UNIVERSITY OF BRITISH COLUMBIA DEPARTMENT OF CIVIL ENGINEERING

FORWARD DIRECTIVITY AND DIRECTIONALITY EFFECTS ON SEISMIC RESPONSE OF BUILDINGS

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EALIER STUDIES ON NEAR-FAULT EFFECTS

- After the damaging earthquakes Northridge 1994 and Kobe 1995 strong polarity in ground motions were observed. Studies attributed damage to tall buildings to the presence of long period pulses from rupture directivity.

- Due to the potentially damaging effects that rupture directivity posed to the built environment, amplification factors to the design spectrum were introduced in UBC97.

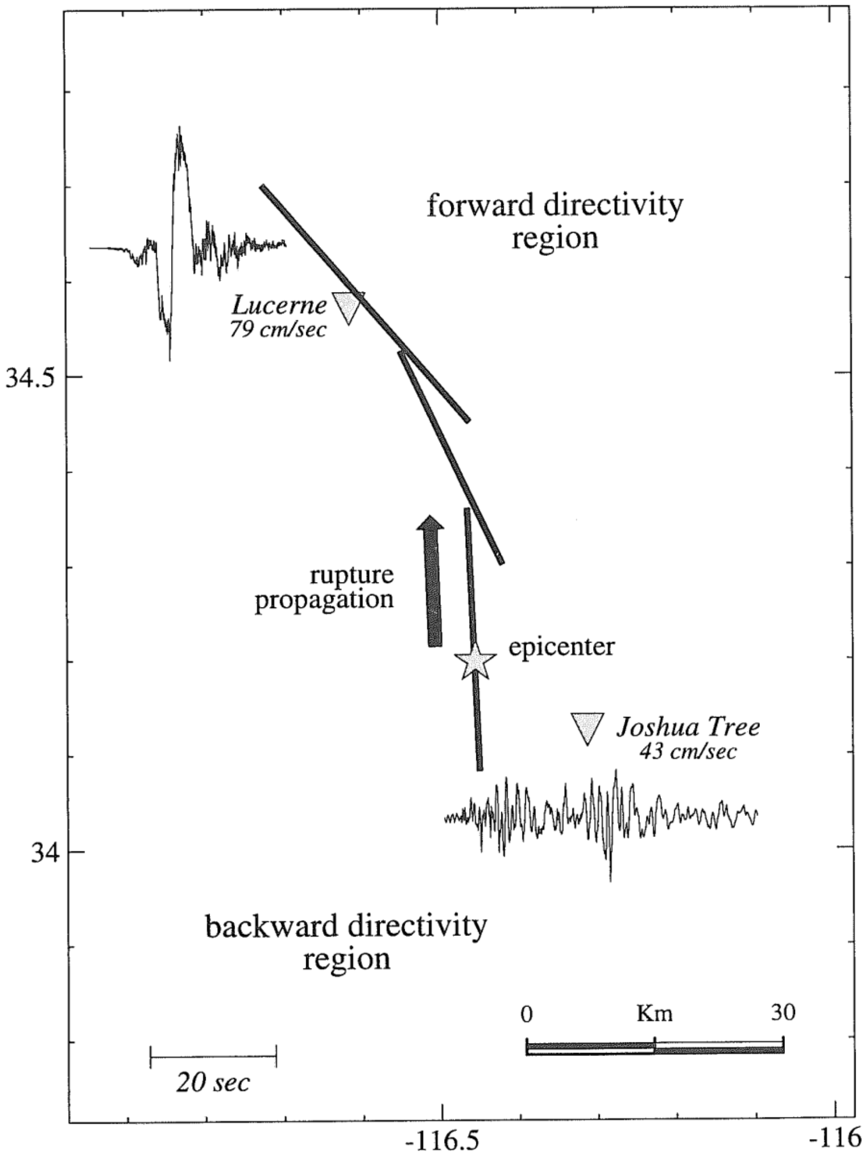
STUDIES ON RUPTURE DIRECTIVITY

- In the past decade rupture directivity and its effects on seismic response of buildings has been investigated (Somerville et. al., 1995,1997; Alavi and Krawlinker, 2001; Kalkan and Kunnath, 2006).

- Somerville et. al. (1997) found that forward directivity effects cause ground motions having strong long periods in the strike-normal component at periods longer than 0.6s.

- These studies concluded forward directivity was one of the most relevant features in near-fault ground motions and of importance for long period structures.

