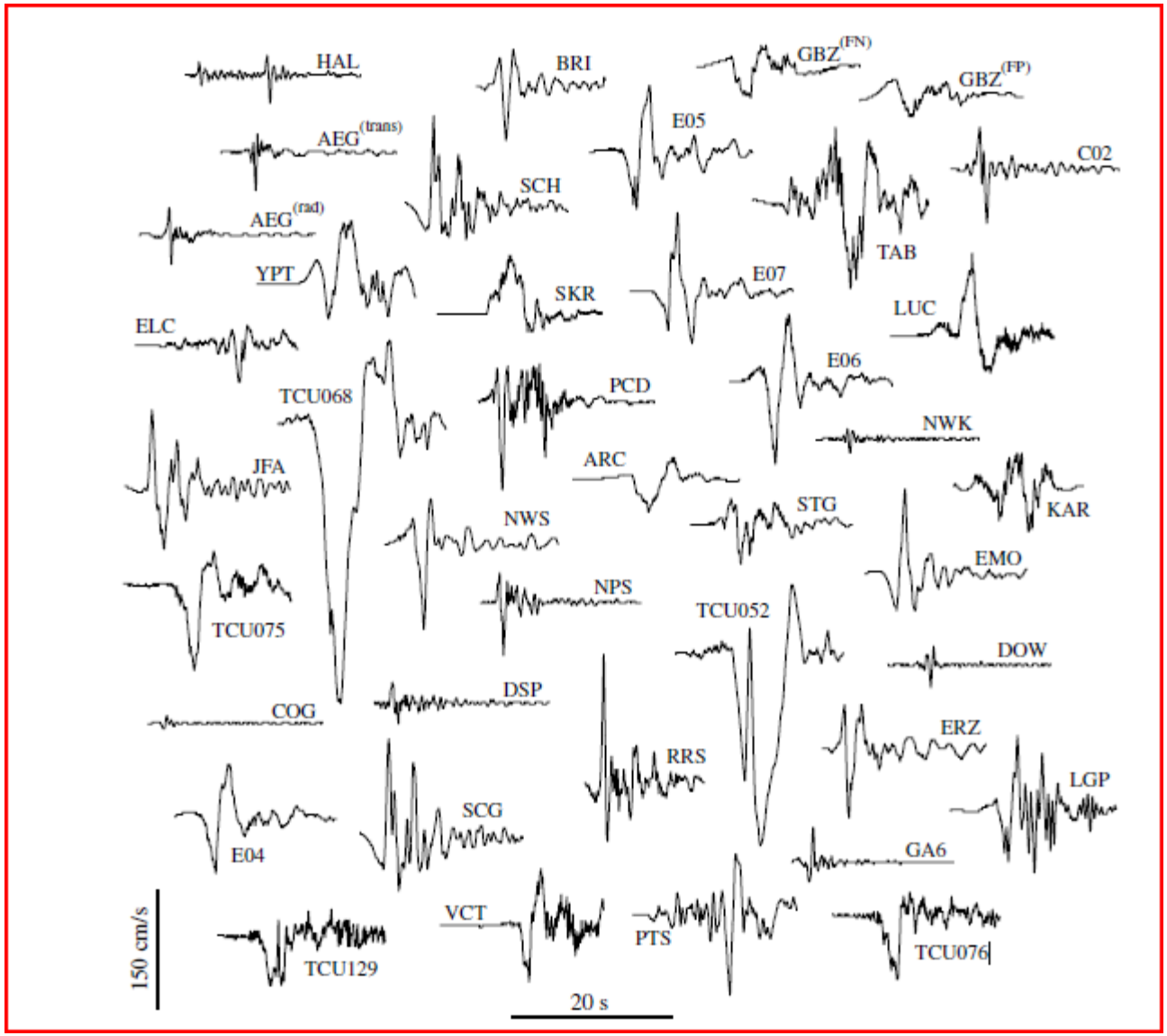
(a) Krawinkler and Alavi

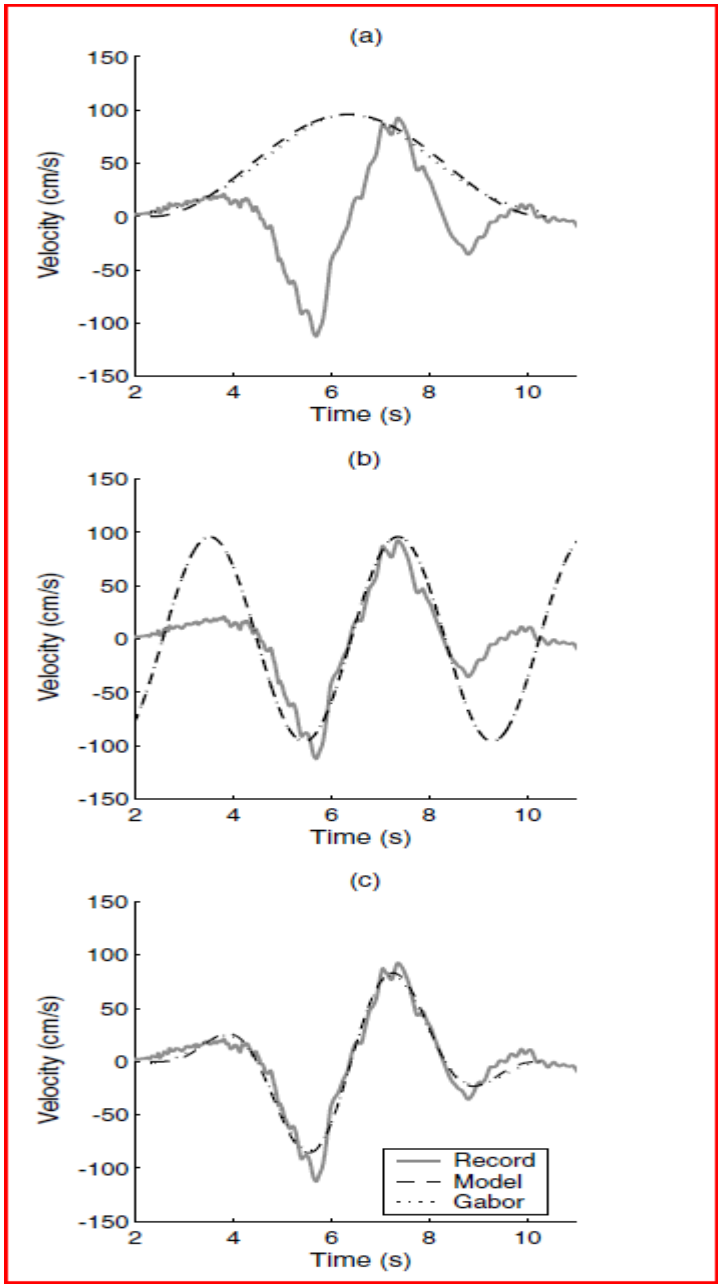


(b) Sasani and Bertero

PULSE SIMULATION




HAL
BRI
GBZ(FN)
GBZ(FP)
AEG(trans)
E05
C02
SCH
AEG(rad)
TAB
YPT
E07
SKR
LUC
ELC
E06
TCU068
PCD
NWK
JFA
ARC
KAR
STG
NWS
EMO
NPS
TCU075
TCU052
DOW
DSP
COG
ERZ
RRS
LGP
SCG
E04
GA6
VCT
PTS
TCU076
TCU129
150 cm/s
20 s


(a)
150
100
50
0
-50
-100
-150
Velocity (cm/s)
2
4
6
8
10
Time (s)
(b)
150
100
50
0
-50
-100
-150
Velocity (cm/s)
2
4
6
8
10
Time (s)
(c)
150
100
50
0
-50
-100
-150
Velocity (cm/s)
Record
Model
Gabor
2
4
6
8
10
Time (s)

Wavelet functions

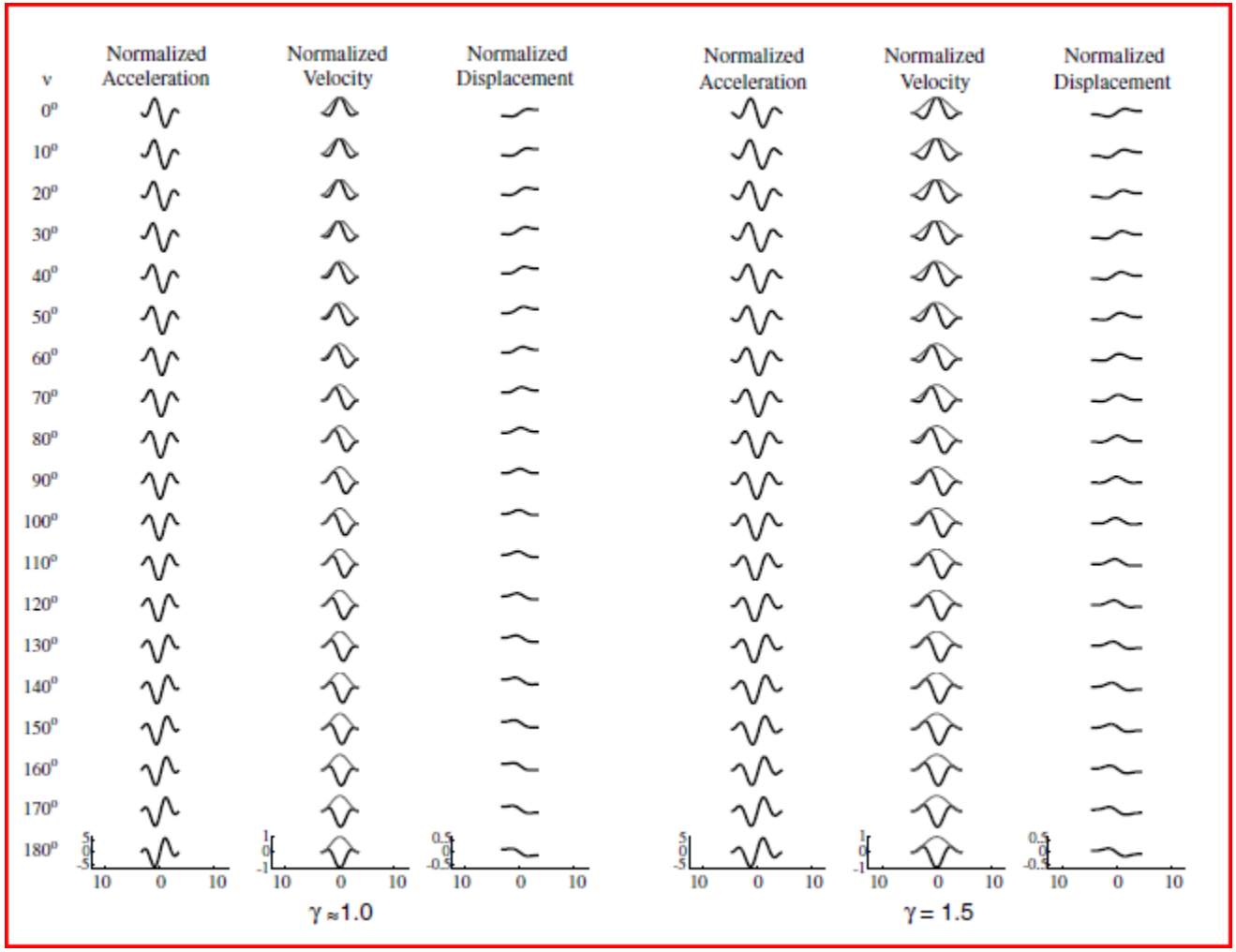
$$v(t) = \begin{cases} A\,\frac{1}{2}\left[1 + \cos\left(\frac{2\pi f_P}{\gamma}(t - t_0)\right)\right]\cos[2\pi f_P(t - t_0) + v], \\ 0, \quad \text{otherwise} \end{cases} \tag{3}$$

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

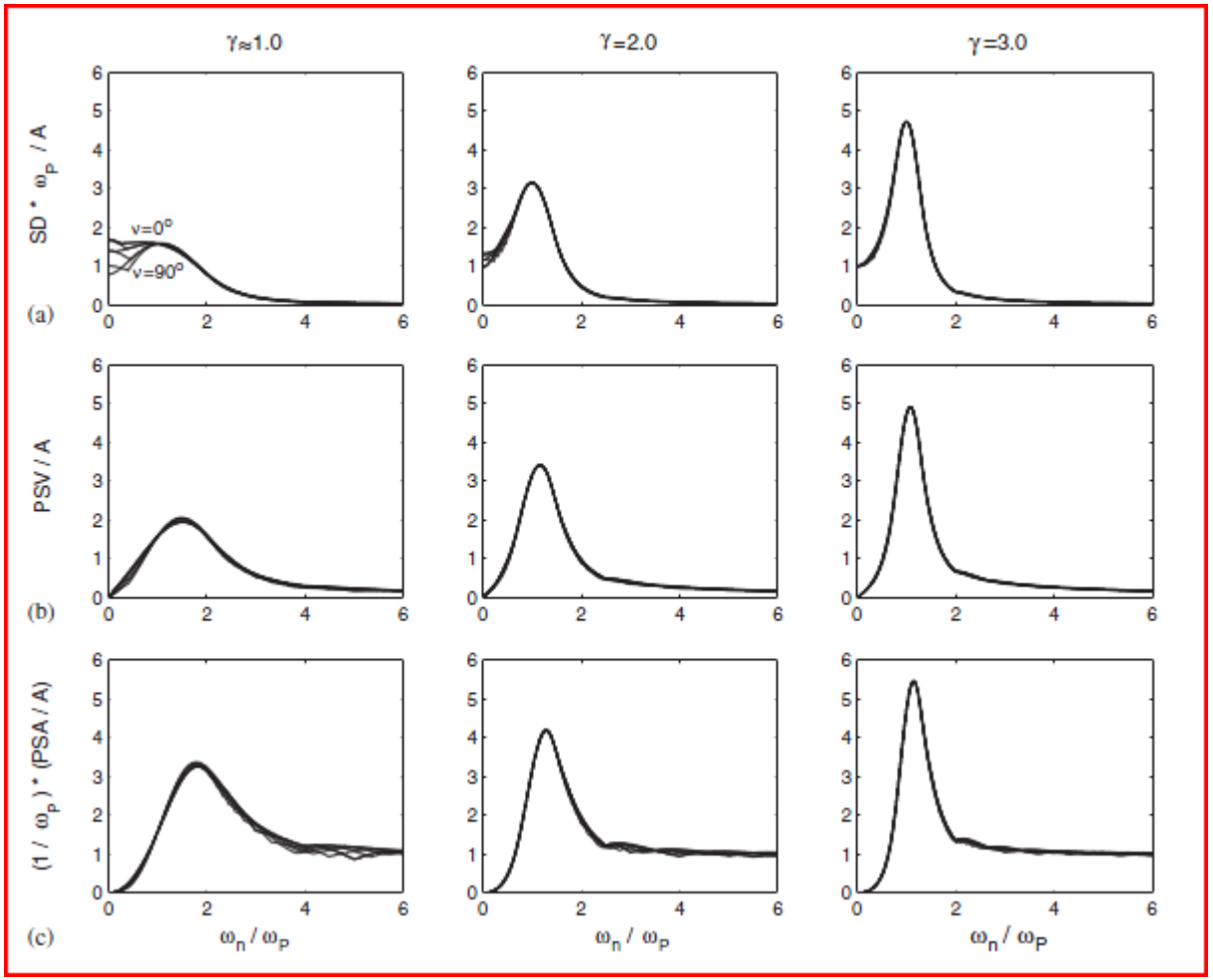
$$a(t) = \begin{cases} -\frac{A\pi f_P}{\gamma}\left[\sin\left(\frac{2\pi f_P}{\gamma}(t - t_0)\right)\cos[2\pi f_P(t - t_0) + v] \right. \\ \left. \quad + \gamma \sin[2\pi f_P(t - t_0) + v]\left[1 + \cos\left(\frac{2\pi f_P}{\gamma}(t - t_0)\right)\right]\right], \quad t_0 - \frac{\gamma}{2f_P} \le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

