Single-Degree-of-Freedom (SDOF) and Response Spectrum

Ahmed Elgamal

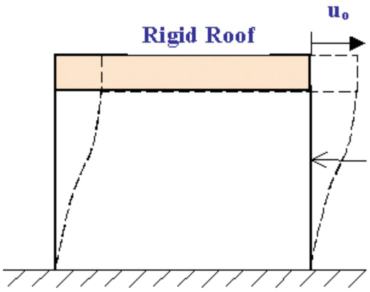
Dynamics of a Simple Structure

The Single-Degree-Of-Freedom (SDOF) Equation

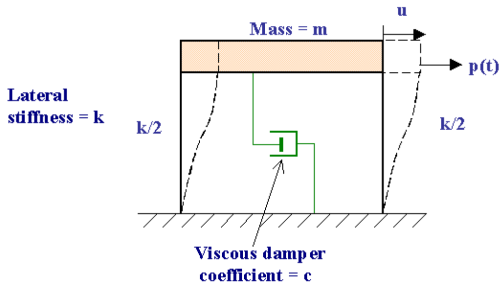
References

Dynamics of Structures, Anil K. Chopra, Prentice Hall, New Jersey, ISBN 0-13-855214-2 (Chapter 3).

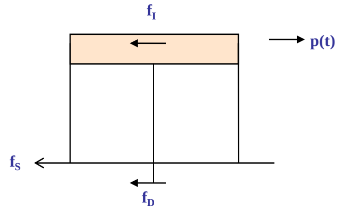
Elements of Earthquake Engineering And Structural Dynamics, André Filiatrault, Polytechnic International Press, Montréal, Canada, ISBN 2-553-00629-4 (Section 4.2.3).



Equation of motion (external force)



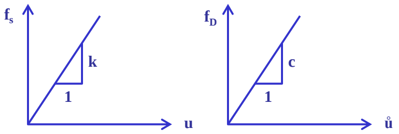
Free-Body Diagram (FBD)



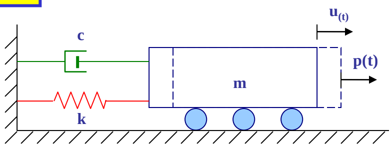
$$f_I + f_D + f_s = p(t)$$

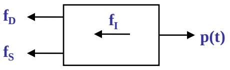
where f_I,f_D, and f_s are forces due to Inertia, Damping and Stiffness respectively:

$$\boxed{m\ddot{u} + c\dot{u} + ku = p(t)}$$



$f_s = k\,u$ $\quad$ $f_D = c\,\dot{u}$





FBD

Mass-spring damper system

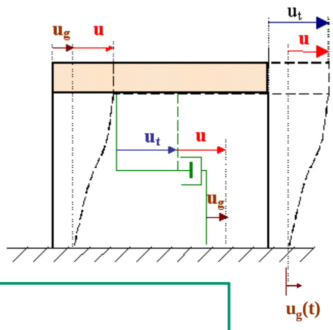
Earthquake Ground Motion (u_g)

$$f_I + f_D + f_s = 0$$

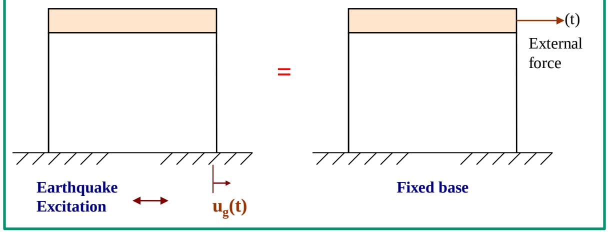
$$f_I = m\ddot{u}_t = m(\ddot{u}_g + \ddot{u})$$

$$m(\ddot{u} + \ddot{u}_g) + c\dot{u} + ku = 0$$

$$m\ddot{u} + c\dot{u} + ku = -m\ddot{u}_g$$



You may note that:



u = relative displacement (displacement of the structure relative to the ground)
u_t = total displacement
f_I = m x (total or absolute acceleration)

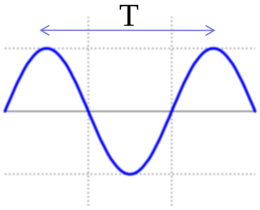
Undamped natural frequency

Property of structure when allowed to vibrate freely without external excitation

$\omega = \sqrt{\frac{k}{m}}$ Undamped natural circular frequency of vibration (radians/second)

$f = \frac{\omega}{2\pi}$ natural cyclic frequency of vibration (cycles/second or 1/second or Hz)

$T = \frac{1}{f}$ natural period of vibration (second)



T is the time required for one cycle of free vibration

If damping is present, replace ω by ω_D

where $\omega_D = \omega\sqrt{1-\xi^2}$ natural frequency*, and

$\xi = \frac{c}{2m\omega}$ fraction of critical damping coefficient (**damping ratio**, zeta)

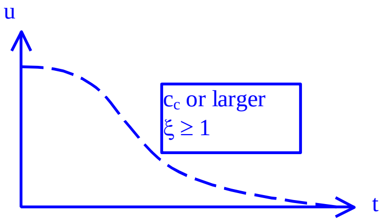
$= \frac{c}{c_c}$ $= \frac{c}{2\sqrt{km}}$ (dimensionless measure of damping)

$c_c = 2m\omega = 2\sqrt{km}$ c_c = critical damping

* Note: In earthquake engineering, $\omega_D = \omega$ approximately, since ζ is usually below 0.2 (or 20%)

---

c_c is the least level of damping that prevents oscillation



e.g., damper on a swinging door

In general $\xi < 0.2$, i.e., $\omega_D \approx \omega$, $f_D \approx f$, $T = T_D$

ξ may be in the range of 0.02 – 0.2 or 2% - 20%

5% is sometimes a typical value.

in terms of ξ

$$m\ddot{u} + c\dot{u} + ku = -m\ddot{u}_g$$

$$\ddot{u} + \frac{c}{m}\dot{u} + \frac{k}{m}u = -\ddot{u}_g$$

$$\ddot{u} + 2\xi\omega\dot{u} + \omega^2 u = -\ddot{u}_g$$

Note: After the phase of forced vibration (due to external force or base excitation, or initial conditions), the structure continues to vibrate in a “free vibration” mode till it stops due to damping. The ratio between amplitude in two successive cycles is

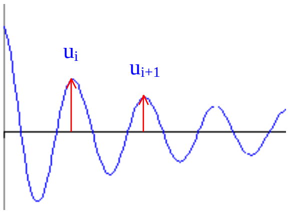
$$\frac{u_i}{u_{i+1}} \approx e^{2\pi\xi}$$

where we define the logarithmic decrement as

$\delta = 2\pi\xi = \ln\left(\frac{u_i}{u_{i+1}}\right)$ if you measure a free vibration response you can find ξ.

Note: for peaks j cycles apart

$$\ln\left(\frac{u_i}{u_{i+j}}\right) = j\delta = 2j\pi\xi$$



Free vibration

Why is $c_c = 2m\omega = 2\sqrt{km}$

Critical viscous damping

The free vibration equation may be written as

$$m\ddot{x} + c\dot{x} + kx = 0$$

and the general solution is

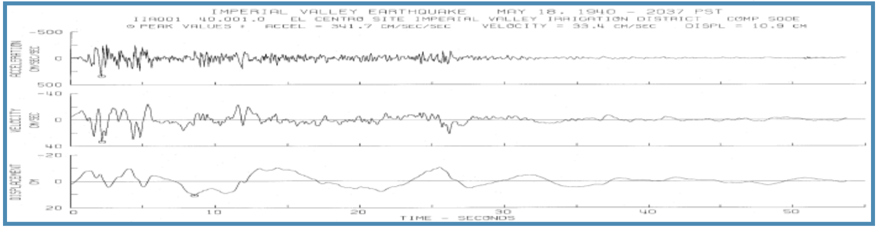
$$x = C_1\, e^{\left[\frac{-c}{2m} + \sqrt{\left(\frac{c}{2m}\right)^2 - \left(\frac{k}{m}\right)}\right] t} + C_2\, e^{\left[\frac{-c}{2m} - \sqrt{\left(\frac{c}{2m}\right)^2 - \left(\frac{k}{m}\right)}\right] t}$$

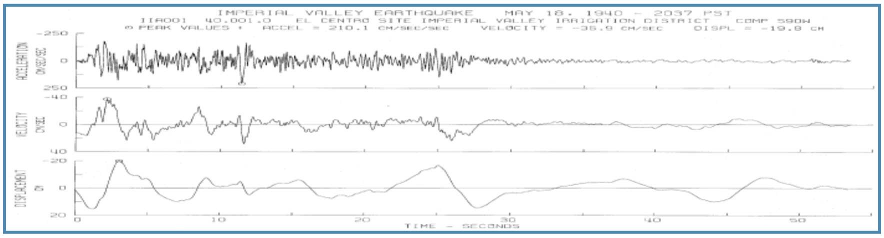
if $\left(\frac{c}{2m}\right)^2 = \frac{k}{m}$, the radical part of the exponent will vanish. This will produce aperiodic response (non-oscillatory). In this case

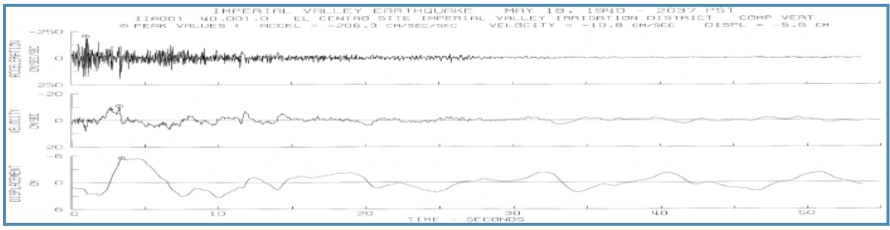
$$\frac{c^2}{(2m)^2} = \frac{k}{m} \quad \text{or} \quad c = 2\sqrt{km} = c_c$$

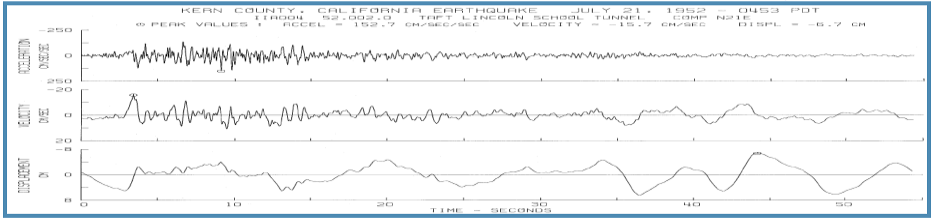
since $\omega = \sqrt{\frac{k}{m}}$, c_c is also equal to $2m\omega$ (note that $2\sqrt{km} = 2\sqrt{m\omega^2 m} = 2m\omega$)

