Evolution of the State of the Practice

by

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Historical Perspective

Development of the Equivalent Linear Procedure to account for the Non-linear behavior of Soils under Dynamic Loading Conditions

Kanai proposed the use of the continuous solution to the wave equation to study site effects on earthquake ground motions -- early 1950's

C. Martin Duke brought Kanai's work to attention of US researchers & practitioners -- 1958

Met with strong resistance from structural engineers in the USA

H. B. Seed presented a paper at the WCEE advancing the concerns with the behavior of soils during earthquakes and the potential effects of local site conditions on earthquake ground motions -- 1960

Donald Hudson (Caltech) proposed the use of values of damping that are dependent on the level of deformation in structural elements -- 1963

Penzien, Parmelee & Seed developed a bilinear procedure & wrote a computer program to calculate the response of soft soil sites -- 1963

G. R. Martin suggested the need to incorporate the influence of the level of shaking in calculating response of earth dams -- 1965

Idriss examined the laboratory test results by Thiers & Seed & suggested the use of strain-compatible modulus & damping values in site response calculations -- 1966

Idriss & Seed used the bilinear solution to show that strain-compatible modulus & damping values can be used in a linear program to produce comparable results; i.e. Equivalent Linear Solution -- 1968

Researchers at the University of Michigan (under the leadership of Professor Richart) carried out a comprehensive testing program to measure modulus & damping values. They showed dependence of these values on amplitude of vibration – this work was initiated beginning in the early 1960's.

Analyses of shaking table tests on earth slopes suggested the need to have the ability to use different damping values in various parts of the slope & to the development of a variable damping FE program -- 1969

Schnabel started his research using the program developed in 1969 & initiating comparisons using a continuous solution to check accuracy -- 1970

Both the discrete variable damping solution & the continuous solution used frequency-dependent damping resulting in suppression of high frequencies

Lysmer suggested that the viscosity coefficient in the complex modulus expression be replaced by the damping ratio; thus making the damping ratio frequency-independent -- 1971

These developments & using Cooley & Tukey fast Fourier transform made it possible to have an efficient continuous solution that can be programmed to provide for incorporating strain-compatible modulus & damping values -- 1972