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

Effect of γ and ν factors



Effect of γ and ν factors



Period-magnitude relationship

$$\log T_P = -2.9 + 0.5M_w$$

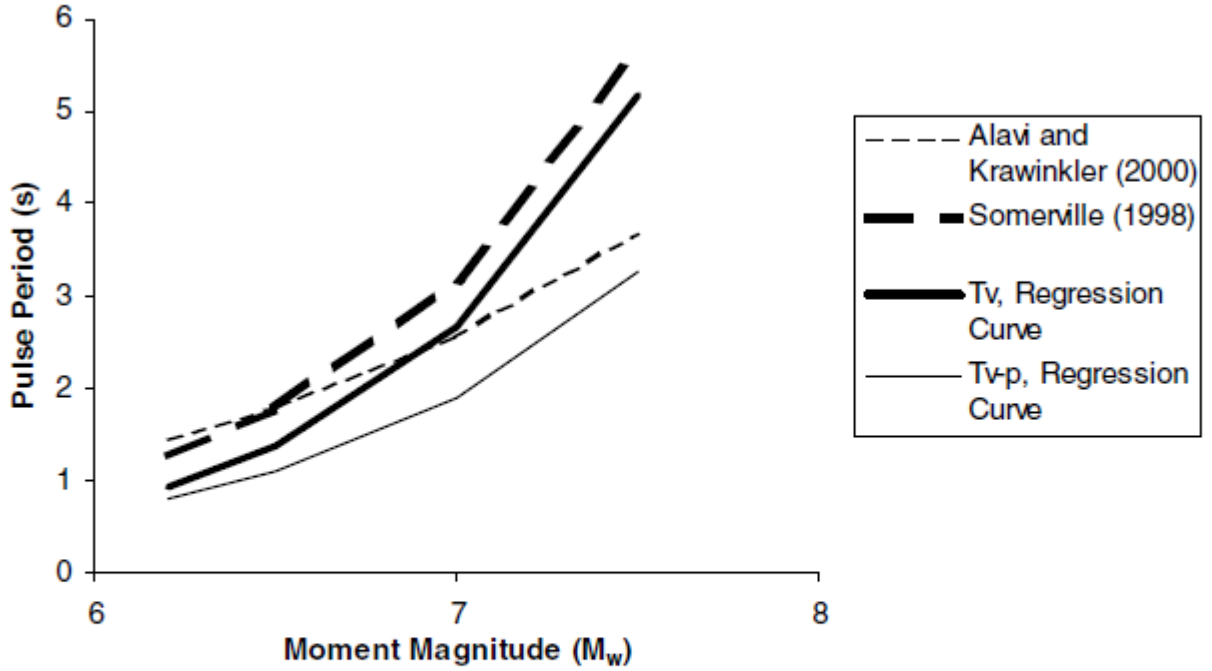
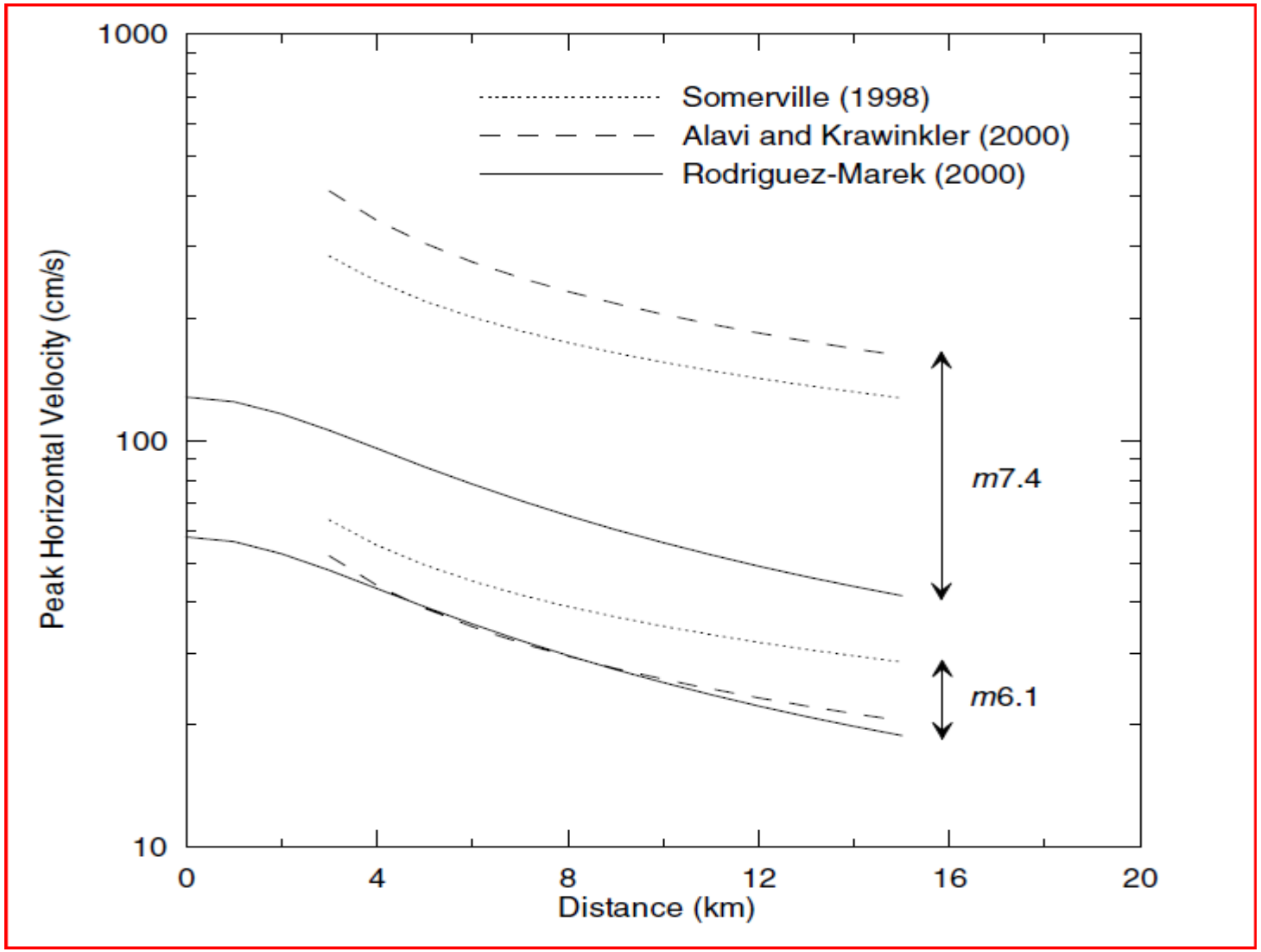


Fig. 4.12. Comparison of Rodriguez-Marek (2000) model with those proposed by Somerville (1998) for pulse period (T_v) and by Alavi and Krawinkler (2000) for the period of the maximum pseudo-velocity response spectral value ($T_{v\text{-}p}$) (from Rodriguez-Marek 2000).

AMPLITUDE ATTENUATION



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

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

Energy flux index

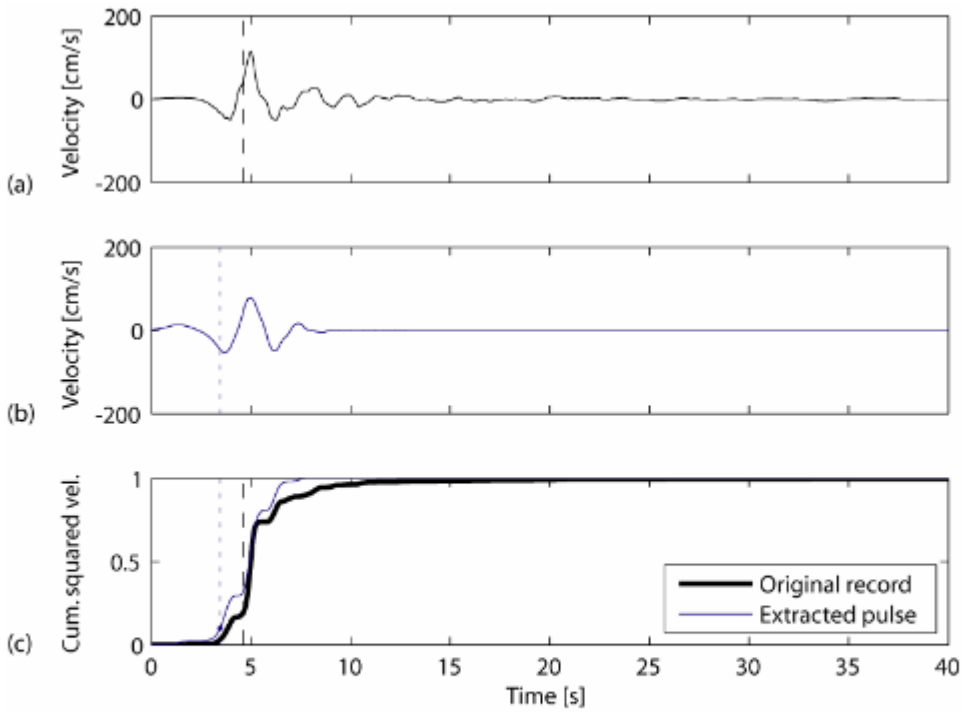


Figure 6. An early-arriving pulse (the 1979 Imperial Valley, EC Meloland Overpass FF recording). (a) Original ground motion. (b) Extracted pulse. (c) Cumulative squared velocities. The times corresponding to $t_{20\%,orig}$ and $t_{10\%,pulse}$ are marked with vertical lines.

Synthetic accelerograms

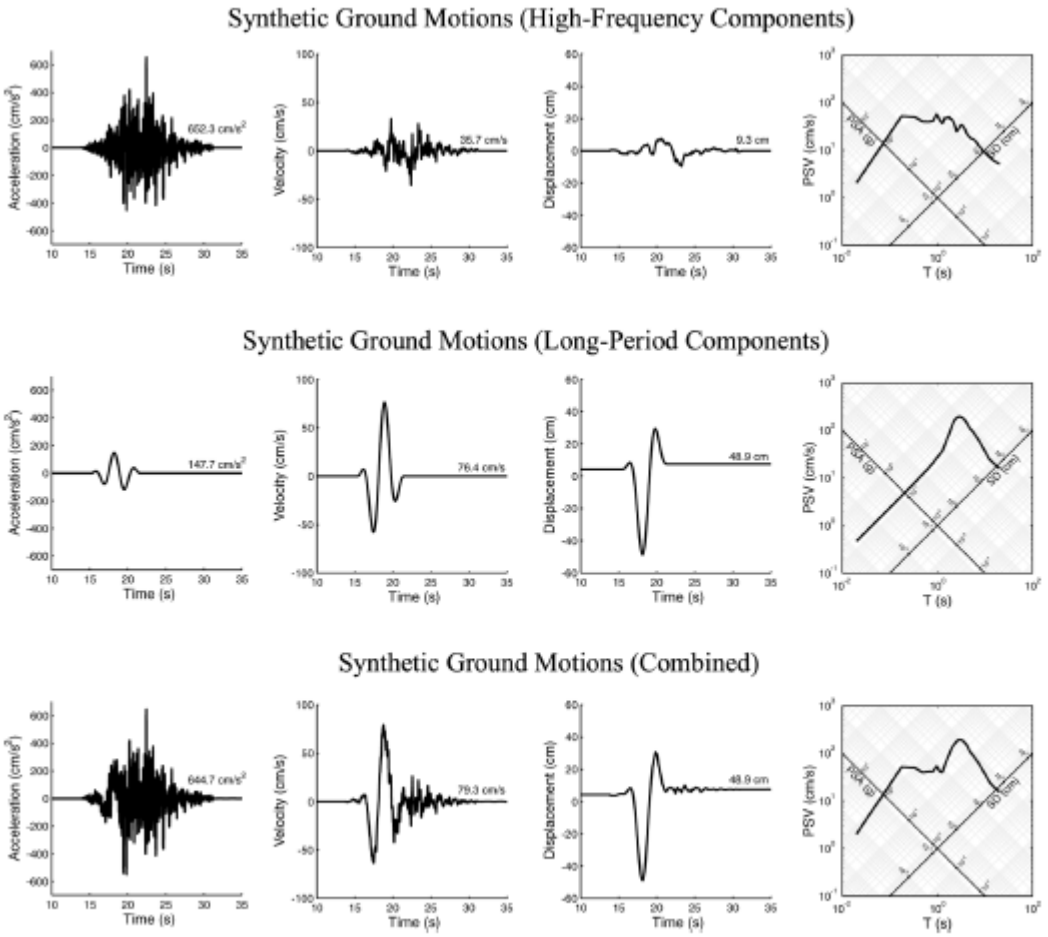
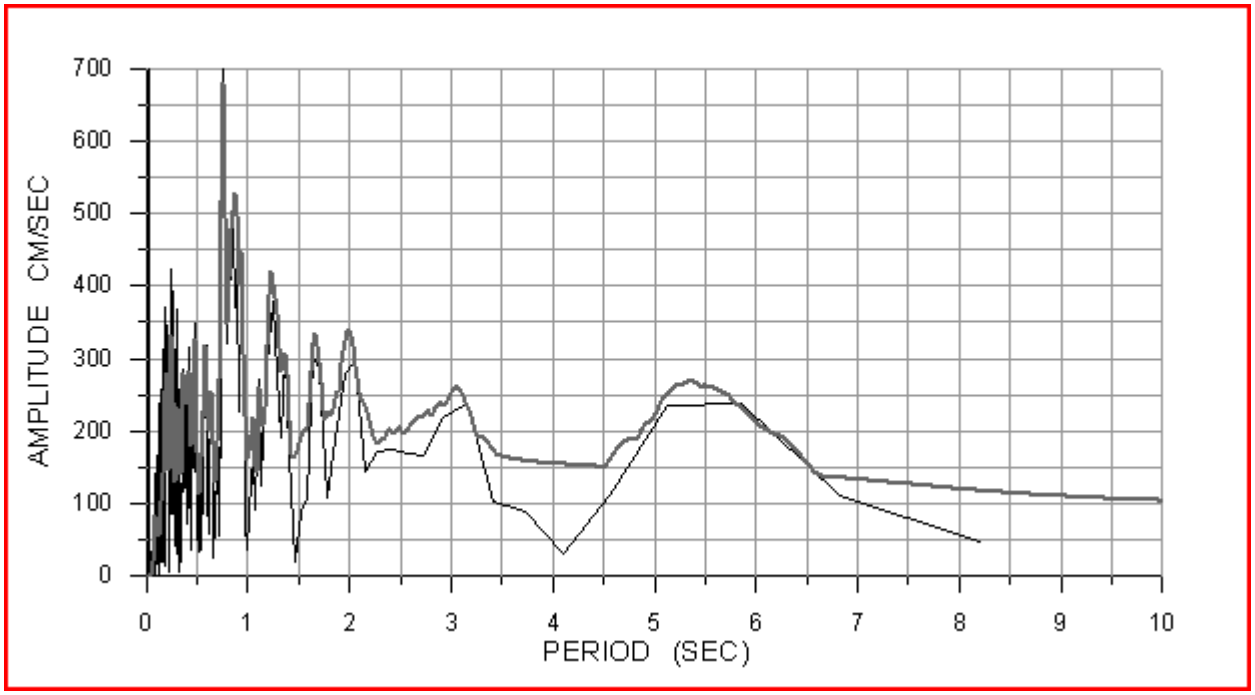


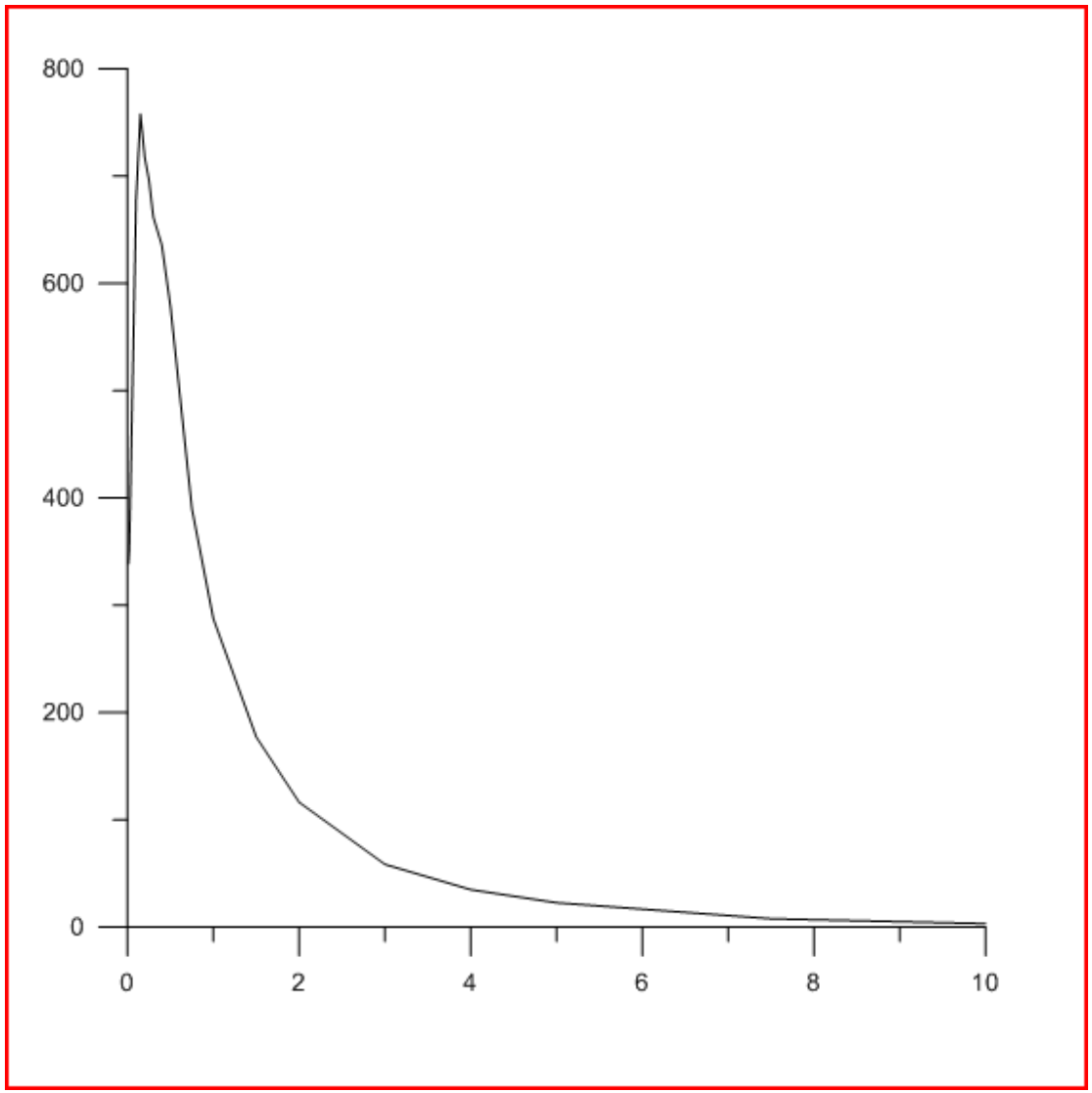
Figure 12. Synthesis of near-fault ground motions for the generic earthquake illustrated in Figure 11.

