FB-MultiPier

Bridge Software Institute

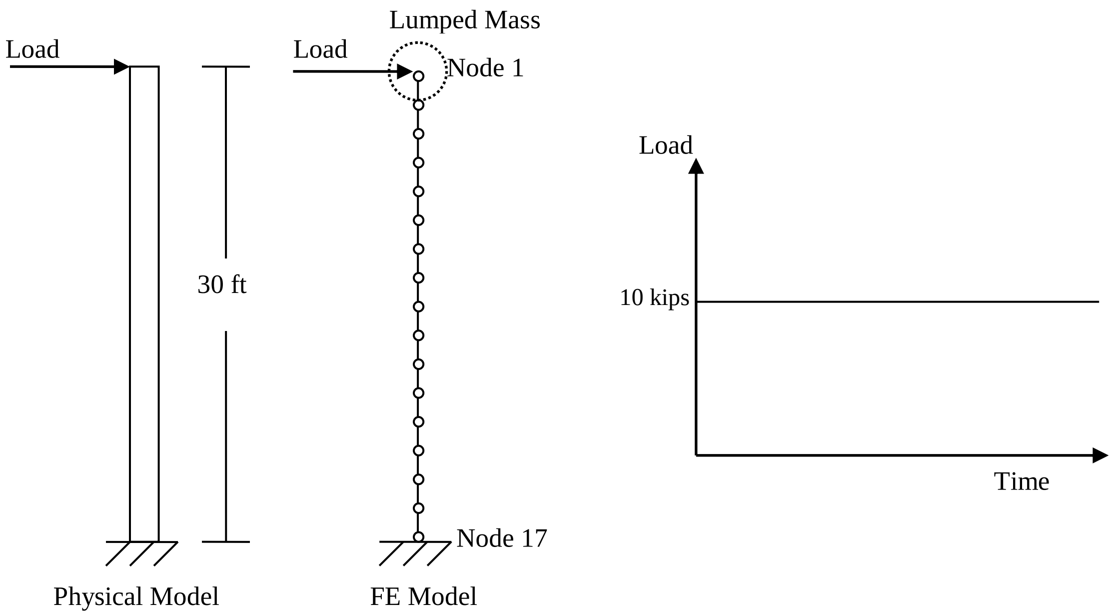
Dynamic Analysis Comparison

FB-MultiPier vs ADINA

Example 1

Single Pile Subject to a Pulse Load at the Pile Head

Problem: The single 24” square prestressed concrete pile is subject to a pulse load applied at the pile head.



Solution Parameters:

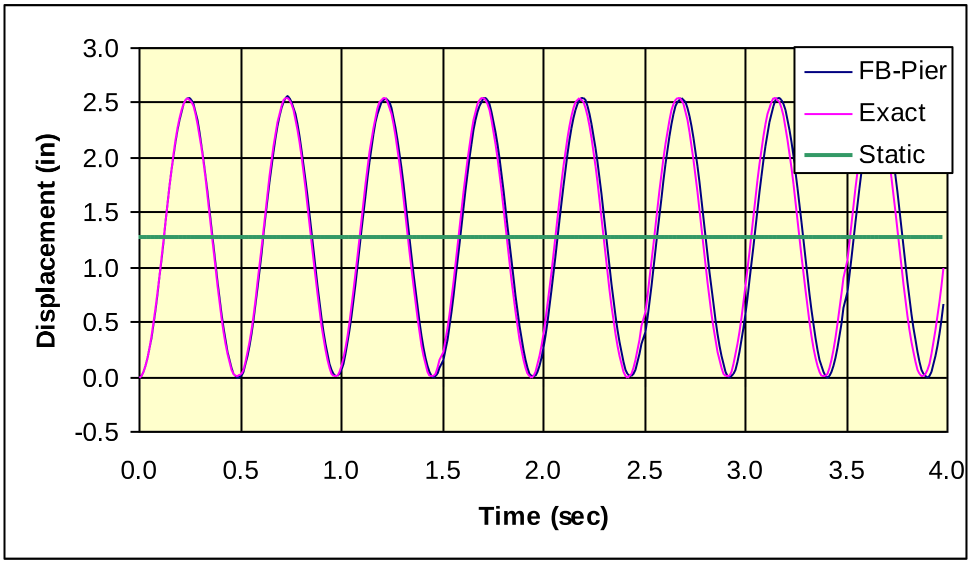
Newmark Average Acceleration
$\Delta t = 0.02$ seconds
Undamped solution
Pile lumped mass = 0.0467 kip-sec^2 / in

File:

sp_pulse.in

Results:

The plot of pile head displacement versus time matches the exact solution. The peak amplitude of displacement is twice the static response.

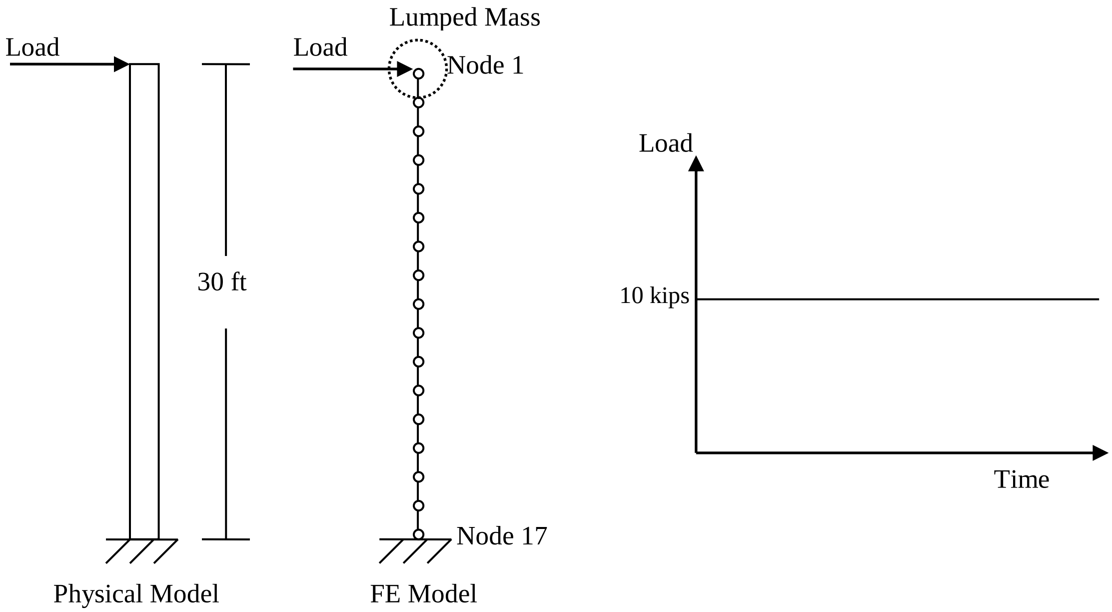


Verified by: Exact solution

Example 2

Single Pile Subject to a Pulse Load at the Pile Head with Damping

Problem: The single 24" square prestressed concrete pile is subject to a pulse load applied at the pile head.

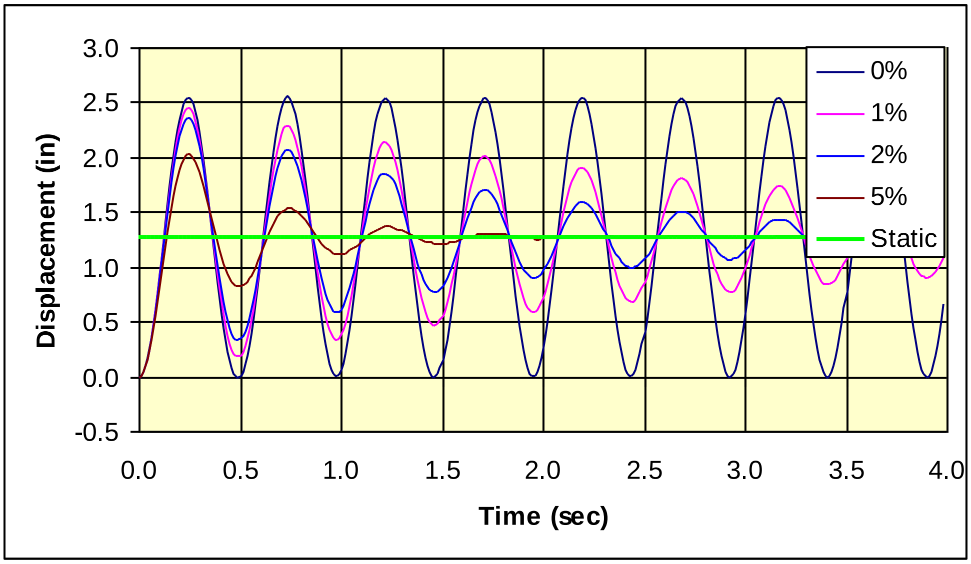


Solution Parameters:
Newmark Average Acceleration
$\Delta t = 0.02$ seconds
Pile lumped mass = 0.0467 kip-sec^2 / in
Lumped damper 0, 1, 2, and 5% damping

File:
sp_pulseDamping.in

Results:

The plot of pile head displacement versus time matches the exact solution. The peak amplitude of displacement is twice the static response and the amplitudes decay with damping.

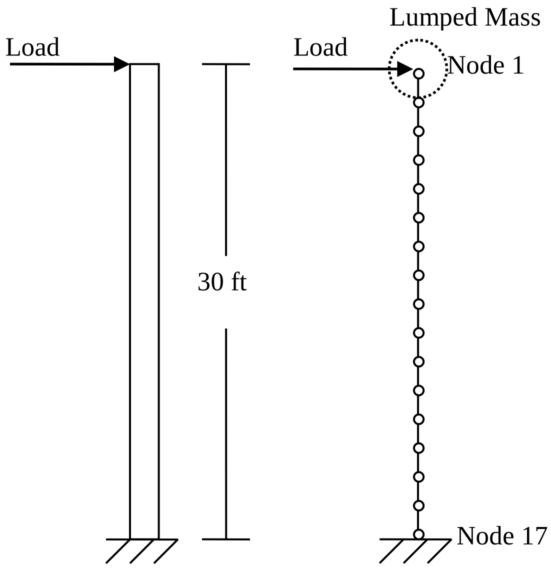


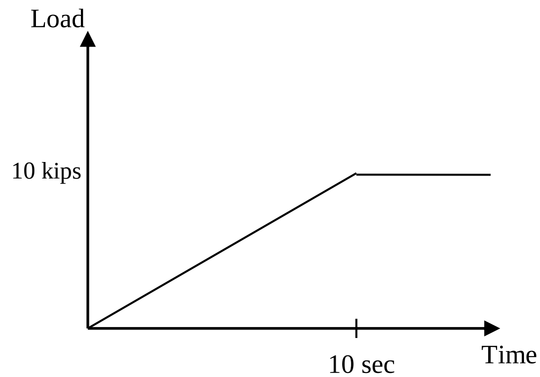
Verified by: Exact solution

Example 3

Single Pile Subject to a Ramp Load at the Pile Head

Problem: The single 24” square prestressed concrete pile is subject to a pulse load applied at the pile head.