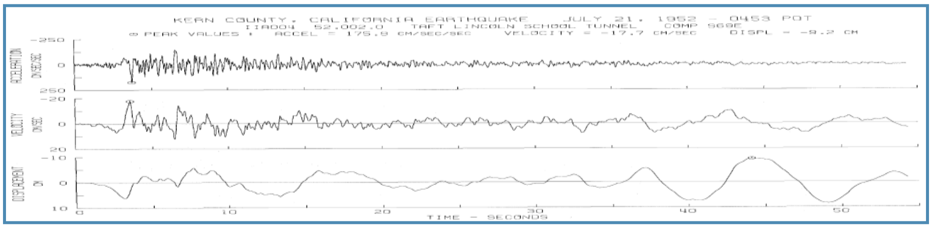
and also $c_c = 2\sqrt{km} = 2\sqrt{k(k/\omega^2)} = \frac{2k}{\omega}$

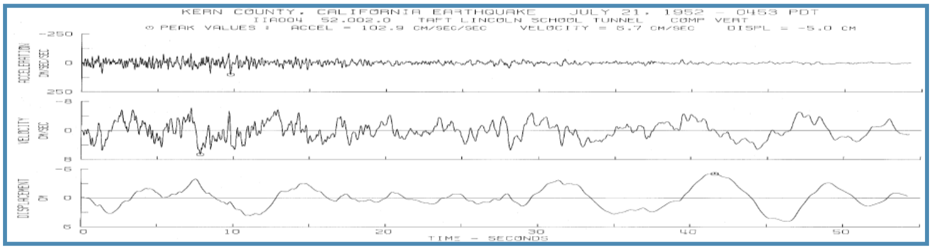

IMPERIAL VALLEY EARTHQUAKE MAY 18, 1940 - 2037 PST
IIA001 40.001.0 EL CENTRO SITE IMPERIAL VALLEY IRRIGATION DISTRICT COMP S00E
⊙ PEAK VALUES : ACCEL = 341.7 CM/SEC/SEC VELOCITY = 33.4 CM/SEC DISPL = 10.9 CM
ACCELERATION CM/SEC/SEC
-500
0
500
VELOCITY CM/SEC
-40
0
40
DISPLACEMENT CM
-20
0
20
0
10
20
30
40
50
TIME - SECONDS


IMPERIAL VALLEY EARTHQUAKE MAY 18, 1940 - 2037 PST
IIA001 40.001.0 EL CENTRO SITE IMPERIAL VALLEY IRRIGATION DISTRICT COMP S90W
⊙ PEAK VALUES : ACCEL = 210.1 CM/SEC/SEC VELOCITY = -36.9 CM/SEC DISPL = -19.8 CM
ACCELERATION CM/SEC/SEC
-250
0
250
VELOCITY CM/SEC
-40
0
40
DISPLACEMENT CM
-20
0
20
0
10
20
30
40
50
TIME - SECONDS


IMPERIAL VALLEY EARTHQUAKE MAY 18, 1940 - 2037 PST
IIA001 40.001.0 EL CENTRO SITE IMPERIAL VALLEY IRRIGATION DISTRICT COMP VERT
⊙ PEAK VALUES : ACCEL = -206.3 CM/SEC/SEC VELOCITY = -10.8 CM/SEC DISPL = -5.6 CM
ACCELERATION CM/SEC/SEC
-250
0
250
VELOCITY CM/SEC
-20
0
20
DISPLACEMENT CM
-6
0
6
0
10
20
30
40
50
TIME - SECONDS


KERN COUNTY, CALIFORNIA EARTHQUAKE JULY 21, 1952 - 0453 PDT
IIA004 52.002.0 TAFT LINCOLN SCHOOL TUNNEL COMP N21E
⊙ PEAK VALUES : ACCEL = 152.7 CM/SEC/SEC VELOCITY = -15.7 CM/SEC DISPL = -6.7 CM
ACCELERATION CM/SEC/SEC
-250
0
250
VELOCITY CM/SEC
-20
0
20
DISPLACEMENT CM
-8
0
8
0
10
20
30
40
50
TIME - SECONDS


KERN COUNTY, CALIFORNIA EARTHQUAKE JULY 21, 1952 - 0453 PDT
IIA004 52.002.0 TAFT LINCOLN SCHOOL TUNNEL COMP S69E
⊙ PEAK VALUES : ACCEL = 175.9 CM/SEC/SEC VELOCITY = -17.7 CM/SEC DISPL = -9.2 CM
ACCELERATION CM/SEC/SEC
-250
0
250
VELOCITY CM/SEC
-20
0
20
DISPLACEMENT CM
-10
0
10
0
10
20
30
40
50
TIME - SECONDS


KERN COUNTY, CALIFORNIA EARTHQUAKE JULY 21, 1952 - 0453 PDT
IIA004 52.002.0 TAFT LINCOLN SCHOOL TUNNEL COMP VERT
⊙ PEAK VALUES : ACCEL = 102.9 CM/SEC/SEC VELOCITY = 5.7 CM/SEC DISPL = -5.0 CM
ACCELERATION CM/SEC/SEC
-250
0
250
VELOCITY CM/SEC
-8
0
8
DISPLACEMENT CM
-6
0
6
0
10
20
30
40
50
TIME - SECONDS

Deformation Response Spectrum

For a given EQ excitation calculate $|u_{max}|$ from SDOF response with a certain ξ and within a range of natural periods or frequencies.

$|u_{max}|$ for each frequency will be found from the computed u(t) history at this frequency.

A plot of $|u_{max}|$ vs. natural period is constructed representing the deformation (or displacement) response spectrum (S_d).

From this figure, one can directly read the maximum relative displacement of any structure of natural period T (and a particular value of ξ as damping)

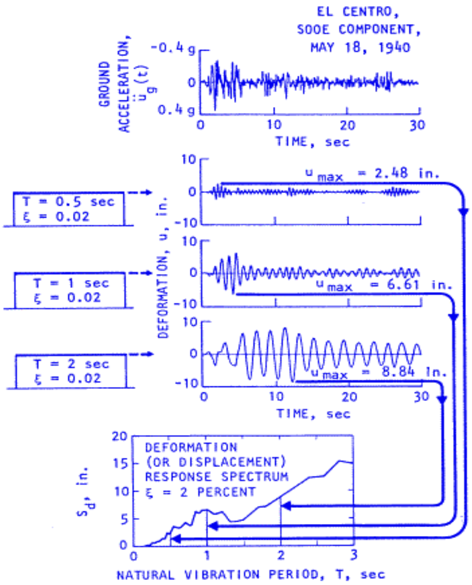


Figure 17. Computation of deformation (or displacement) response spectrum

From: Chopra, Dynamics of Structures, A Primer

Example

Units for natural frequency calculation (SI units)

Weight = 9.81 kN = 9810 N = 9810 kg (m /s$^{2)}$

Gravity (g) = 9.81m/s^2

Mass (m) = W/g = 9180/9.81 = 1000 kg

Stiffness (k) = 81 kN/m = 81000 N/m = 81000 kg (m/s^2)/m = kg /s^2

ω = SQRT (k/m) = SQRT (81000/1000) = 9 radians/sec

f = ω / (2 π) = 1.43 Hz (units of 1/s or cycles/sec)

Units for natural frequency calculation (English units)

Weight (W) = 193.2 Tons = 193.2 (2000) = 386,400 lbs = 386.4 kips

g = 386.4 in/sec/sec (or in/s^2)

Mass (m) = W/g = 1.0 kips s^2 /in

Stiffness (k) = 144 kips/in

ω =SQRT (k/m) = 12 radians/sec

f = ω / (2 π) = 1.91 Hz (units of 1/s or cycles/sec)

Note: The weight of an object is the force of gravity on the object and may be defined as the mass times the acceleration of gravity, w = mg. Weight is what is measured by a scale (e.g., weight of a person). Since the weight is a force, its SI unit is Newton.

Concept of Equivalent lateral force f_s

If f_s is applied as a static force, it would cause the deformation u.

Thus at any instant of time:

$f_s = ku(t)$, or in terms of the mass $f_s(t) = m\omega^2 u(t)$

$$\omega = \sqrt{\frac{k}{m}}$$

The maximum force will be

$$f_{s,max} = m\omega^2 u_{max} = ku_{max} \quad = mS_a = kS_d$$

$$S_a = \frac{k}{m} S_d \qquad S_a = \omega^2 S_d$$

S_d = deformation or displacement response spectrum

$S_a = \omega^2 S_d$ = pseudo-acceleration response spectrum

The maximum strain energy E_{max} stored in the structure during shaking is:

$$E_{max} = \frac{1}{2} k u^2_{max} = \frac{1}{2} k S_d^2 = \frac{1}{2} \frac{k}{\omega^2} \omega^2 S_d^2 = \frac{1}{2} m \omega^2 S_d^2 = \frac{1}{2} m S_V^2$$

where $S_V = \omega S_d$ = pseudo-velocity response spectrum

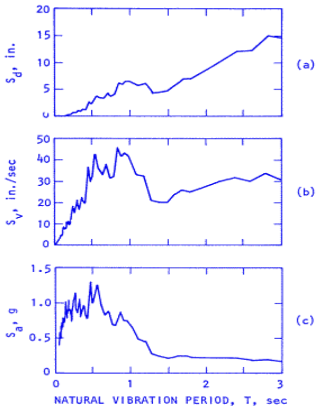


Figure 19. (a) Deformation (or Displacement), (b) pseudo-velocity and (c) pseudoacceleration response spectra. El Centro ground motion—S00°E component. Damping ratio ξ = 2 percent

From: Chopra,
Dynamics of Structures, A Primer

Note that S_d, S_v and S_a are inter-related by

$$S_a = \omega^2 S_d = \omega S_V$$

S_a, S_v are directly related to S_d

by ω^2 and ω respectively or by $(2\pi f)^2$ and $2\pi f$;

or $\left(\frac{2\pi}{T}\right)^2$ and $\left(\frac{2\pi}{T}\right)$ as shown in Figure.

Due to this direct relation, a 4-way plot is usually used to display S_a, S_v and S_d on a single graph as shown in Figure. In this figure, the logarithm of period T, S_a, S_v and S_d is used.