Procedure for accelerogram simulation Program **QUAKE**

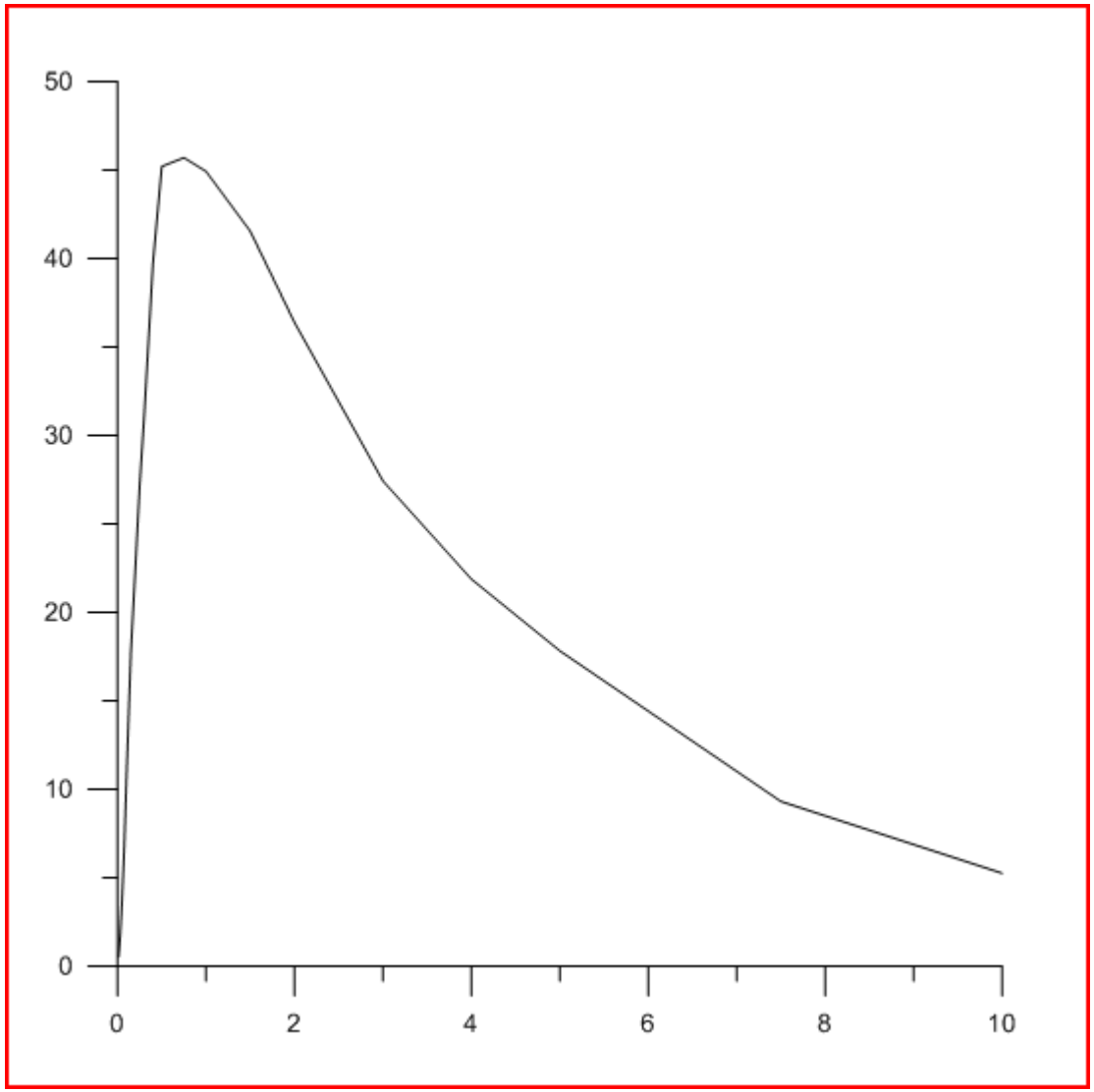


Correlation between Fourier and velocity spectra

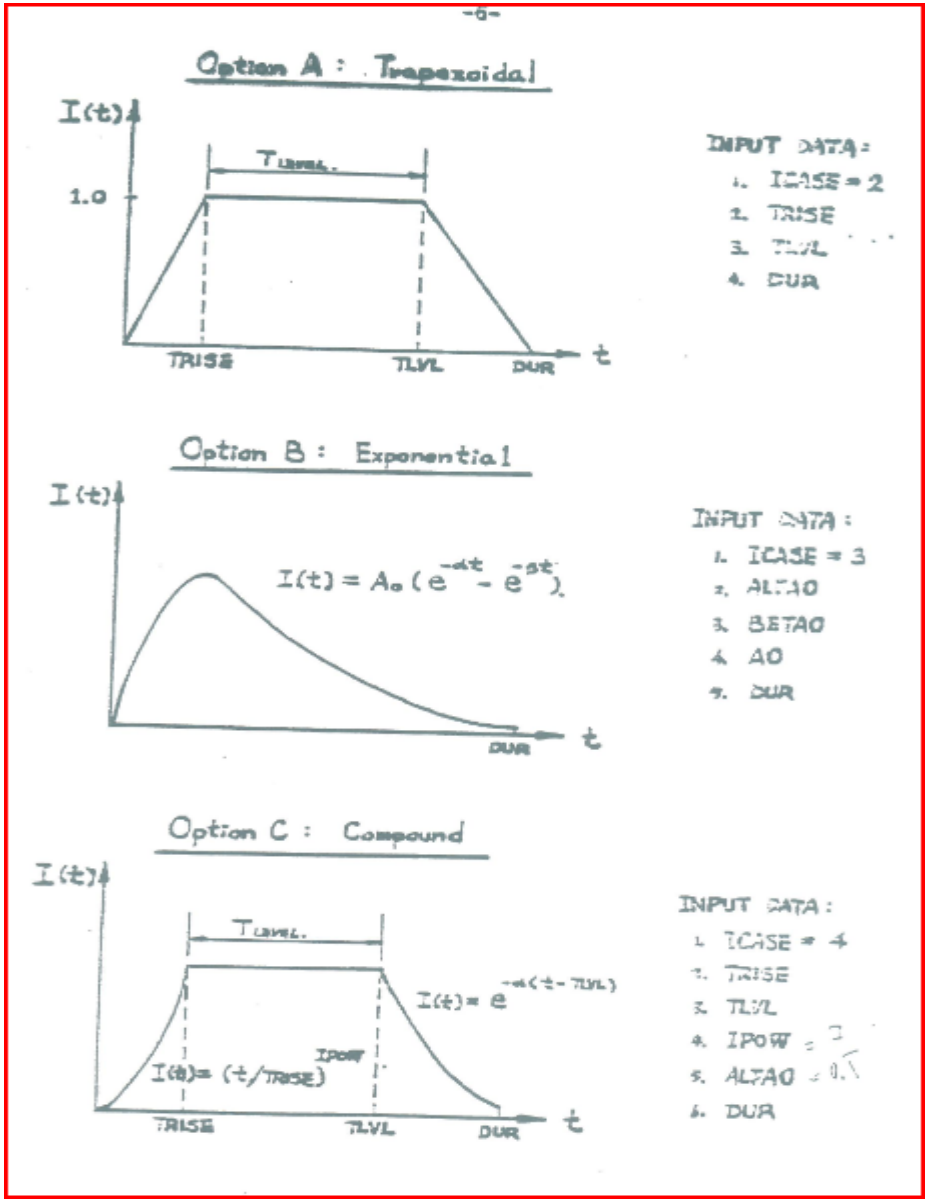
Target acceleration spectrum



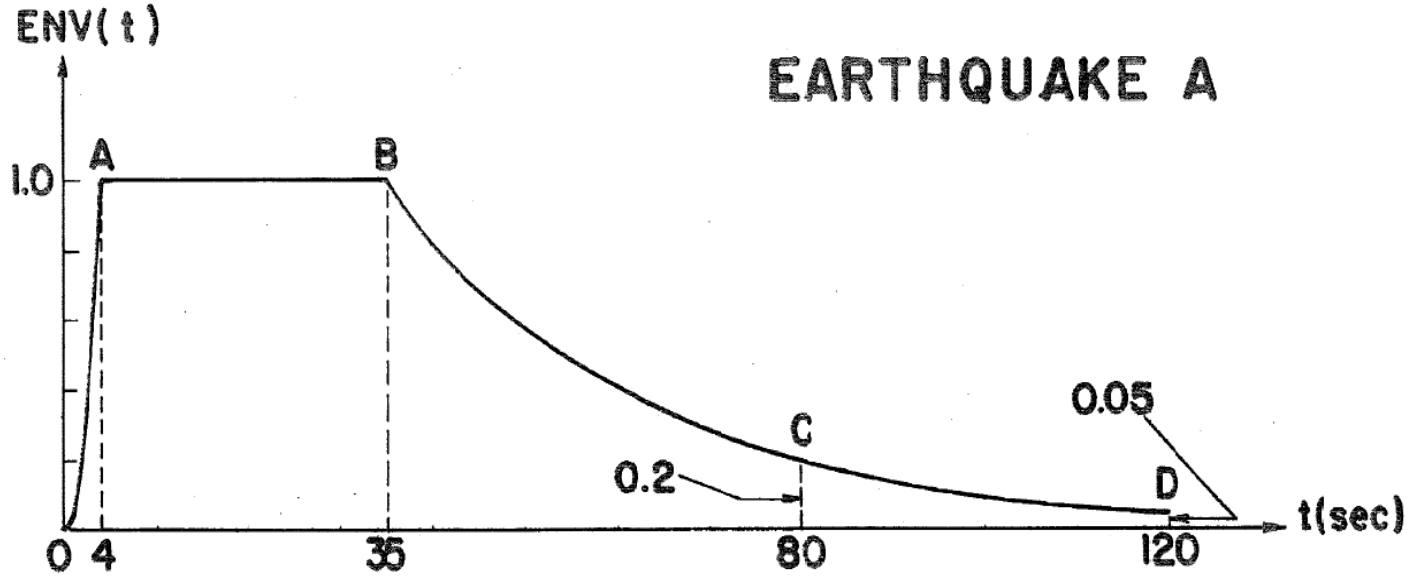
Target velocity spectrum SA=SV ·2π/T



Time history envelopes



Time history envelopes M ≥ 8



OA : $ENV(t) = t^2/16$

AB : 1.0

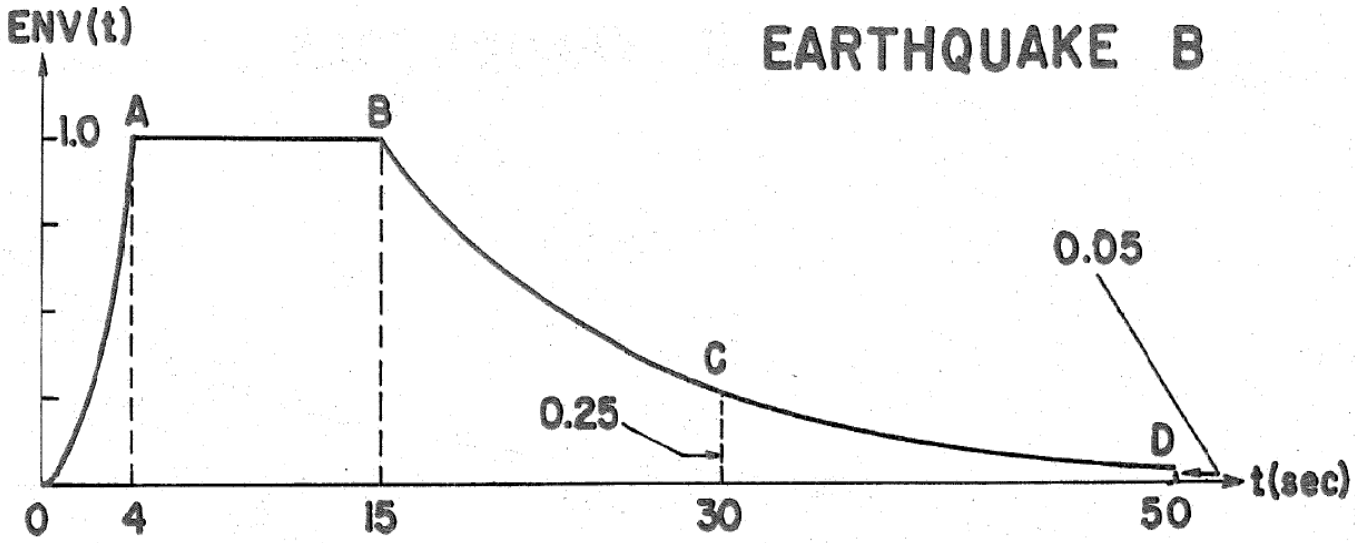
BC : $\exp(-0.0357(t-35))$

CD : $0.05+0.0000938(120-t)^2$

Figure 1

Envelope function for earthquake type A

Time history envelopes M ~ 7



$OA: ENV(t) = t^2/16$

$AB: 1.0$

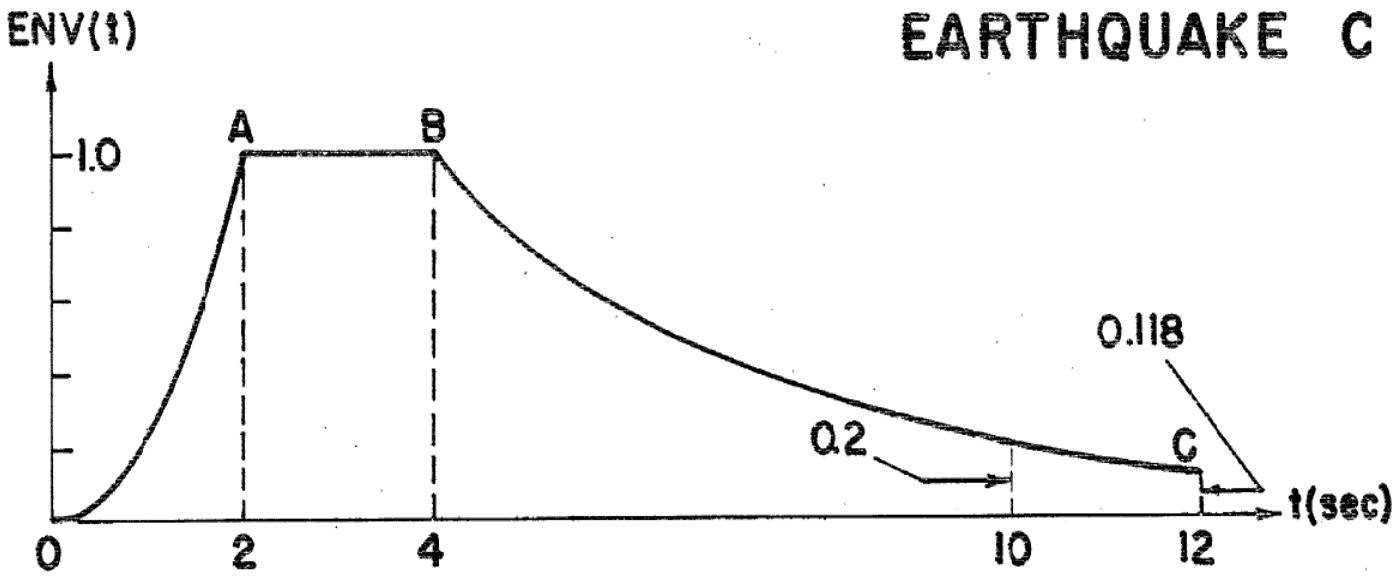
$BC: \exp[-0.0992(t-15)]$

$CD: 0.05 + 0.005(50-t)^2$

Figure 2

Envelope function for earthquake type B

Time history envelopes M = 5.5 ~ 6



$OA: \quad ENV(t) = t^2/4$

