Do transfer forces in the Podium need to be amplified by Ω_0 and R_{Upper}/R_{Lower} ?

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Updated 1/20/2025

Department of Health Care Access and Information

Outline

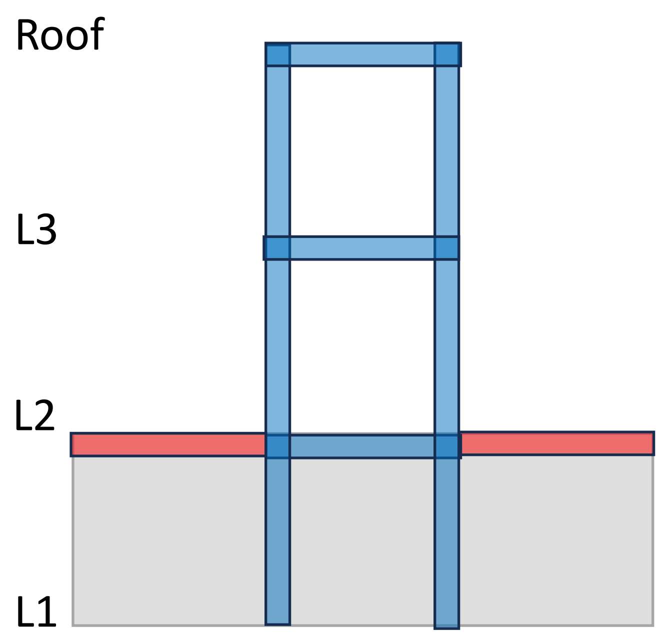
- *Code Requirements for vertical combination of forces and diaphragm transfer forces where horizontal irregularity Type 4 exists*
- *Case study ETABS model of a 7-story Special Reinforced Concrete Moment frame building satisfying the code requirements for a RC-II building*
- *Comparison of Elastic and Nonlinear response from IDARC and ETABS as validation of computer program accuracy and results.*
- *Addition of an extended stiff podium with a transfer diaphragm at the first level and reinforce concrete shear walls as the lateral force resisting system*
- *Observations and recommendations*

Code Context: Vertical Combinations (ASCE 7-22)

- **Section 12.2.3: Combination of framing systems in the same direction**

12.2.3.1 R, C_d, and Ω_0 Values for Vertical Combinations Where a structure has a vertical combination in the same direction, the following requirements shall apply.

1. Where the lower system has a lower response modification coefficient, R, the design coefficients (R, Ω_0, and C_d) for the upper system are permitted to be used to calculate the forces and drifts of the upper system. For the design of the lower system, the design coefficients (R, Ω_0, and C_d) for the lower system shall be used. Forces transferred from the upper system to the lower system shall be increased by multiplying by the ratio of the higher response modification coefficient to the lower response modification coefficient.
2. Where the upper system has a lower response modification coefficient, the design coefficients (R, Ω_0, and C_d) for the upper system shall be used for both systems.



Code Context: Vertical Combinations (ASCE 7-22)

Section 12.2.3: Combination of framing systems in the same direction

Example: For a 7 story Moment frame structure over a one-story podium structure

- How are the forces for the lower structure calculated?
  - Model building as one structure and use the corresponding R's when determining the demands in the upper and lower structure?
    - ➢ What building system and R would you use when estimating the period used for calculation of the base shear for the lower structure?
    - ➢ Are the forces determined from a response spectra analysis or ELF?
  - Calculate the base shear for the lower structure with that mass only and add forces amplified by R/ρ to the lower structure (Two-stage)?
    - ➢ Calculate base shear coefficient based on period and R of the lower structure.
    - ➢ Calculate base shear coefficient based on period of the combined system.
- Any other options?

12.2.3.1 R, C_d, and Ω_0 Values for Vertical Combinations Where a structure has a vertical combination in the same direction, the following requirements shall apply.

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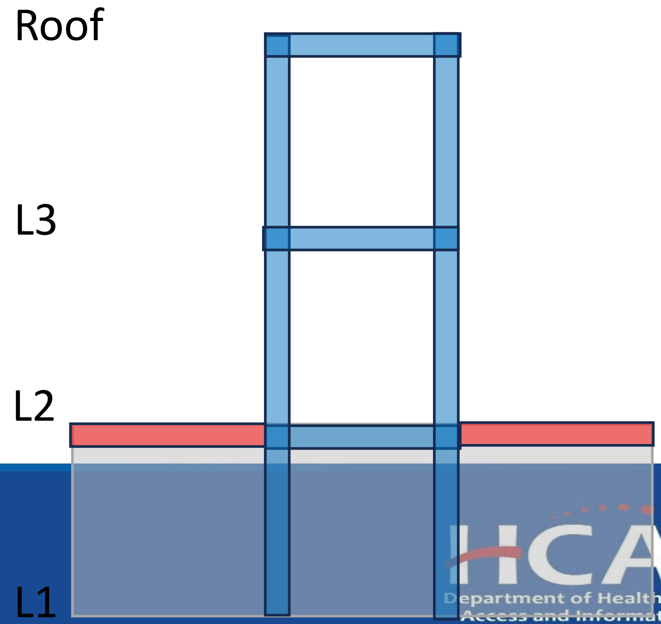
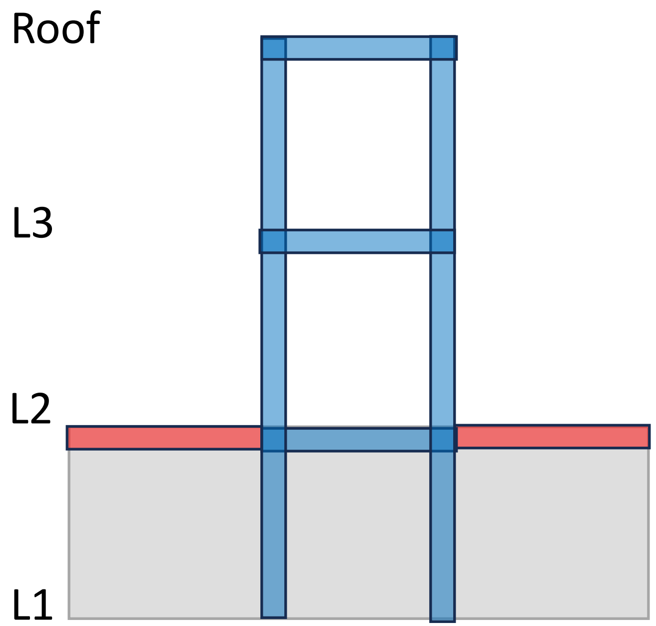


Code Context: Vertical Combinations (ASCE 7-22)

- **Section 12.2.3.2 : Two Stage Analysis**

12.2.3.2 Two-Stage Analysis Procedure for Vertical Combinations of Systems A two-stage equivalent lateral force procedure is permitted to be used for structures that have a flexible upper portion above a rigid lower portion, provided the design of the structure complies with all of the following.

(a) The stiffness of the lower portion shall be at least 10 times the stiffness of the upper portion. For purposes of determining this ratio, the base shear shall be computed and distributed vertically according to Section 12.8. Using these forces, the stiffness for each portion shall be computed as the ratio of the base shear for that portion to the elastic displacement, δ_e, computed at the top of that portion, considering the portion fixed at its base. For the lower portion, the applied forces shall include the reactions from the upper portion, modified as required in Item (d).



Code Context: Vertical Combinations (ASCE 7-22)

- **Section 12.2.3.2 : Two Stage Analysis**

(b) The period of the entire structure shall not be greater than 1.1 times the period of the upper portion considered as a separate structure supported at the transition from the upper to the lower portion.

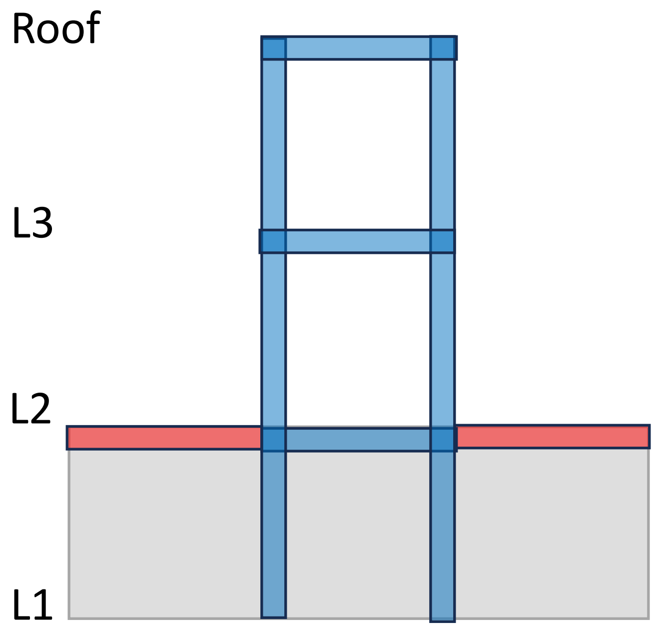
(c) The upper portion shall be designed as a separate structure using the appropriate values of R and ρ.