Thus, the birth of the Computer Program

SHAKE

And the rest is history

Factors that Influence Site Response

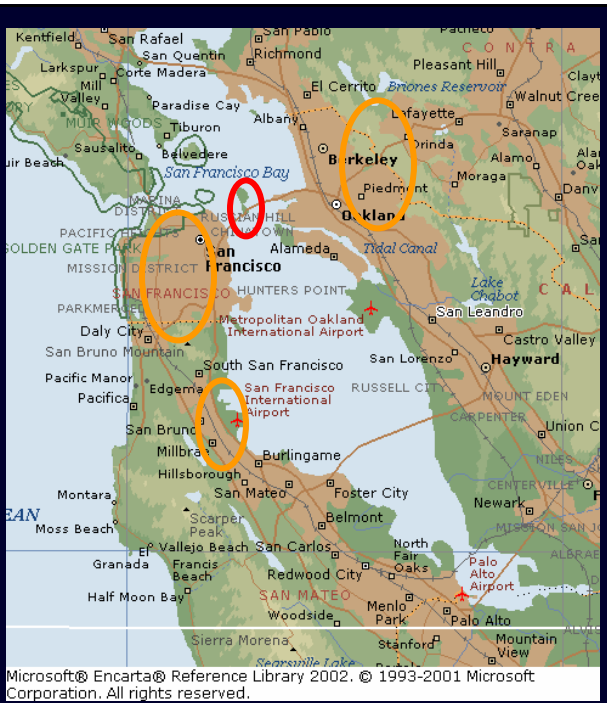
Input Motion

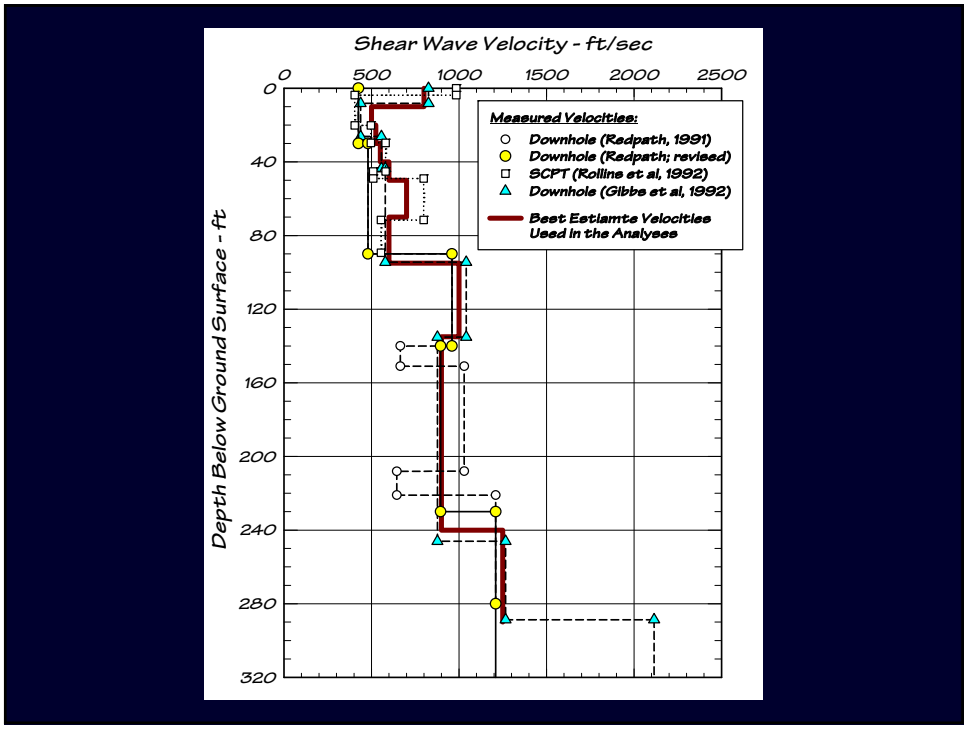
Soil Profile

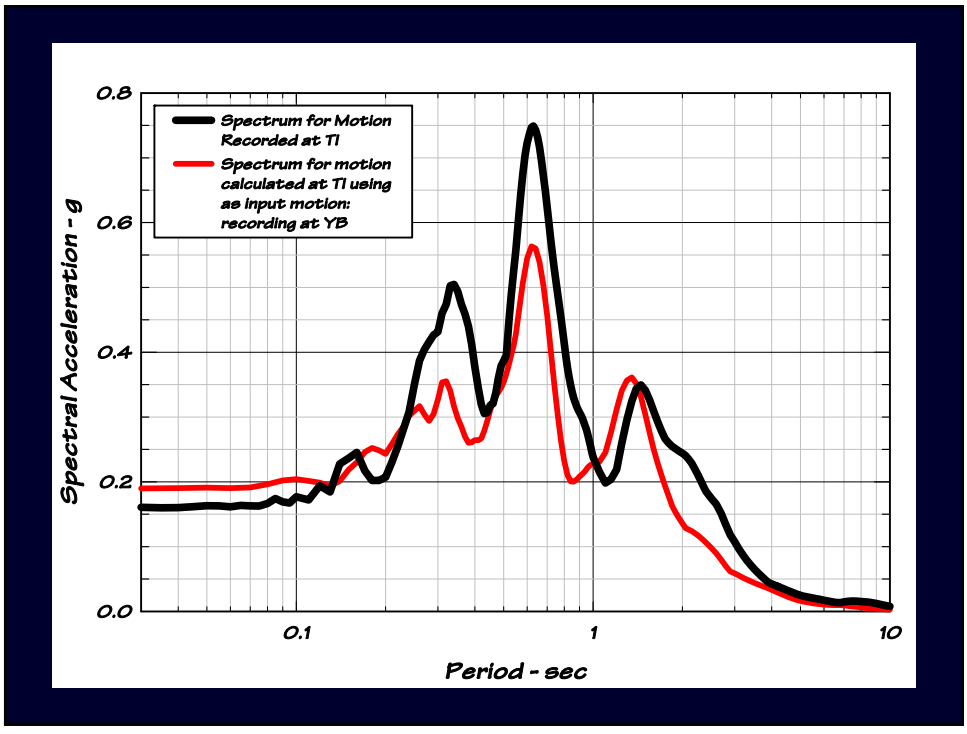
Soil Properties

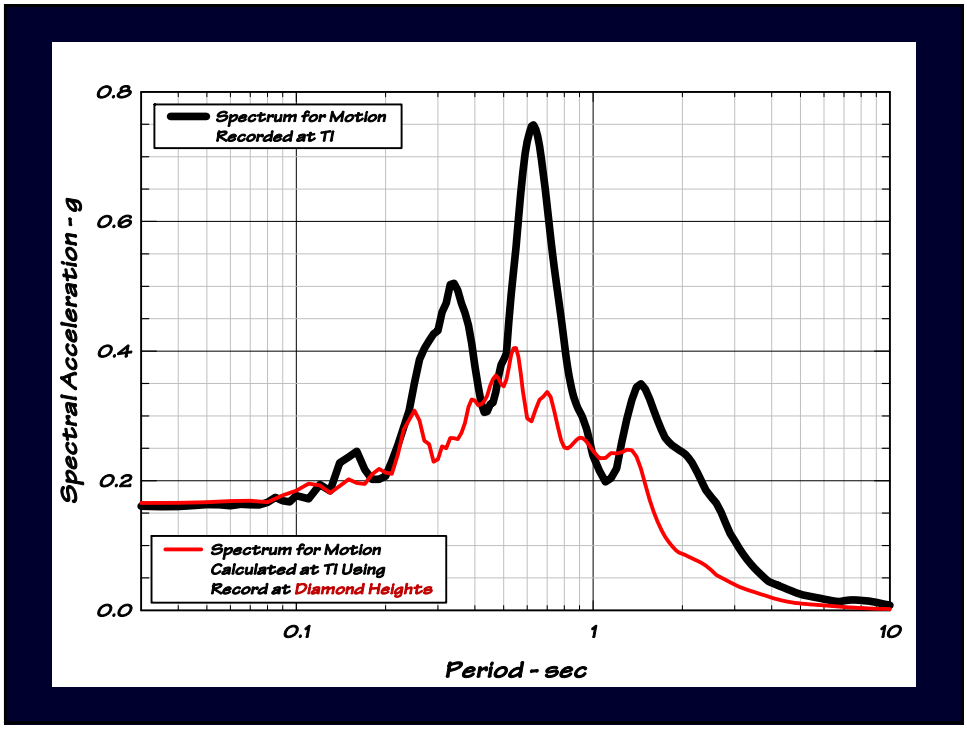
Method of Analysis

Treasure Island & Yerba Buena Island Sites
SF-Oakland Bay Area




Shear Wave Velocity - ft/sec
0
500
1000
1500
2000
2500
Depth Below Ground Surface - ft
0
40
80
120
160
200
240
280
320
Measured Velocities:
Downhole (Redpath, 1991)
Downhole (Redpath; revised)
SCPT (Rollins et al, 1992)
Downhole (Gibbs et al, 1992)
Best Estiamte Velocities Used in the Analyses


Spectral Acceleration - g
0.0
0.2
0.4
0.6
0.8
0.1
1
10
Period - sec
Spectrum for Motion Recorded at TI
Spectrum for motion calculated at TI using as input motion: recording at YB