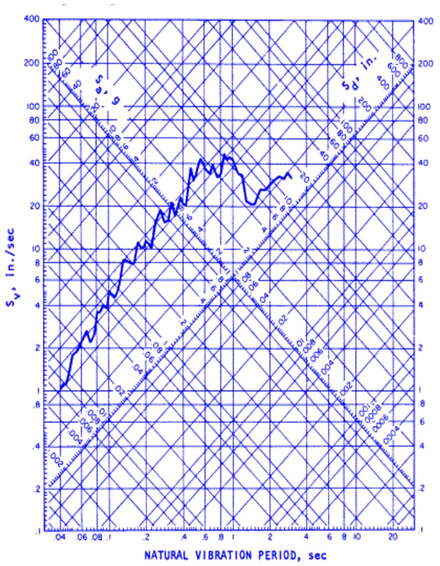


Figure 20. Four-way logarithmic plot of response spectrum. El Centro ground motion—S00°E component. Damping ratio ξ = 2 percent

From: Chopra, Dynamics of Structures, A Primer

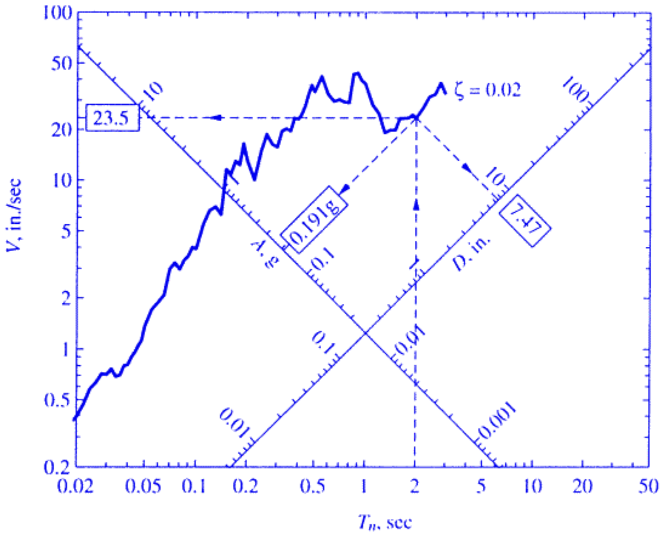


Figure 6.6.3 Combined D–V–A response spectrum for El Centro ground motion; $\zeta = 2\%$.

From: Chopra, Dynamics of Structures

In order to cover the damping range of interest, it is common to perform the same calculations for ξ =0.0, 0.02, 0.05, 0.10, and 0.20 (see Figure)

Typical Notation:

$S_v \equiv PSV \equiv V$

$S_a \equiv PSA \equiv A$

$S_d \equiv SD \equiv D$

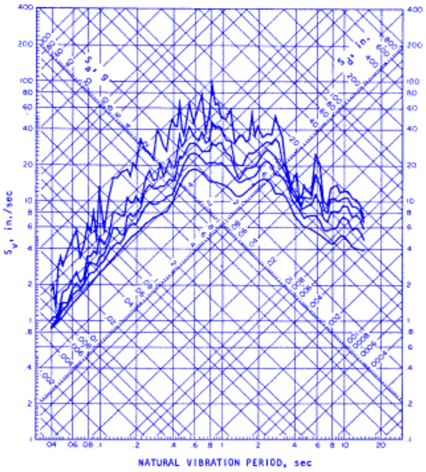
Example (El-Centro motion):
Find maximum displacement and base shear of tower
with f = 2 Hz, ξ = 2%
and k = 1.5 MN/m

Period T = 1/f = 0.5 second
S_d = 2.5 inches = 0.0635 m
$Force_{max} = ku_{max}$
= 1.5 MN/m x 0.0635m = 95.25 kN

RESPONSE SPECTRUM

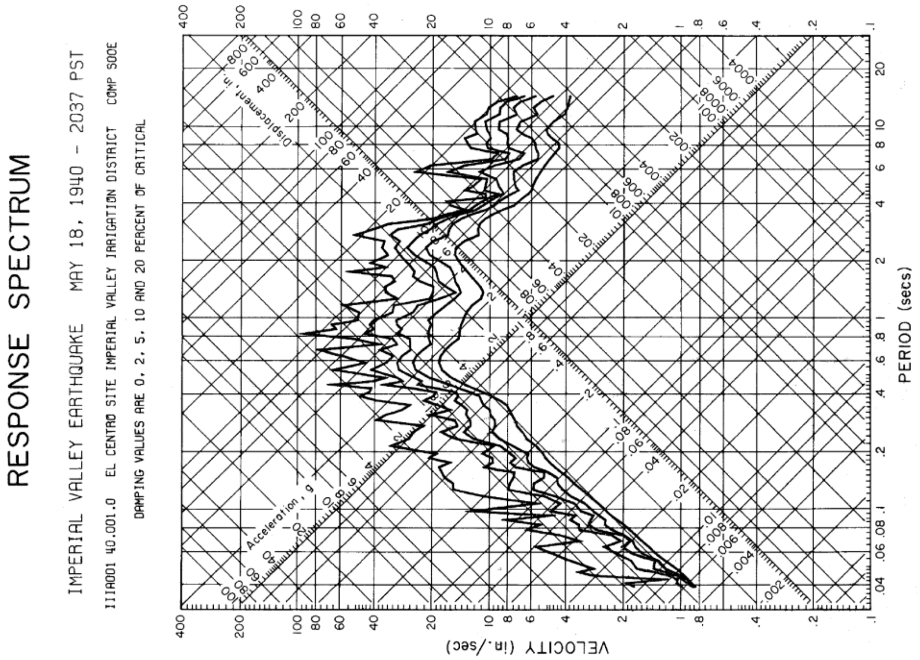
IMPERIAL VALLEY EARTHQUAKE
MAY 18, 1940 — 2037 PST

IIIA001 40.001.0 EL CENTRO SITE
IMPERIAL VALLEY IRRIGATION DISTRICT COMP SOOE
DAMPING VALUES ARE 0, 2, 5, 10, AND 20 PERCENT OF CRITICAL

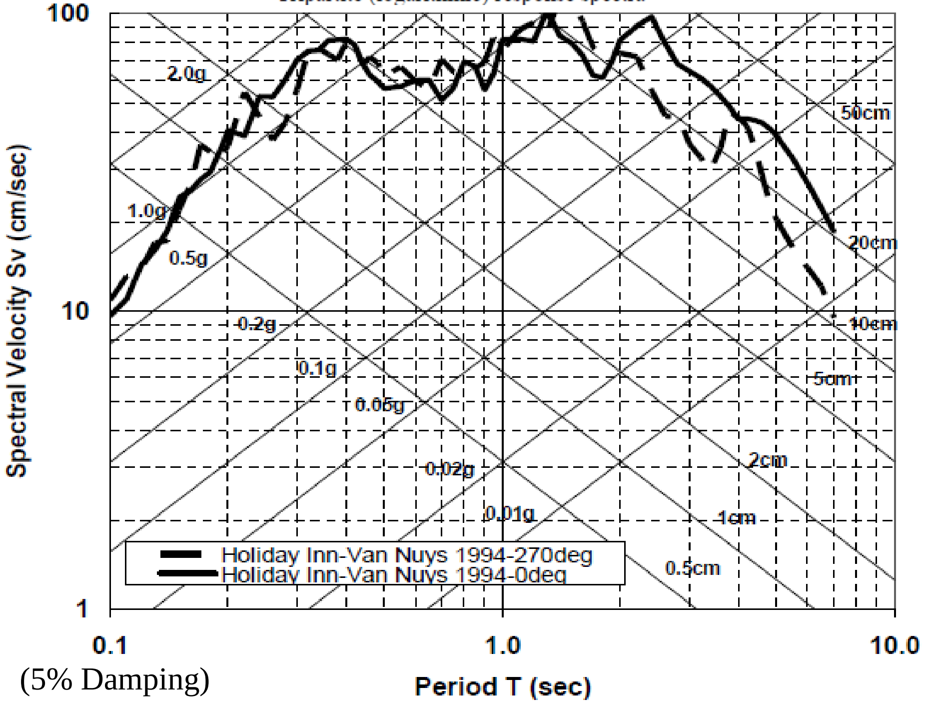


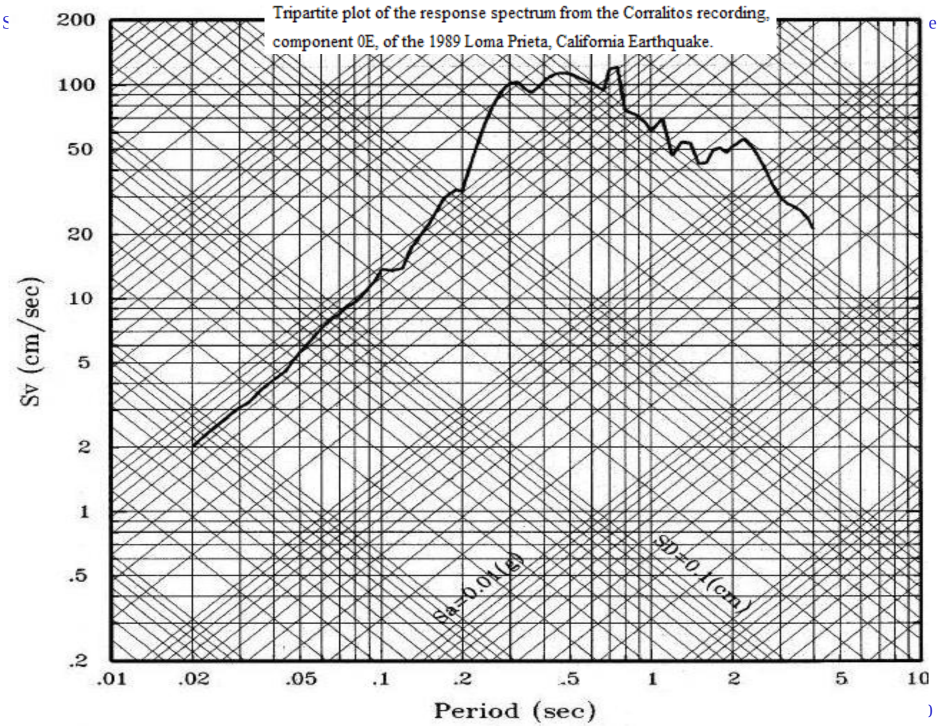
From: Chopra, Dynamics of Structures, A Primer

Figure 21. Four-way logarithmic plot of response spectrum. El Centro ground motion—S00°E component (after Hudson, 1979)



Tripartite (logarithmic) response spectra




Tripartite plot of the response spectrum from the Corralitos recording, component 0E, of the 1989 Loma Prieta, California Earthquake.

Inspection of this figure shows that the maximum response at short period (high frequency stiff structure) is controlled by the ground acceleration, low frequency (long period) by ground displacement, and intermediate period by ground velocity.