(d) The lower portion shall be designed as a separate structure using the appropriate values of R and ρ while meeting the requirements of Section 12.2.3.1. The reactions from the upper portion shall be those determined from the analysis of the upper portion, where the effects of the horizontal seismic load, E_h, are amplified by the ratio of the R/ρ of the upper portion over R/ρ of the lower portion. This ratio shall not be less than 1.0.

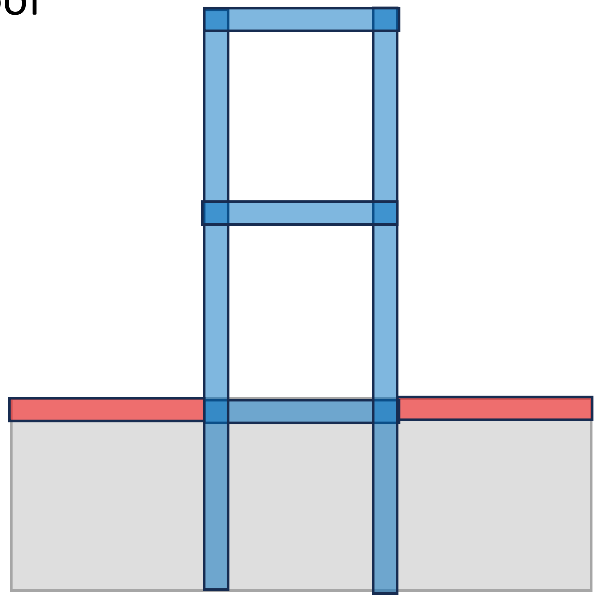
(e) The upper portion is analyzed with the equivalent lateral force or modal response spectrum procedure, and the lower portion is analyzed with the equivalent lateral force procedure.

(f) The structural height of the upper portion shall not exceed the height limits of Table 12.2-1 for the seismic force-resisting system used, where the height is measured from the base of the upper portion.

(g) Where Horizontal Irregularity Type 4 or Vertical Irregularity Type 3 exists at the transition from the upper to the lower portion, the reactions from the upper portion shall be amplified in accordance with Sections 12.3.3.4, 12.10.1.1, and 12.10.3.3, in addition to amplification required by Item (d).



Code Context: Two-Stage (7-22)



- Section 12.2.3.2: Two-Stage Analysis

(d) The lower portion shall be designed as a separate structure using the appropriate values of R and ρ while meeting the requirements of Section 12.2.3.1. The reactions from the upper portion shall be those determined from the analysis of the upper portion, where the effects of the horizontal seismic load, E_h, are amplified by the ratio of the R/ρ of the upper portion over R/ρ of the lower portion. This ratio shall not be less than 1.0.

(g) Where Horizontal Irregularity Type 4 or Vertical Irregularity Type 3 exists at the transition from the upper to the lower portion, the reactions from the upper portion shall be amplified in accordance with Sections 12.3.3.4, 12.10.1.1, and 12.10.3.3, in addition to amplification required by Item (d).

Added in ASCE 7-22 and in 2022 CBC Section 1617A.1.5.3

C12.2.3.2 Two-Stage Analysis Procedure

Where horizontal structural irregularity Type 4 (out-of-plane offset) or vertical structural irregularity Type 3 (in-plane discontinuity) is present at the transition from the upper portion to the lower portion, the requirement for the overstrength effects is associated with the expected peak capacity of the upper portion. The ratio of R/ρ values (that of the lower portion to that of the upper portion) is associated with the effect of the upper portion mass on the lower portion, which is a separate consideration. These two effects are required to be used in combination where applicable. Overstrength effects include but are not limited to the requirements of Section 12.3.3.4 for elements supporting discontinued walls or frames and the requirements of Sections 12.10.1 and 12.10.3.3 for diaphragm transfer forces. See also Commentary Section C12.3.3.4.

12.3.3.4 Elements Supporting Discontinuous Walls or Frames Structural elements supporting discontinuous walls or frames of structures that have horizontal irregularity Type 4 of Table 12.3-1 or vertical irregularity Type 3 of Table 12.3-2 shall be designed to resist the seismic load effects, including overstrength of Section 12.4.3. The connections of such discontinuous walls or frames to the supporting members shall be adequate to transmit the forces for which the discontinuous walls or frames were required to be designed.

12.10.1.1 Diaphragm Design Forces Floor and roof diaphragms shall be designed to resist in-plane seismic design forces from the structural analysis but shall not be less than that determined in accordance with Equation (12.10-1) as follows:

$$F_{px} = \frac{\sum_{i=x}^{n} F_i}{\sum_{i=x}^{n} w_i} w_{px} \qquad (12.10\text{-}1)$$

where

F_{px} = Diaphragm design force at level x;
F_i = Design force applied to level i;
w_i = Weight tributary to level i; and
w_{px} = Weight tributary to the diaphragm at level x.

The force determined from Equation (12.10-1) shall not be less than

$$F_{px} = 0.2 S_{DS} I_e w_{px} \qquad (12.10\text{-}2)$$

The force determined from Equation (12.10-1) need not exceed

$$F_{px} = 0.4 S_{DS} I_e w_{px} \qquad (12.10\text{-}3)$$

Diaphragms shall be designed for the inertial forces determined from Equations (12.10-1) through (12.10-3) and for applicable transfer forces resisted by the diaphragm between vertical seismic force-resisting elements. For structures that have a horizontal structural irregularity of Type 4 in Table 12.3-1, the transfer forces between horizontally offset vertical seismic force-resisting elements shall be increased by the overstrength factor of Section 12.4.3 before being added to the diaphragm inertial forces. For structures that have horizontal or vertical structural irregularities of the types indicated in Section 12.3.3.5, the requirements of that section shall also apply.

Code Context: Two-Stage (7-22)

- Section 12.2.3.2: Two-Stage Analysis

12.10.3.3 Transfer Forces in Diaphragms Diaphragms designed in accordance with this section shall be designed for the inertial forces determined from Equations (12.10-4) and (12.10-5) and for applicable transfer forces acting through the diaphragm between vertical seismic force-resisting elements. For structures that have a horizontal structural irregularity of Type 4 in Table 12.3-1, the transfer forces between horizontally offset vertical seismic force-resisting elements shall be increased by the overstrength factor of Section 12.4.3 before being added to the diaphragm inertial forces. For structures that have other horizontal or vertical structural irregularities of the types indicated in Section 12.3.3.5, the requirements of that section shall also apply.

EXCEPTION: One- and two-family dwellings of light-frame construction shall be permitted to use $\Omega_0 = 1.0$.

12.3.3.5 Increase in Forces Caused by Irregularities for Seismic Design Categories D through F For structures assigned to Seismic Design Category D, E, or F and having a horizontal structural irregularity of Type 1, 2, 3, or 4 in Table 12.3-1 or a vertical structural irregularity of Type 3 in Table 12.3-2, the design forces determined from Section 12.10.1.1 shall be increased 25% at each diaphragm level where the irregularity occurs for the following elements of the seismic force-resisting system:

1. Connections of diaphragms to vertical elements and to collectors, and
2. Collectors and their connections, including connections to vertical elements of the seismic force-resisting system.

EXCEPTION: Forces calculated using the seismic load effects including overstrength of Section 12.4.3 need not be increased.

12.10.3.2 Seismic Design Forces for Diaphragms, Including Chords and Collectors Diaphragms, including chords, collectors, and their connections to the vertical elements, shall be designed to resist in-plane seismic design forces given by Equation (12.10-4):

$$F_{px} = \frac{C_{px}}{R_s} w_{px} \quad (12.10\text{-}4)$$

The force F_{px} determined from Equation (12.10-4) shall not be less than:

$$F_{px} = 0.2 S_{DS} I_e w_{px} \quad (12.10\text{-}5)$$

C_{px} shall be determined as illustrated in Figure 12.10-2.