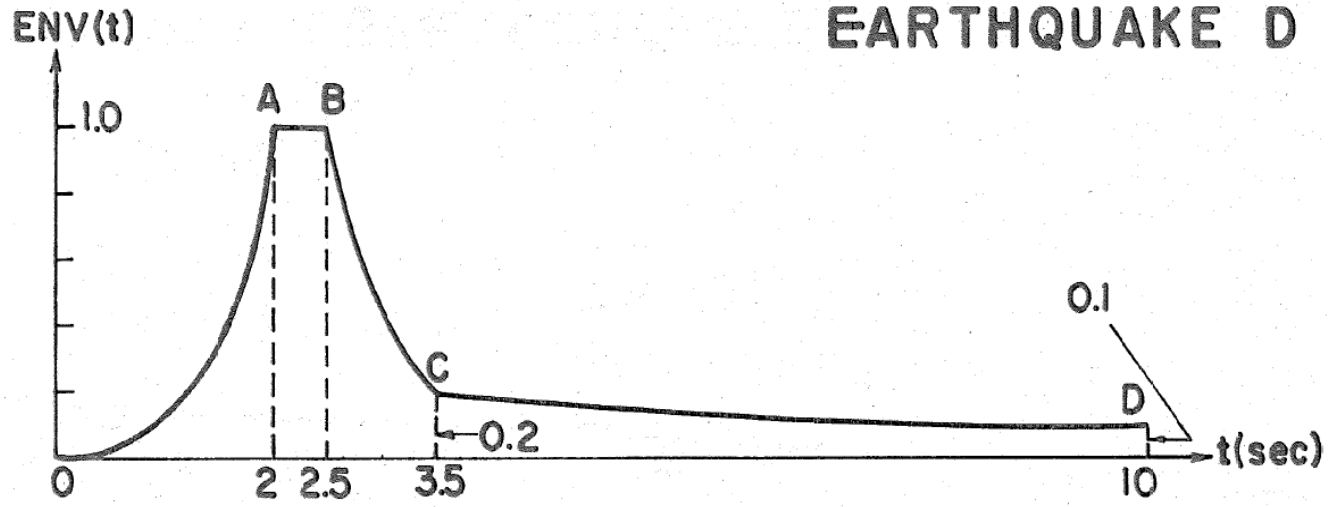
$AB: \quad 1.0$

$BC: \quad \exp[-0.268(t-4)]$

Figure 3

Envelope function for earthquake type C

Time history envelopes M = 4.5 ~ 5.5



$OA: ENV(t) = t^3/8$

$AB: \quad 1.0$

$BC: \quad \exp[-1.606(t-2.5)]$

$CD: \quad 0.1 + 0.00237(10-t)^2$

Figure 4

Envelope function for earthquake type D

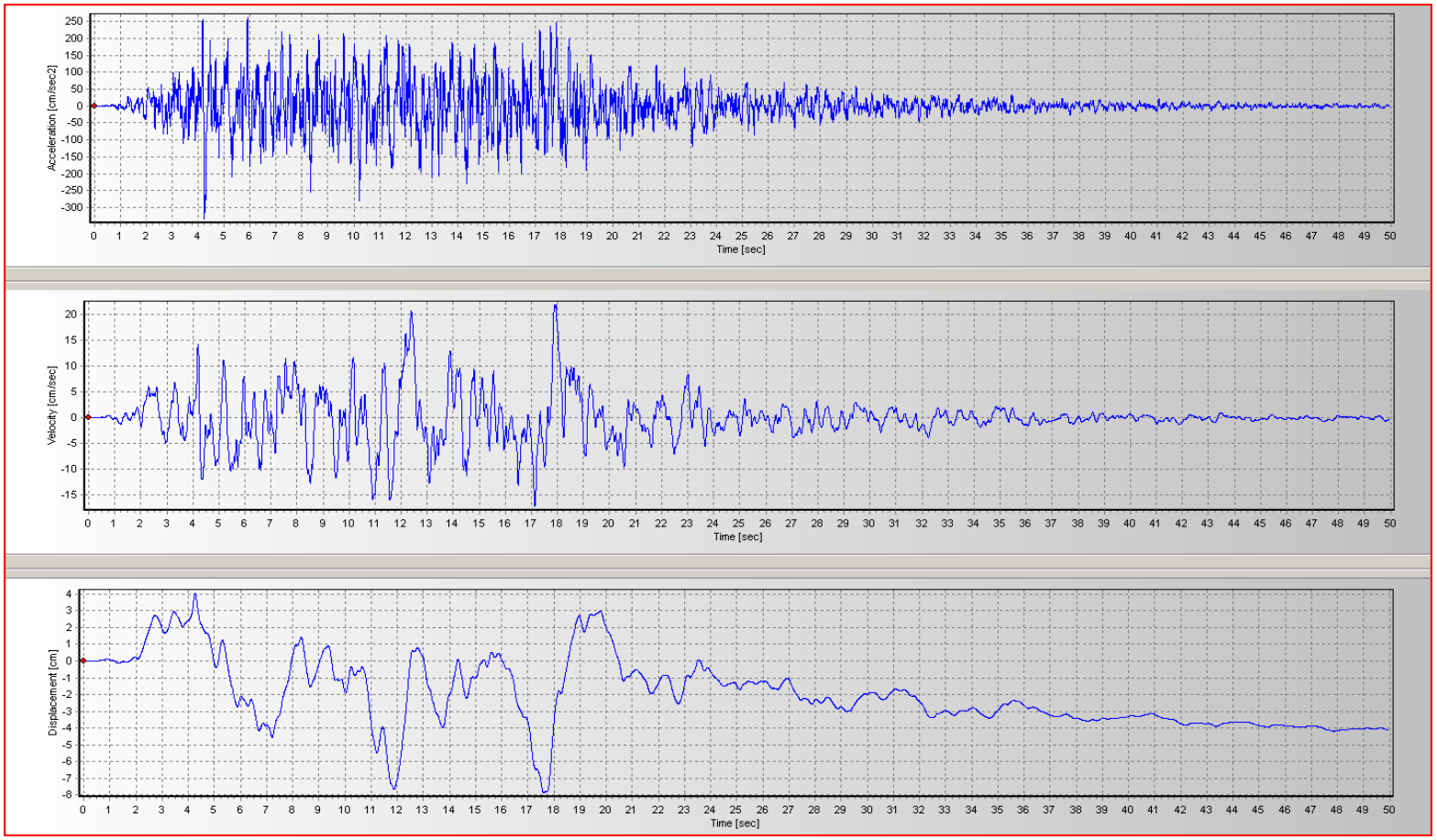
ΑΡΧΕΙΟ DATA

Δεν χρειάζεται αλλαγή στις δύο πρώτες γραμμές.

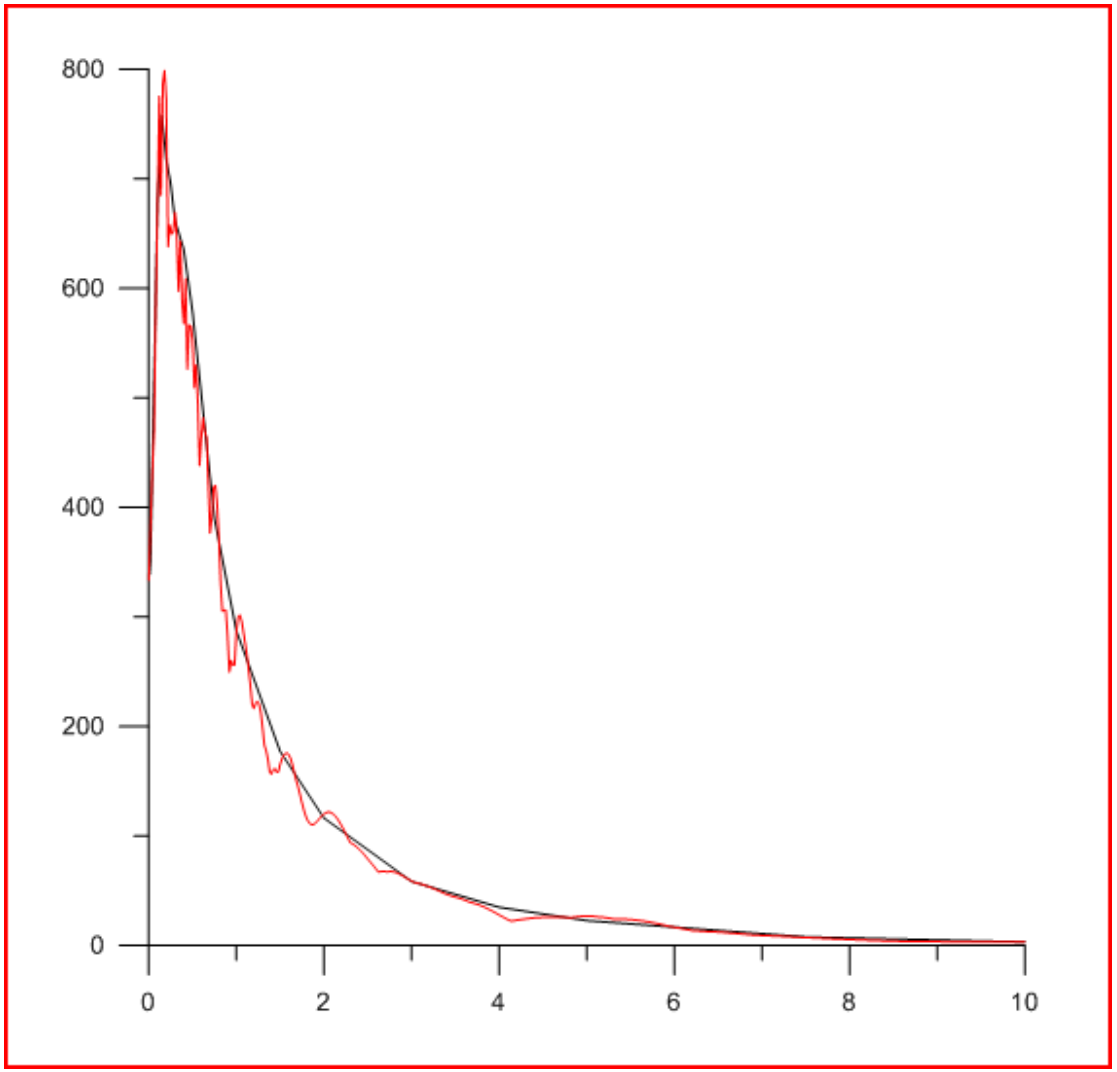
3η	I5, 6F10.4, I5	ICASE, TRISE, TLVL, DUR, A0, ALFA0, BETA0, IPOW
4η	3F10.4, 5I5	DELT, AGMX, FIX, NDAMP, NCYCLE, NPA, NKK, NRES
5η	8F10.0	DAMPING
6η	2F10.4	T, SV

ΑΡΧΕΙΟ ΑΠΟΤΕΛΕΣΜΑΤΩΝ ACCRES

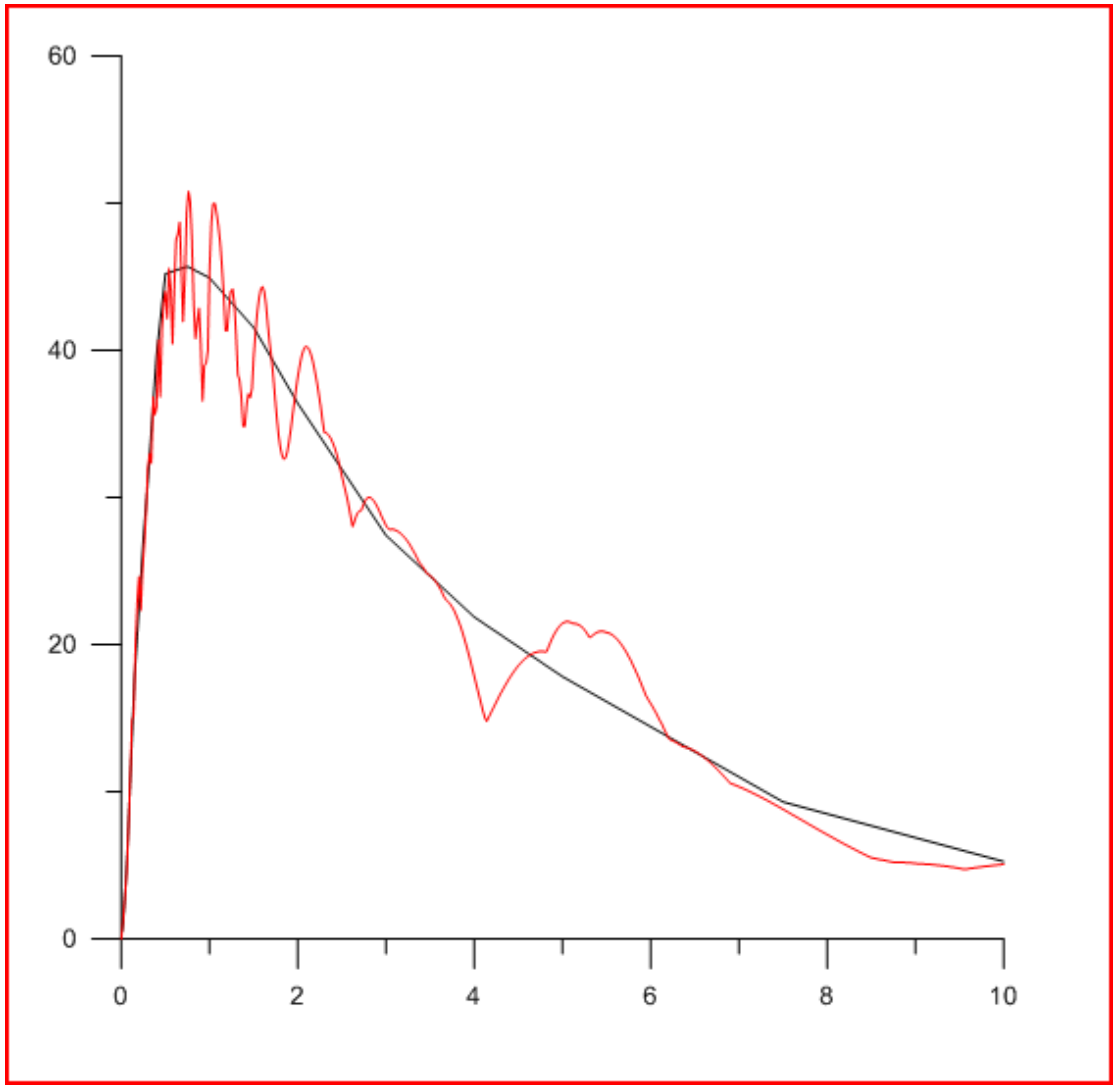
Initial high frequency accelerogram



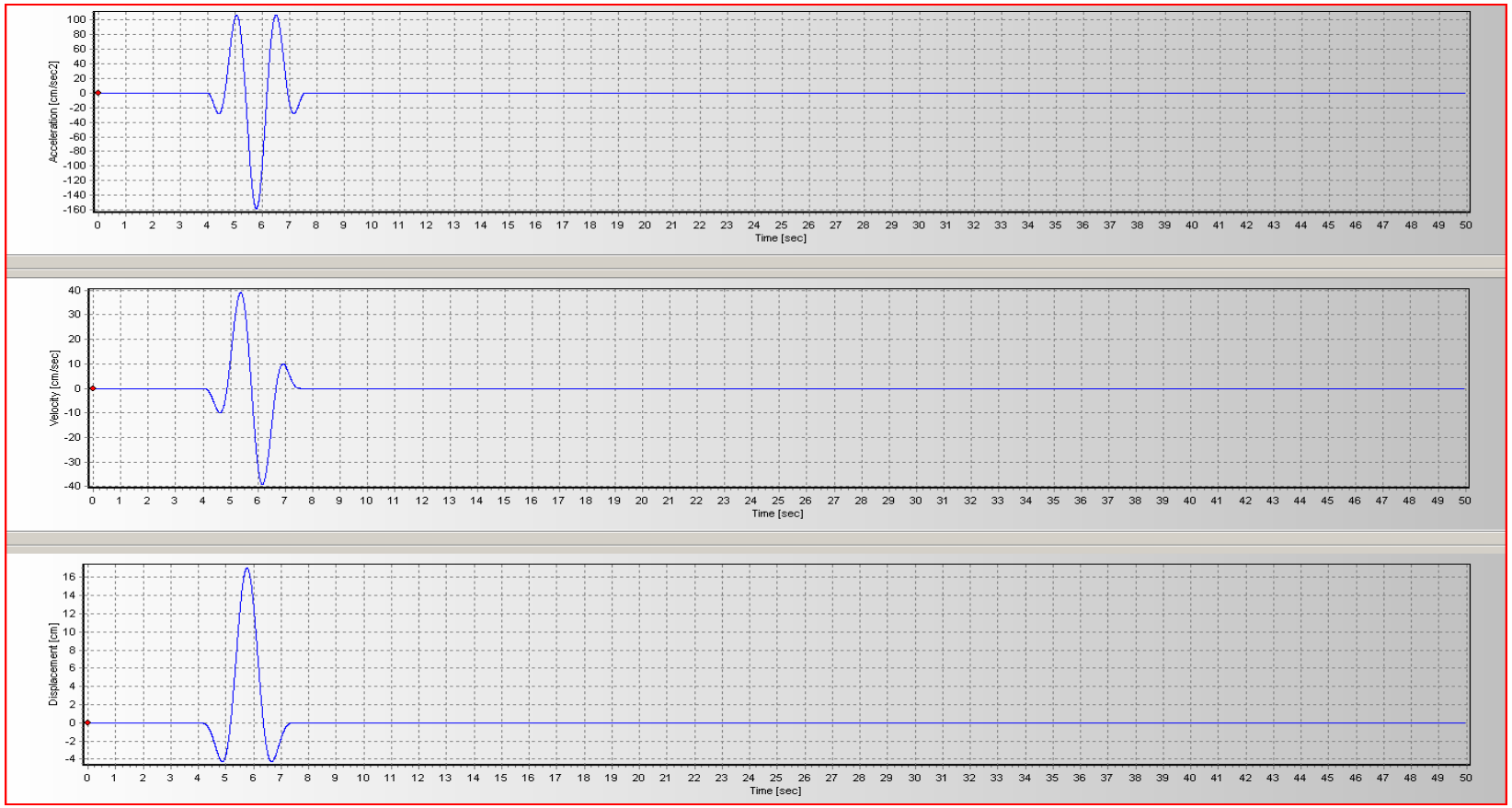
Target and simulated acceleration spectra