Get copy of El-Centro
(May 18, 1940)
earthquake record
S00E (N-S component)
ftp nisee.ce.berkeley.edu
(128.32.43.154)
login: anonymous
password: your_indent
cd pub/a.k.chopra
get el_centro.data
quit

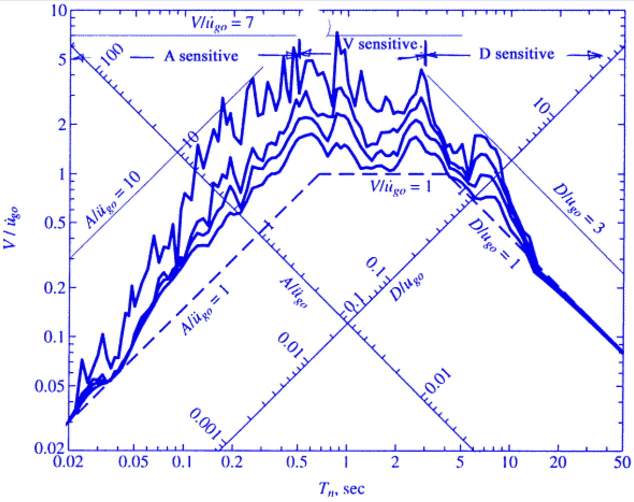


Figure 6.8.2 Response spectrum for El Centro ground motion plotted with normalized scales $A/\ddot{u}_{go}$, $V/\dot{u}_{go}$, and D/u_{go}; $\zeta = 0, 2, 5,$ and 10%.

From: Chopra, Dynamics of Structures

Note that response spectrum
for relative velocity
may be obtained from
the SDOF response history,
and similarly for $\ddot{u}^t = (\ddot{u} + \ddot{u}_g)$.
These spectra are known
as relative velocity
and total acceleration
response spectra,
and are different from the
pseudo velocity
and pseudo acceleration
spectra S_v and S_a
(which are directly
related to S_d).
e.g. for $\xi = 0\%$
$m(\ddot{u} + \ddot{u}_g) + k u = 0$
or $(\ddot{u} + \ddot{u}_g) + \omega^2 u = 0$

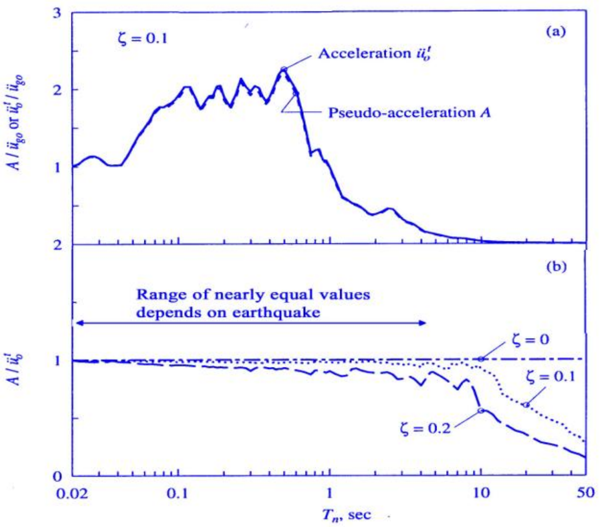
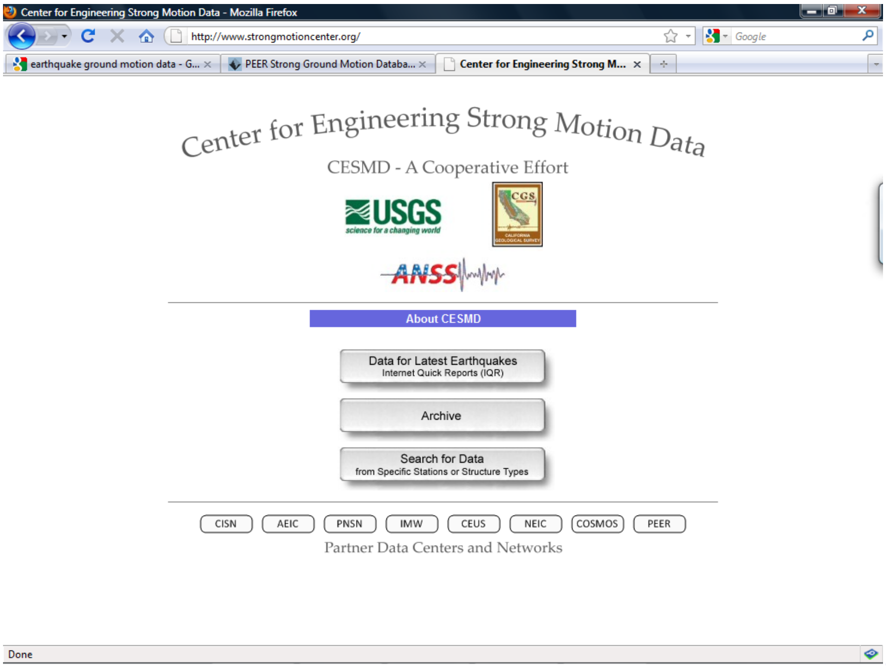


Figure 6.12.2 (a) Comparison between pseudo-acceleration and acceleration response spectra; $\zeta = 10\%$; (b) ratio $A/\ddot{u}_o^t$ for $\zeta = 0$, 10, and 20%.

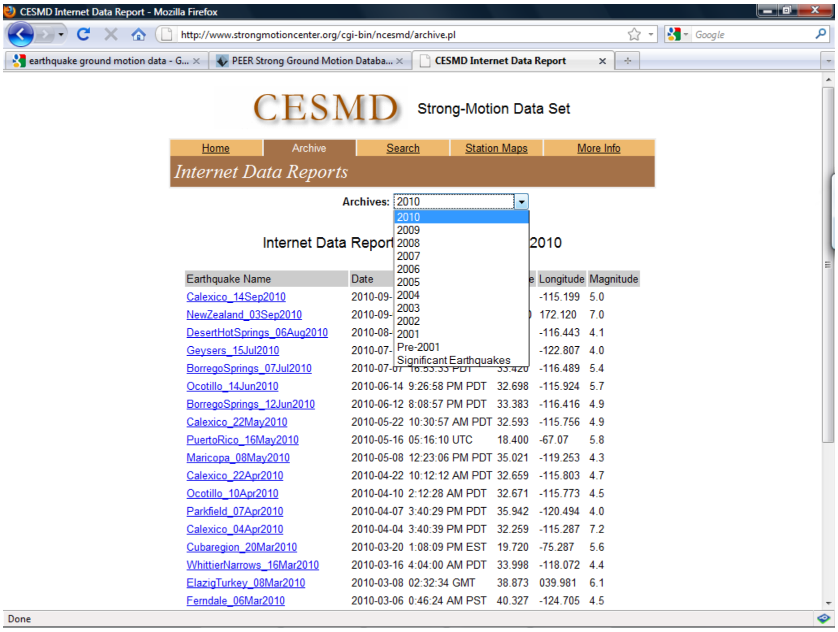
From: Chopra, Dynamics of Structures



Center for Engineering Strong Motion Data

CESMD - A Cooperative Effort

Partner Data Centers and Networks

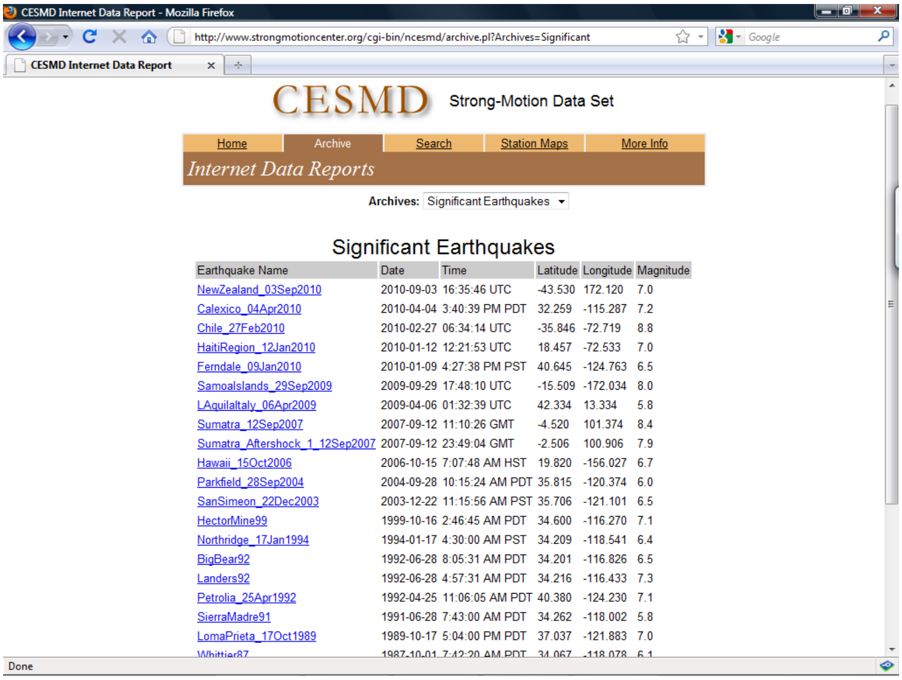


Archives: 2010

2010
2009
2008
2007
2006
2005
2004
2003
2002
2001
Pre-2001
Significant Earthquakes