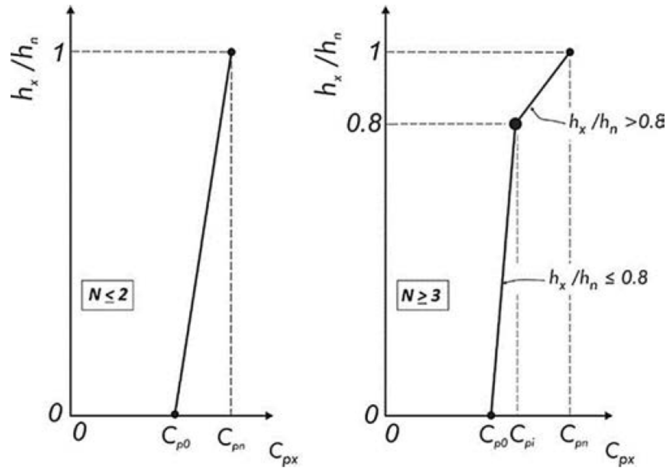


Figure 12.10-2. Calculating the design acceleration coefficient, C_{px}, in buildings with $N \le 2$ and in buildings with $N \ge 3$.

and

$$C_{pn} = \sqrt{(\Gamma_{m1}\Omega_0 C_s)^2 + (\Gamma_{m2} C_{s2})^2} \ge C_{pi} \quad (12.10\text{-}7)$$

Design acceleration coefficient, C_{pi}, shall be the greater of the values given by Equations (12.10-8) and (12.10-9):

$$C_{pi} = 0.8 C_{p0} \quad (12.10\text{-}8)$$

$$C_{pi} = 0.9 \Gamma_{m1} \Omega_0 C_s \quad (12.10\text{-}9)$$

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Broader Context: Irregularities: ASCE 7-22

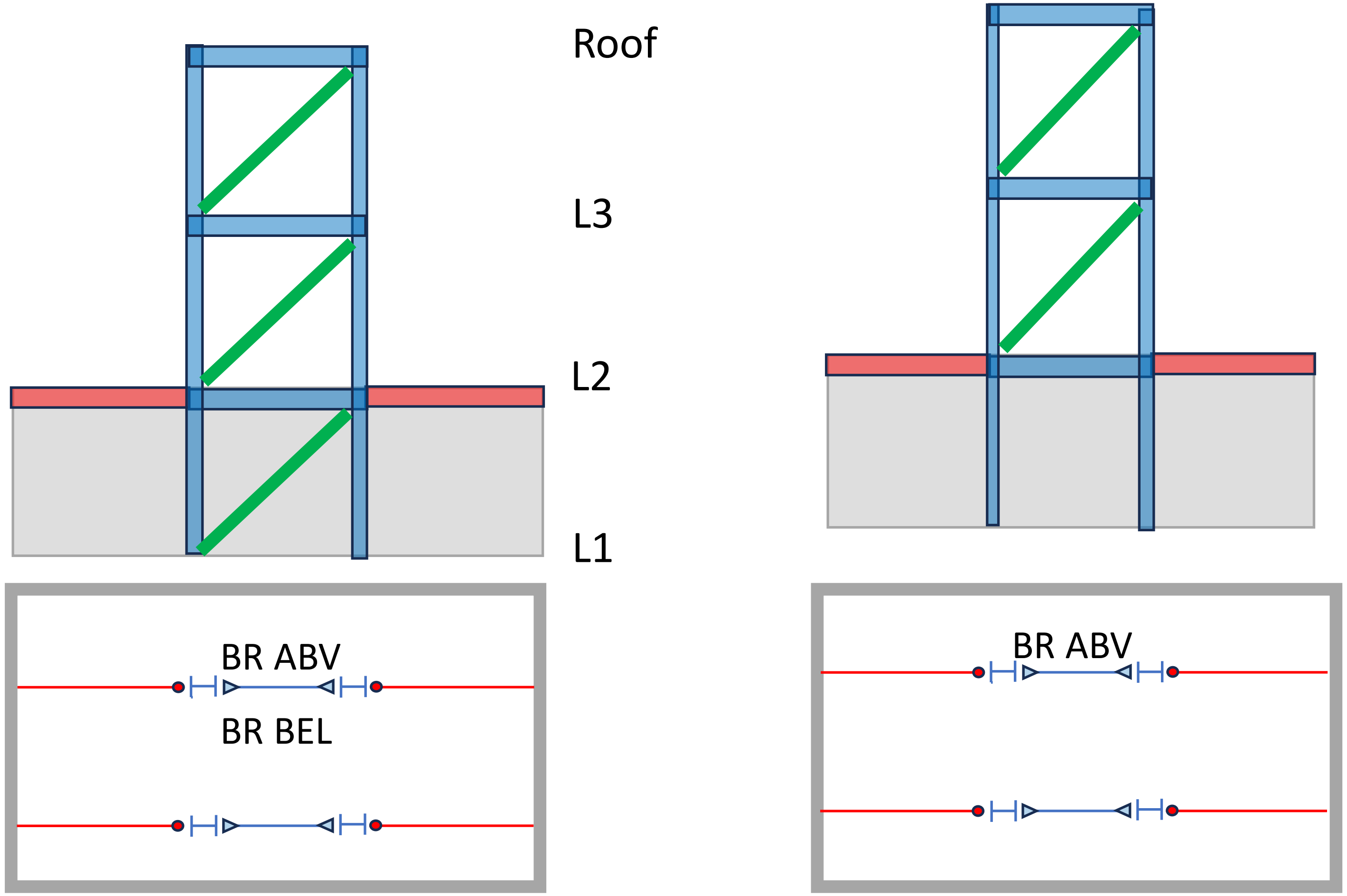


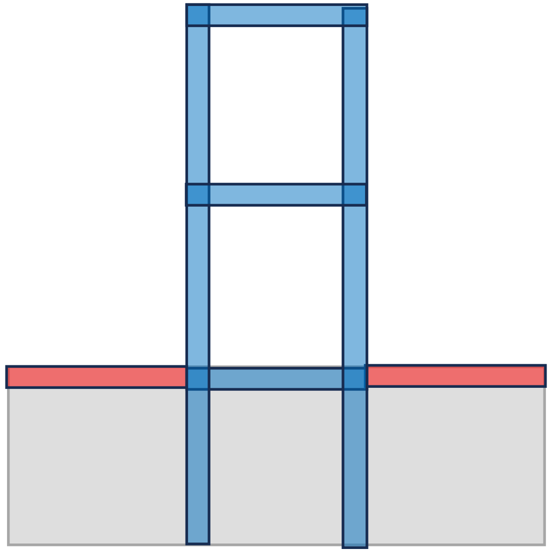
Table 12.3-2 Vertical Structural Irregularity

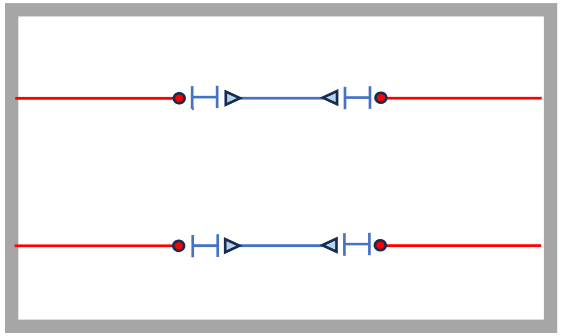
- **Type 3 In-Plane Discontinuity in Vertical Lateral Force-Resisting Irregularity** is defined to exist where there is an in-plane offset of a vertical seismic force-resisting element resulting in overturning demands on supporting structural elements.

Right image situation is clearly a Type 3 Vertical Irregularity.

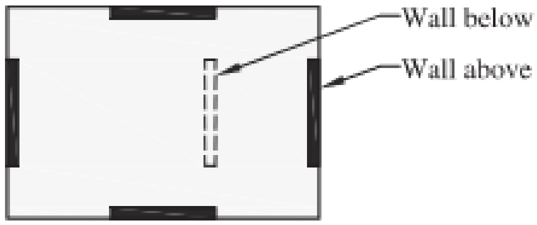
Is the left image situation also one? The brace is continuous, but the vast majority of the load will transfer out from the braced frame at L2 to the shear walls.

Broader Context: Are these irregularities present (7-22)





- Table 12.3-1 Horizontal Structural Irregularity
  - **Type 4 Out-of-Plan Offset Irregularity**: Out-of-plane offset irregularity, defined to exist where there is a discontinuity in a lateral force-resistance path, such as an out-of-plane offset of at least one of the vertical elements.



Type 4. Out-of-plane offset

Figure is from ASCE 7-16 since ASCE 7-22 has a typo

- Table 12.3-2 Vertical Structural Irregularity
  - **Type 3 In-Plane Discontinuity in Vertical Lateral Force-Resisting Irregularity** is defined to exist where there is an in-plane offset of a vertical seismic force-resisting element resulting in overturning demands on supporting structural elements.