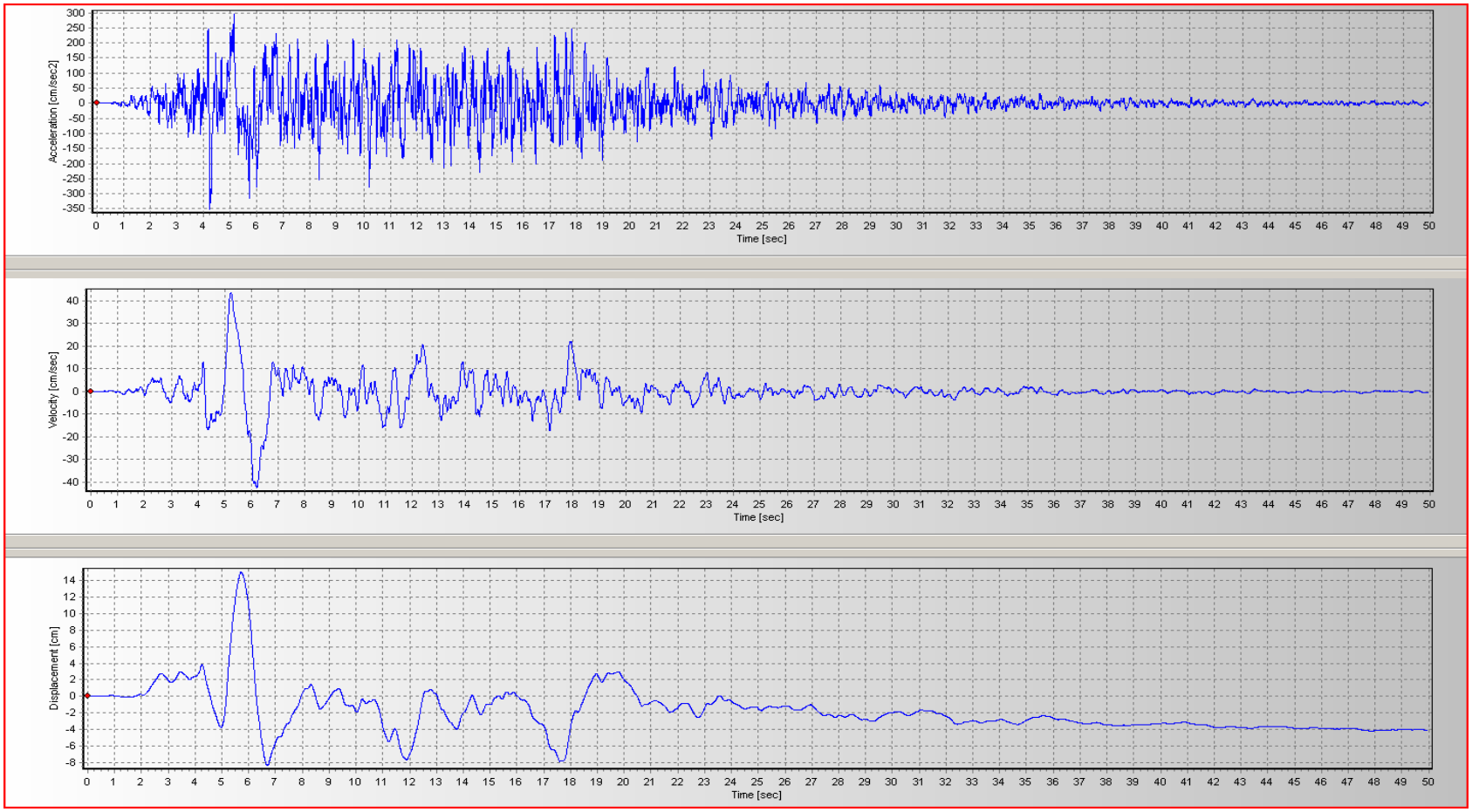
Target and simulated velocity spectra



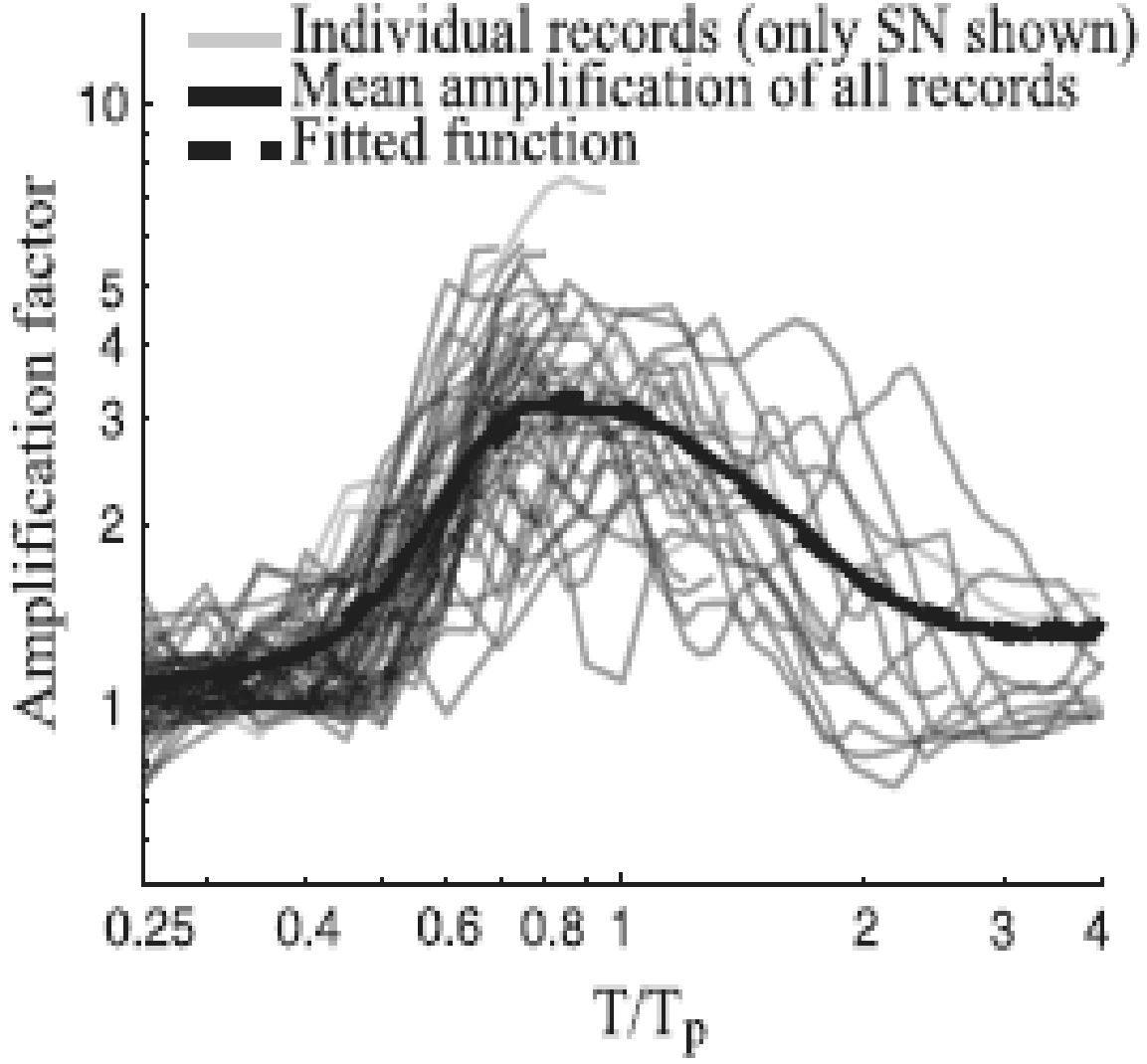
Simulated pulse for A=50 cm/sec, T=1.78 sec, γ=2, ν=90



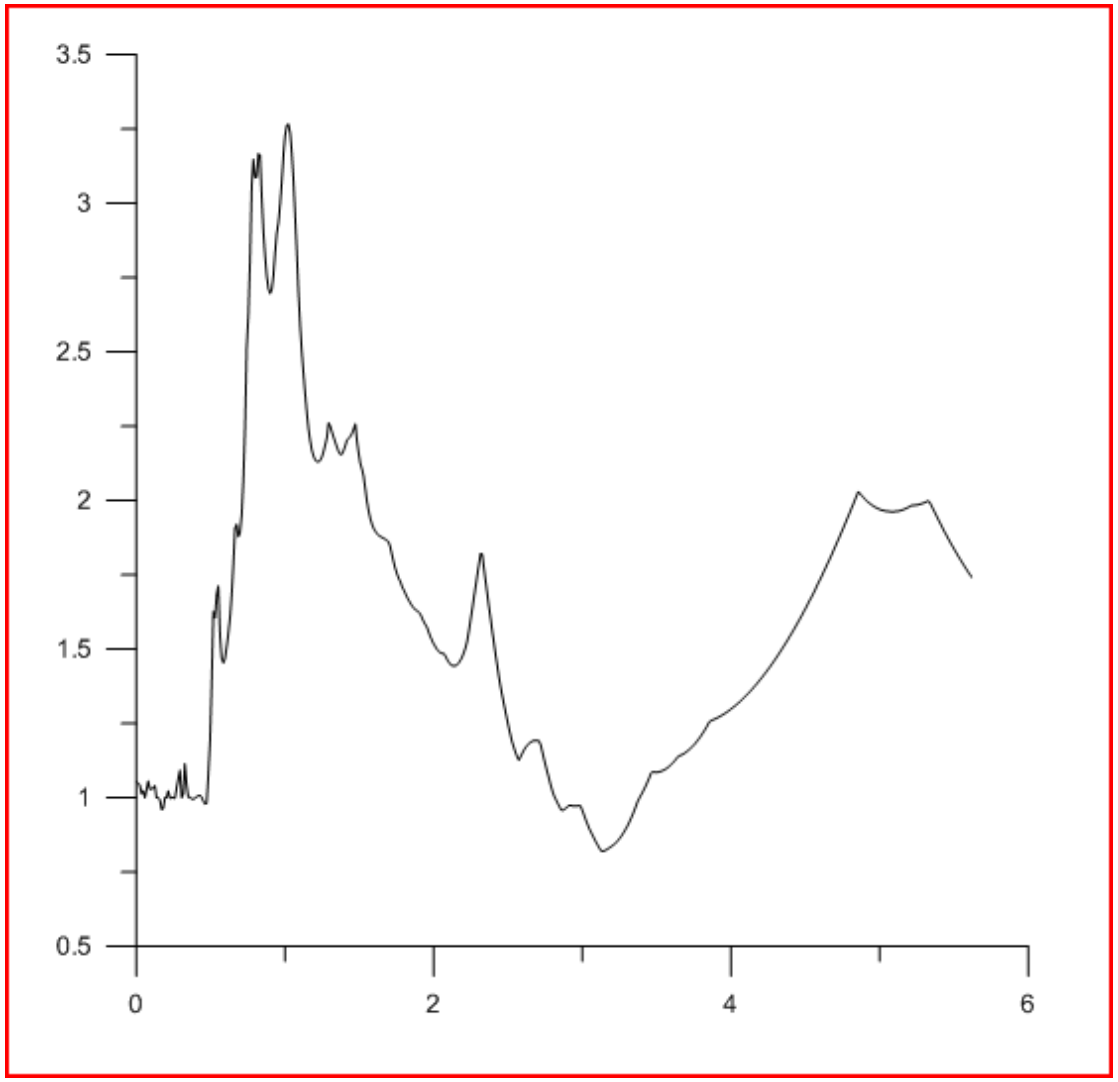
Combined high frequency and pulse simulations



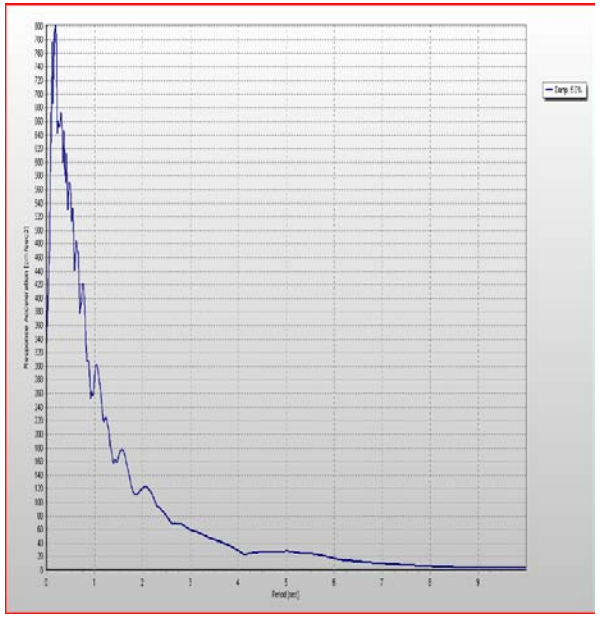
BELL SHAPED AMPLIFICATION AROUND Tp

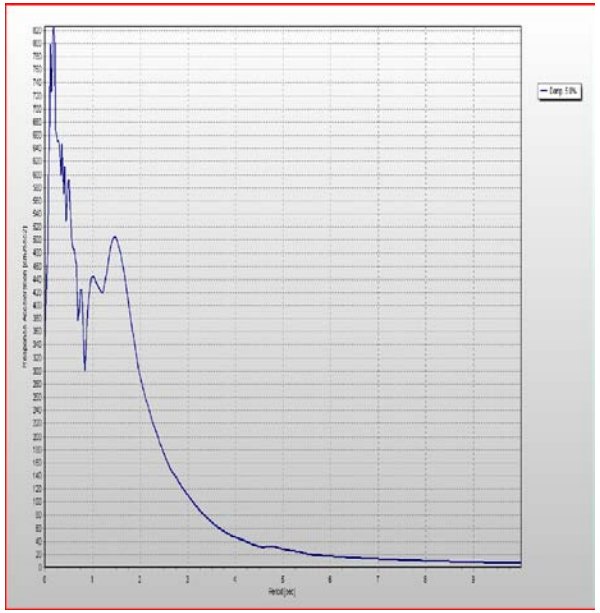


Ratio between combined and high frequency simulations versus T/Tp

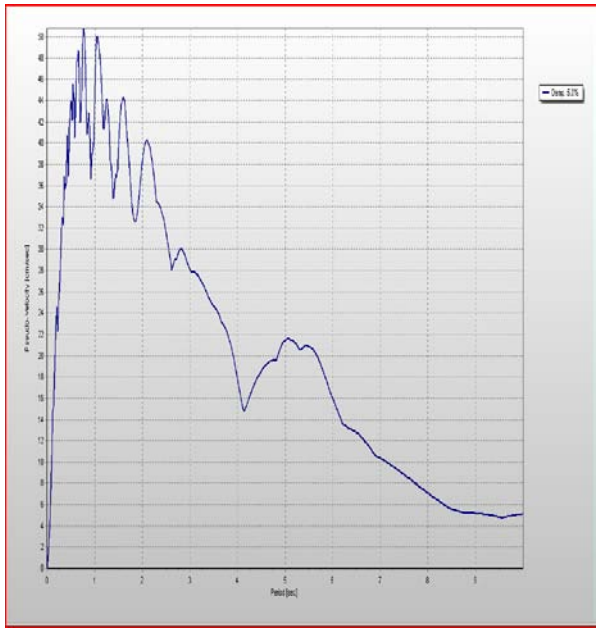


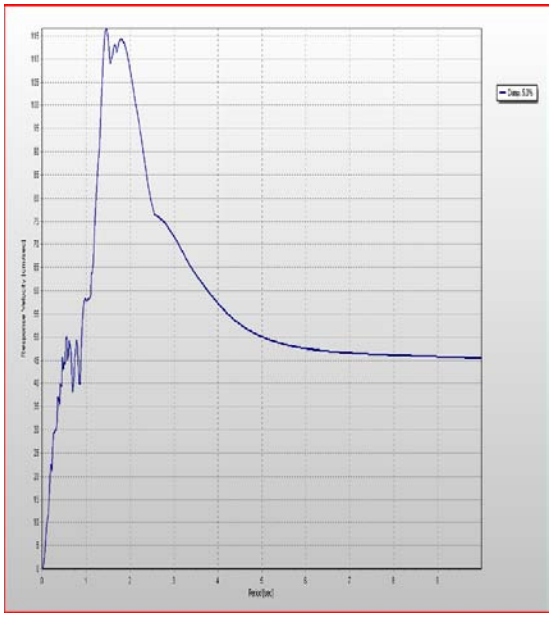
Acceleration spectra for high frequency and combined simulations



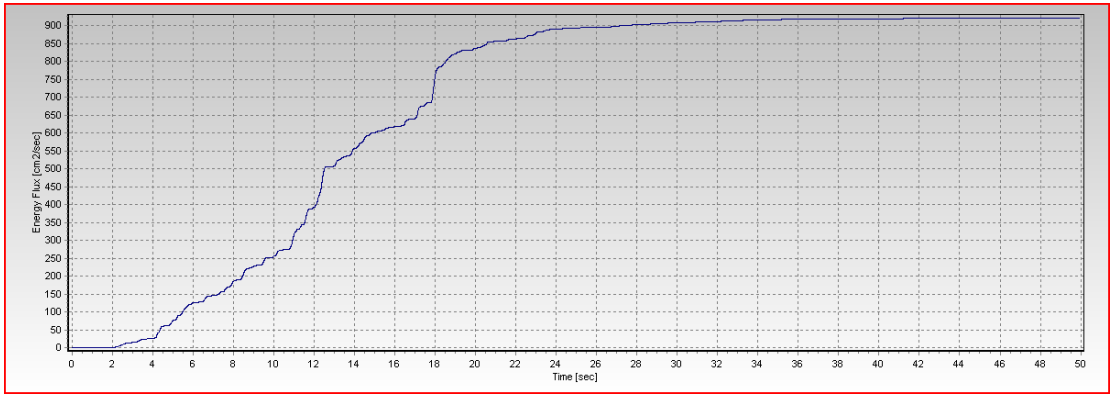


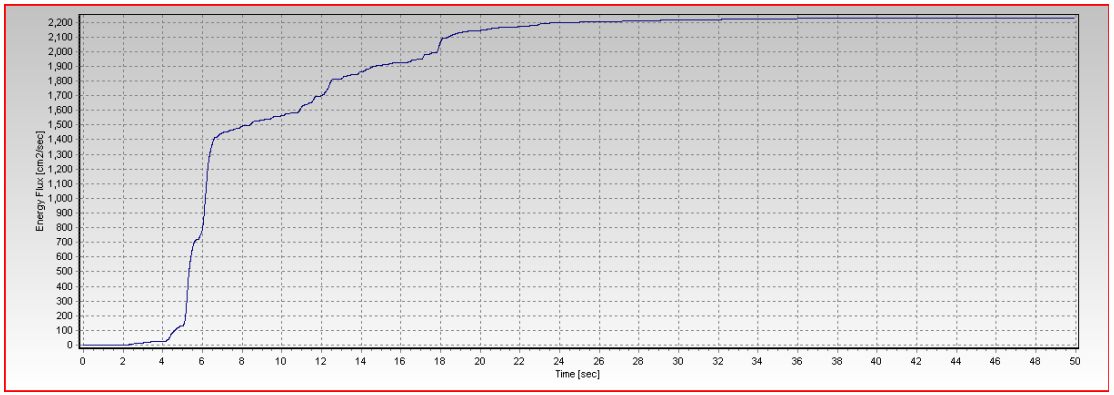
Velocity spectra for high frequency and combined simulations