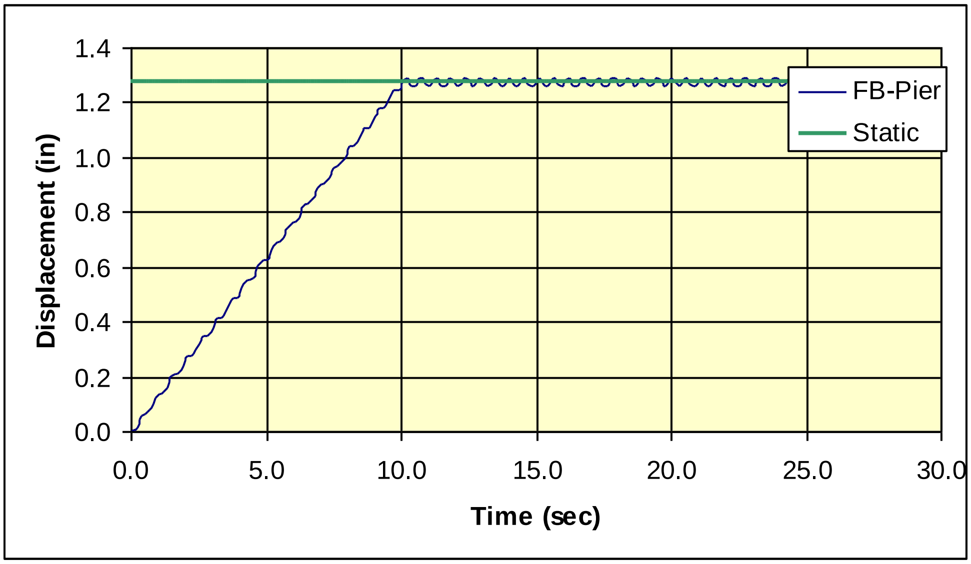


Solution Parameters:
Newmark Average Acceleration
Δt = 0.1 seconds
Undamped solution
Pile lumped mass = 0.0467 kip-sec^2 / in

File:
sp_ramp.in

Results:

The plot of pile head displacement versus time matches the static solution after 10 seconds.

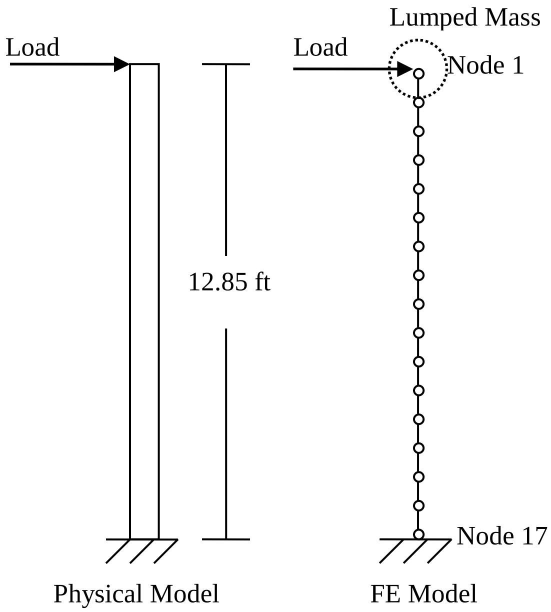


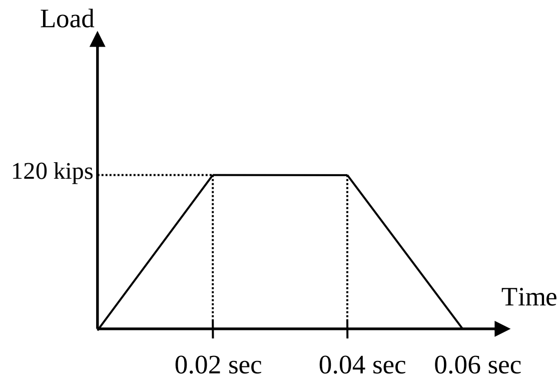
Verified by: Static solution

Example 4

Single Pile Subject to a Blast Load at the Pile Head

Problem: The single 24” square prestressed concrete pile is subject to a pulse load applied at the pile head.



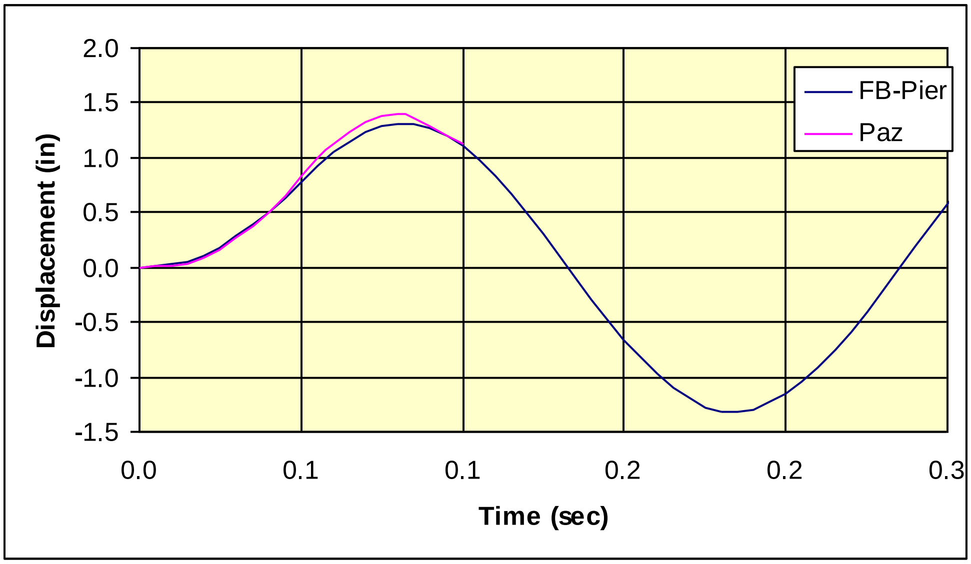


Solution Parameters:
Newmark Average Acceleration
Δt = 0.02 seconds
Undamped solution
Pile lumped mass = 0.1 kip-sec^2 / in

File:
sp_blast.in

Results:

The plot of pile head displacement versus time is close to the Paz solution. The Paz solution is approximate due to the coarseness in the solution to Duhamel's Integral.

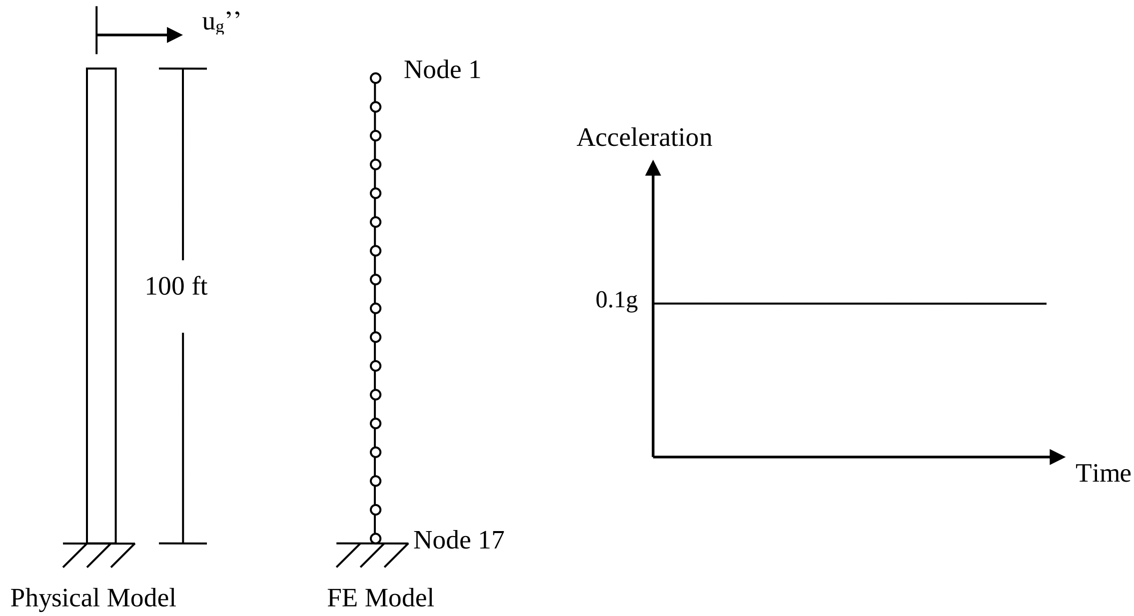


Verified by: Paz. <u>Structural Dynamics</u>. p. 73

Example 5

Single Pile Subject to a Constant Acceleration

Problem: The single 24” square prestressed concrete pile is subject to a constant acceleration.