Spectrum for Motion Recorded at TI
Spectrum for Motion Calculated at TI Using Record at Diamond Heights
Spectral Acceleration - g
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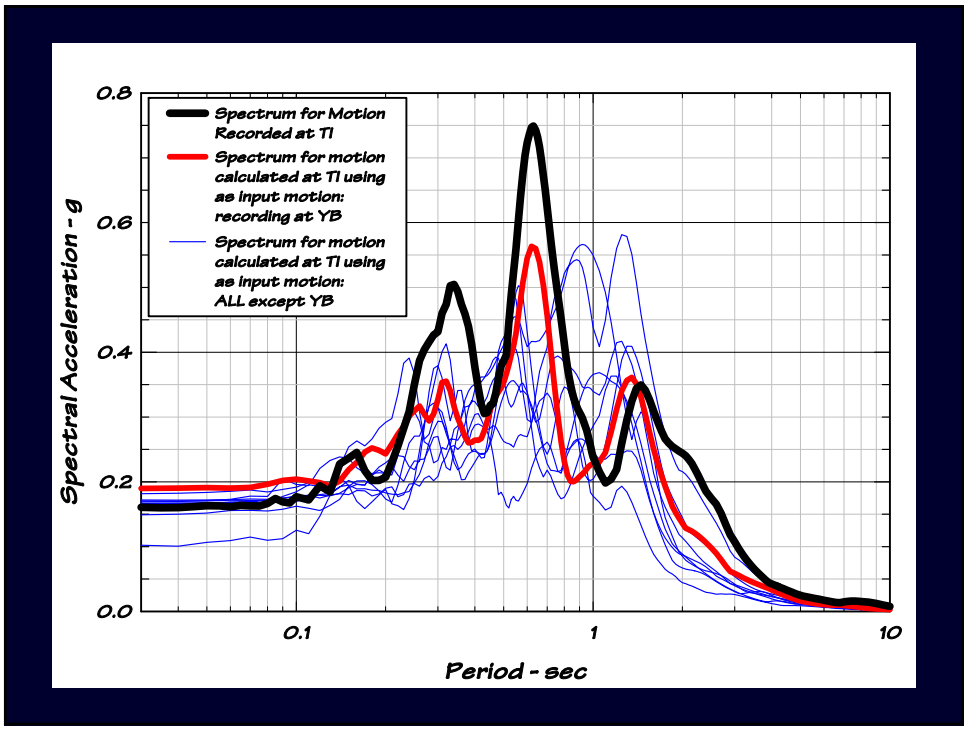
0.2
0.4
0.6
0.8
0.1
1
10
Period - sec


Spectrum for Motion Recorded at TI
Spectrum for motion calculated at TI using as input motion: recording at YB
Spectrum for motion calculated at TI using as input motion: ALL except YB
Spectral Acceleration - g
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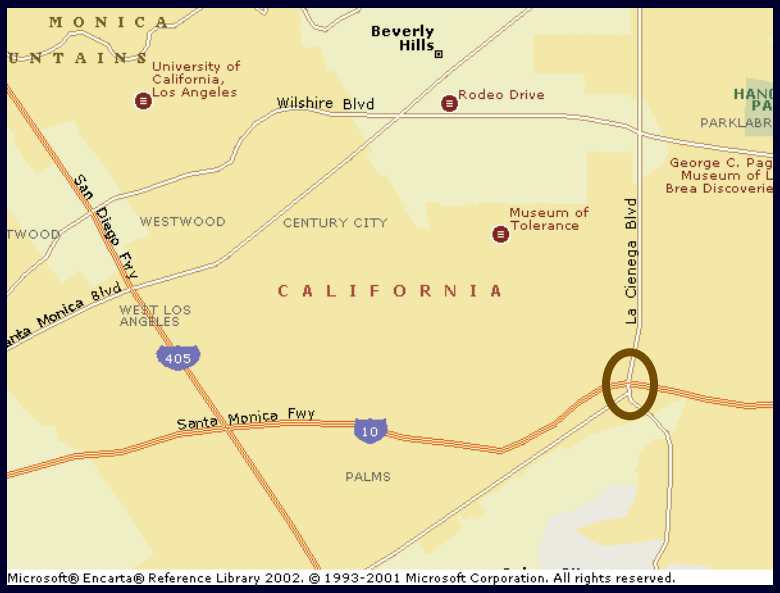
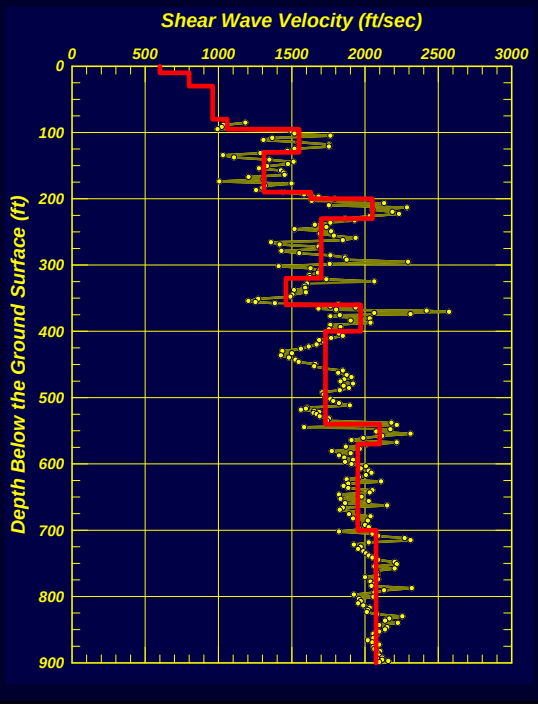
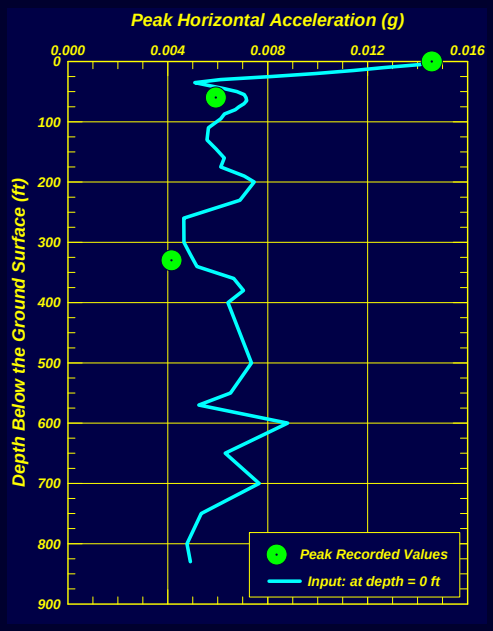
0.2
0.4
0.6
0.8
0.1
1
10
Period - sec