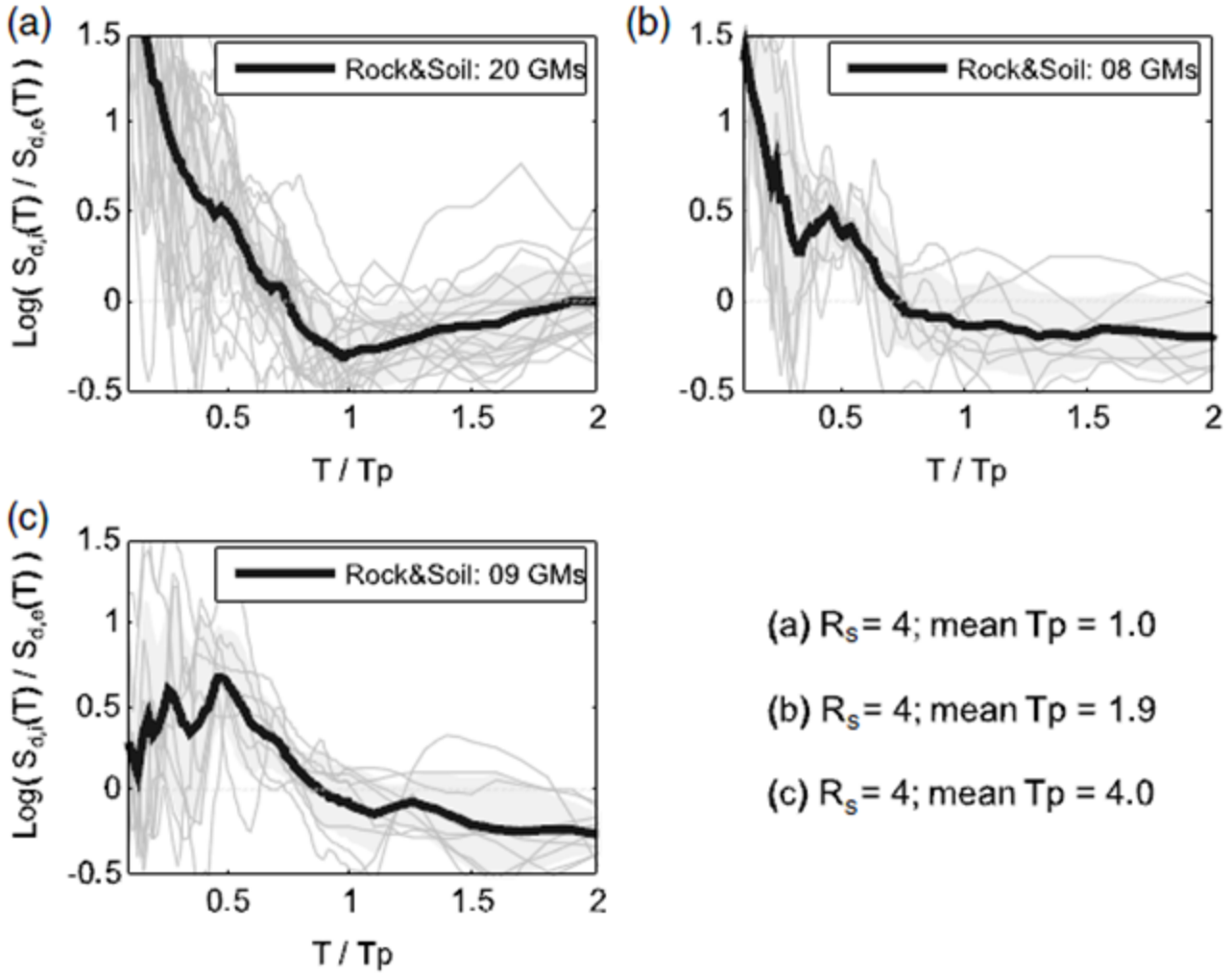


Energy flux for high frequency and combined simulations

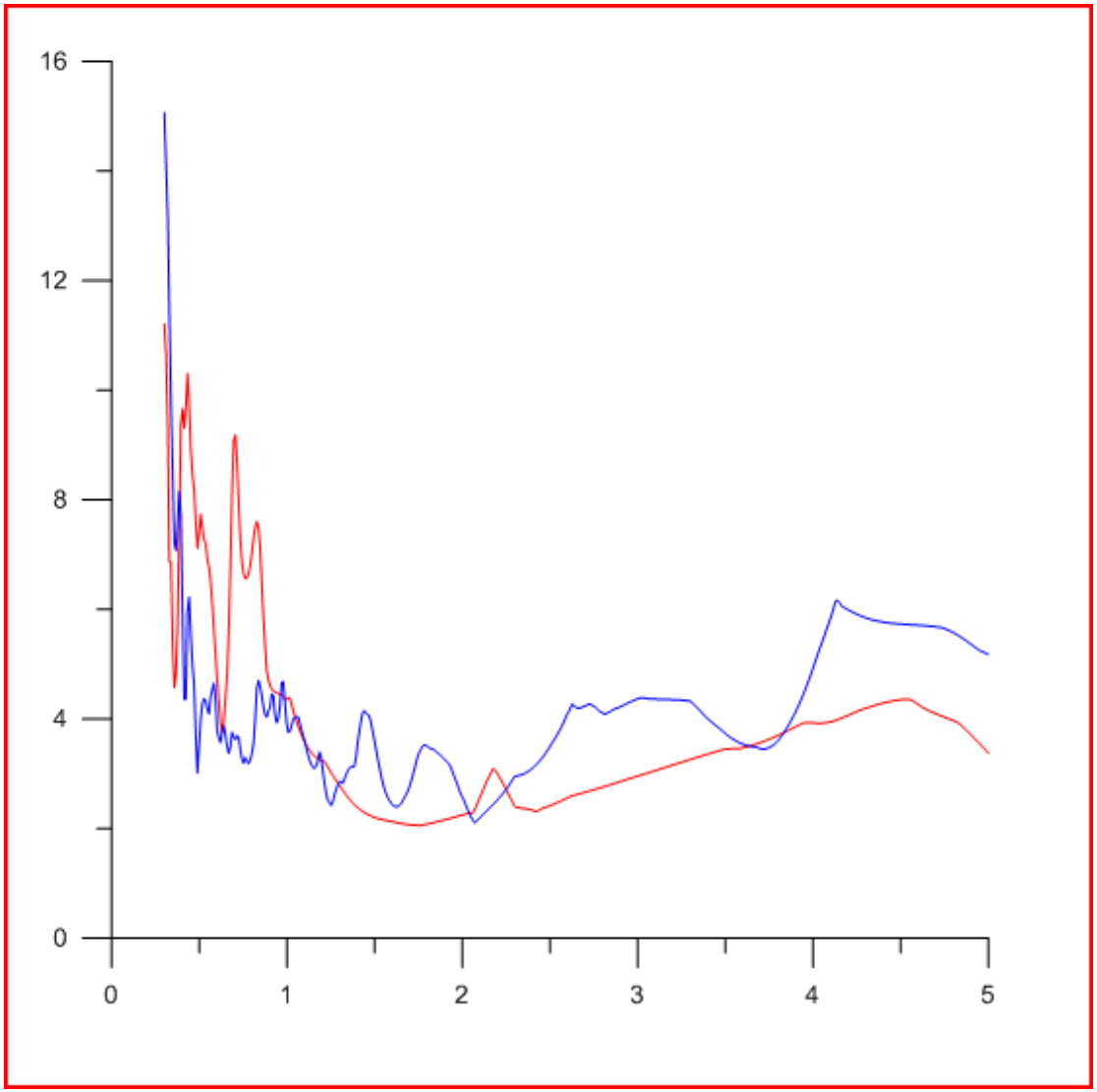




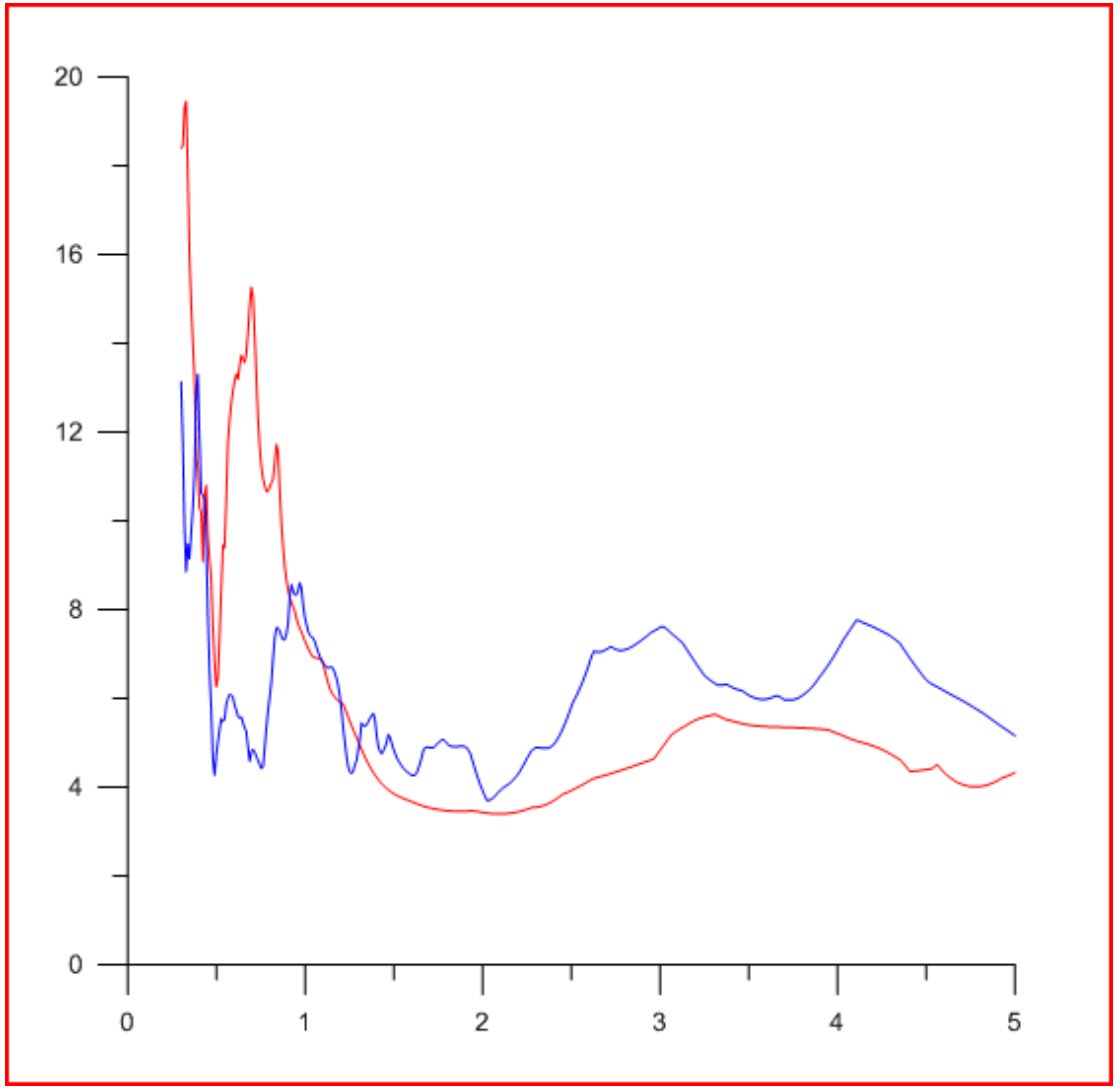
INELASTIC VERSUS ELASTIC DISPLACEMENT



Ductilities μ for high frequency and combined simulations and Ry=4



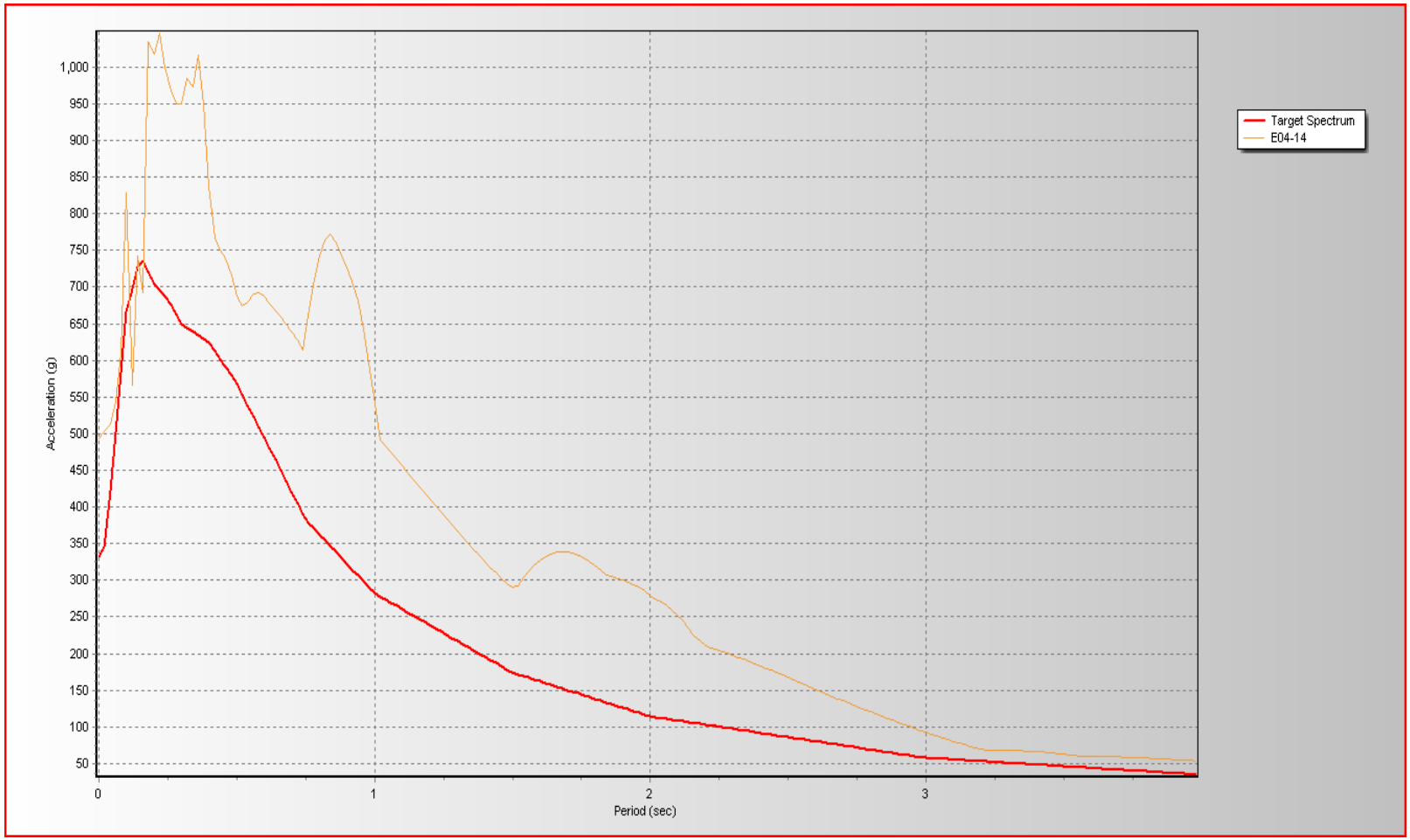
Ductilities μ for high frequency and combined simulations and Ry=6