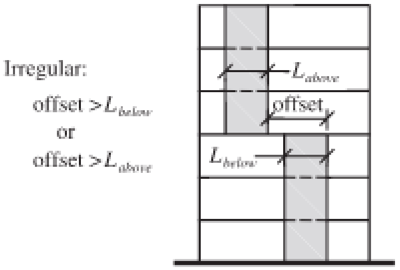


Figure is from ASCE 7-16 since it is missing in ASCE 7-22

Case Study Example: 7 - Story Concrete SMF

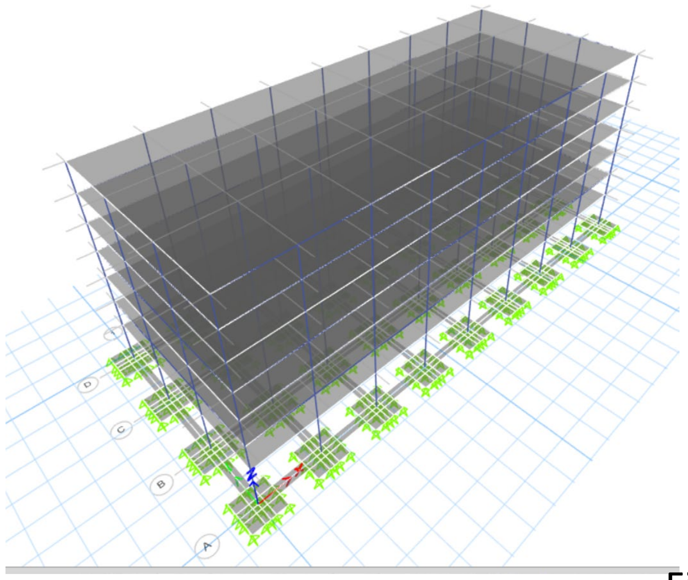
Models and analysis are intended to simulate design for a Special Moment Frame RC-II Building

Example: 7 - Story Concrete Special Moment Frame

- *Building is a modified version of the 7-story Van Nuys building with the following modifications*

- *General Assumptions - Linear Elastic Properties*
  - *Building modeled on shallow foundations*
  - *Beam and column dimensions modified to satisfy ACI and ASCE 7 strength and drift requirements*
  - *Only Longitudinal direction considered.*
  - *Beam Stiffness = 0.3 EI*
  - *Column Stiffness = 0.3 – 0.5 EI*
  - *No shear failures*
  - *Strong column weak beam satisfied*
  - *Fixed Base assumptions*

  - *Building Periods Longitudinal Direction*
    - *Mode 1 = 1.45 second*
    - *Mode 2 = 0.54 seconds*
    - *Mode 3 = 0.28 seconds*



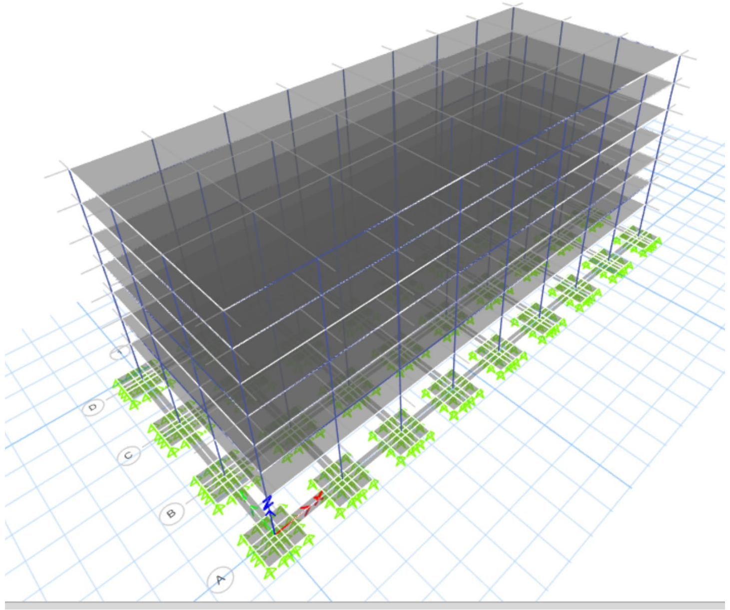
Model 1
Fixed Base Model

Example: 7 - Story Concrete Special Moment Frame

- ***Ground motion data***
  - $S_{DS} = 1.62$
  - $S_{D1} = 0.64g$

Base Shear Calculation

S_{DS}	1.620	g
S_{D1}	0.640	g
C_t	0.016	
h_n	65.7	ft
x	0.9	
C_u	1.40	S_{D1} > 0.4 s
R	8.0	Reinforced Concrete SMRF
I_e	1.0	Risk Category II
$T_{Building}$	1.450	Fixed based period
T_0	0.079	sec
T_s	0.395	sec
T_a	0.69	sec
T	0.97	sec
$\mathbf{C_s}$	**0.08**	
V =	**826**	kips



Model 1

Fixed Base Model

ASCE 7- 22 Design Check – Forces (ELF Method)

- $S_{DS} = 1.62$
- $S_{D1} = 0.64g$

S_{DS}	1.620	g
S_{D1}	0.640	g
C_t	0.016	
h_n	65.7	ft
x	0.9	
C_u	1.40	S_{D1} > 0.4 s
R	8.0	Reinforced Concrete SMRF
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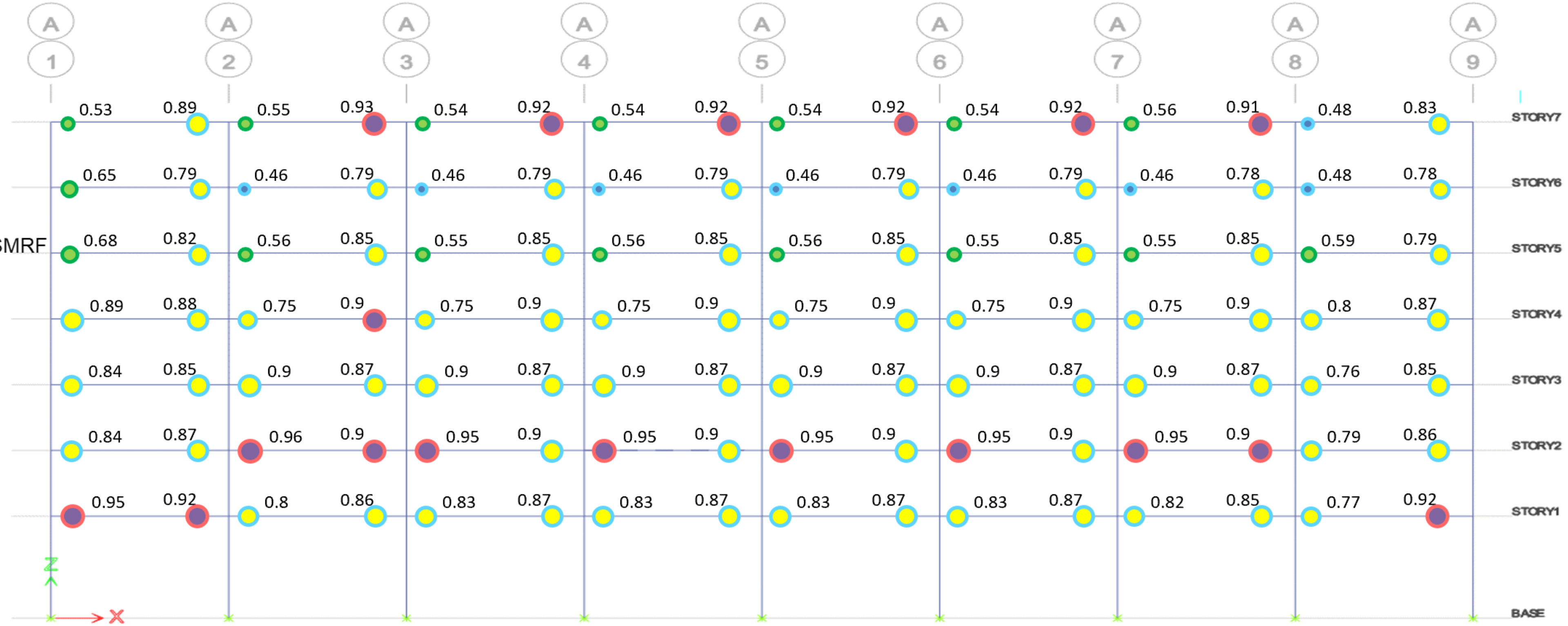
T	0.97	sec
C_s	**0.08**	
V =	**826**	kips