Internet Data Report 2010

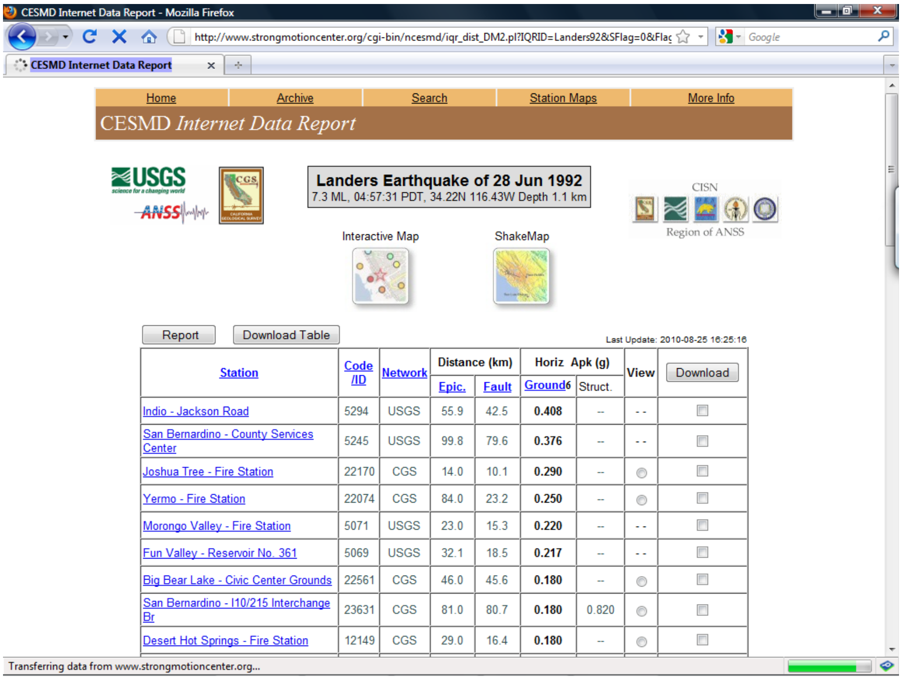
Earthquake Name	Date		e	Longitude	Magnitude
Calexico_14Sep2010	2010-09-			-115.199	5.0
NewZealand_03Sep2010	2010-09-			172.120	7.0
DesertHotSprings_06Aug2010	2010-08-			-116.443	4.1
Geysers_15Jul2010	2010-07-			-122.807	4.0
BorregoSprings_07Jul2010	2010-07-07 16:53:33 PDT		33.420	-116.489	5.4
Ocotillo_14Jun2010	2010-06-14 9:26:58 PM PDT		32.698	-115.924	5.7
BorregoSprings_12Jun2010	2010-06-12 8:08:57 PM PDT		33.383	-116.416	4.9
Calexico_22May2010	2010-05-22 10:30:57 AM PDT		32.593	-115.756	4.9
PuertoRico_16May2010	2010-05-16 05:16:10 UTC		18.400	-67.07	5.8
Maricopa_08May2010	2010-05-08 12:23:06 PM PDT		35.021	-119.253	4.3
Calexico_22Apr2010	2010-04-22 10:12:12 AM PDT		32.659	-115.803	4.7
Ocotillo_10Apr2010	2010-04-10 2:12:28 AM PDT		32.671	-115.773	4.5
Parkfield_07Apr2010	2010-04-07 3:40:29 PM PDT		35.942	-120.494	4.0
Calexico_04Apr2010	2010-04-04 3:40:39 PM PDT		32.259	-115.287	7.2
Cubaregion_20Mar2010	2010-03-20 1:08:09 PM EST		19.720	-75.287	5.6
WhittierNarrows_16Mar2010	2010-03-16 4:04:00 AM PDT		33.998	-118.072	4.4
ElazigTurkey_08Mar2010	2010-03-08 02:32:34 GMT		38.873	039.981	6.1
Ferndale_06Mar2010	2010-03-06 0:46:24 AM PST		40.327	-124.705	4.5



Archives: Significant Earthquakes

Significant Earthquakes

Earthquake Name	Date	Time	Latitude	Longitude	Magnitude
NewZealand_03Sep2010	2010-09-03	16:35:46 UTC	-43.530	172.120	7.0
Calexico_04Apr2010	2010-04-04	3:40:39 PM PDT	32.259	-115.287	7.2
Chile_27Feb2010	2010-02-27	06:34:14 UTC	-35.846	-72.719	8.8
HaitiRegion_12Jan2010	2010-01-12	12:21:53 UTC	18.457	-72.533	7.0
Ferndale_09Jan2010	2010-01-09	4:27:38 PM PST	40.645	-124.763	6.5
SamoaIslands_29Sep2009	2009-09-29	17:48:10 UTC	-15.509	-172.034	8.0
LAquilaItaly_06Apr2009	2009-04-06	01:32:39 UTC	42.334	13.334	5.8
Sumatra_12Sep2007	2007-09-12	11:10:26 GMT	-4.520	101.374	8.4
Sumatra_Aftershock_1_12Sep2007	2007-09-12	23:49:04 GMT	-2.506	100.906	7.9
Hawaii_15Oct2006	2006-10-15	7:07:48 AM HST	19.820	-156.027	6.7
Parkfield_28Sep2004	2004-09-28	10:15:24 AM PDT	35.815	-120.374	6.0
SanSimeon_22Dec2003	2003-12-22	11:15:56 AM PST	35.706	-121.101	6.5
HectorMine99	1999-10-16	2:46:45 AM PDT	34.600	-116.270	7.1
Northridge_17Jan1994	1994-01-17	4:30:00 AM PST	34.209	-118.541	6.4
BigBear92	1992-06-28	8:05:31 AM PDT	34.201	-116.826	6.5
Landers92	1992-06-28	4:57:31 AM PDT	34.216	-116.433	7.3
Petrolia_25Apr1992	1992-04-25	11:06:05 AM PDT	40.380	-124.230	7.1
SierraMadre91	1991-06-28	7:43:00 AM PDT	34.262	-118.002	5.8
LomaPrieta_17Oct1989	1989-10-17	5:04:00 PM PDT	37.037	-121.883	7.0
Whittier87	1987-10-01	7:42:20 AM PDT	34.067	-118.078	6.1



CESMD Internet Data Report - Mozilla Firefox

http://www.strongmotioncenter.org/cgi-bin/ncesmd/iqr_dist_DM2.pl?IQRID=Landers92&SFlag=0&Flag

CESMD Internet Data Report

CESMD *Internet Data Report*

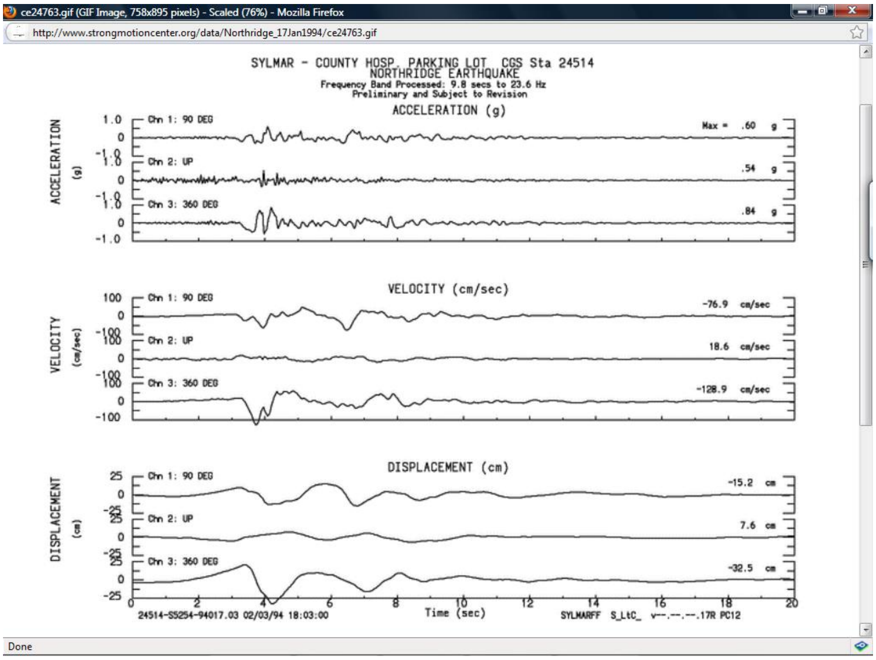
Landers Earthquake of 28 Jun 1992

7.3 ML, 04:57:31 PDT, 34.22N 116.43W Depth 1.1 km

Last Update: 2010-08-25 16:25:16

Station	Code /ID	Network	Distance (km)		Horiz Apk (g)		View	Download
			Epic.	Fault	Ground6	Struct.		
Indio - Jackson Road	5294	USGS	55.9	42.5	**0.408**	--	- -	☐
San Bernardino - County Services Center	5245	USGS	99.8	79.6	**0.376**	--	- -	☐
Joshua Tree - Fire Station	22170	CGS	14.0	10.1	**0.290**	--	○	☐
Yermo - Fire Station	22074	CGS	84.0	23.2	**0.250**	--	○	☐
Morongo Valley - Fire Station	5071	USGS	23.0	15.3	**0.220**	--	- -	☐
Fun Valley - Reservoir No. 361	5069	USGS	32.1	18.5	**0.217**	--	- -	☐
Big Bear Lake - Civic Center Grounds	22561	CGS	46.0	45.6	**0.180**	--	○	☐
San Bernardino - I10/215 Interchange Br	23631	CGS	81.0	80.7	**0.180**	0.820	○	☐
Desert Hot Springs - Fire Station	12149	CGS	29.0	16.4	**0.180**	--	○	☐

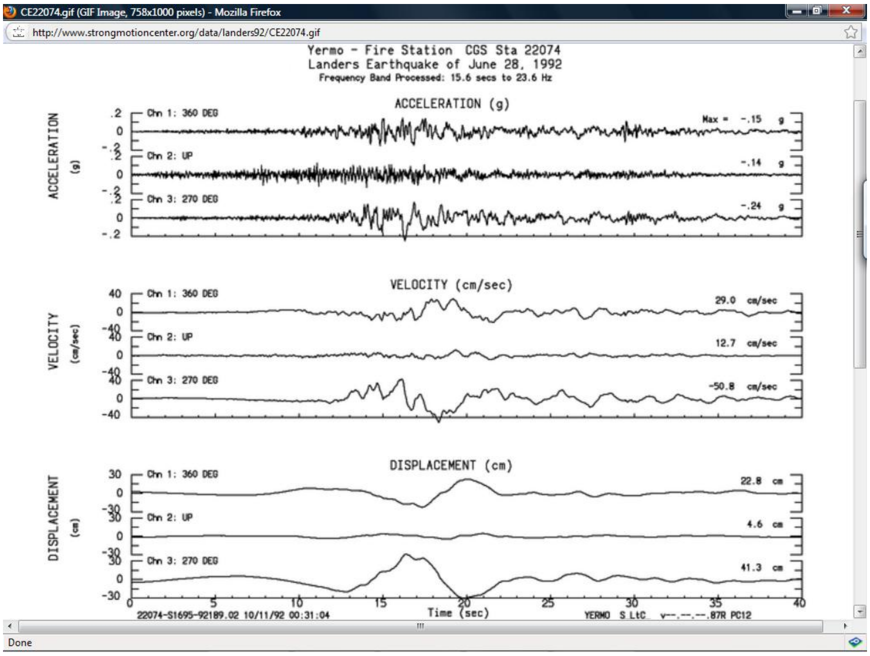
Transferring data from www.strongmotioncenter.org...