Solution Parameters:

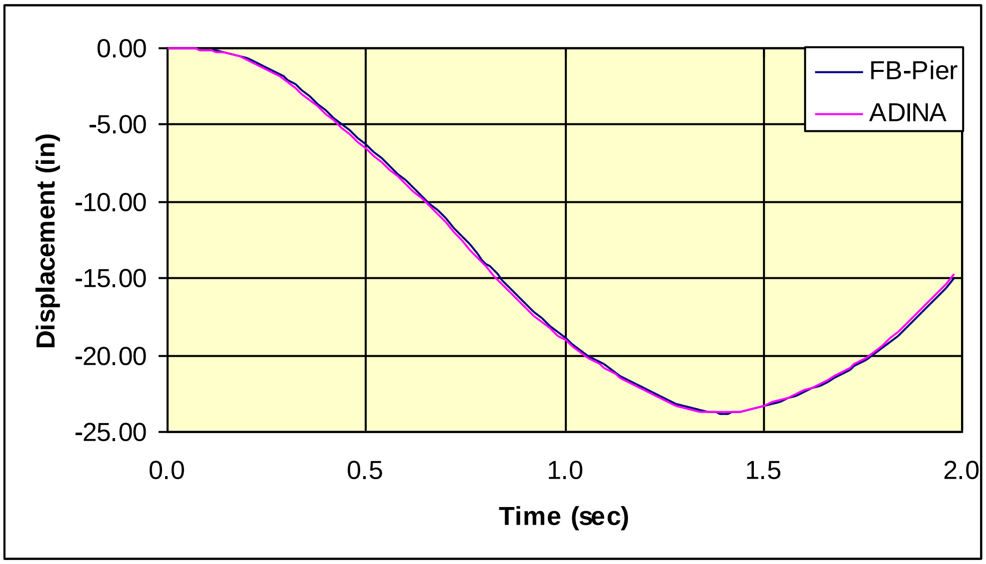
Newmark Average Acceleration
Δt = 0.02 seconds
Undamped solution
Pile mass density (using consistent mass matrix) = 2.25e-7 kip-sec^2 / in^4

File:

sp_constGroundAccel.in

Results:

The plot of pile head displacement matches the ADINA solution.

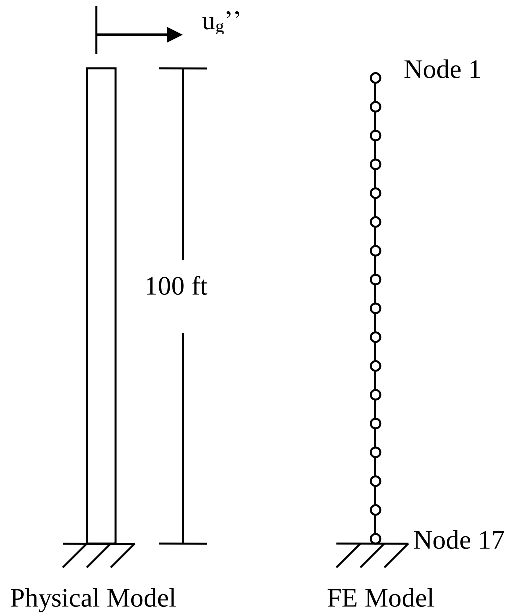


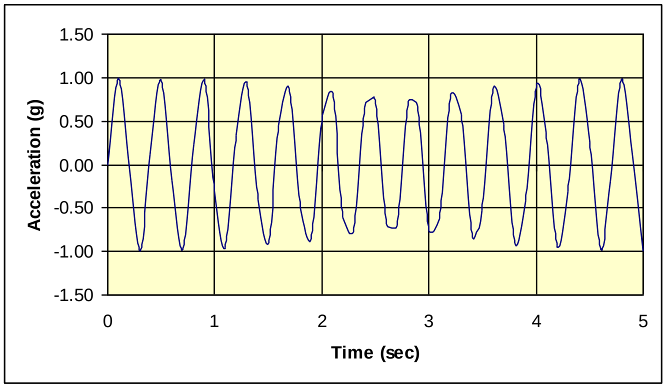
Verified by: ADINA

Example 6

Single Pile Subject to a Sinusoidal Ground Acceleration

Problem: The single 24” square prestressed concrete pile is subject to a sinusoidal ground acceleration.



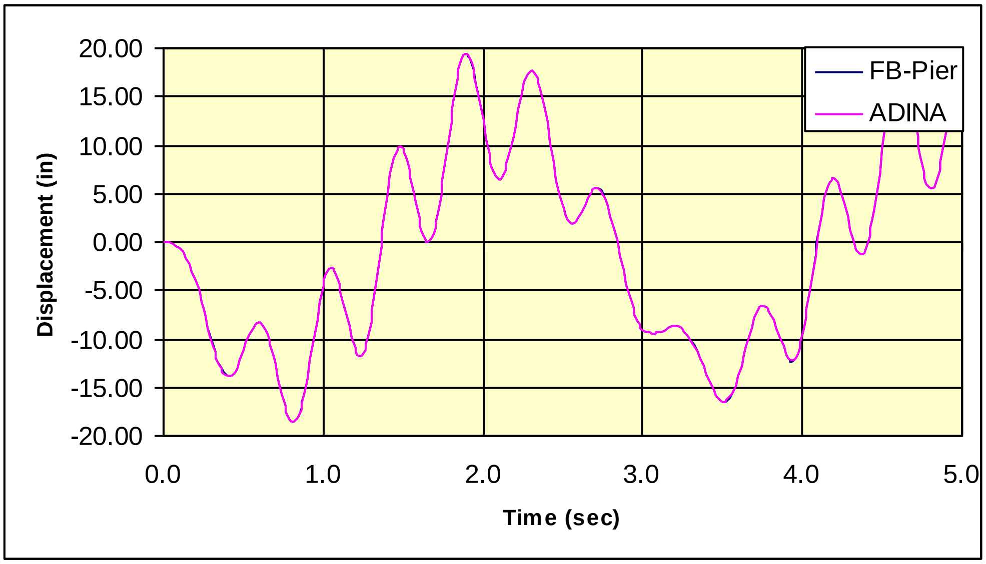


Solution Parameters:
Newmark Average Acceleration
$\Delta t = 0.02$ seconds
Undamped solution
Pile mass density (using consistent mass matrix) = 2.25e-7 kip-sec^2 / in^4

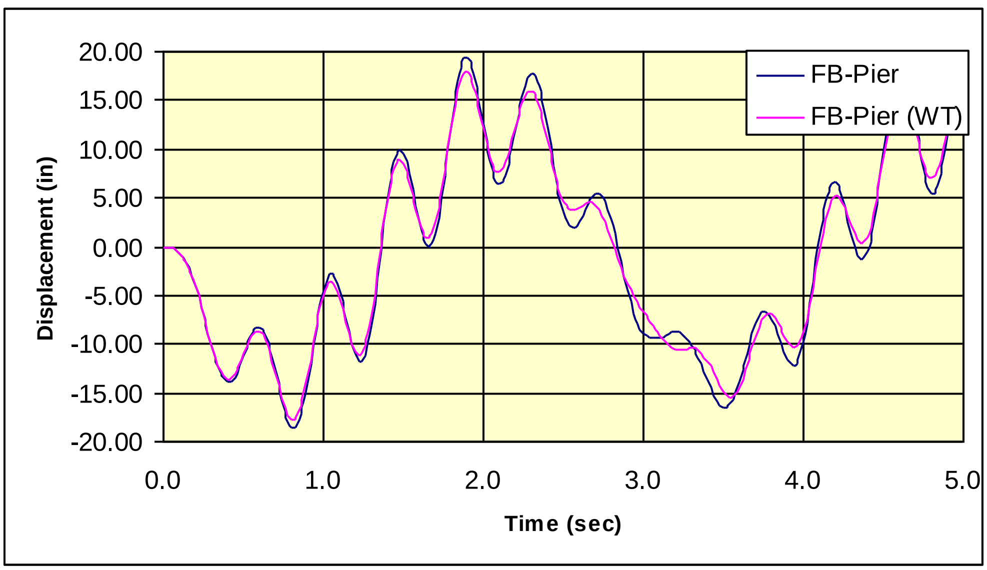
File:
sp_sineGroundAccel.in
sp_sineGroundAccel_LA.in
sp_sineGroundAccel_WT.in

Results:

The plot of pile head displacement matches the ADINA solution.



The plot of pile head displacement matches for solutions using Newmark's Average and Wilson Theta's method.

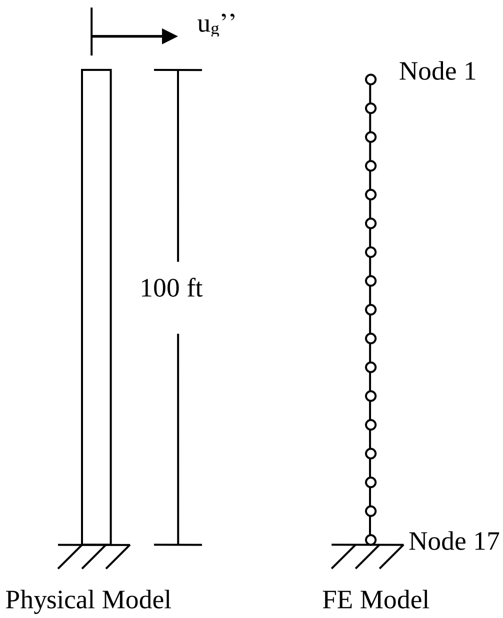


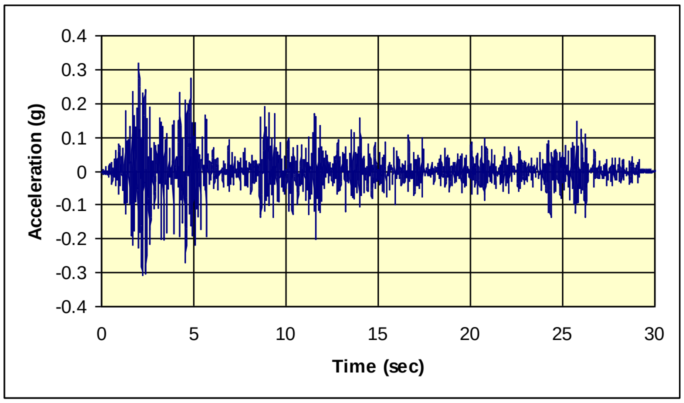
Verified by: ADINA

Example 7

Single Pile Subject to an El Centro Ground Acceleration

Problem: The single 24” square prestressed concrete pile is subject to an El Centro Earthquake ground acceleration.