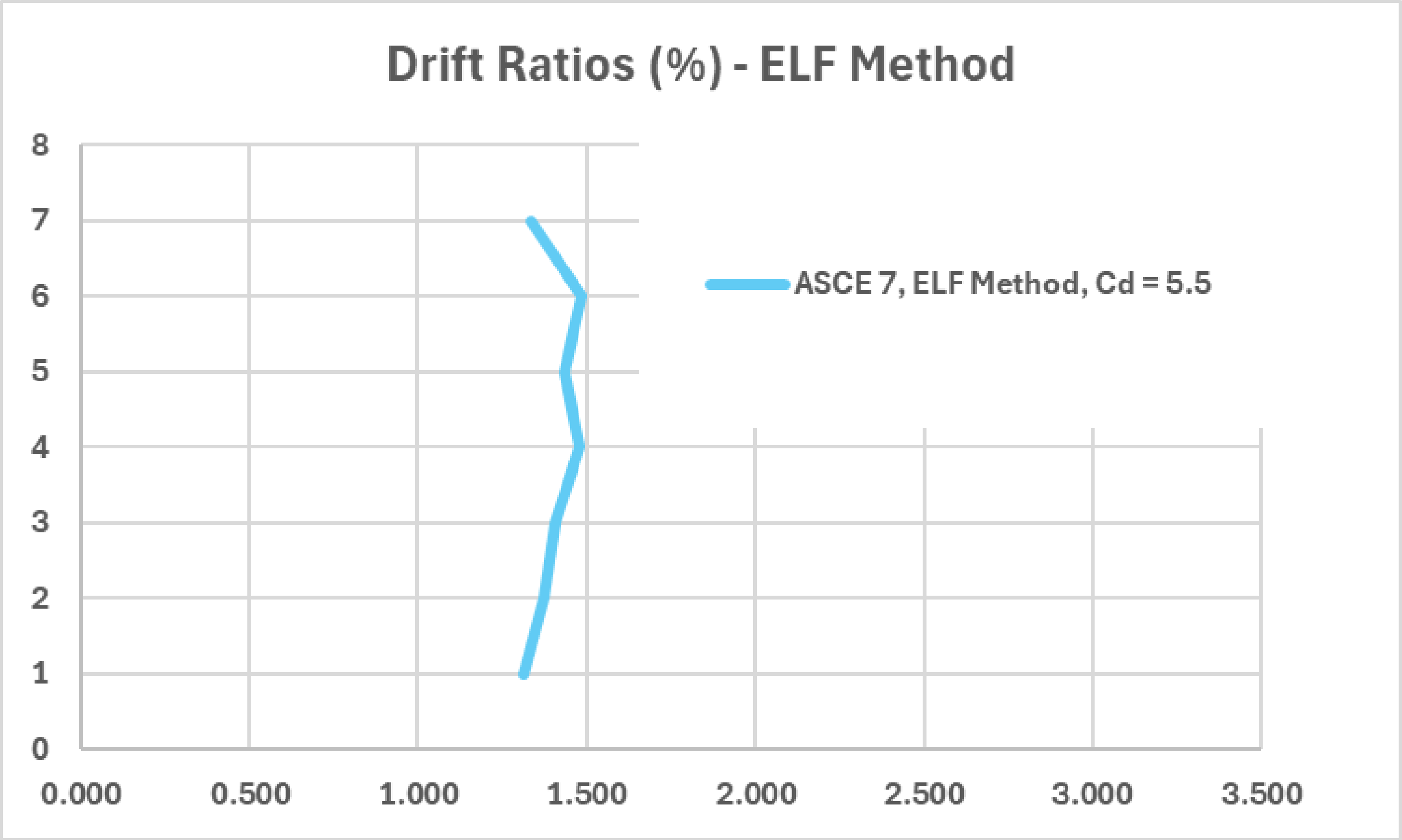
Beam moment DCRs. Left is + moment DCR, Right is – moment DCR
Loading +X Direction, ELF Method

Example 7-Story Building (Concrete MF)

ASCE 7- 22 Design Check Drifts (ELF Method)

- $S_{DS} = 1.62$
- $S_{D1} = 0.64g$

S_{DS}	1.620	g
S_{D1}	0.640	g
C_t	0.016	
h_n	65.7	ft
x	0.9	
C_u	1.40	S_{D1} > 0.4 s
R	8.0	Reinforced Concrete SMRF
I_e	1.0	Risk Category II
$T_{Building}$	1.450	Fixed based period
T_0	0.079	sec
T_s	0.395	sec
T_a	0.69	sec
T	0.97	sec
C_s	**0.08**	
V =	**826**	



Example 7-Story Building (Concrete MF)

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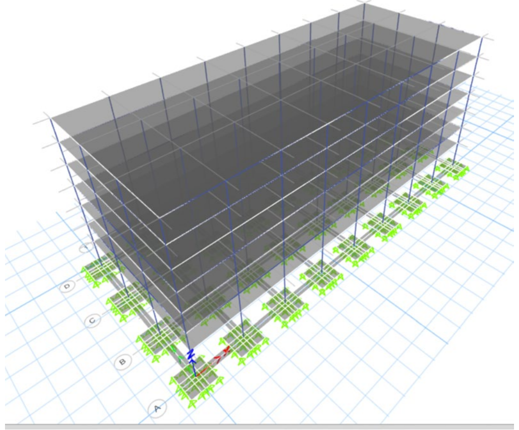
Example: 7 - Story Concrete Special Moment Frame

- *General Assumptions – Nonlinear Analysis model*
- *Two models created an ETABS model and an IDARC model for verification*

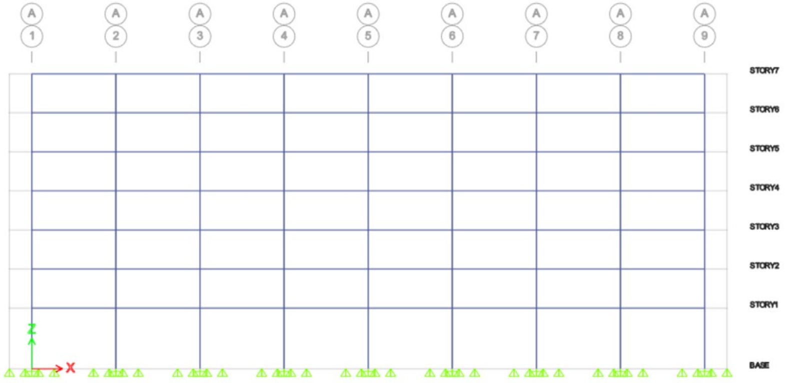
- *ETABS Model – Nonlinear direct integration*
  - *Newmark Direct Integration Method - Alpha = 0.1 Beta = 0.005*
  - *Hysteretic model – Takeda*
  - *Post yield stiffness ≈ 10 – 15%*

- *IDARC Model (Used as verification of the ETABS model inelastic results)*
  - *Stiffness sand mass similar to ETABS elastic model dynamic properties*
  - *Hysteretic model 3 Parameter model modified to match Takeda Model*
  - *Post yield stiffness 0.15%*
  - *Unload stiffness similar to Takeda model*
  - *Newmark Direct Integration Method - Alpha = 0.1 Beta = 0.005*



Model 1

Fixed Base Model



Example 7-Story Building (Concrete MF)

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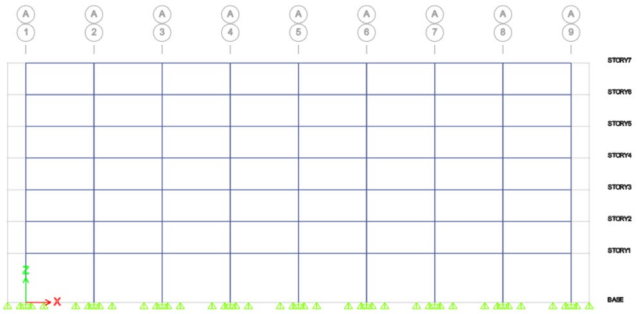
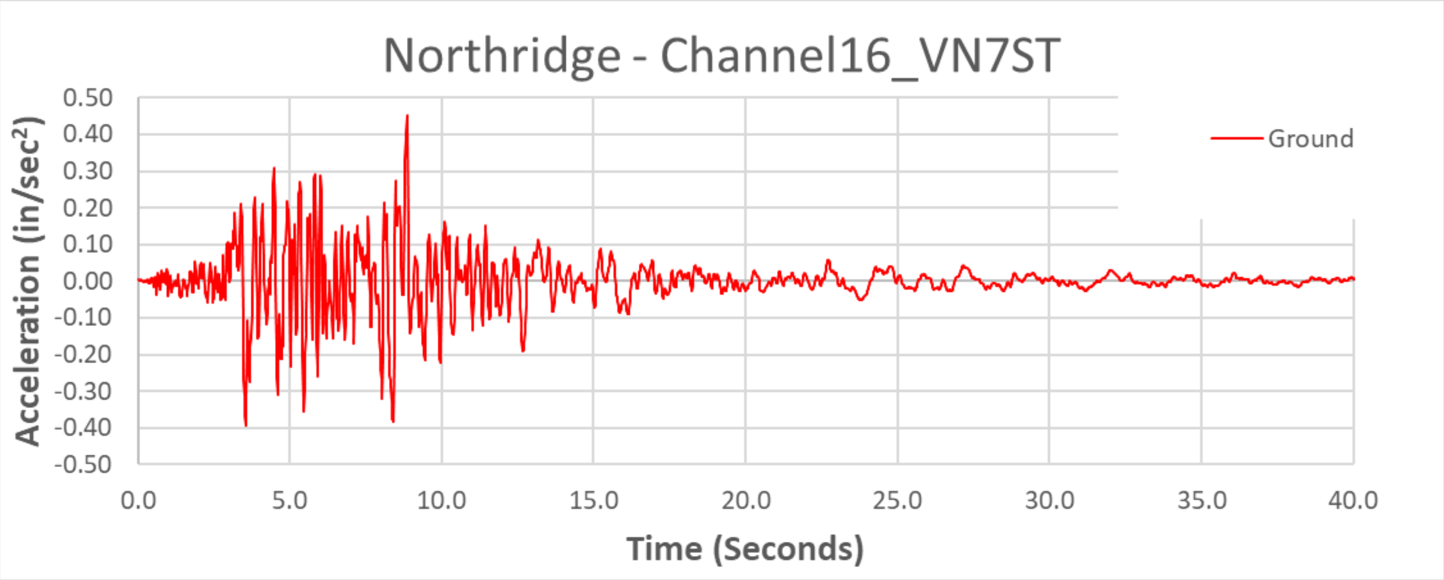
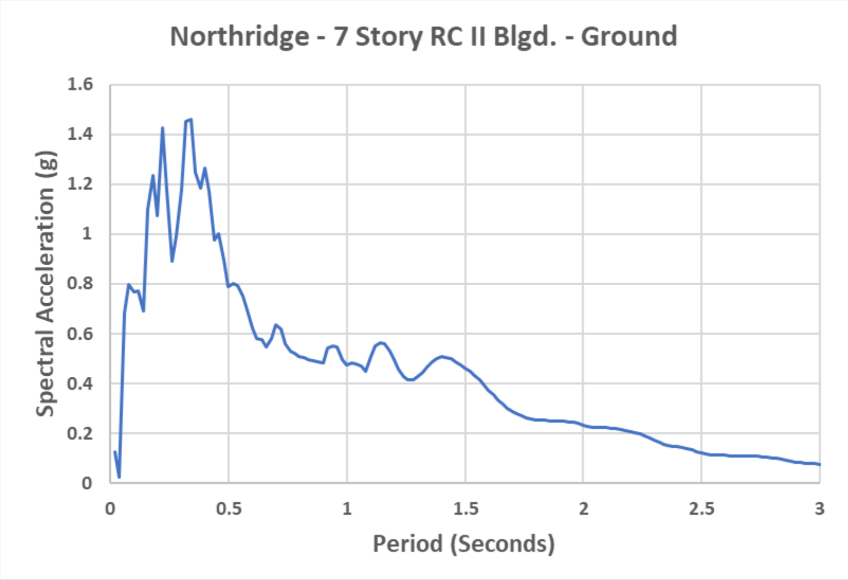
Earthquake Record – Northridge (Van Nuys)