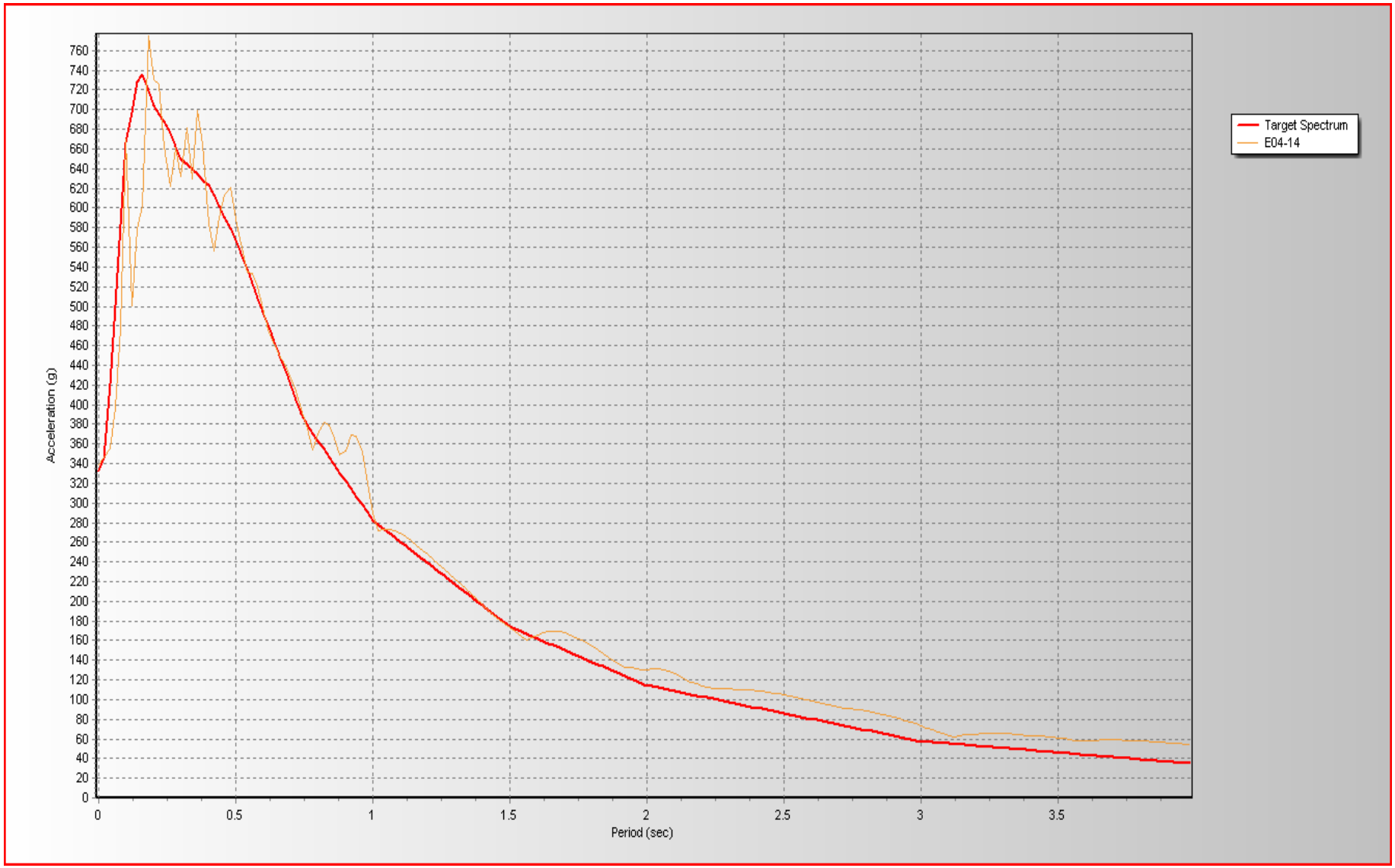


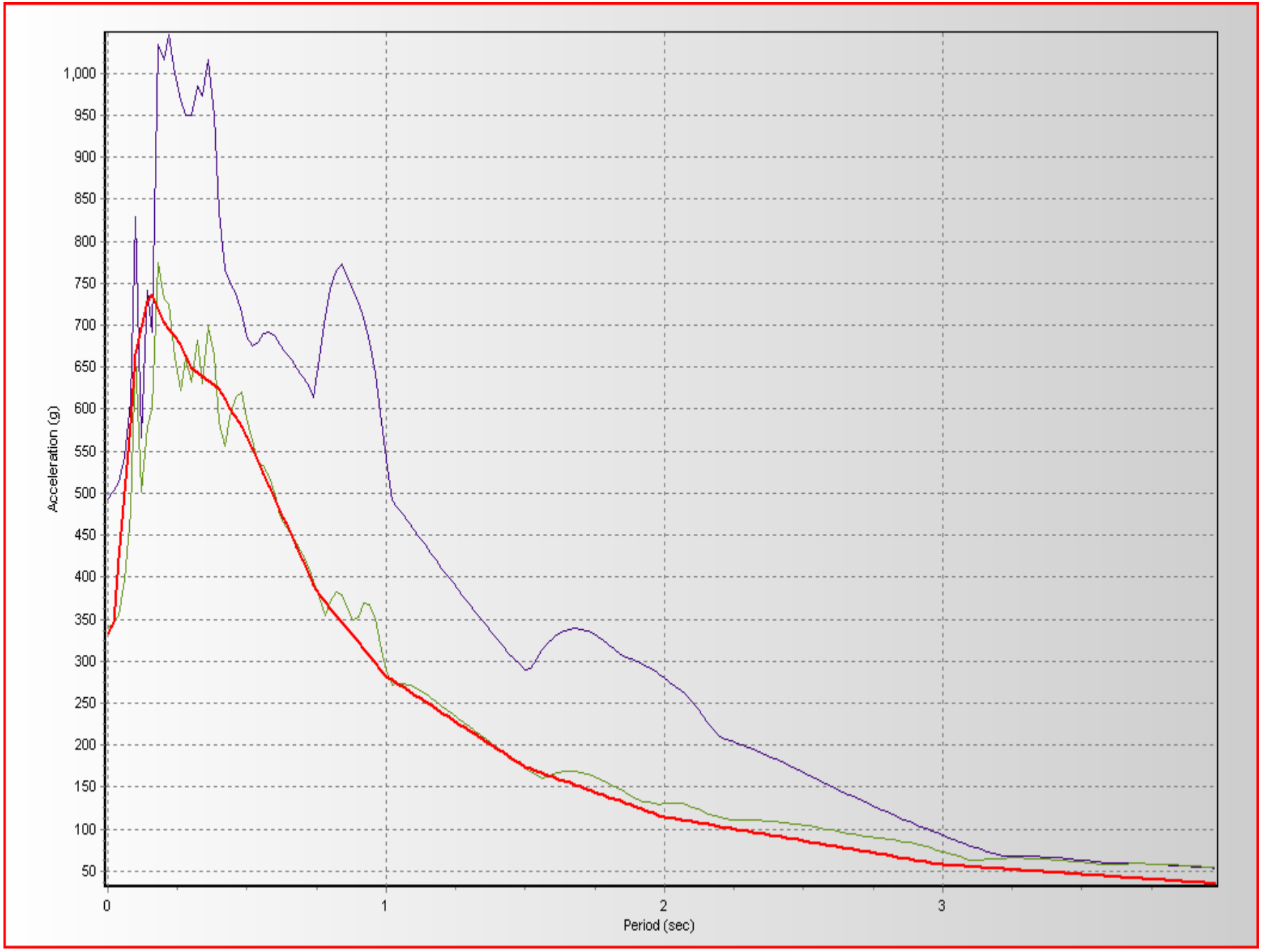
SEMI-ARTIFICIAL ACCELEROGRAMS

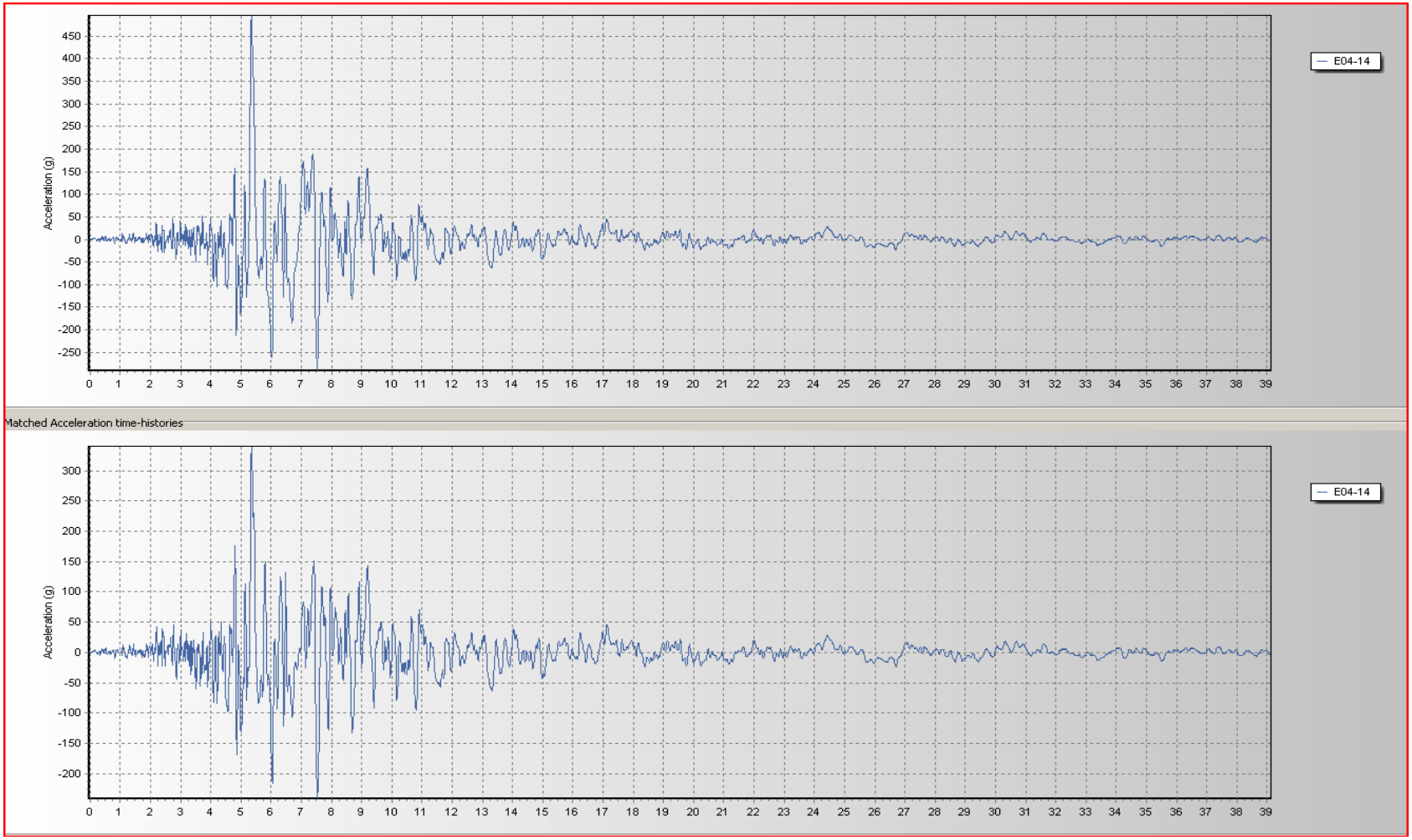
Fitting of existing accelerogram to target acceleration spectrum

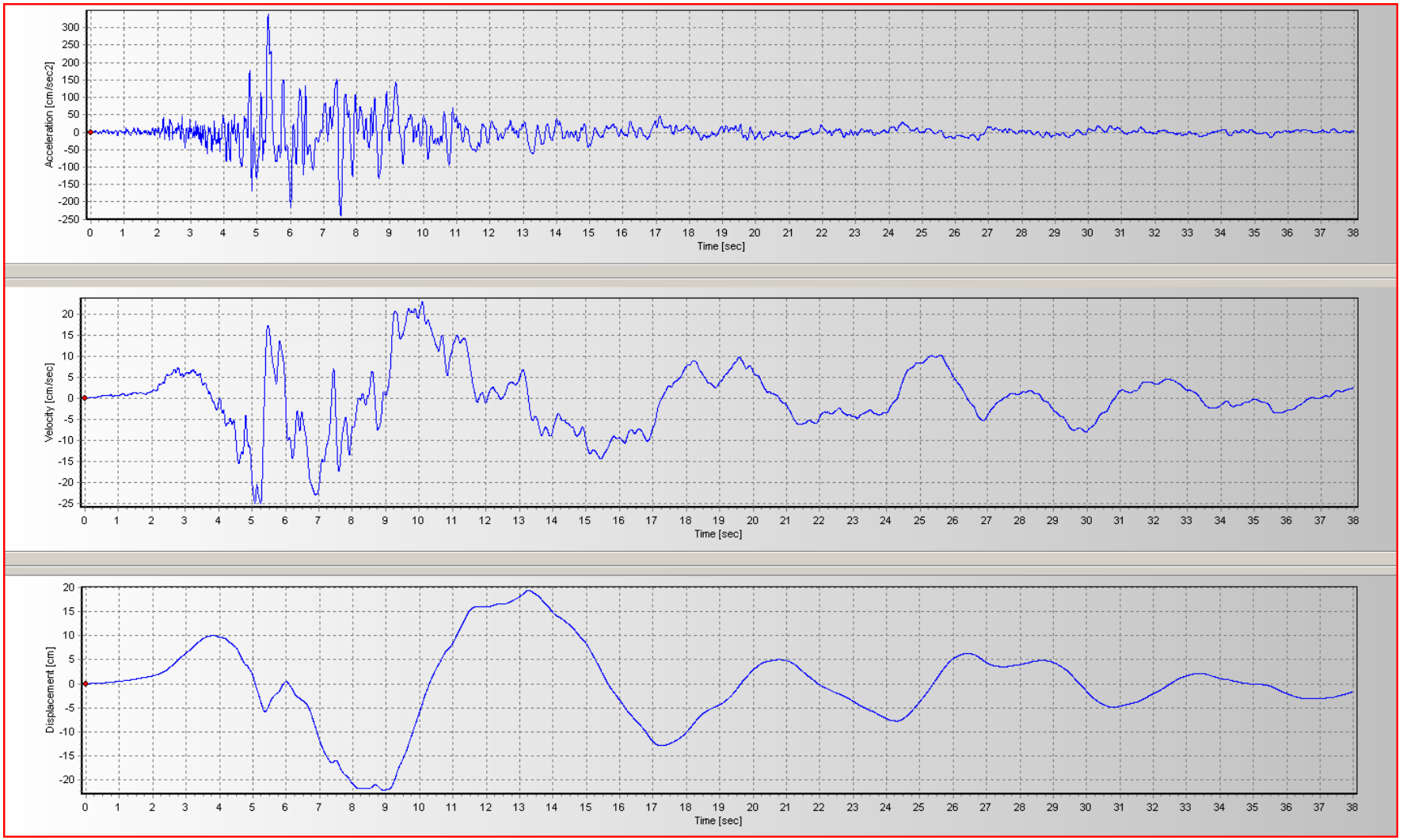
ORIGINAL AND TARGET SPECTRA

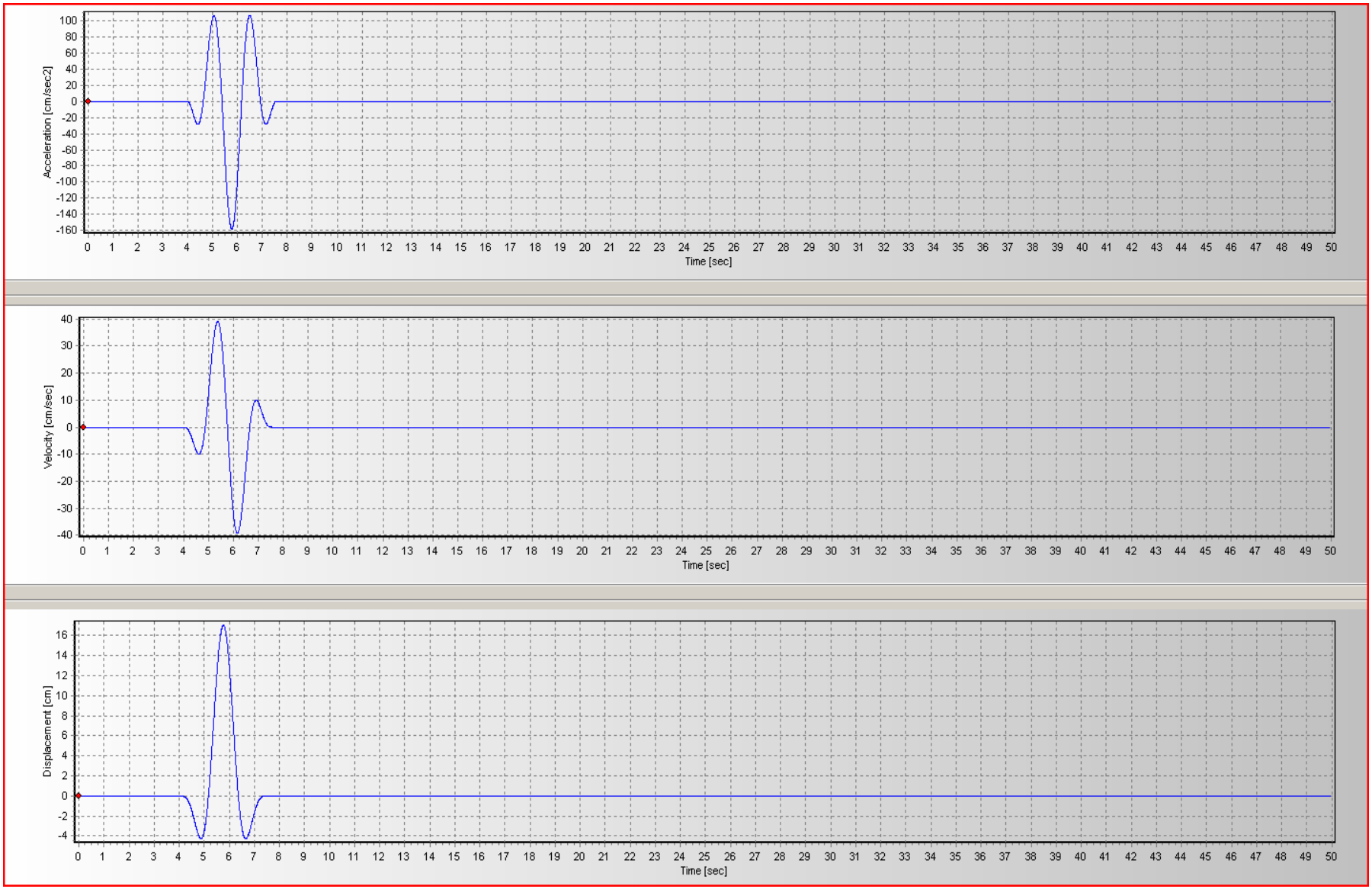


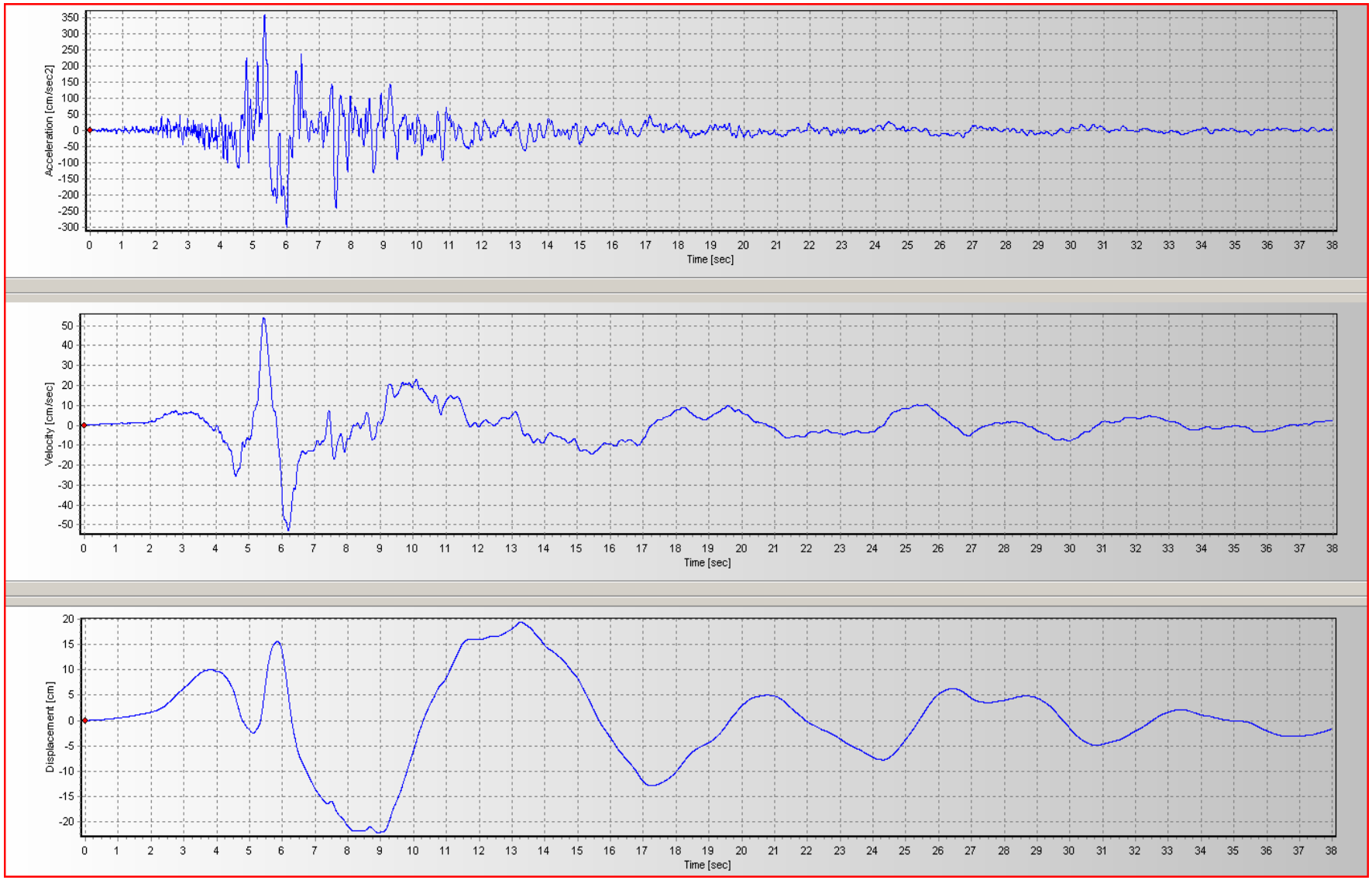

Target Spectrum
E04-14
Acceleration (g)
Period (sec)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
420
440
460
480
500
520
540
560
580
600
620
640
660
680
700
720
740
760
0
0.5
1
1.5
2
2.5
3
3.5