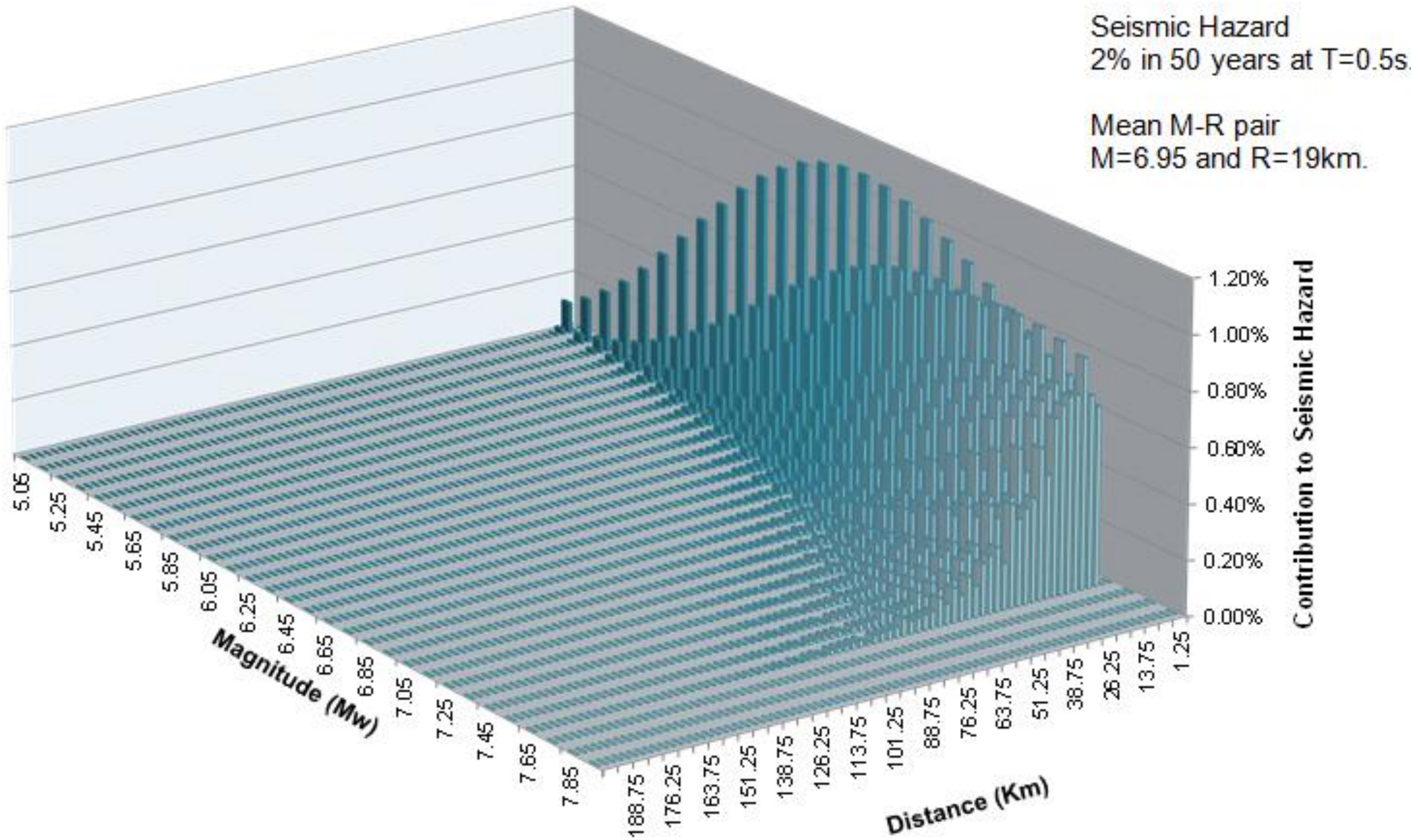
RUPTURE DIRECTIVITY

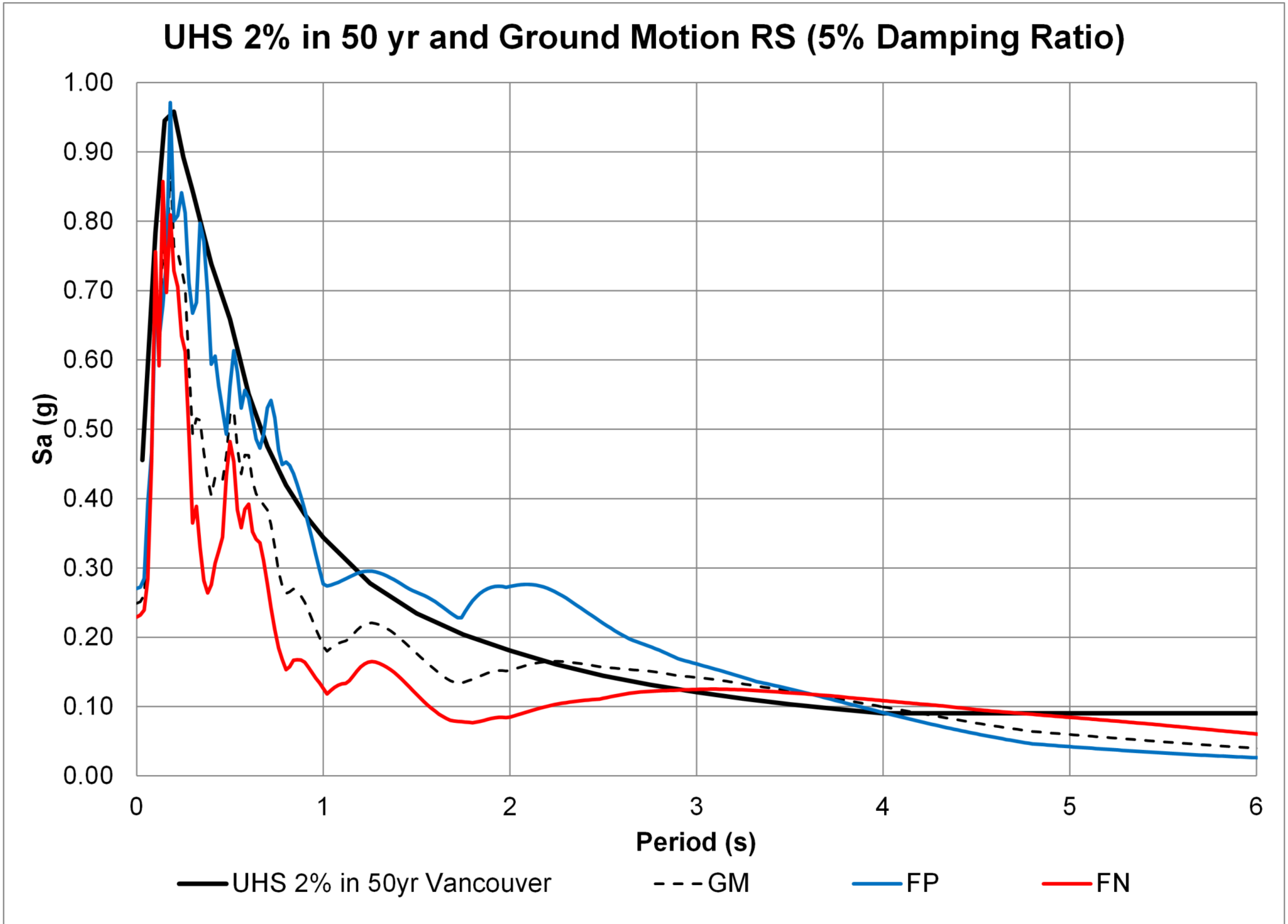


- Conditions required for forward directivity:
    - Rupture front propagates toward the site
    - Direction of slip on the fault is aligned with the site

Somerville et. al. 1997

M-R DEAGGREGATION FOR SHALLOW EARTHQUAKES IN VANCOUVER





UHS 2% in 50 yr and Ground Motion RS (5% Damping Ratio)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Sa (g)
0
1
2
3
4
5
6
Period (s)
UHS 2% in 50yr Vancouver
GM
FP
FN

DIRECTIONALITY OF NEAR FAULT RECORD FROM IMPERIAL VALLEY EQ 1979 Mw6.5