- *PGA – 0.453g*



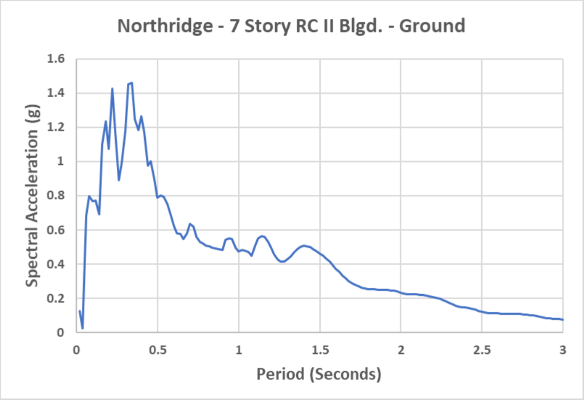


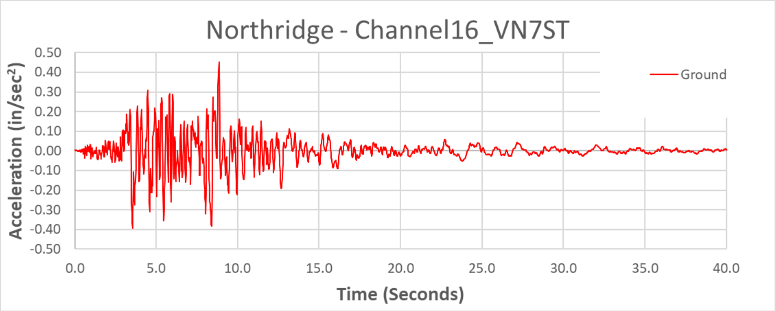


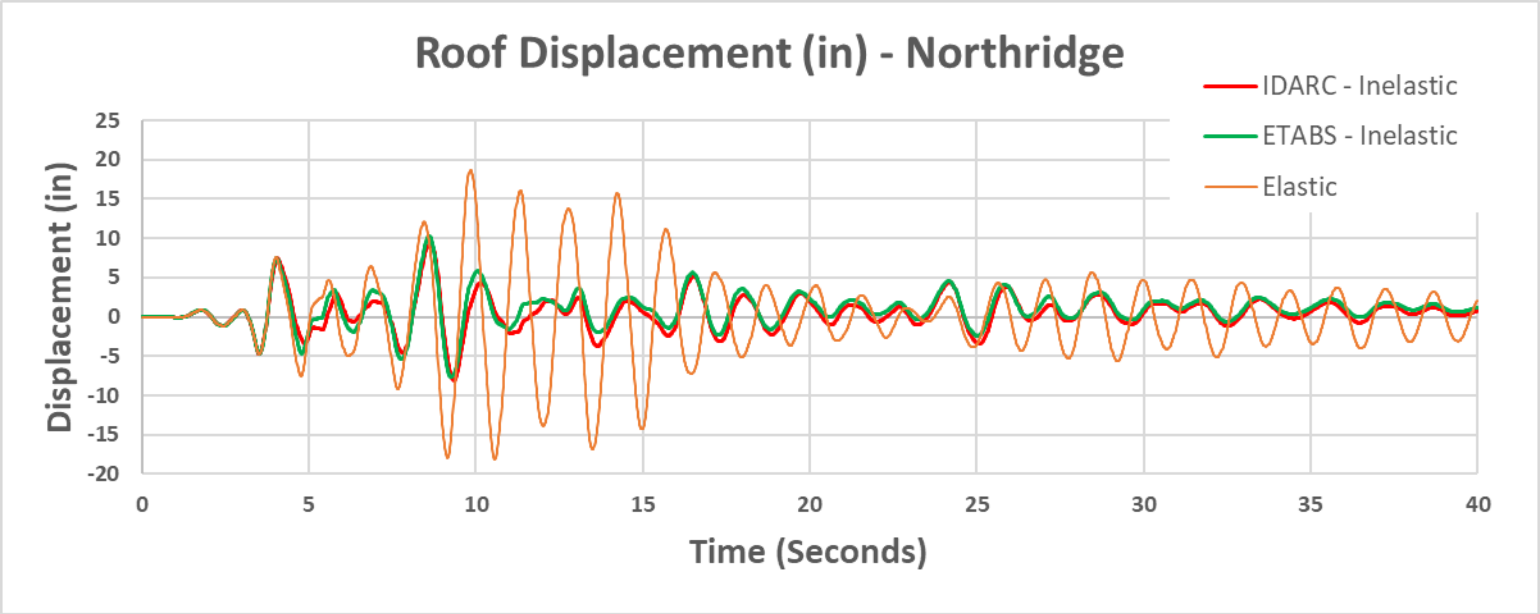
Example 7-Story Building (Concrete MF)

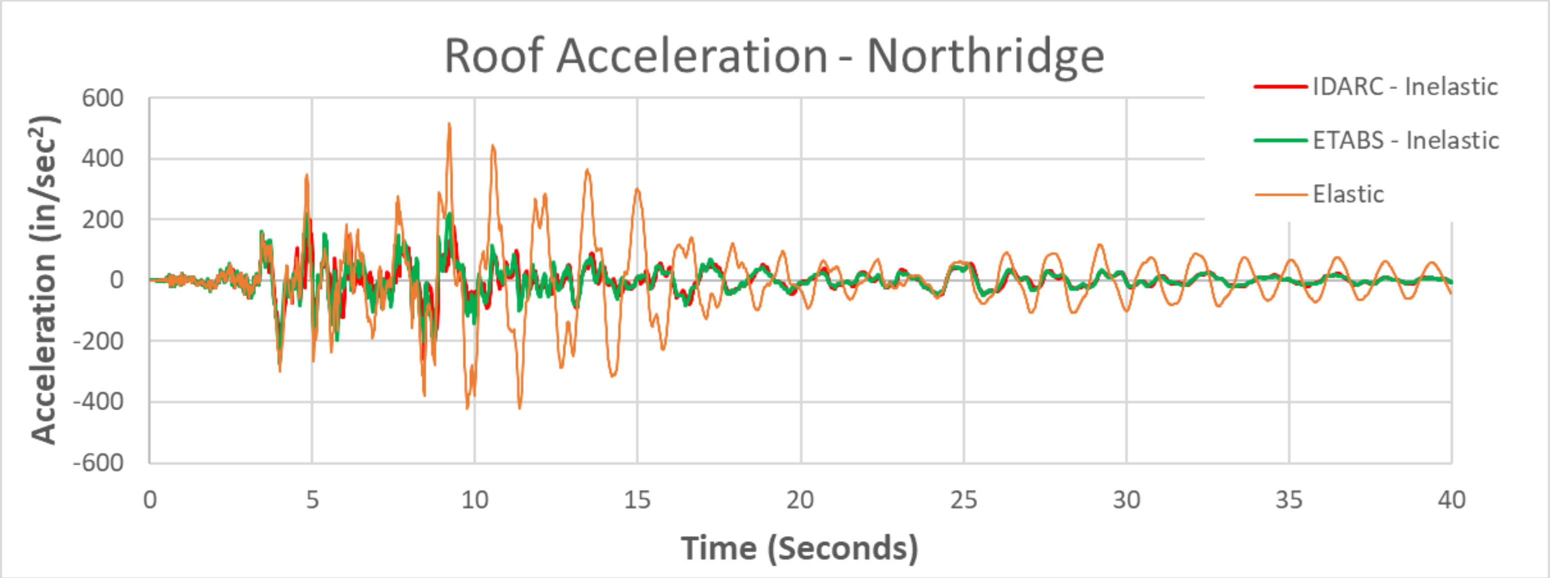
Time History Comparisons – Northridge (Van Nuys)