La Cienega Site
Los Angeles

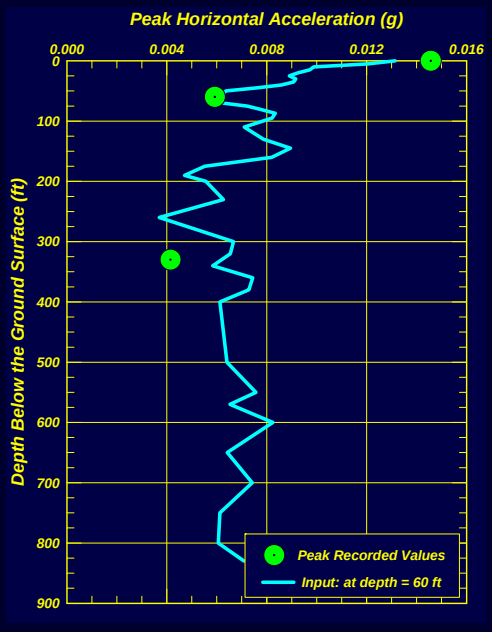




Shear Wave Velocities
La Cienega Site
Los Angeles



Event on 26 April 1997
Magnitude = 5.1
Hypocentral Dist. = 49 km



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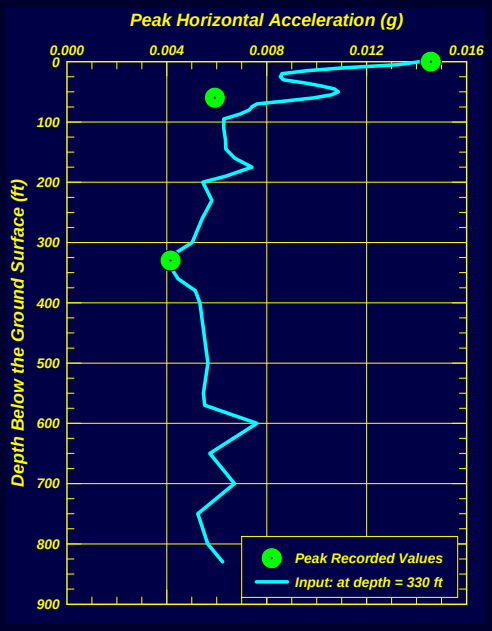