(degrees):

Rotated Time Histories: $X1 := X \cdot \cos(\theta) + Y \cdot \sin(\theta)$ $\quad Y1 := -X \cdot \sin(\theta) + Y \cdot \cos(\theta)$

Response Spectra: $gs := X1 \cdot g$

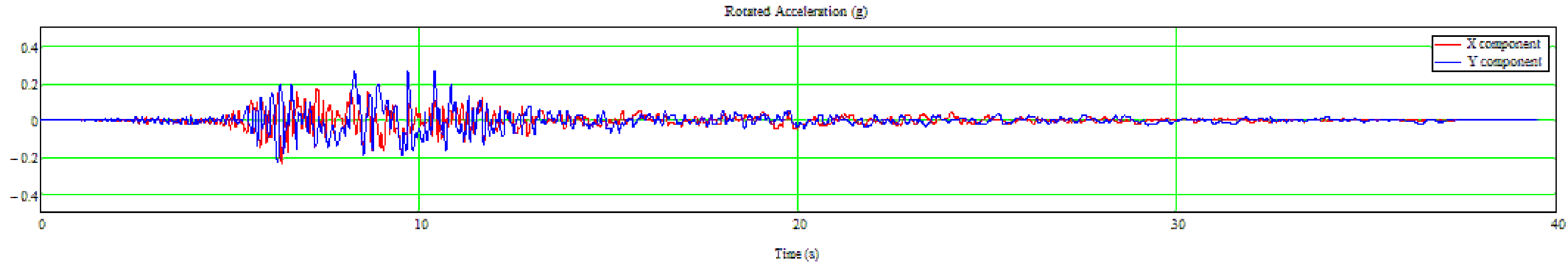
Reference:C:\MEME\UBC\Programs\animations\Response Spectra subroutine for gs.xmcd(R)

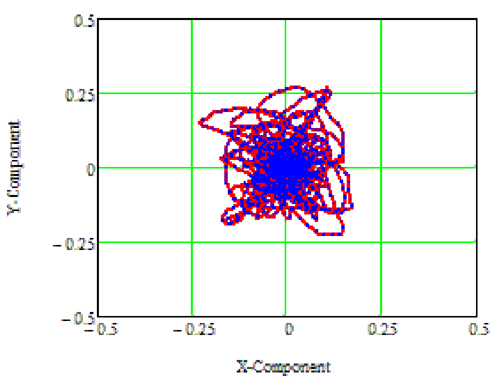
$RX1 := Spectra$ $\quad gs := Y1 \cdot g$

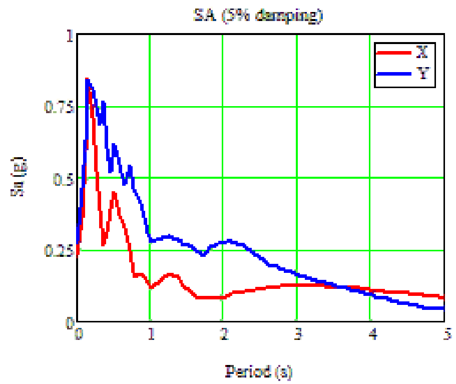
Reference:C:\MEME\UBC\Programs\animations\Response Spectra subroutine for gs.xmcd(R)