- ***PGA – 0.453g***
- Model 1 (FB)
- 1^{st} Mode Period = 1.45 seconds





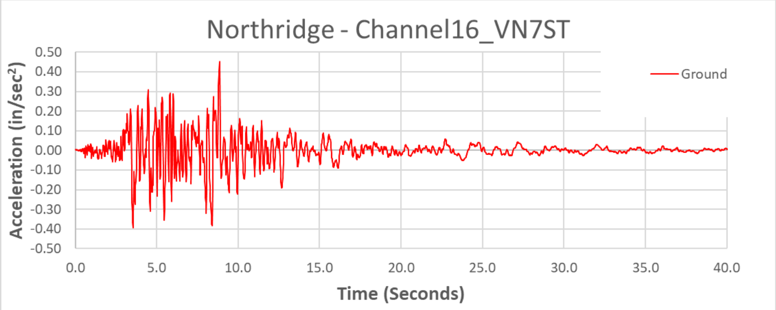


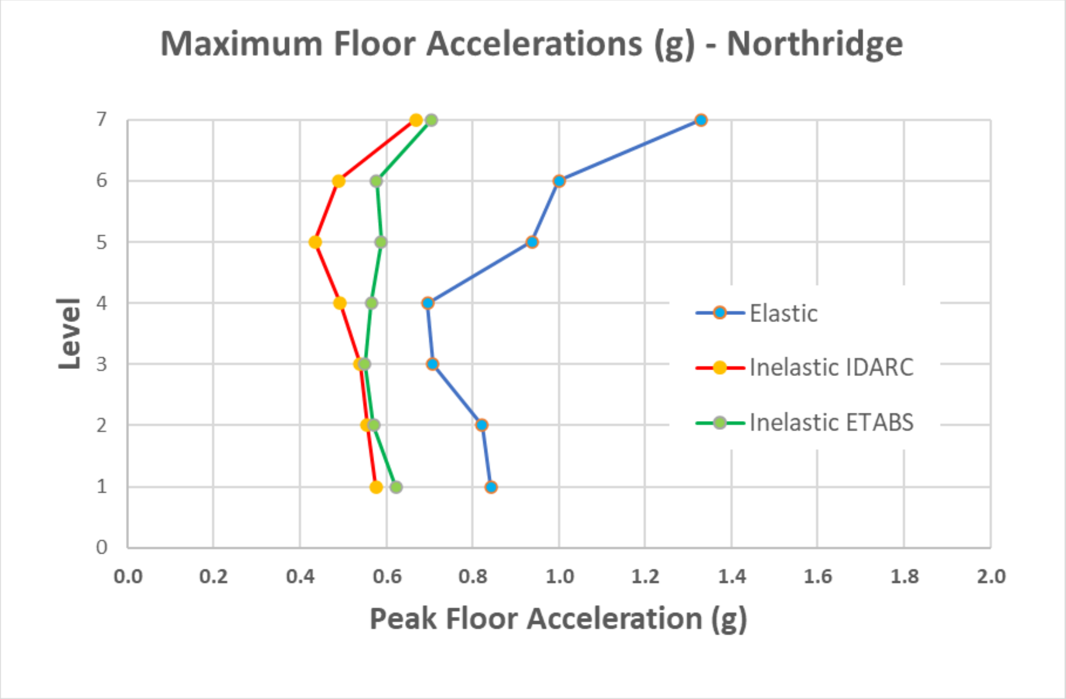


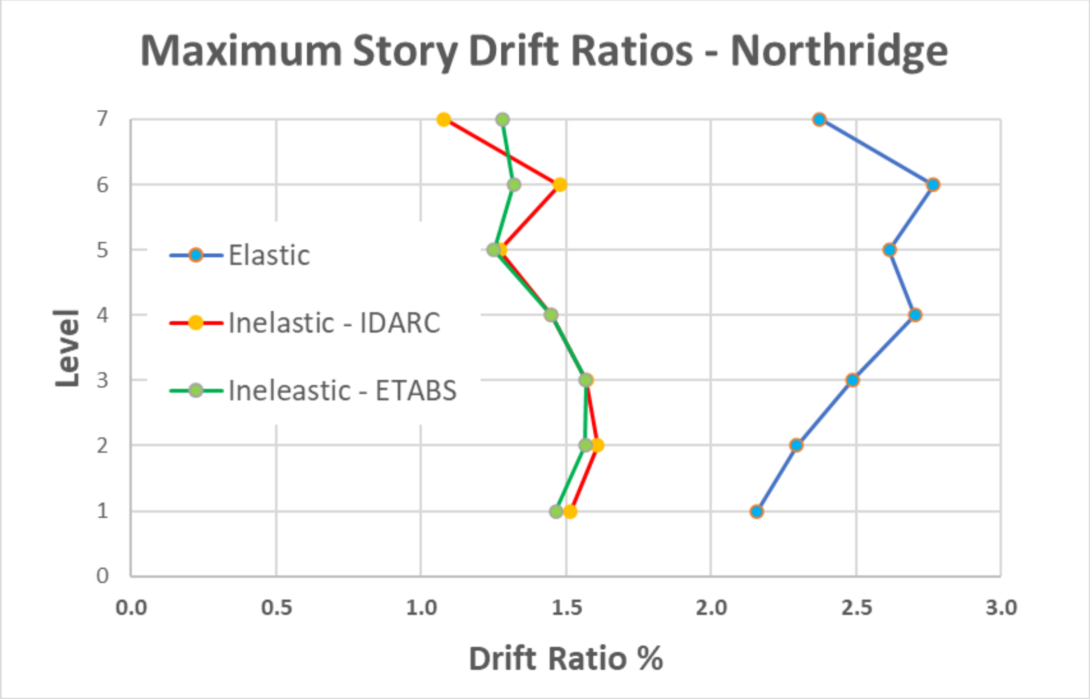
Example 7-Story

Comparison of Maximum Responses – Northridge (Van Nuys)

- ***PGA – 0.453 g***
- Model 1 (FB)
- 1st Mode Period = 1.45 seconds





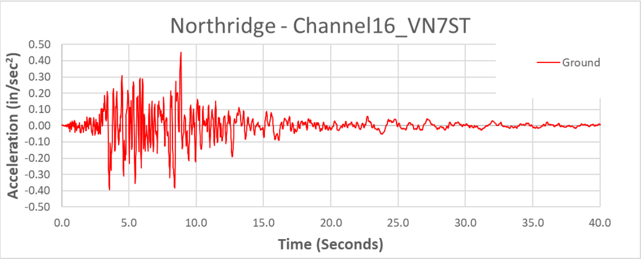


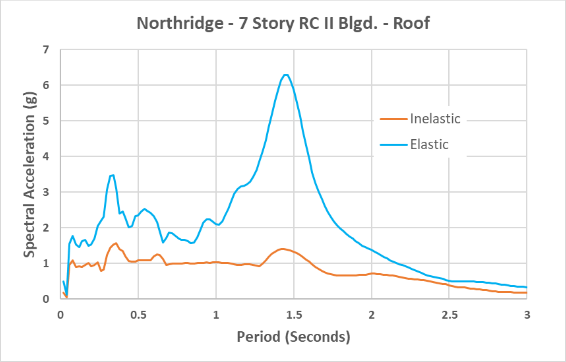
Floor Response Spectrum – Northridge (7-story hotel site)

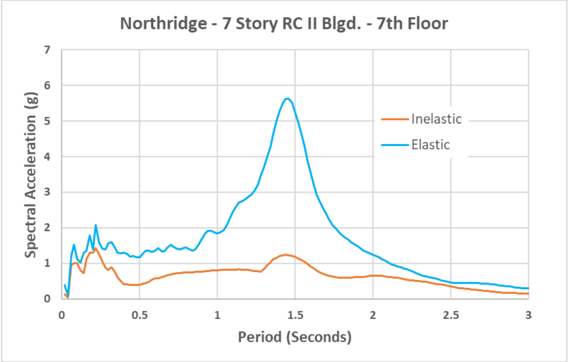
- ***PGA – 0.453 g***

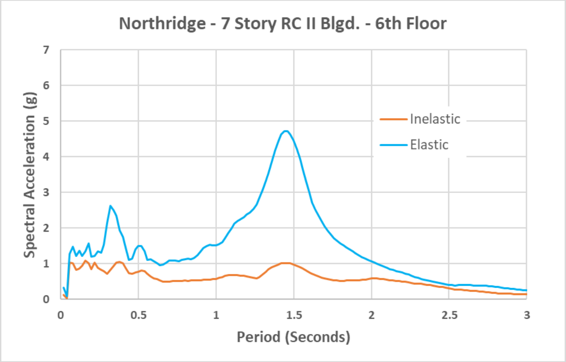
Model 1 (FB)