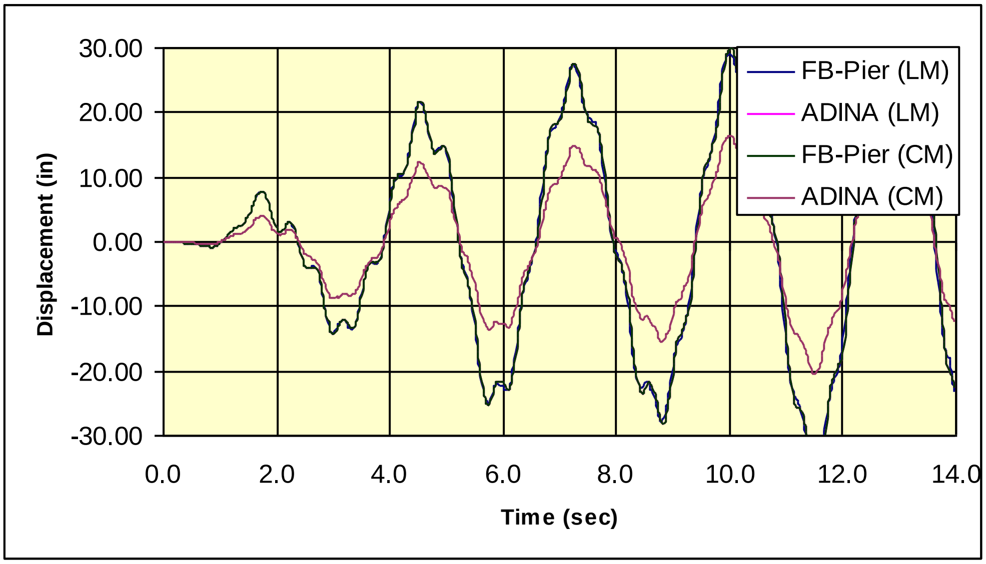


Solution Parameters:
Newmark Average Acceleration
$\Delta t = 0.02$ seconds
Undamped solution
Pile mass density = 2.25e-7 kip-sec^2 / in^4

File:
sp_ElCentroAccel.in

Results:

The plot of pile head displacement matches the ADINA solution for both the lumped mass. The FB-MultiPier consistent mass solution is also very similar to the lumped mass solution. Note that the ADINA consistent mass solution is significantly different. The displaced shape is the same, but noticeably smaller in amplitude. ADINA uses a different consistent mass matrix (see ADINA – Theory and Modeling Guide).

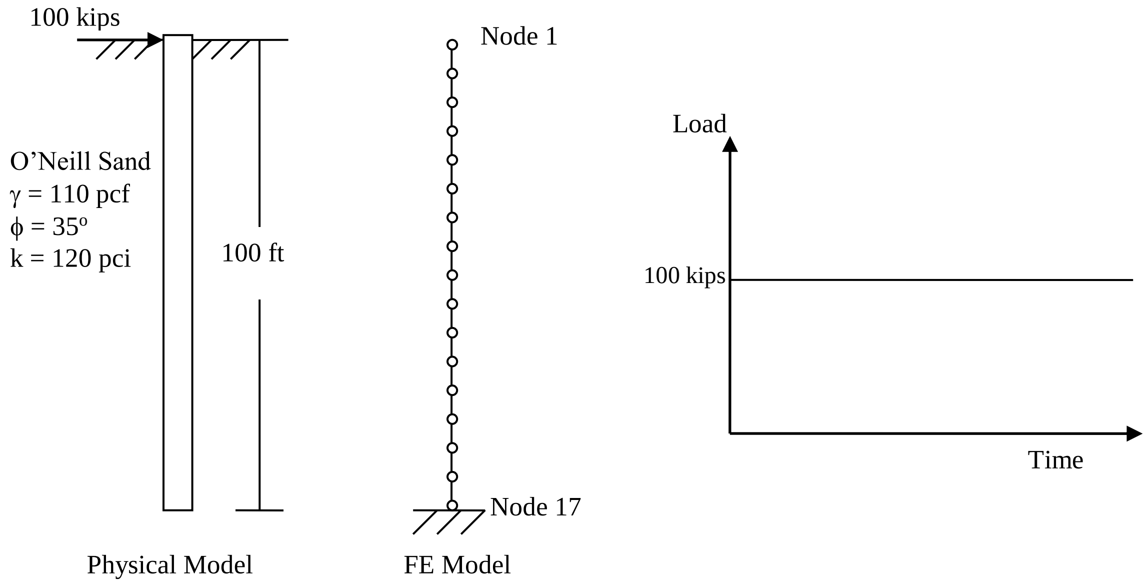


Verified by: ADINA

Example 8

Single Pile with Soil Subject to a Pulse Load

Problem: The 72” concrete drilled shaft is subject to a pulse load. A single of layer of O’Neill Sand is used.

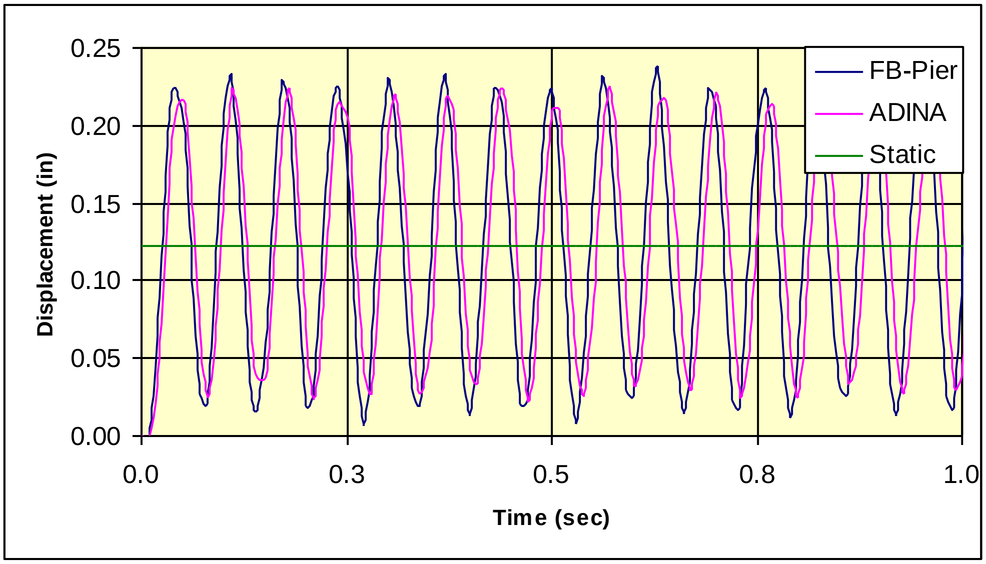


Solution Parameters:
Newmark Average Acceleration
$\Delta t = 0.01$ seconds
Undamped solution
Pile mass density = 2.25e-7 kip-sec^2 / in^4

File:
sp_pulseWithSoil.in

Results:

The plot of pile head displacement is similar to the ADINA response. The results appear to converge when the time step is reduced from $\Delta t = 0.02$ sec to $\Delta t = 0.01$ sec. Both program are using Newmark's Average Acceleration Method, however, the results are still different. The slight difference in response frequencies in most likely due to the linear discretization of the O'Neill soil curve in ADINA. The soil curve used in FB-MultiPier is hyperbolic and the ADINA nonlinear soil springs are composed of approximate linear segments. Both solutions oscillate about the static solution as expected.

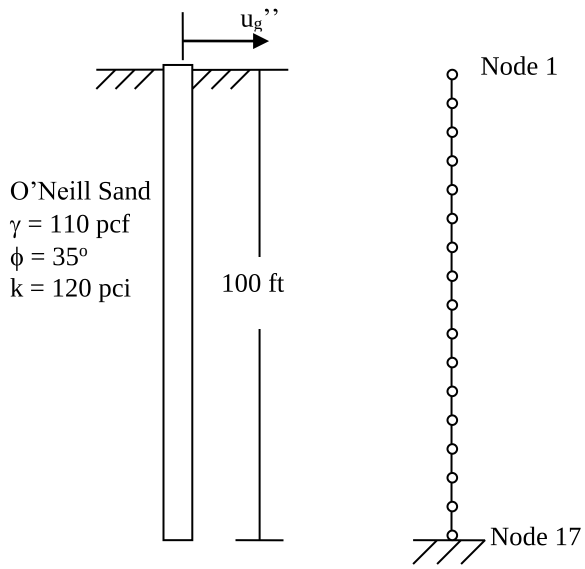


Verified by: ADINA

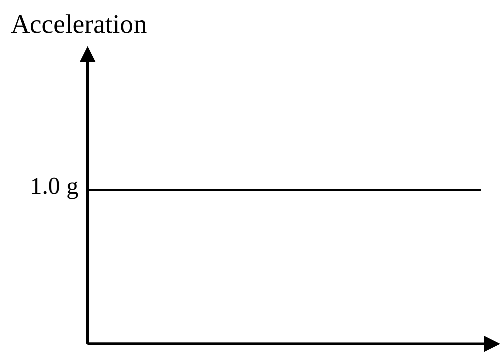
Example 9

Single Pile with Soil Subject to a Constant Ground Acceleration

Problem: The 72” concrete drilled shaft is subject to a constant ground acceleration of 1g. A single of layer of O’Neill Sand is used.



Physical Model FE Model

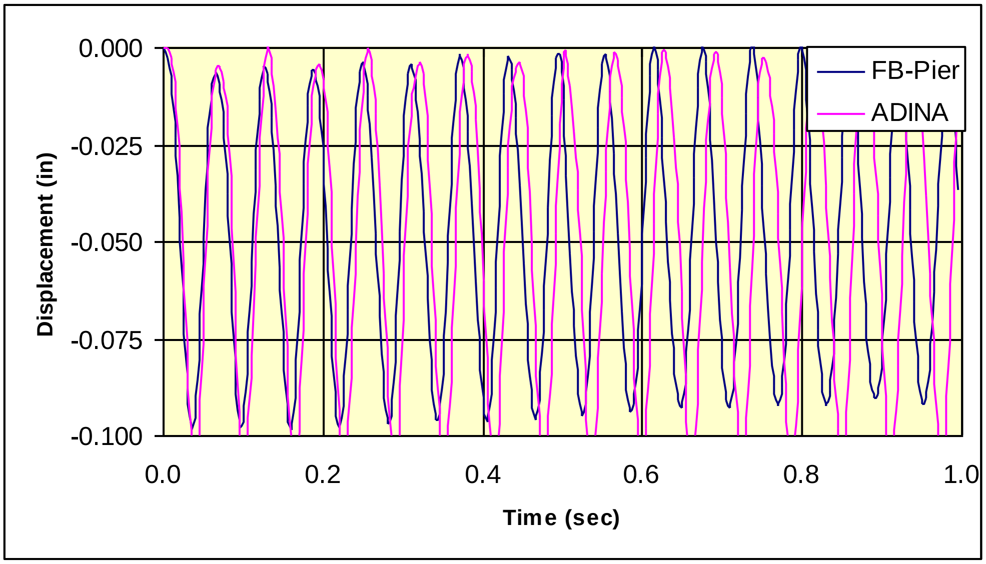


Solution Parameters:
Newmark Average Acceleration
$\Delta t = 0.005$ seconds
Undamped solution
Pile mass density = 2.25e-7 kip-sec^2 / in^4

File:
sp_constAccelWithSoil.in

Results:

The plot of pile head displacement is similar to the ADINA response. The results appear to converge when the time step is reduced from Δt = 0.01 sec to Δt = 0.005 sec. Both program are using Newmark's Average Acceleration Method, however, the results are still different. The slight difference in response frequencies in most likely due to the linear discretization of the O'Neill soil curve in ADINA. The soil curve used in FB-MultiPier is hyperbolic and the ADINA nonlinear soil springs are composed of approximate linear segments. Both solutions oscillate about the static solution as expected.