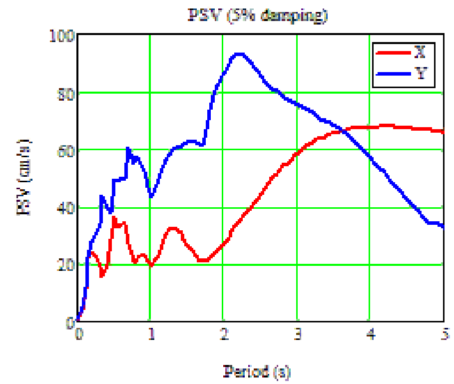
$RY1 := Spectra$ $\quad gs := 0$

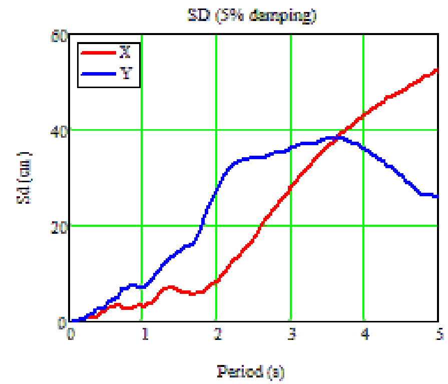
Rotation Angle: $\alpha \rightarrow 0$







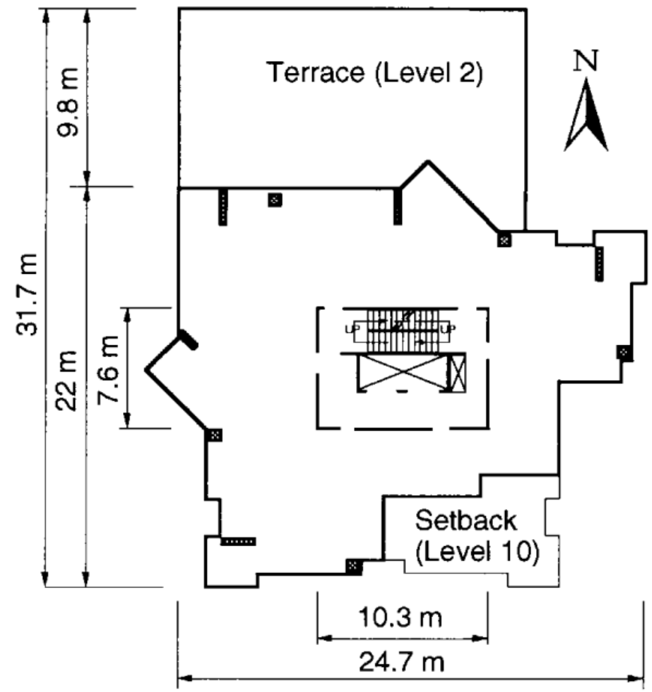




CASE STUDY

This residential building is 30 storey reinforced concrete. Lateral force resisting system is provided by a core wall.

The building is located in downtown Vancouver. The building model has been calibrated against ambient vibration modal testing.



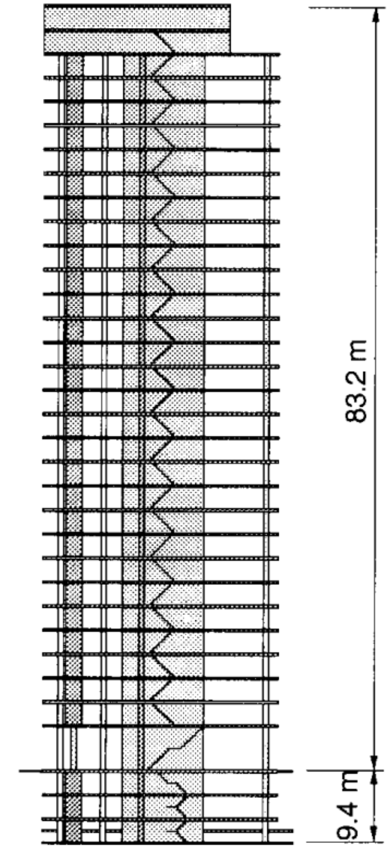
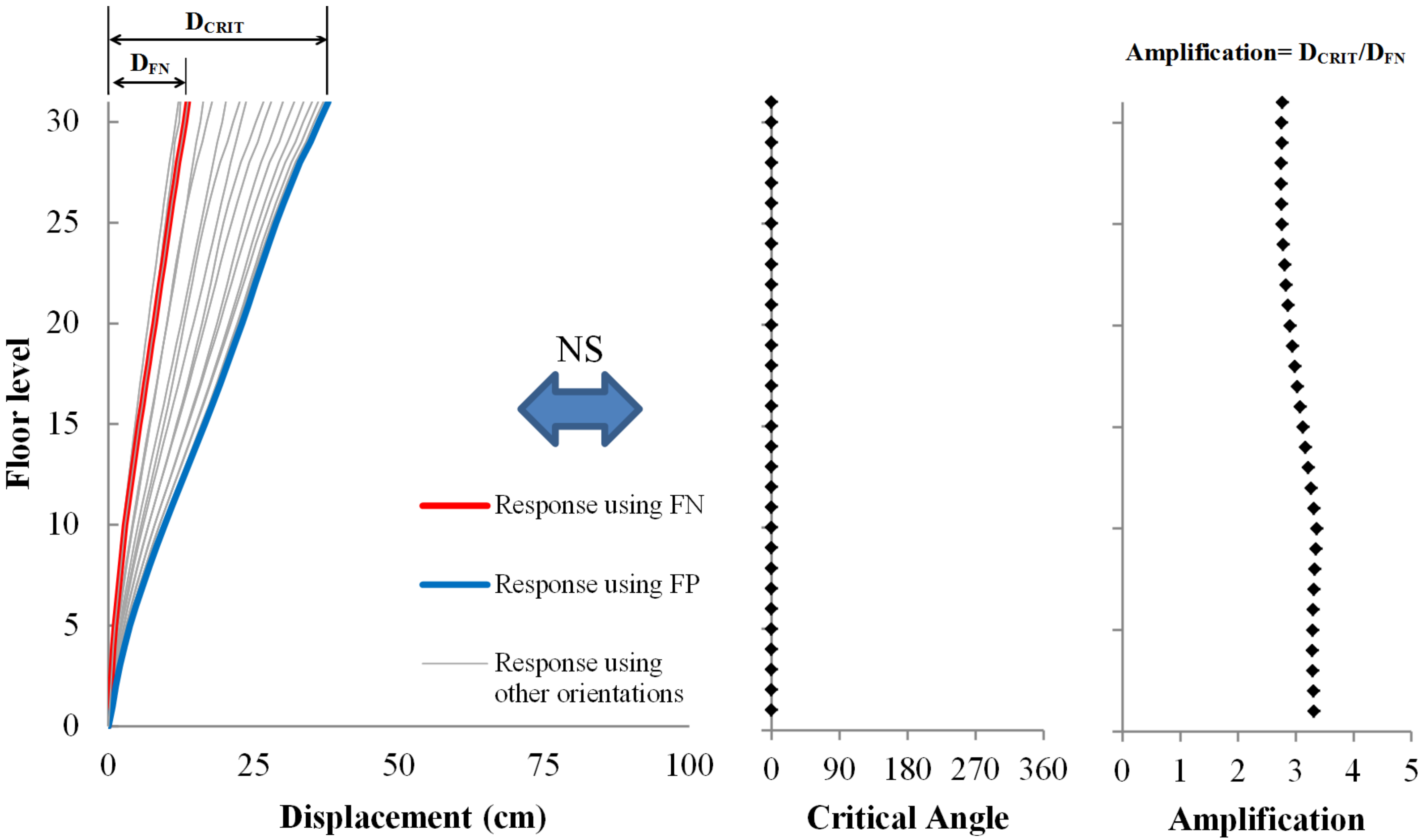