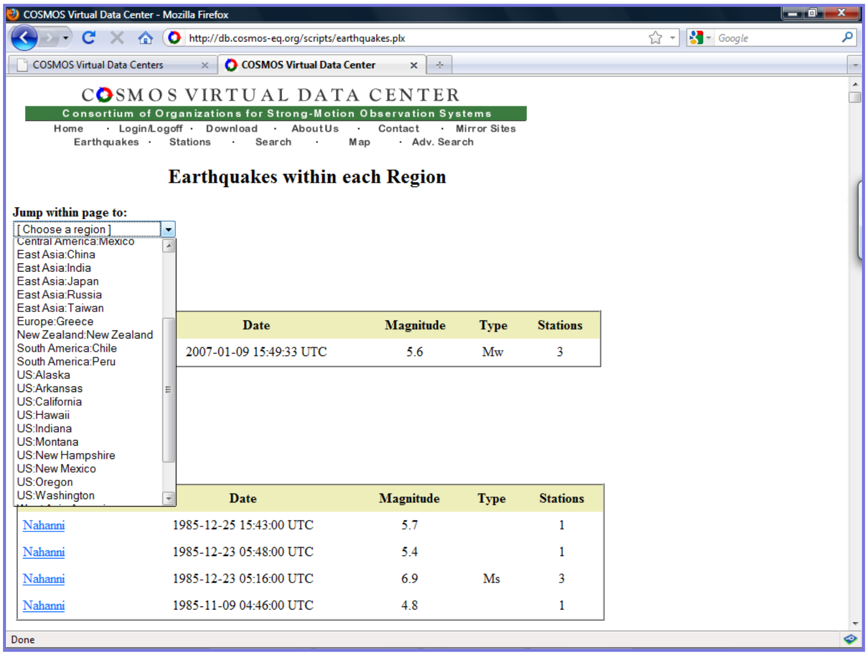


ce24763.gif (GIF Image, 758x895 pixels) - Scaled (76%) - Mozilla Firefox

http://www.strongmotioncenter.org/data/Northridge_17Jan1994/ce24763.gif

Done





COSMOS VIRTUAL DATA CENTER

Consortium of Organizations for Strong-Motion Observation Systems

Home · Login/Logoff · Download · About Us · Contact · Mirror Sites
Earthquakes · Stations · Search · Map · Adv. Search

Earthquakes within each Region

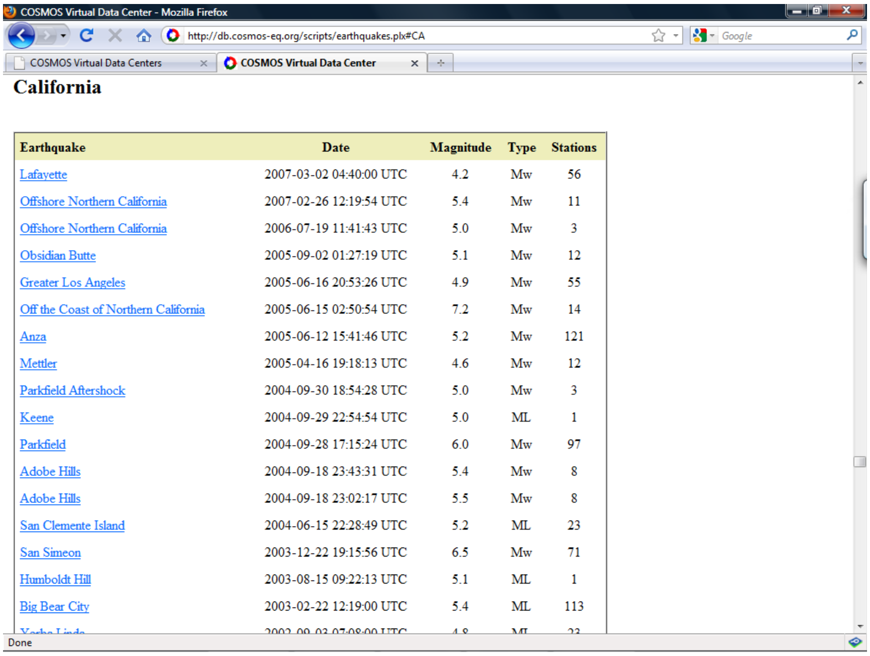
Jump within page to:

[Choose a region]

- Central America:Mexico
- East Asia:China
- East Asia:India
- East Asia:Japan
- East Asia:Russia
- East Asia:Taiwan
- Europe:Greece
- New Zealand:New Zealand
- South America:Chile
- South America:Peru
- US:Alaska
- US:Arkansas
- US:California
- US:Hawaii
- US:Indiana
- US:Montana
- US:New Hampshire
- US:New Mexico
- US:Oregon
- US:Washington

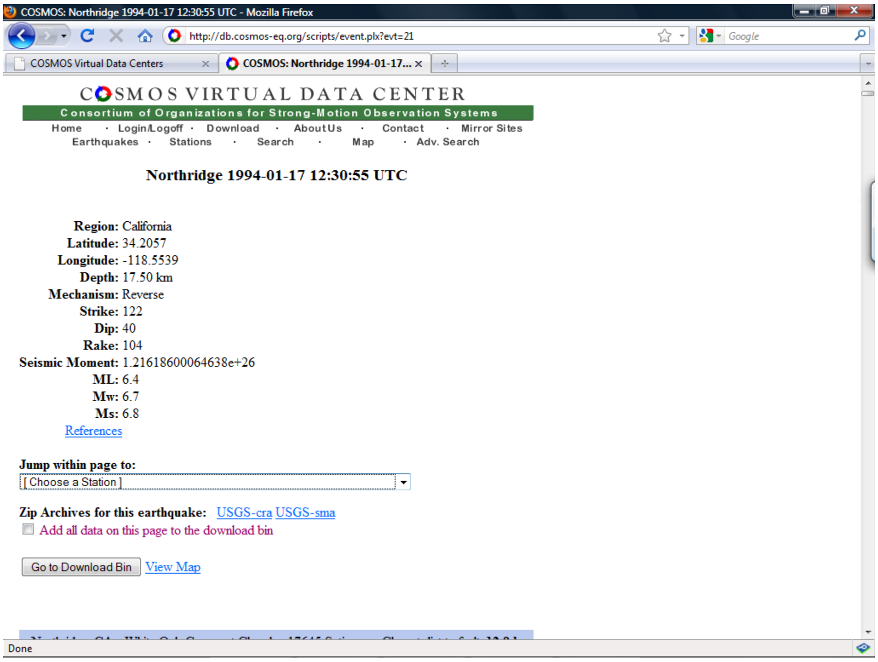
Date	Magnitude	Type	Stations
2007-01-09 15:49:33 UTC	5.6	Mw	3

	Date	Magnitude	Type	Stations
Nahanni	1985-12-25 15:43:00 UTC	5.7		1
Nahanni	1985-12-23 05:48:00 UTC	5.4		1
Nahanni	1985-12-23 05:16:00 UTC	6.9	Ms	3
Nahanni	1985-11-09 04:46:00 UTC	4.8		1



California

Earthquake	Date	Magnitude	Type	Stations
Lafayette	2007-03-02 04:40:00 UTC	4.2	Mw	56
Offshore Northern California	2007-02-26 12:19:54 UTC	5.4	Mw	11
Offshore Northern California	2006-07-19 11:41:43 UTC	5.0	Mw	3
Obsidian Butte	2005-09-02 01:27:19 UTC	5.1	Mw	12
Greater Los Angeles	2005-06-16 20:53:26 UTC	4.9	Mw	55
Off the Coast of Northern California	2005-06-15 02:50:54 UTC	7.2	Mw	14
Anza	2005-06-12 15:41:46 UTC	5.2	Mw	121
Mettler	2005-04-16 19:18:13 UTC	4.6	Mw	12
Parkfield Aftershock	2004-09-30 18:54:28 UTC	5.0	Mw	3
Keene	2004-09-29 22:54:54 UTC	5.0	ML	1
Parkfield	2004-09-28 17:15:24 UTC	6.0	Mw	97
Adobe Hills	2004-09-18 23:43:31 UTC	5.4	Mw	8
Adobe Hills	2004-09-18 23:02:17 UTC	5.5	Mw	8
San Clemente Island	2004-06-15 22:28:49 UTC	5.2	ML	23
San Simeon	2003-12-22 19:15:56 UTC	6.5	Mw	71
Humboldt Hill	2003-08-15 09:22:13 UTC	5.1	ML	1
Big Bear City	2003-02-22 12:19:00 UTC	5.4	ML	113



Northridge 1994-01-17 12:30:55 UTC

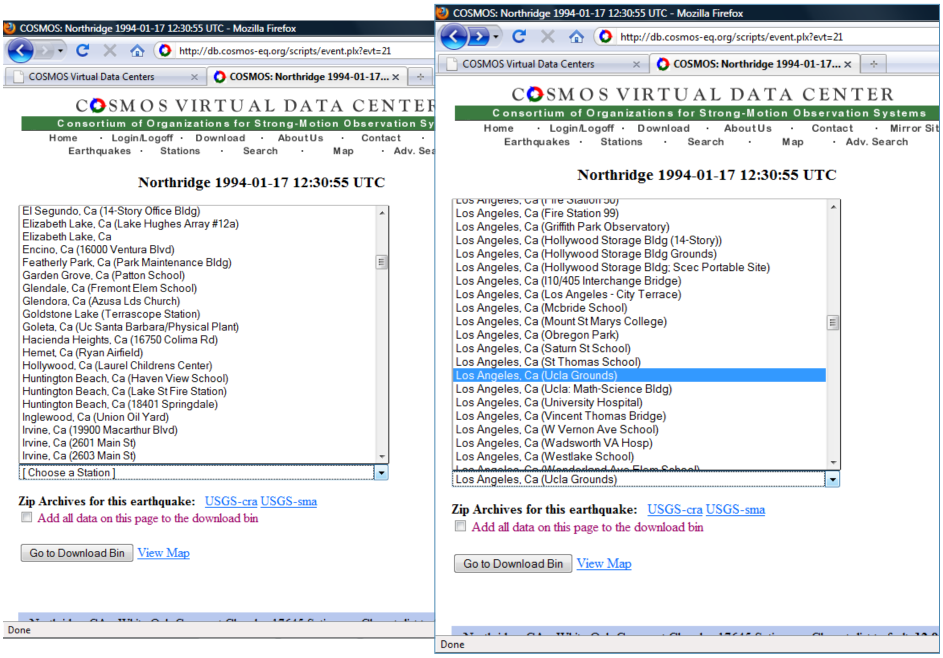
Region: California
Latitude: 34.2057
Longitude: -118.5539
Depth: 17.50 km
Mechanism: Reverse
Strike: 122
Dip: 40
Rake: 104
Seismic Moment: 1.21618600064638e+26
ML: 6.4
Mw: 6.7
Ms: 6.8
References

Jump within page to:

Zip Archives for this earthquake: USGS-cra USGS-sma

☐ Add all data on this page to the download bin

View Map



Northridge 1994-01-17 12:30:55 UTC

El Segundo, Ca (14-Story Office Bldg)
Elizabeth Lake, Ca (Lake Hughes Array #12a)
Elizabeth Lake, Ca
Encino, Ca (16000 Ventura Blvd)
Featherly Park, Ca (Park Maintenance Bldg)
Garden Grove, Ca (Patton School)
Glendale, Ca (Fremont Elem School)
Glendora, Ca (Azusa Lds Church)
Goldstone Lake (Terrascope Station)
Goleta, Ca (Uc Santa Barbara/Physical Plant)
Hacienda Heights, Ca (16750 Colima Rd)
Hemet, Ca (Ryan Airfield)
Hollywood, Ca (Laurel Childrens Center)
Huntington Beach, Ca (Haven View School)
Huntington Beach, Ca (Lake St Fire Station)
Huntington Beach, Ca (18401 Springdale)
Inglewood, Ca (Union Oil Yard)
Irvine, Ca (19900 Macarthur Blvd)
Irvine, Ca (2601 Main St)
Irvine, Ca (2603 Main St)
[Choose a Station]

Zip Archives for this earthquake: USGS-cra USGS-sma

☐ Add all data on this page to the download bin

View Map

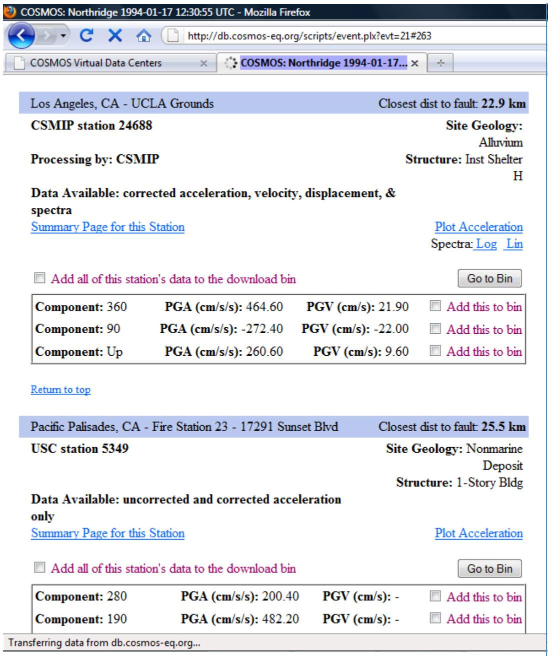
Northridge 1994-01-17 12:30:55 UTC

Los Angeles, Ca (Fire Station 99)
Los Angeles, Ca (Griffith Park Observatory)
Los Angeles, Ca (Hollywood Storage Bldg (14-Story))
Los Angeles, Ca (Hollywood Storage Bldg Grounds)
Los Angeles, Ca (Hollywood Storage Bldg; Scec Portable Site)
Los Angeles, Ca (I10/405 Interchange Bridge)
Los Angeles, Ca (Los Angeles - City Terrace)
Los Angeles, Ca (Mcbride School)
Los Angeles, Ca (Mount St Marys College)
Los Angeles, Ca (Obregon Park)
Los Angeles, Ca (Saturn St School)
Los Angeles, Ca (St Thomas School)
Los Angeles, Ca (Ucla Grounds)
Los Angeles, Ca (Ucla: Math-Science Bldg)
Los Angeles, Ca (University Hospital)
Los Angeles, Ca (Vincent Thomas Bridge)
Los Angeles, Ca (W Vernon Ave School)
Los Angeles, Ca (Wadsworth VA Hosp)
Los Angeles, Ca (Westlake School)
Los Angeles, Ca (Ucla Grounds)

Zip Archives for this earthquake: USGS-cra USGS-sma

☐ Add all data on this page to the download bin

View Map



Los Angeles, CA - UCLA Grounds	Closest dist to fault: **22.9 km**
CSMIP station 24688	**Site Geology:** Alluvium
Processing by: CSMIP	**Structure:** Inst Shelter H

Data Available: corrected acceleration, velocity, displacement, & spectra

Summary Page for this Station

Plot Acceleration

Spectra: Log Lin

☐ Add all of this station's data to the download bin

Component: 360	**PGA (cm/s/s):** 464.60	**PGV (cm/s):** 21.90	☐ Add this to bin
Component: 90	**PGA (cm/s/s):** -272.40	**PGV (cm/s):** -22.00	☐ Add this to bin
Component: Up	**PGA (cm/s/s):** 260.60	**PGV (cm/s):** 9.60	☐ Add this to bin

Return to top

Pacific Palisades, CA - Fire Station 23 - 17291 Sunset Blvd	Closest dist to fault: **25.5 km**
USC station 5349	**Site Geology:** Nonmarine Deposit
	Structure: 1-Story Bldg

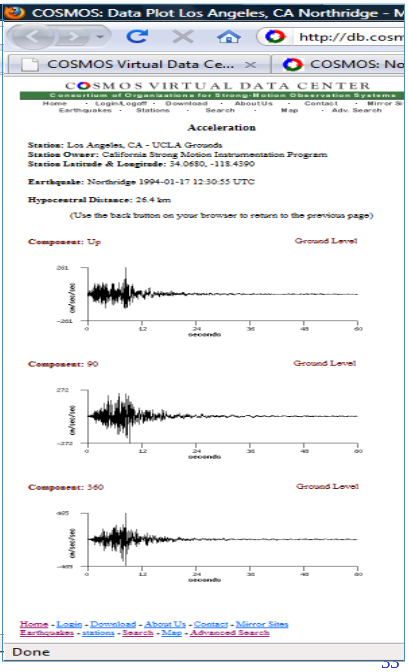
Data Available: uncorrected and corrected acceleration only

Summary Page for this Station

Plot Acceleration

☐ Add all of this station's data to the download bin

Component: 280	**PGA (cm/s/s):** 200.40	**PGV (cm/s):** -	☐ Add this to bin
Component: 190	**PGA (cm/s/s):** 482.20	**PGV (cm/s):** -	☐ Add this to bin



Acceleration

Station: Los Angeles, CA - UCLA Grounds
Station Owner: California Strong Motion Instrumentation Program
Station Latitude & Longitude: 34.0680, -118.4390

Earthquake: Northridge 1994-01-17 12:30:55 UTC

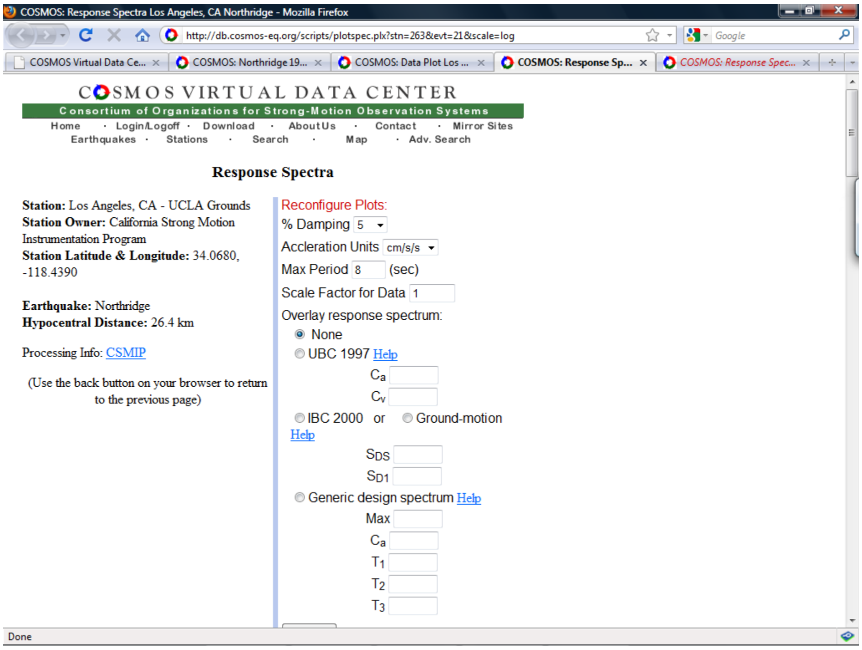
Hypocentral Distance: 26.4 km

(Use the back button on your browser to return to the previous page)

Component: Up Ground Level

Component: 90 Ground Level

Component: 360 Ground Level



Response Spectra

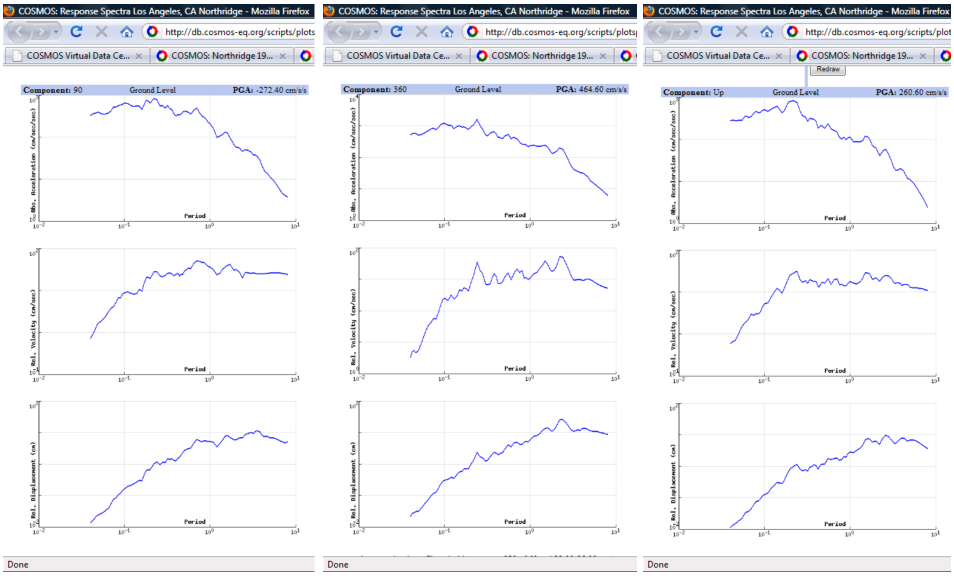
Station: Los Angeles, CA - UCLA Grounds
Station Owner: California Strong Motion Instrumentation Program
Station Latitude & Longitude: 34.0680, -118.4390

Earthquake: Northridge
Hypocentral Distance: 26.4 km

Processing Info: CSMIP

(Use the back button on your browser to return to the previous page)