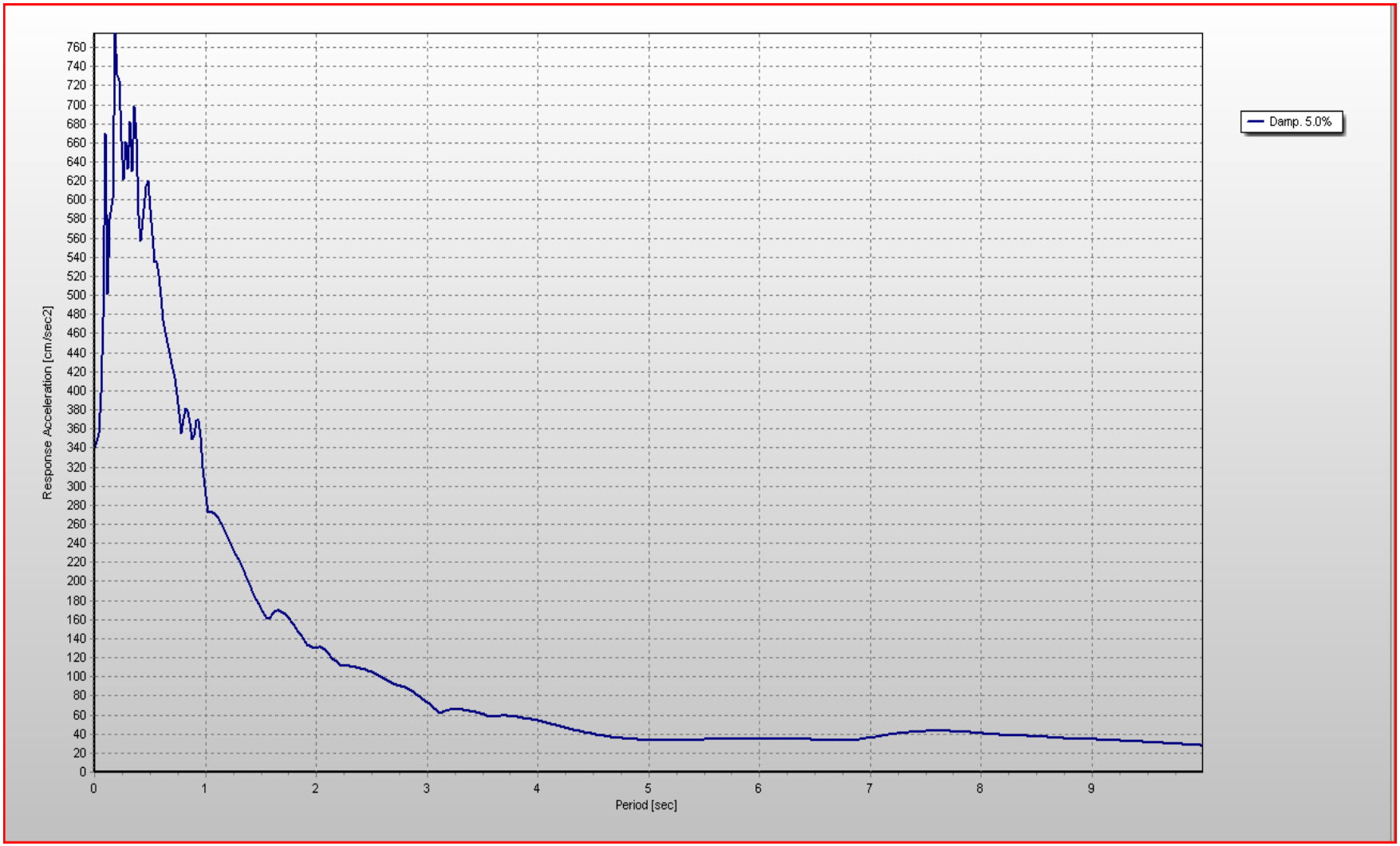

Acceleration (g)
1,000
950
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
1
2
3
Period (sec)

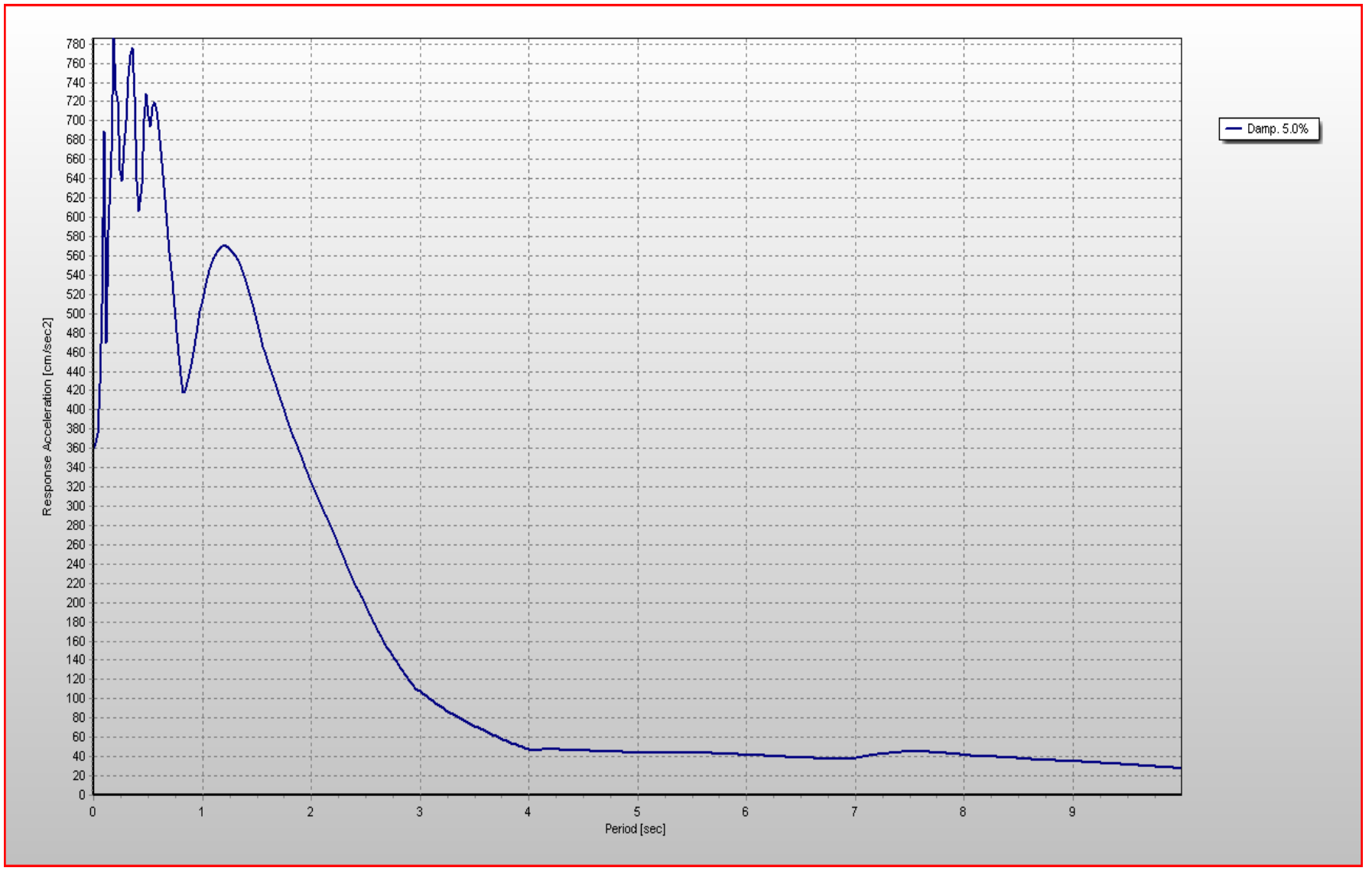

E04-14
Acceleration (g)
Matched Acceleration time-histories
E04-14
Acceleration (g)

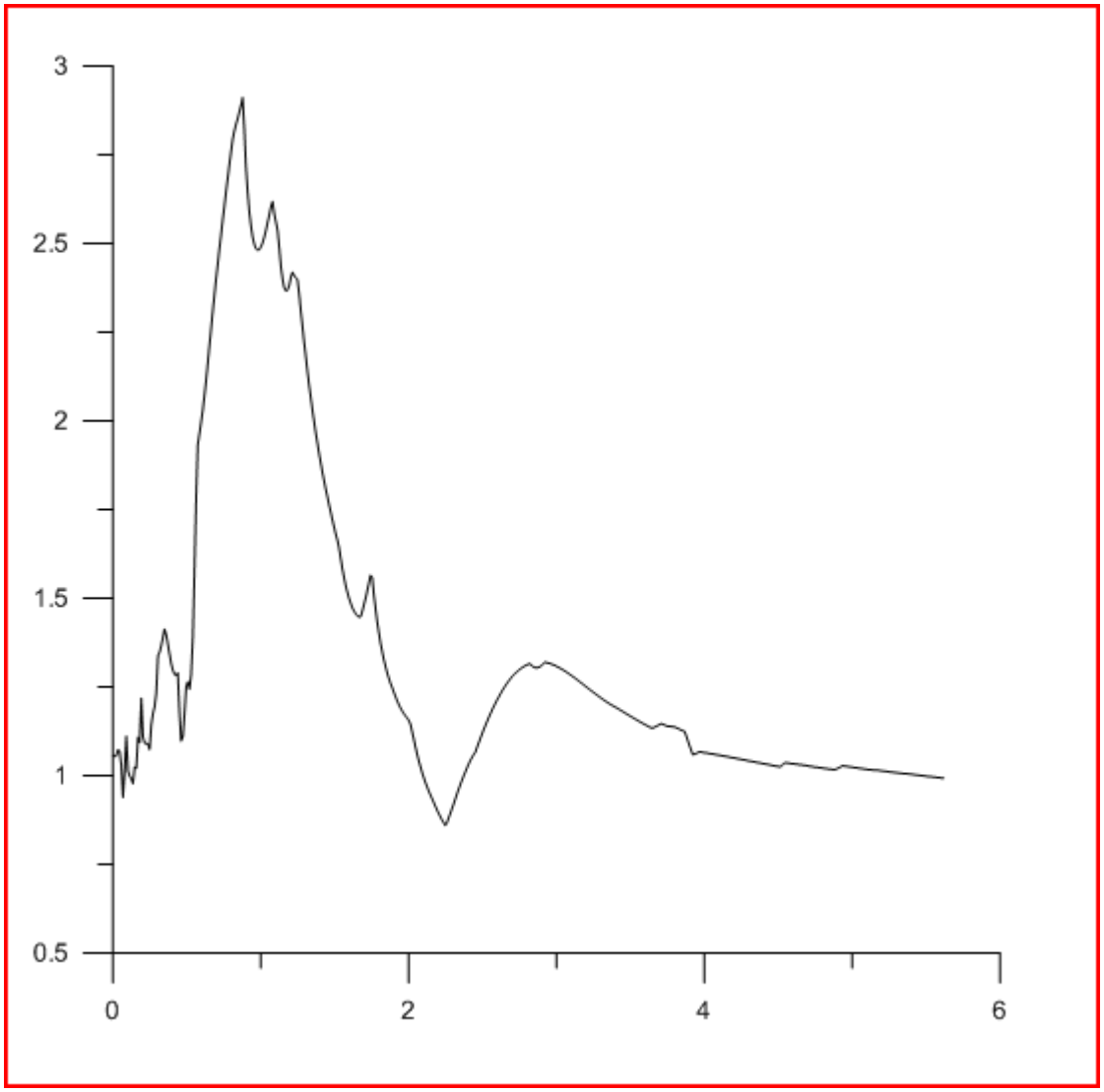

Acceleration [cm/sec2]
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38
Time [sec]
Velocity [cm/sec]
20
15
10
5
0
-5
-10
-15
-20
-25
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38
Time [sec]
Displacement [cm]
20
15
10
5
0
-5
-10
-15
-20
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38
Time [sec]

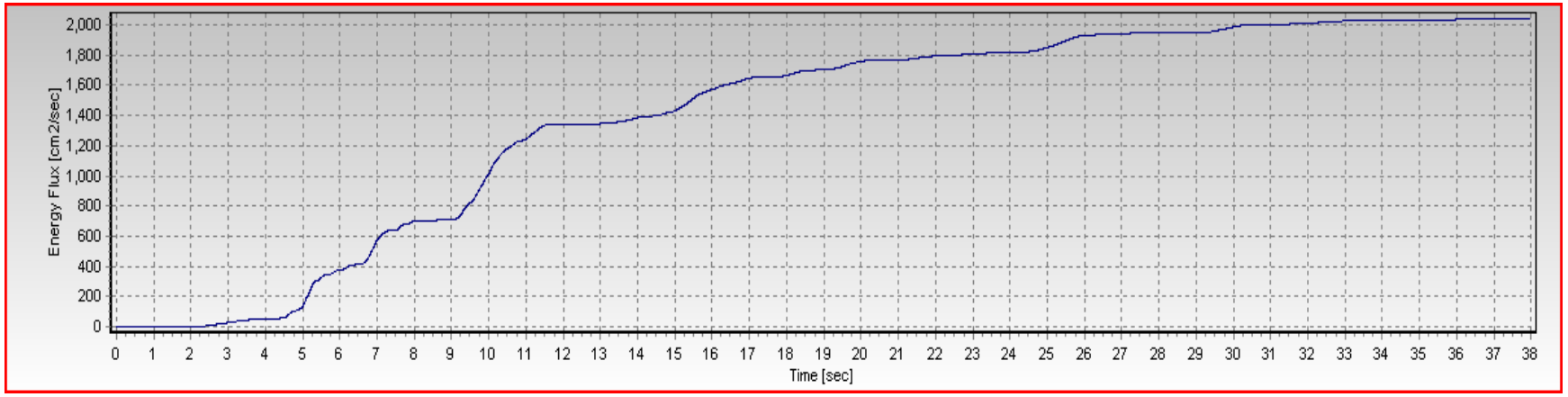

Acceleration [cm/sec2]
100 80 60 40 20 0 -20 -40 -60 -80 -100 -120 -140 -160
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50
Time [sec]
Velocity [cm/sec]
40 30 20 10 0 -10 -20 -30 -40
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50
Time [sec]
Displacement [cm]
16 14 12 10 8 6 4 2 0 -2 -4
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50
Time [sec]

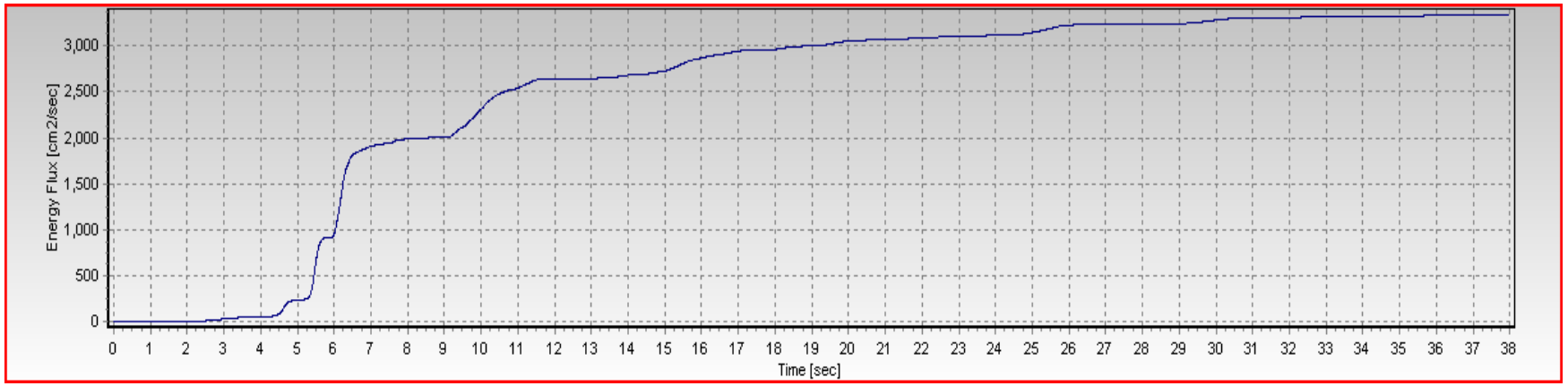

Acceleration [cm/sec2]
350 300 250 200 150 100 50 0 -50 -100 -150 -200 -250 -300
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38
Time [sec]
Velocity [cm/sec]
50 40 30 20 10 0 -10 -20 -30 -40 -50
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38
Time [sec]
Displacement [cm]
20 15 10 5 0 -5 -10 -15 -20
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38
Time [sec]


Response Acceleration [cm/sec2]
760
740
720
700
680
660
640
620
600
580
560
540
520
500
480
460
440
420
400
380
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
0
1
2
3
4
5
6
7
8
9
Period [sec]
Damp. 5.0%


Response Acceleration [cm/sec2]
780
760
740
720
700
680
660
640
620
600
580
560
540
520
500
480
460
440
420
400
380
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
0
1
2
3
4
5
6
7
8
9
Period [sec]
Damp. 5.0%


3
2.5
2
1.5
1
0.5
0
2
4
6


Energy Flux [cm2/sec]
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38
Time [sec]


Energy Flux [cm2/sec]
3,000
2,500
2,000
1,500
1,000
500
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38
Time [sec]