Table 2. Modal damping levels.

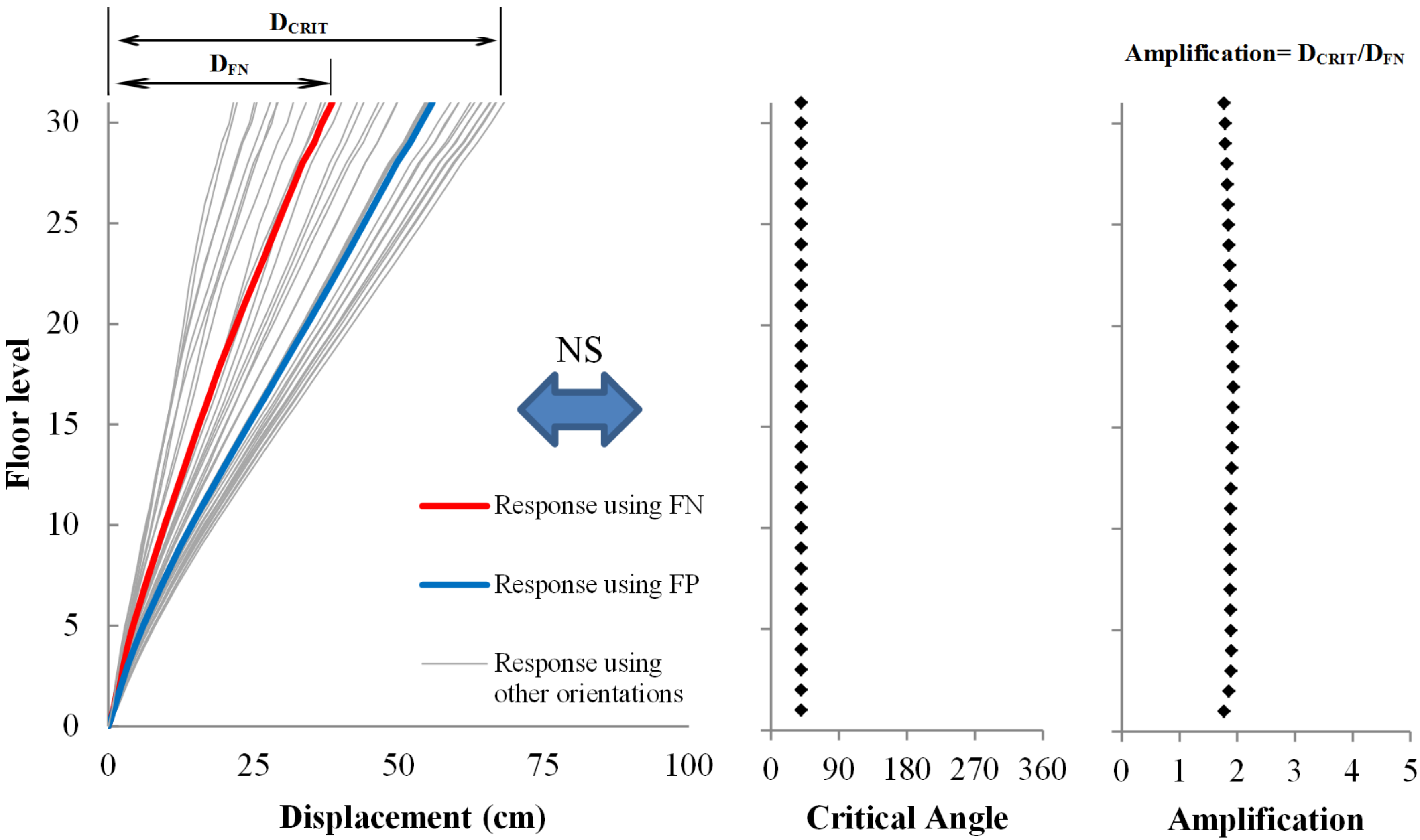
Mode	Frequency (Hz)	Period (s)	Damping, β (%)
N–S first mode	0.55	1.82	3.21
E–W first mode	0.72	1.38	3.10
Torsional first mode	1.12	0.89	3.43
N–S second mode	2.58	0.39	6.07
E–W second mode	3.38	0.30	7.73
Torsional second mode	3.80	0.26	8.59