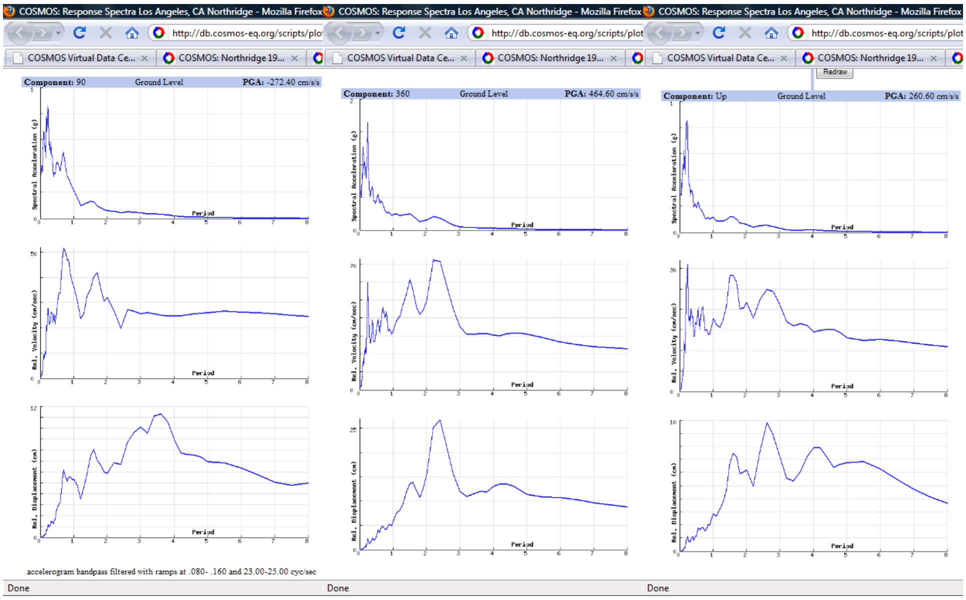
Reconfigure Plots:
% Damping 5
Accleration Units cm/s/s
Max Period 8 (sec)
Scale Factor for Data 1
Overlay response spectrum:
● None
○ UBC 1997 Help
C_a
C_v
○ IBC 2000 or ○ Ground-motion Help
S_{DS}
S_{D1}
○ Generic design spectrum Help
Max
C_a
T_1
T_2
T_3



Component: 90 Ground Level **PGA:** -272.40 cm/s/s

Component: 360 Ground Level **PGA:** 464.60 cm/s/s

Component: Up Ground Level **PGA:** 260.60 cm/s/s



Component: 90 Ground Level **PGA:** -272.40 cm/s/s

Component: 360 Ground Level **PGA:** 464.60 cm/s/s

Component: Up Ground Level **PGA:** 260.60 cm/s/s

accelerogram bandpass filtered with ramps at .080- .160 and 23.00-25.00 cyc/sec

---

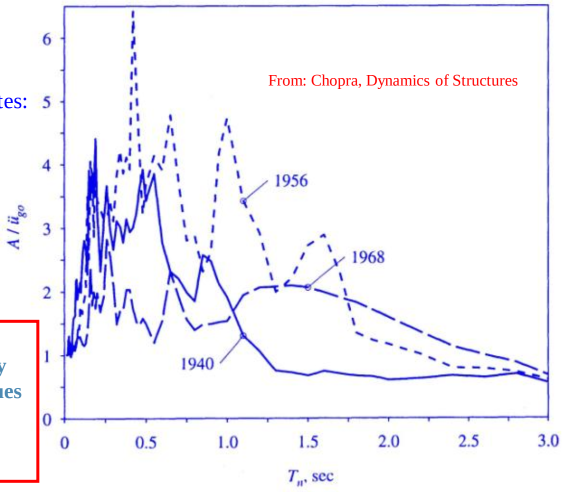
Elastic Design Spectrum

Use recorded ground motions (available)

Use ground motions recorded at similar sites:

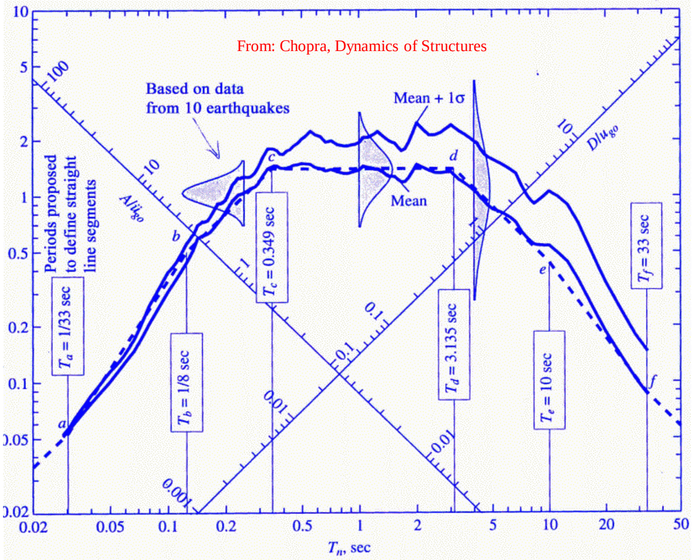
- Magnitude of earthquake
- Distance of site form earthquake fault
- Fault mechanism
- Local Soil Conditions
- Geology/travel path of seismic waves

Motions recorded at the same location. For design, we need an envelope. One way is to take the average (mean) of these values (use statistics to define curves for mean and standard deviation, see next page)



From: Chopra, Dynamics of Structures

Figure 6.9.1 Response spectra for the north–south component of ground motions recorded at the Imperial Valley Irrigation District substation, El Centro, California, during earthquakes of May 18, 1940; February 9, 1956; and April 8, 1968. $\zeta = 2\%$.



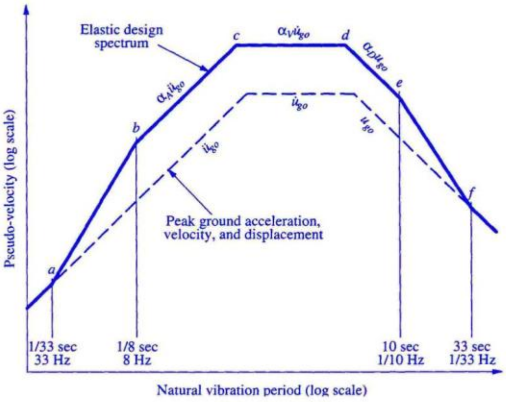
From: Chopra, Dynamics of Structures

Figure 6.9.2 Mean and mean +1σ spectra with probability distributions for V at T_n = 0.25, 1, and 4 sec; ζ = 5%. Dashed lines show an idealized design spectrum. (Based on numerical data from R. Riddell and N. M. Newmark, 1979.)

Mean response spectrum is smooth relative to any of the original contributing spectra

---

As an alternative Empirical approach, the periods shown on the this Figure and the values in the Table can be used to construct a Median elastic design spectrum (or a Median + one Sigma), where Sigma is the Standard Deviation. **For any geographic location, these spectra are built based on an estimate of peak ground acceleration, velocity, and displacement as this location.**



From: Chopra, Dynamics of Structures

Figure 6.9.3 Construction of elastic design spectrum.

The periods and values in Table 6.9.1

were selected to give a good match

to a statistical curve such as Figure 6.9.2

based on an ensemble

of 50 earthquakes on competent soils.

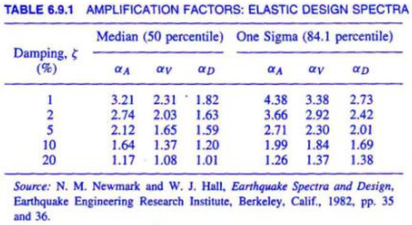
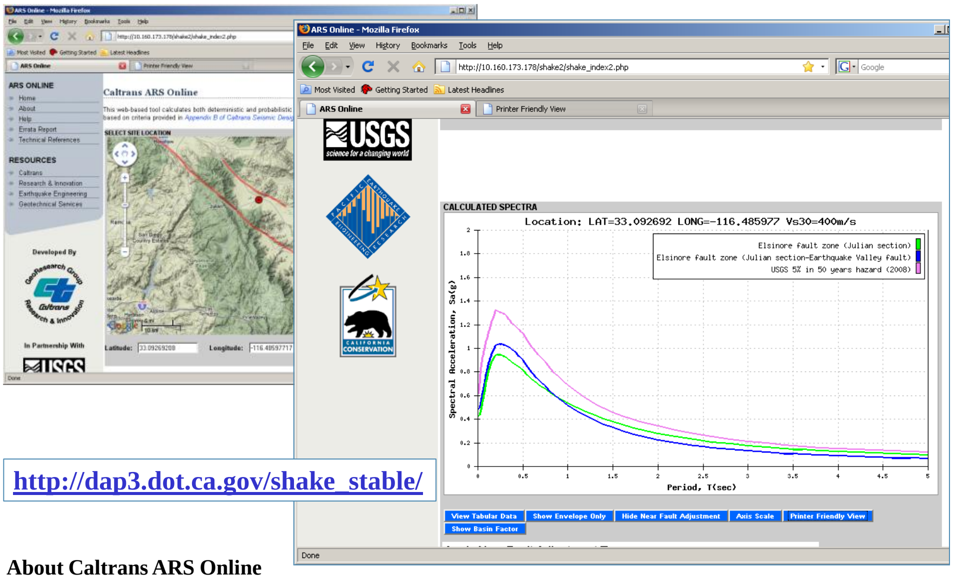


TABLE 6.9.1 AMPLIFICATION FACTORS: ELASTIC DESIGN SPECTRA

Damping, ζ (%)	Median (50 percentile)			One Sigma (84.1 percentile)		
	α_A	α_V	α_D	α_A	α_V	α_D
1	3.21	2.31	1.82	4.38	3.38	2.73
2	2.74	2.03	1.63	3.66	2.92	2.42
5	2.12	1.65	1.59	2.71	2.30	2.01
10	1.64	1.37	1.20	1.99	1.84	1.69
20	1.17	1.08	1.01	1.26	1.37	1.38

Source: N. M. Newmark and W. J. Hall, *Earthquake Spectra and Design*, Earthquake Engineering Research Institute, Berkeley, Calif., 1982, pp. 35 and 36.

(Design Spectrum may include more than one Earthquake fault scenario)



Caltrans ARS Online

This web-based tool calculates both deterministic and probabilistic
based on criteria provided in *Appendix B of Caltrans Seismic Desig*

SELECT SITE LOCATION

Latitude: 33.09269208 Longitude: -116.48597717

CALCULATED SPECTRA

Location: LAT=33.092692 LONG=-116.485977 Vs30=400m/s

Elsinore fault zone (Julian section) 🟩
Elsinore fault zone (Julian section-Earthquake Valley fault) 🟦
USGS 5% in 50 years hazard (2008) 🟪

http://dap3.dot.ca.gov/shake_stable/

About Caltrans ARS Online

This web-based tool calculates both deterministic and probabilistic acceleration response spectra for any location in California based on criteria provided in *Appendix B of Caltrans Seismic Design Criteria*