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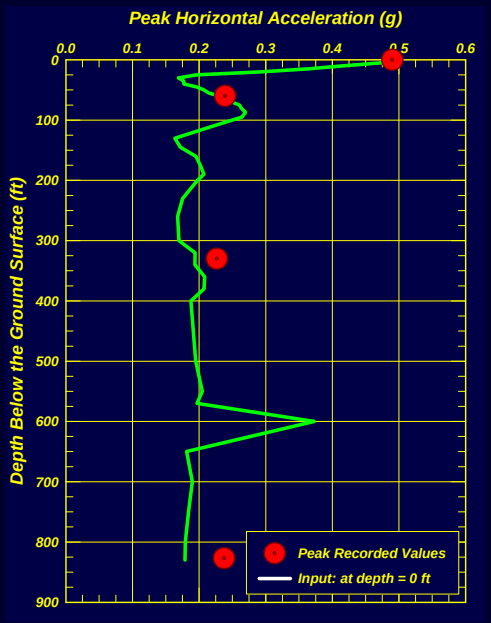
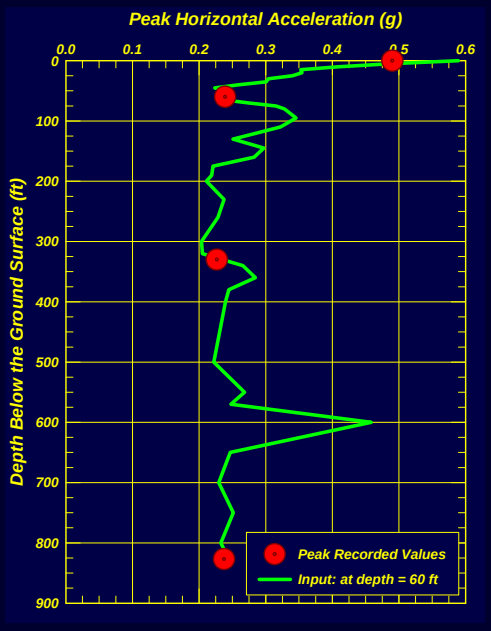
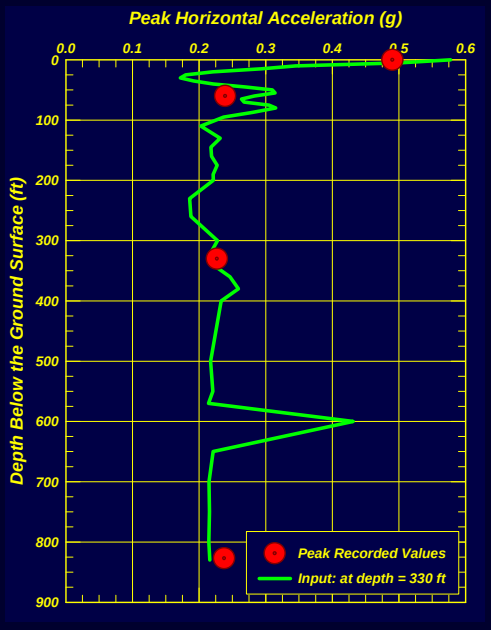


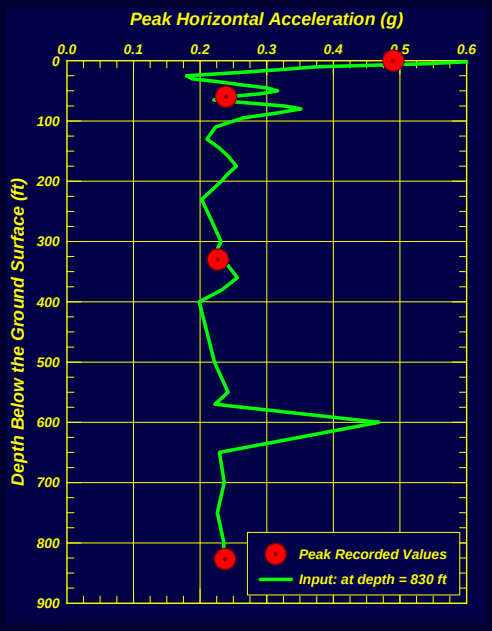
Event on 9 Sep. 2001
Magnitude = 4.2
Hypocentral Dist. = 5.6 km



Event on 9 Sep. 2001
Magnitude = 4.2
Hypocentral Dist. = 5.6 km



Event on 9 Sep. 2001
Magnitude = 4.2
Hypocentral Dist. = 5.6 km



Event on 9 Sep. 2001
Magnitude = 4.2
Hypocentral Dist. = 5.6 km

The equivalent linear procedure has been & continues to be the most widely used procedure in practice for calculating site response & for developing site specific earthquake ground motions and design parameters

It has also been widely used for evaluating existing and new earth structures & for assessing SSI aspects

A plethora of non-linear techniques have been and continue to be developed.

Many of these procedures will be discussed in some detail later today & tomorrow.

The breakout Sessions scheduled for Day 2 will be addressing the issues at hand in far greater details.

Input Motion

Soil Profile

Soil Properties

Method of Analysis

THANK YOU