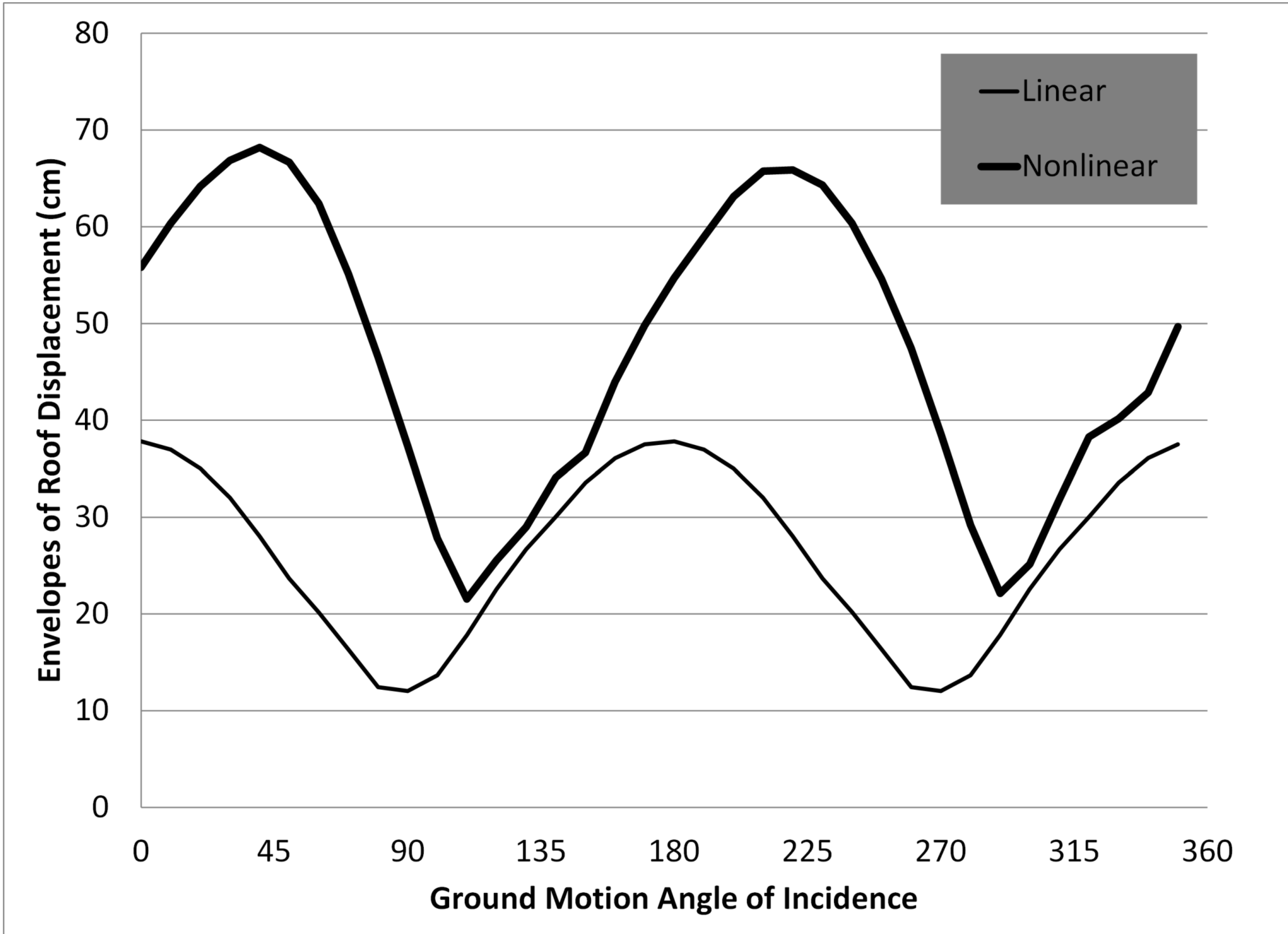
From White and Ventura et. al. 2004.