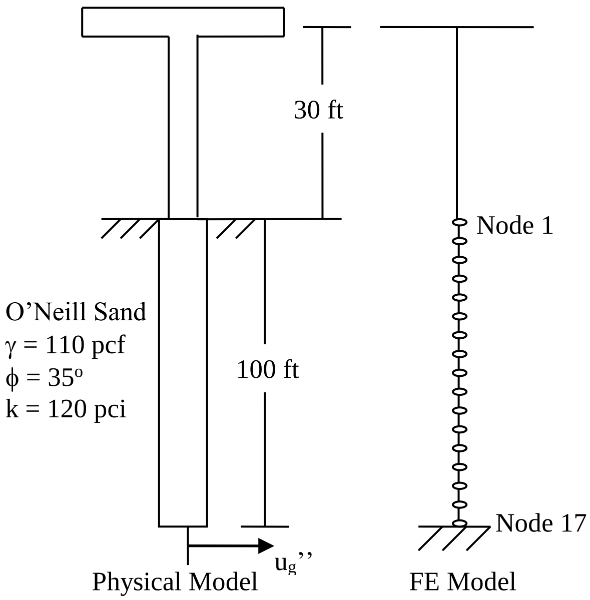


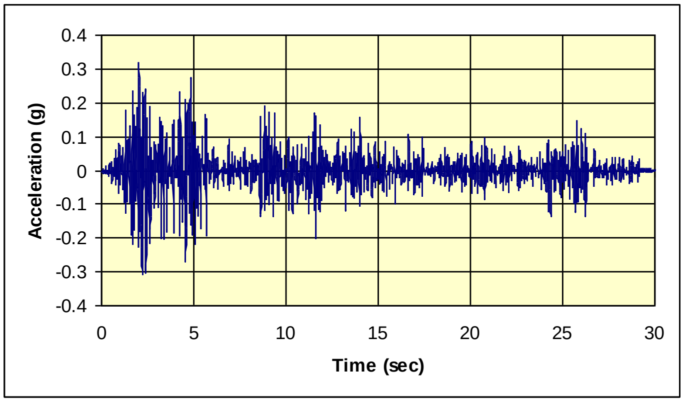
Verified by: ADINA

Example 10

Single Column Pier Subject to an El Centro Ground Acceleration

Problem: The single column pier with a 108" concrete drilled shaft is subject to an El Centro ground acceleration. A single of layer of O'Neill Sand is used.





Solution Parameters:

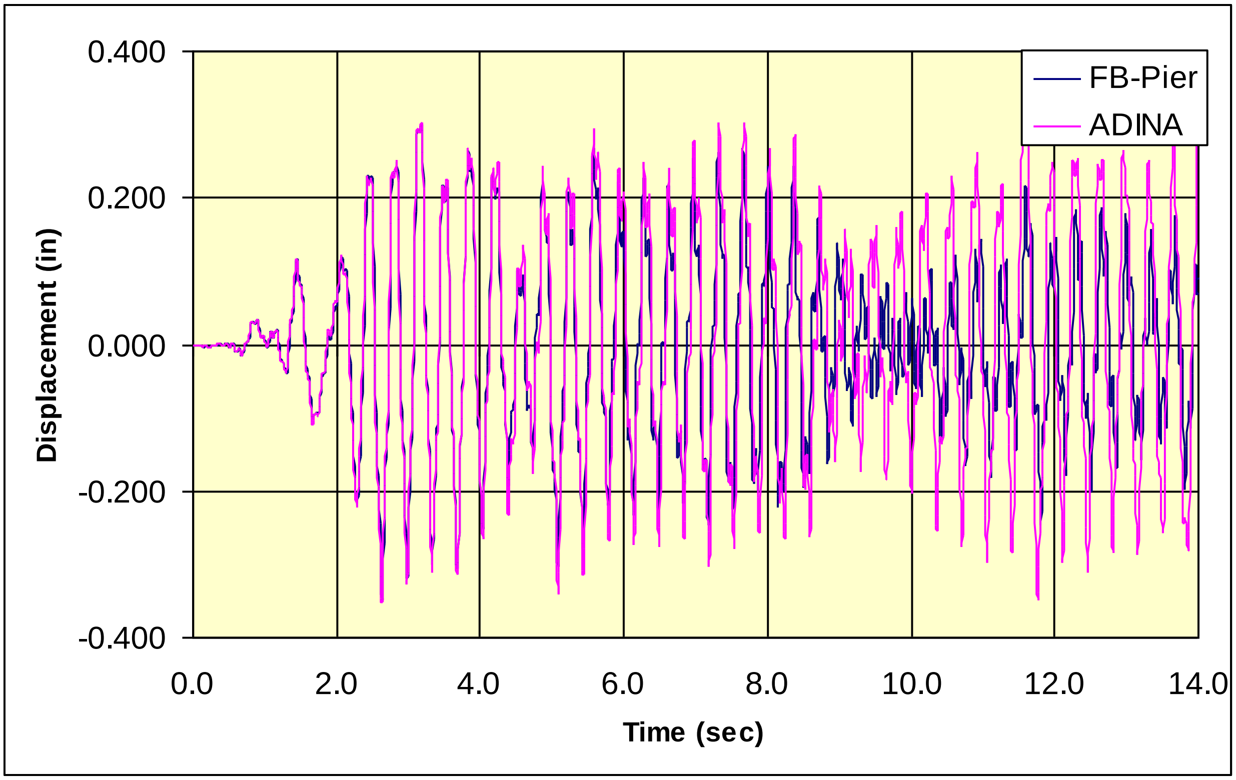
Newmark Average Acceleration
$\Delta t = 0.01$ seconds
Undamped solution
Pile mass density = 2.25e-7 kip-sec^2 / in^4

File:

single11_00dm.in

Results:

The plot of pile head displacement matches the ADINA solution very well until about 9 sec into the solution. The results appear to converge when the time step is reduced from Δt = 0.02 sec to Δt = 0.01 sec.

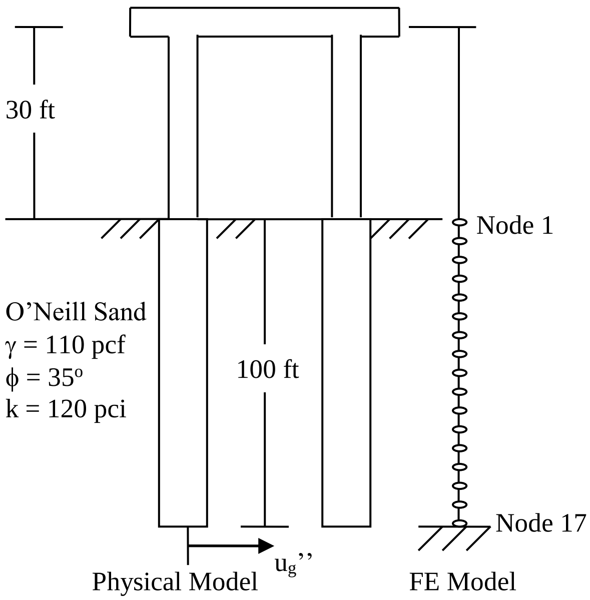


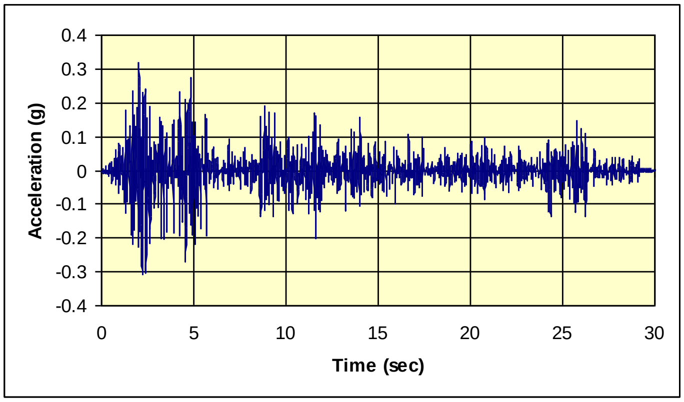
Verified by: ADINA

Example 11

Two Column Pier Subject to an El Centro Ground Acceleration

Problem: The single column pier with 72" concrete drilled shafts is subject to an El Centro ground acceleration. A single of layer of O'Neill Sand is used.