Linear Response History Analysis



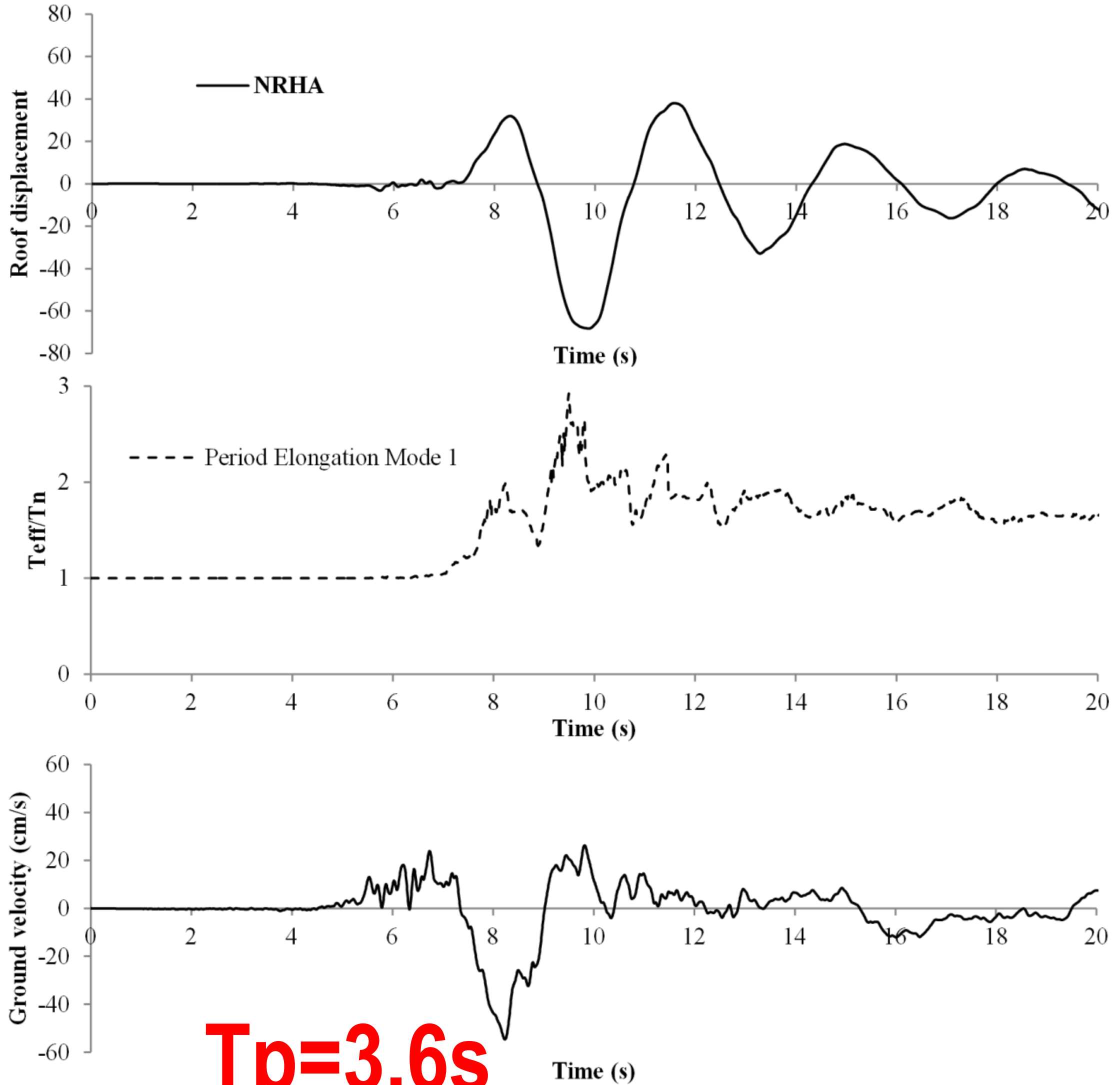
Nonlinear Response History Analysis





Linear
Nonlinear
Envelopes of Roof Displacement (cm)
0
10
20
30
40
50
60
70
80
0
45
90
135
180
225
270
315
360
Ground Motion Angle of Incidence

NRHA at critical angle of incidence



Tp/Tn=2

Tp=3.6s

REMARKS

- FN Component does not always produce the largest displacement response in near-fault sites. It can even produce the smallest response.

- The critical angle of incidence from linear and nonlinear response are not always equal.

- The equal displacement rule does not hold for ground motions having velocity pulses.