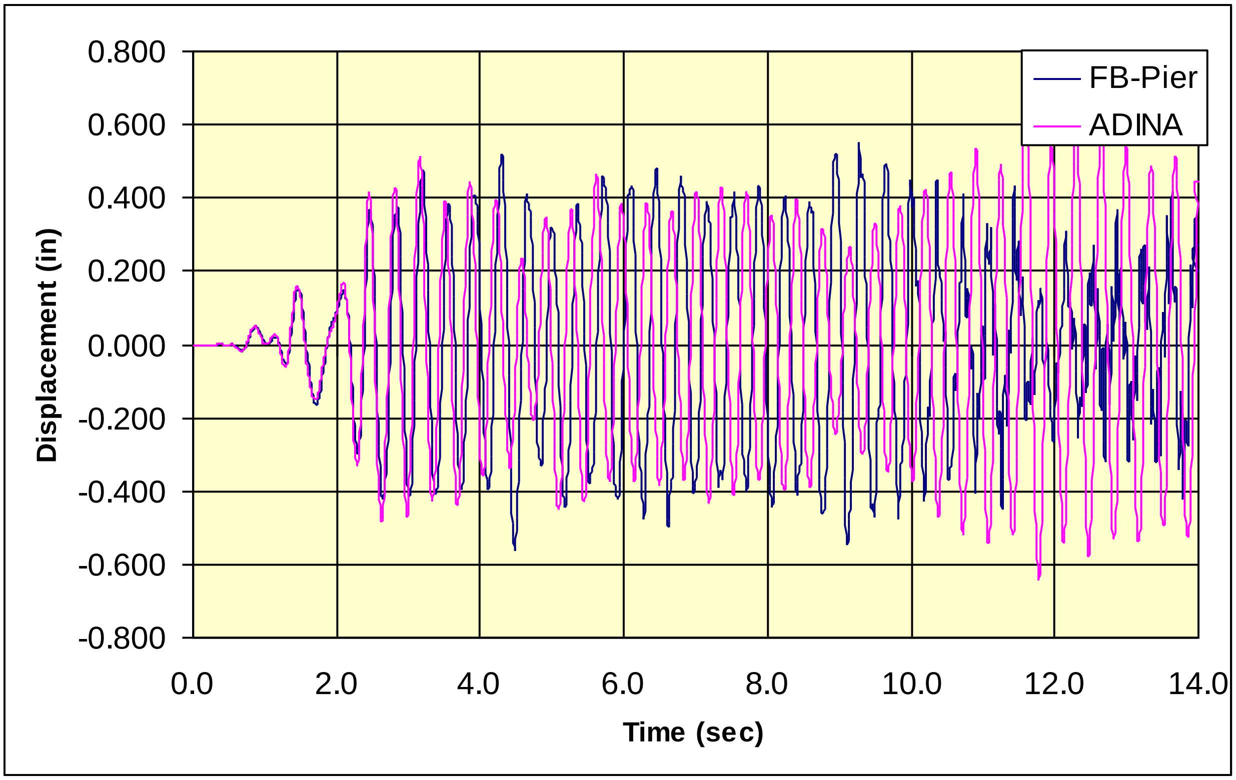


Solution Parameters:
Newmark Average Acceleration
$\Delta t = 0.01$ seconds
Undamped solution
Pile mass density = 2.25e-7 kip-sec^2 / in^4

File:
twocol11_00dm.in

Results:

The plot of pile head displacement matches the ADINA solution very well until about 9 sec into the solution. The results appear to converge when the time step is reduced from Δt = 0.02 sec to Δt = 0.01 sec.

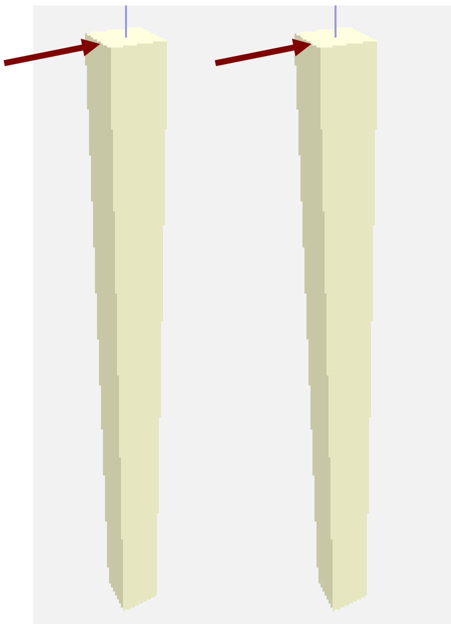


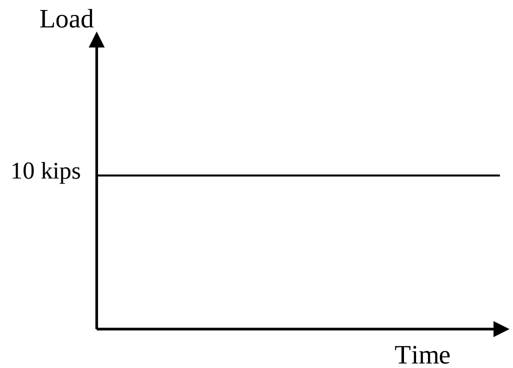
Verified by: ADINA

Example 12

Multiple Piers – Two Identical Piles Subject to a Pulse Load

Problem: Two identical piles are subject to the same pulse load applied at the pile cap. The two piles are isolated. The displacement records should match.



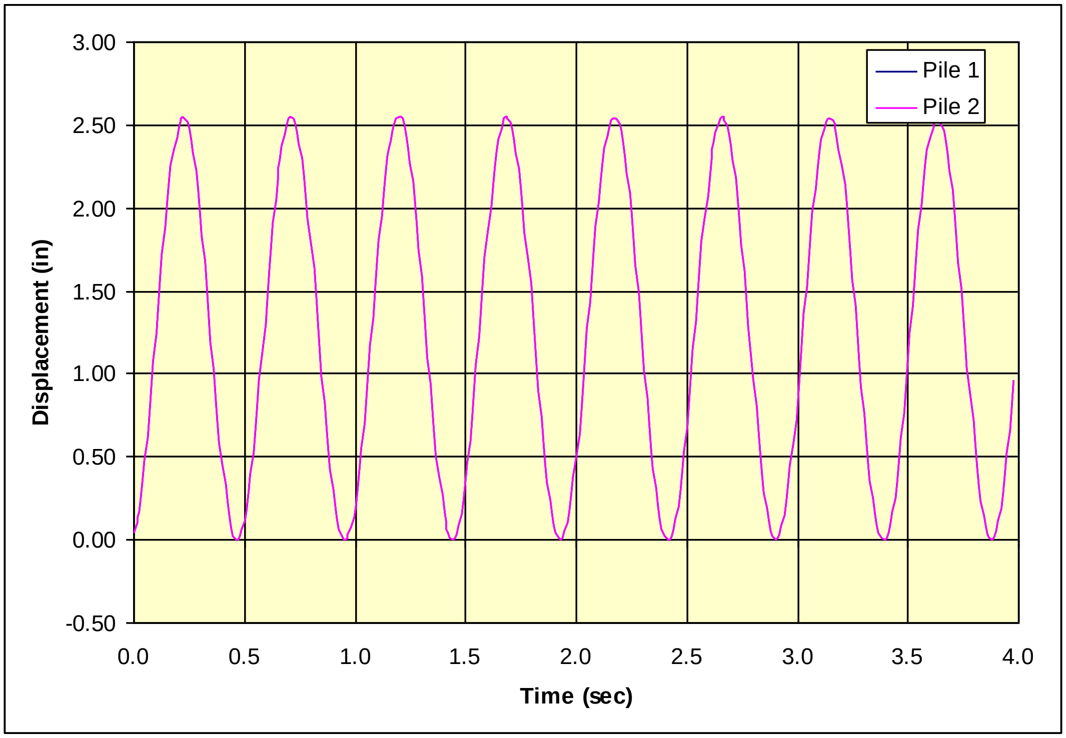


Solution Parameters:
Newmark Average Acceleration
$\Delta t = 0.02$ seconds
Undamped solution
Pile and pier mass density = 2.25e-7 kip-sec^2 / in^4

File:
two identical piles dyn pulse.in

Results:

The plot of pile head displacements for both piles match.

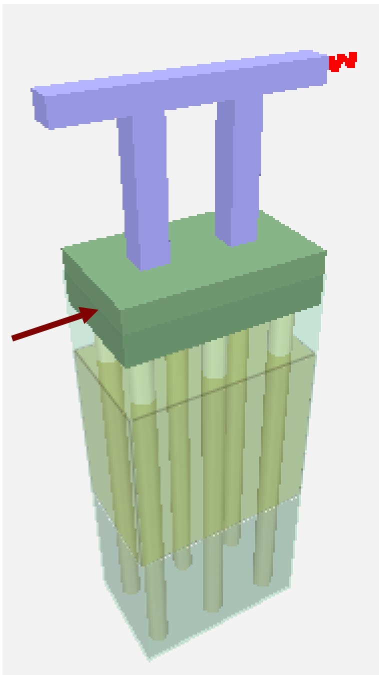


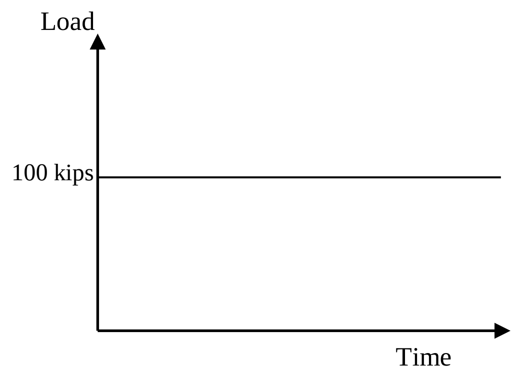
Verified by: FB-MultiPier

Example 13

Multiple Piers – Two Identical Piers Subject to a Pulse Load

Problem: Two identical piers are subject to the same pulse load applied at the pile cap. The two piers are isolated. The displacement records should match.