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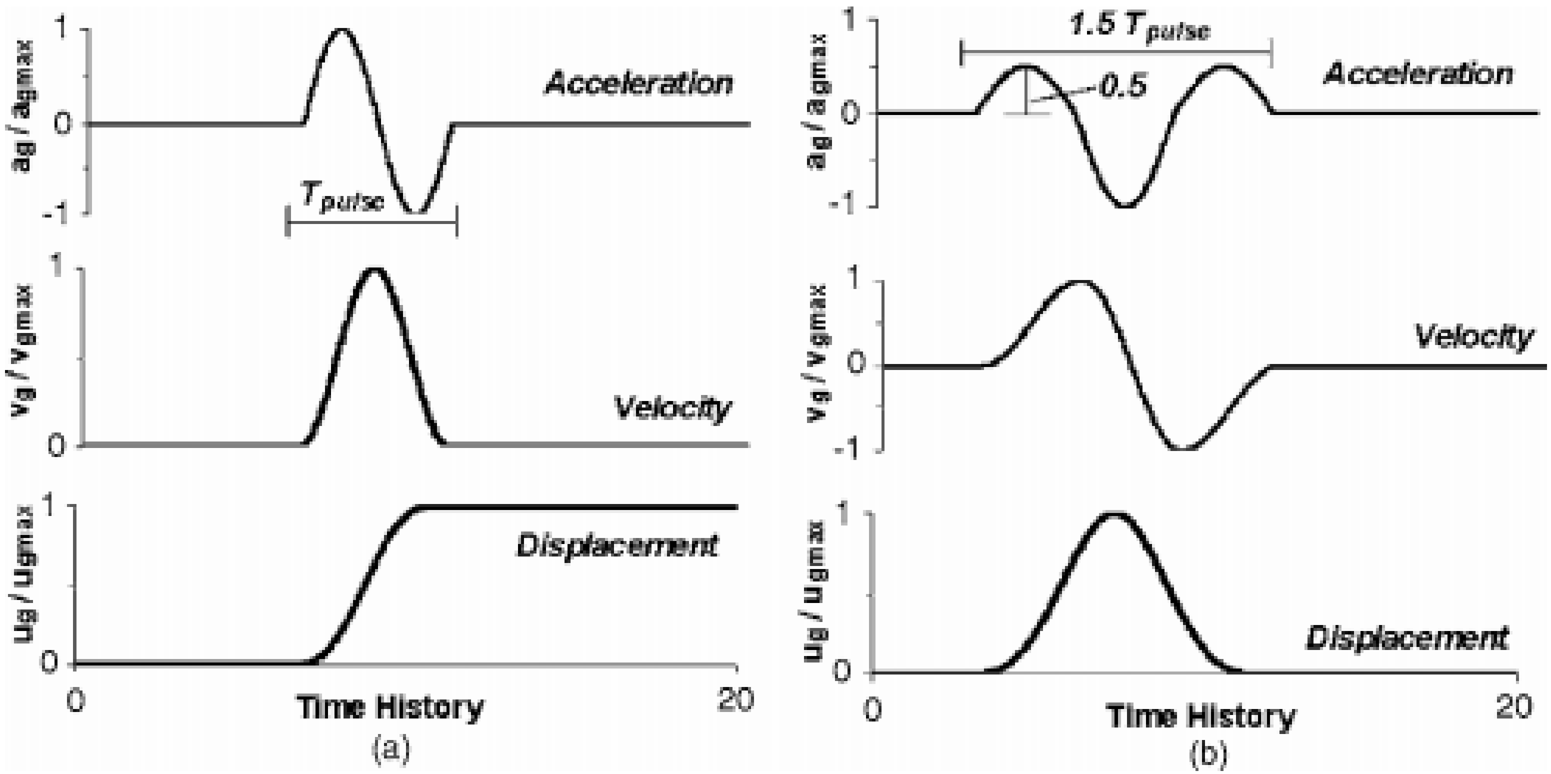
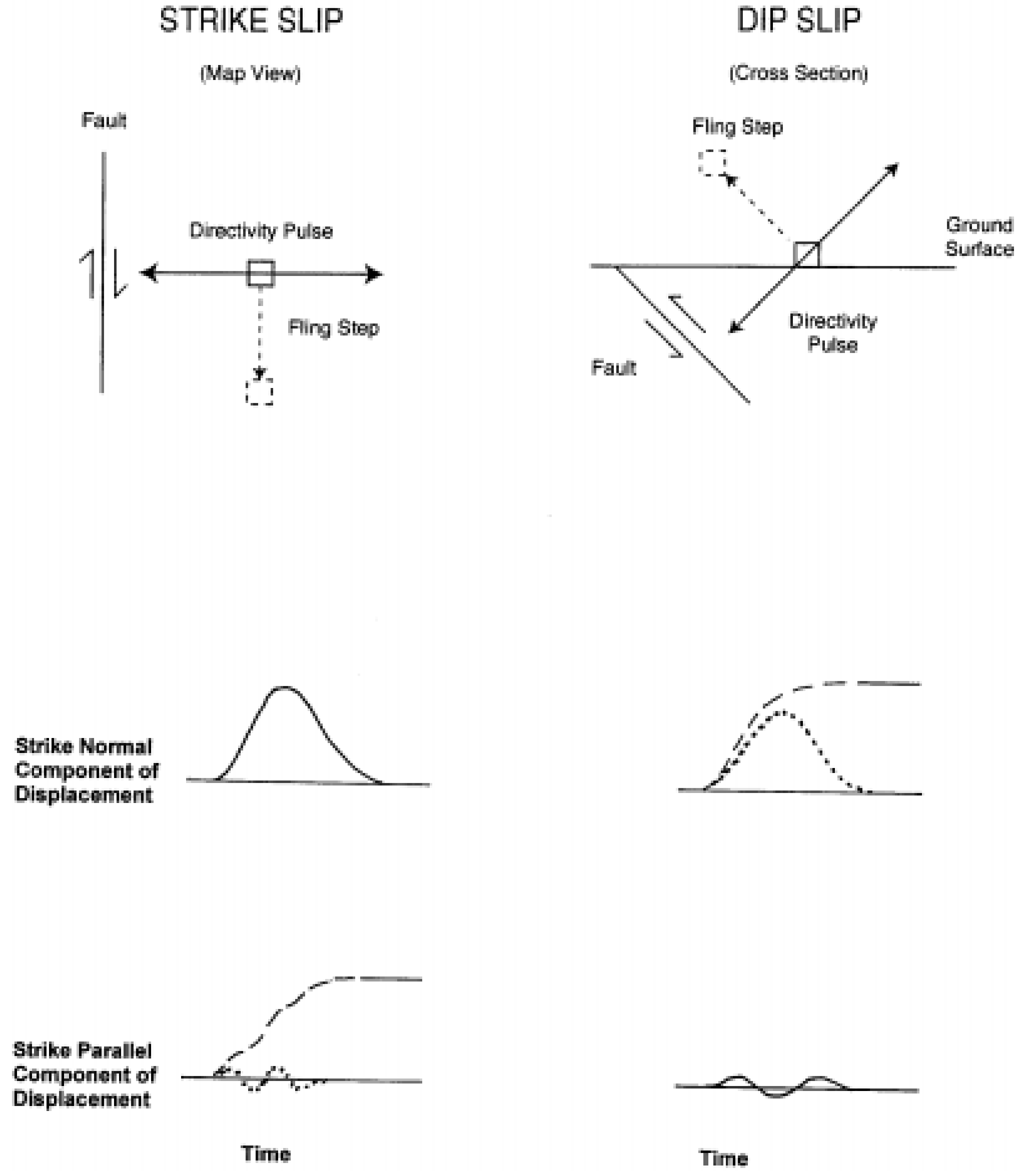


Figure 9. Idealized sinusoidal pulses: (a) fling-step (Type A), (b) forward-directivity (Type B). (Note: curves are normalized by maximum acceleration, velocity, and displacement.)

From Kalkan and Kunnath 2006



From Paul Somerville

Figure 2. Top: Schematic orientation of the rupture directivity pulse and fault displacement ("fling step") for strike-slip (left) and dip-slip (right) faulting. Bottom: Schematic partition of the rupture directivity pulse and fault displacement between the strike normal and strike parallel components of ground displacement. Waveforms containing static ground displacement are shown as dashed lines; versions of these waveforms with the static displacement removed are shown as dotted lines.