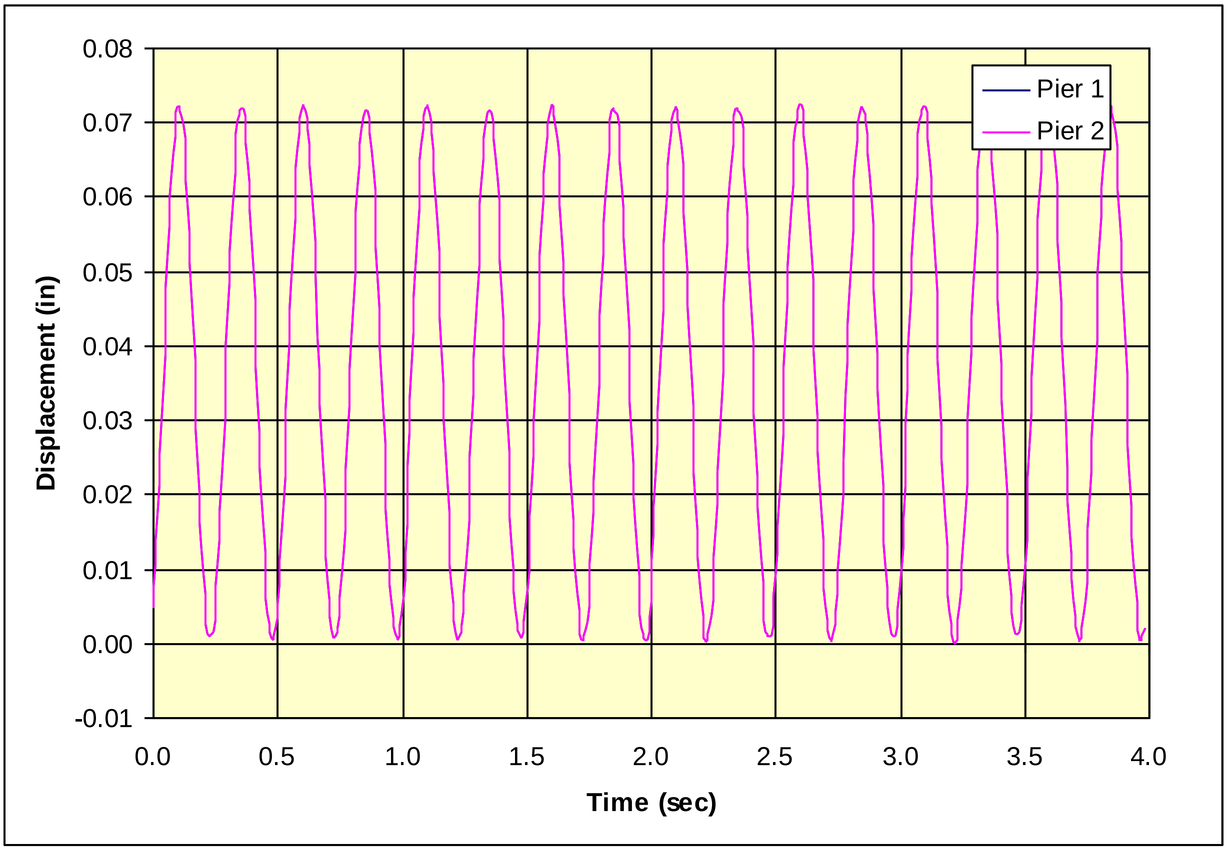


Solution Parameters:
Newmark Average Acceleration
Δt = 0.02 seconds
Undamped solution
Pile and pier mass density = 2.25e-7 kip-sec^2 / in^4

File:
two piers_Example 2_dyn pulse.in

Results:

The plot of pile head displacements for both piers match.

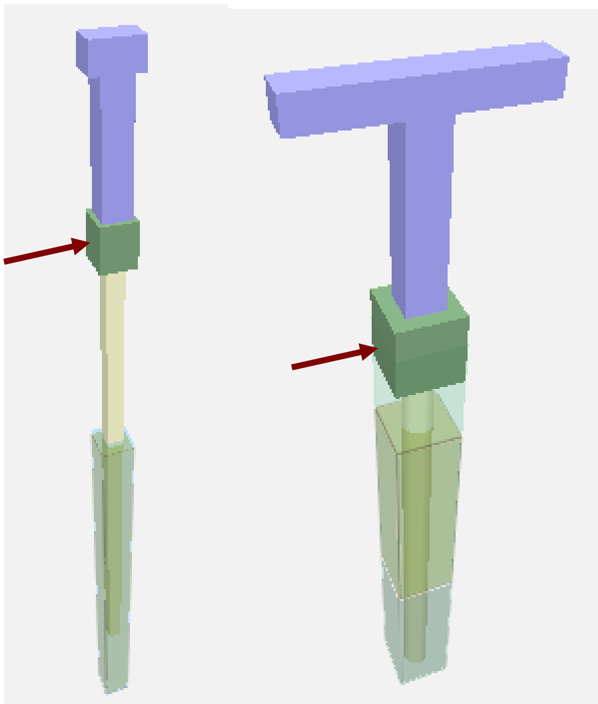


Verified by: FB-MultiPier

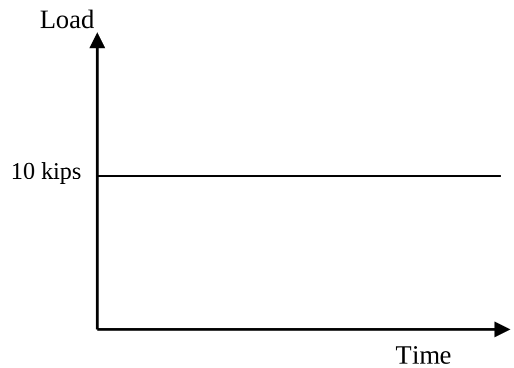
Example 14

Multiple Piers – Two Different Piers Subject to a Pulse Load

Problem: Two different piers are subject to the same pulse load applied at the pile cap. The two piers are isolated. The displacement records should match the single pier solutions.



(Pier 1) **(Pier 2)**

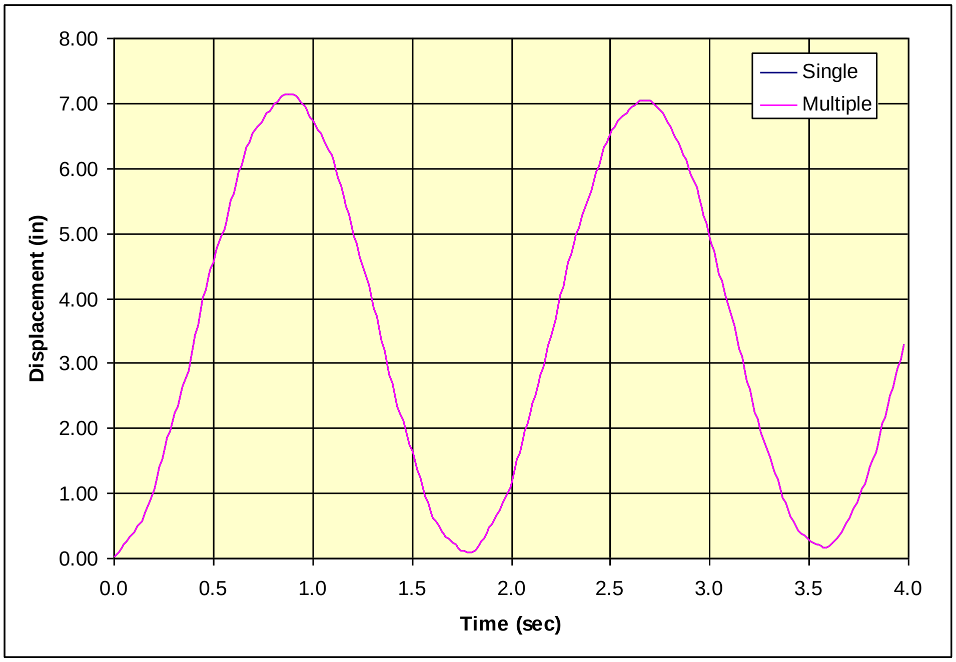


Solution Parameters:
Newmark Average Acceleration
$\Delta t = 0.02$ seconds
Undamped solution
Pile and pier mass density = 2.25e-7 kip-sec^2 / in^4

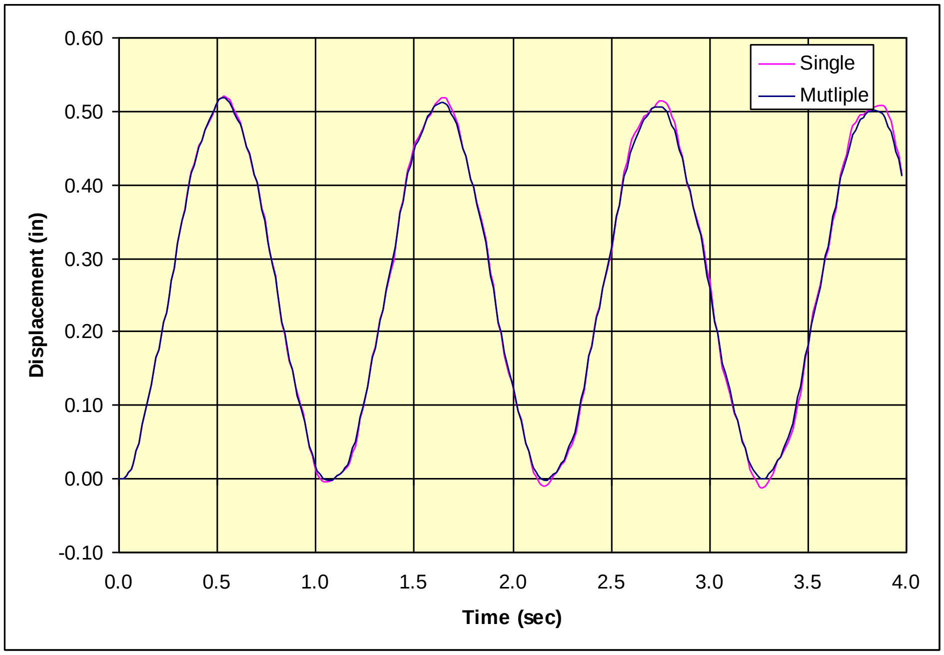
File:
two piers_Pier1 and Pier2_dyn pulse.in

Results:

Pile head displacement results for Pier 1.



Pile head displacement results for Pier 2.

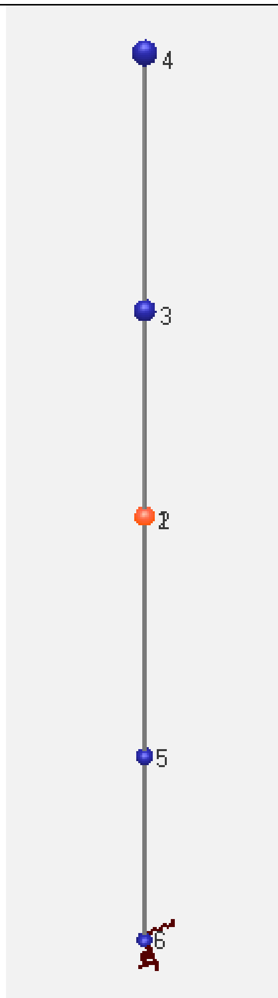


Verified by: FB-MultiPier

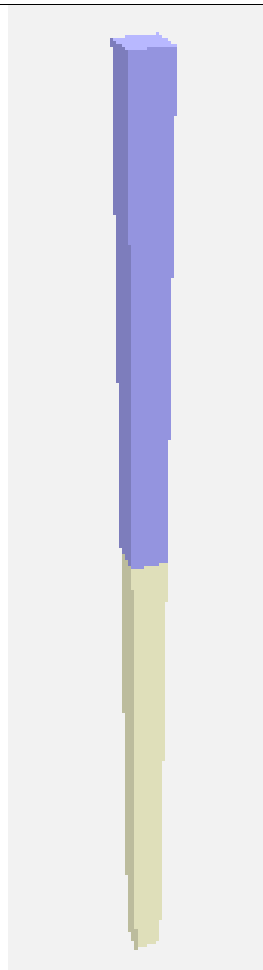
Example 15

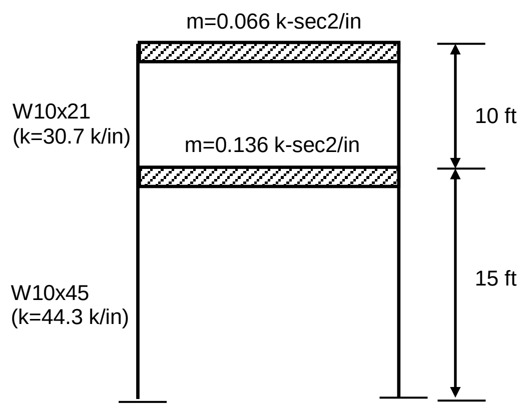
Response Spectrum Analysis – Two Story Shear Building

Problem: A two story frame is modeled as a shear building. The models are loaded using a response spectrum for a constant 0.1g acceleration and no damping. The objective is to compare the frequency results and the shear building floor displacements. The bottom floor is modeled with a pile and the top floor is modeled with a pier column (since the section properties are different between the two floors). Two modes are used in the modal combination.



Thin Element Mode


Thick Element Mode



Frame Model

File:
2 story col_modal.in

Response Spectrum:

Results:

	ω1 (rad/sec)	ω2 (rad/sec)	Δ – 1st floor (in)	Δ – 2nd floor (in)
FB-MultiPier	11.83	32.90	1.406	1.780
Paz Solution	11.83	32.89	1.426	1.789

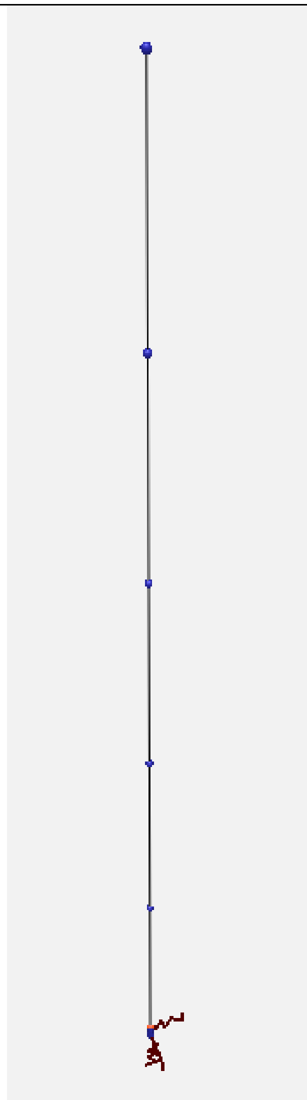
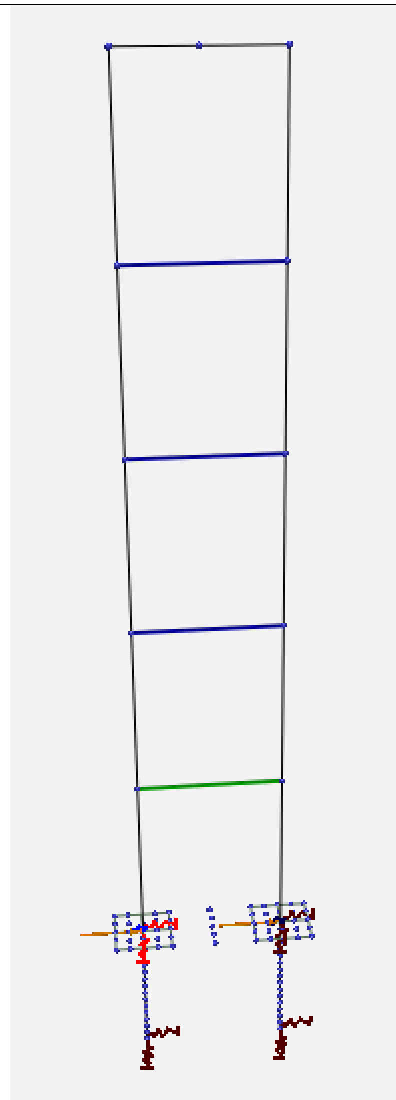
Verified By:

Paz, M. "Structural Dynamics", 3rd Ed. VNR, p 241 (Example 11.2).

Example 16

Response Spectrum Analysis – Five Story Shear Building versus Frame

Problem: A five story frame is modeled as both a shear building and frame. The models are loaded using a response spectrum of the El Centro earthquake with 5% structural damping. The objective is to compare the column base shear and overturning moment results for both models. A time history analysis of the frame was also conducted for comparison to validate the modal analysis results. The modal contribution factors are checked to ensure that most of the modal response is captured in the first five vibration modes.

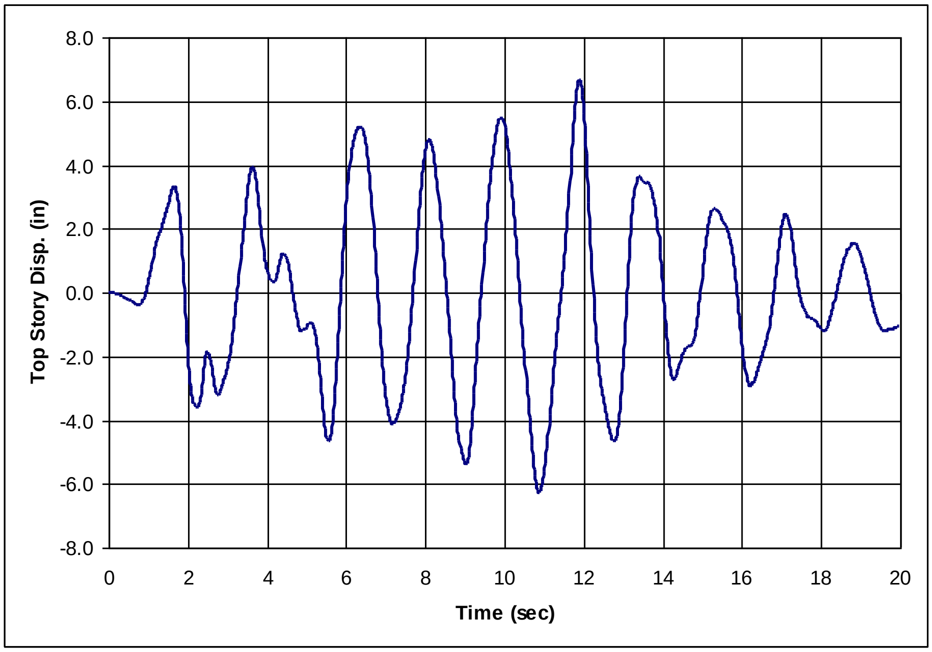
	
Shear Building	Frame

File:
5 story col_modal.in, 5 story col_modal_frame.in, 5 story col_timehistory_frame.in

Results:

Model	Col #1 Base Shear (kip)	Col #2 Base Shear (kip)	Total Base Shear (kip)	Overturning Moment (kip-ft)	Top Floor Disp. (in)
Shear Building	67.3	n/a	67.3	n/a	6.89
Chopra Solution	66.5	n/a	66.5	2,572	6.79
Frame	33.2	33.2	66.4	2,229	6.77
Frame (Time history)	28.9	36.3	65.2	2,205	6.67

Time history results:



Modal contribution factors:

Mode	% Contribution
1	87.85
2	8.71
3	2.42
4	0.75
5	0.16
Total	99.89

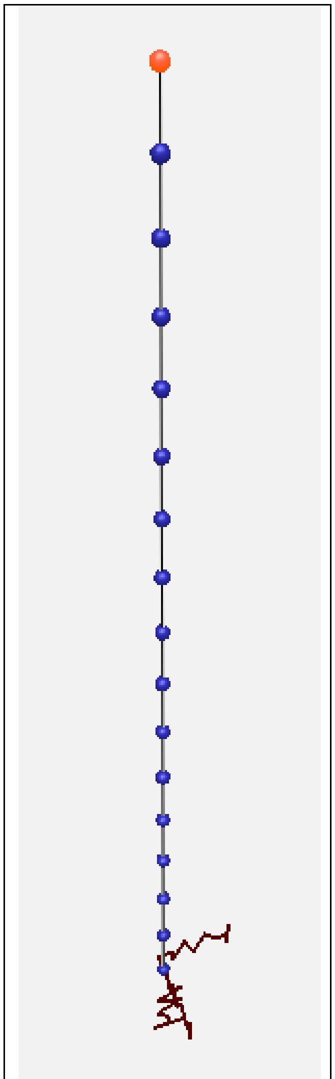
Verified By:

Chopa, A. "Dynamics of Structures", 2nd Ed. Prentice Hall, p 523 (Example 13.8.2).
Chopa, A. "Dynamics of Structures", 2nd Ed. Prentice Hall, p 450 (Table 12.11.1 – Modal Contribution Factors).

Example 17

Response Spectrum Analysis – Two Excitation Directions

Problem: A single pile is subject to a constant 0.1g ground acceleration that is applied in both the x and y direction. Different factors are used to control the percentage application in each direction and the results are compared.



Single Pile

File:
sp_2DSpectrum_100x_0y.in, sp_2DSpectrum_100x_50y.in**,** sp_2DSpectrum_0x_100y.in, sp_2DSpectrum_50x_100y.in**,** sp_2DSpectrum_100x_100y.in

Results:

Pile Head Displacement:

Case	x %	y %	x-disp (in)	y-disp (in)
1	100	0	0.1743	0.0000
2	100	50	0.1743	0.0774
3	0	100	0.0000	0.1549
4	50	100	0.0872	0.1549
5	100	100	0.1743	0.1549

The different load cases show the variation in displacement depending on the direction factor. When a 50% direction factor is used, the displacement is exactly half of the 100% direction factor displacement, as expected.