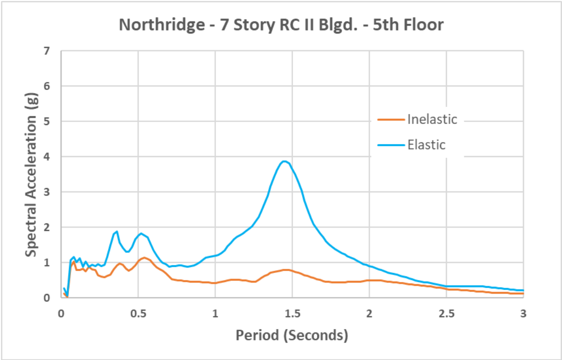
Mode 1 = 1.45 s
Mode 2 = 0.54 s
Mode 3 = 0.28 s

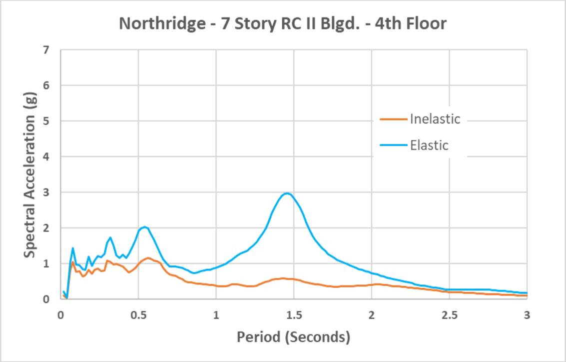


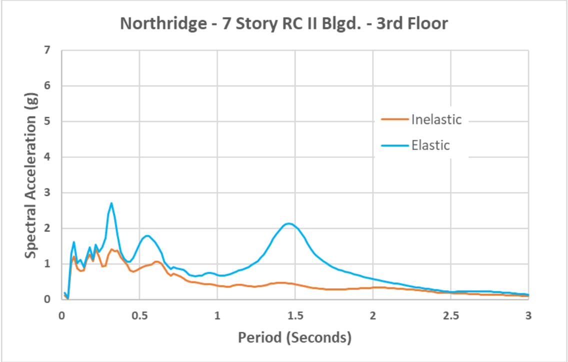


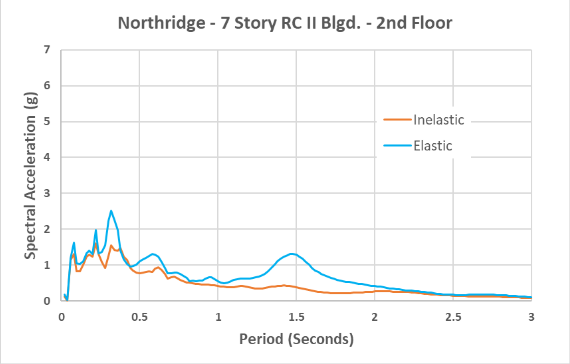


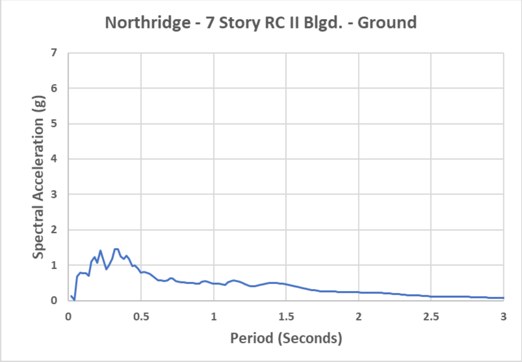






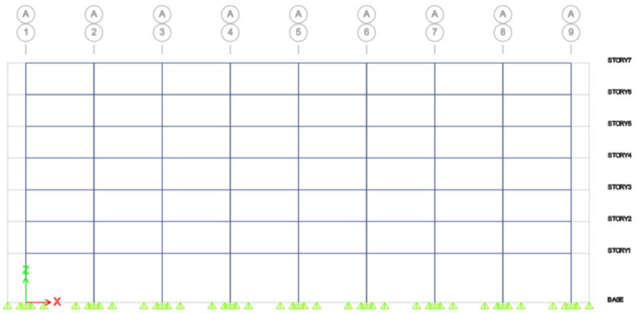


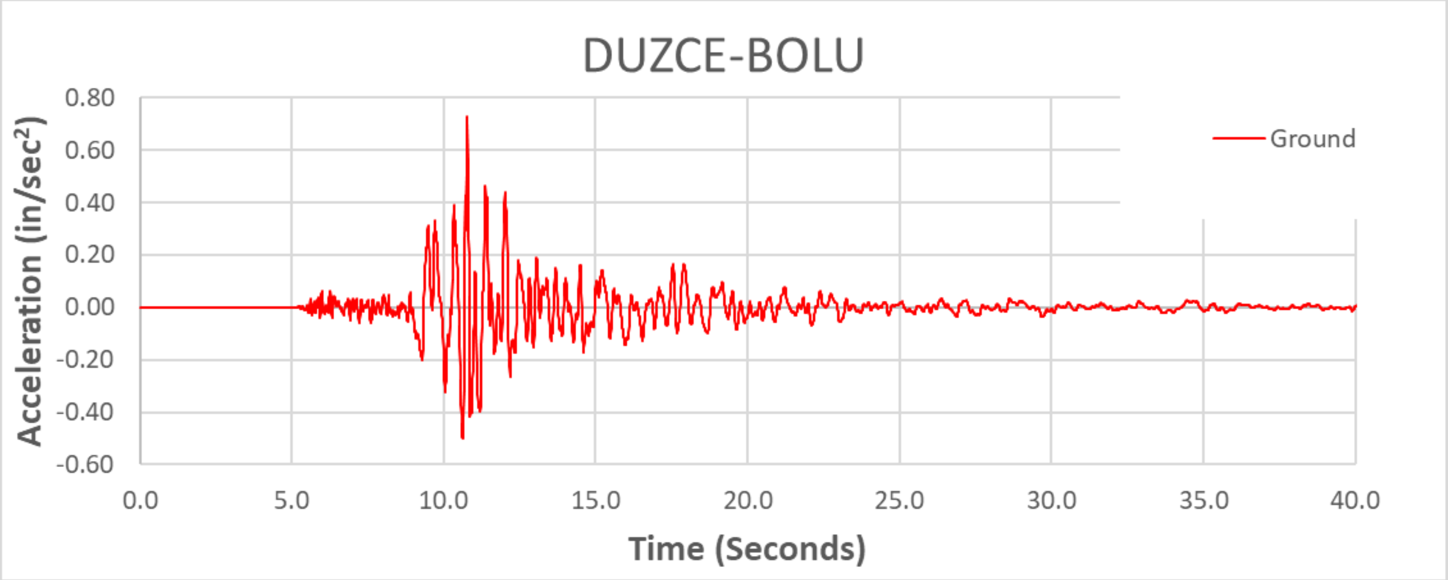


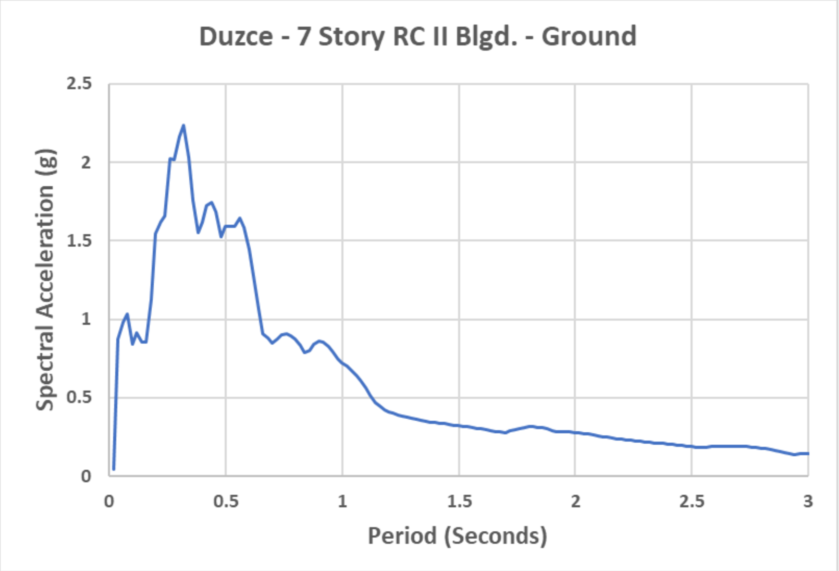


Earthquake Record – Duzce - Bolu

- *PGA – 0.726 g*







Example 7-Story Building (Concrete MF)

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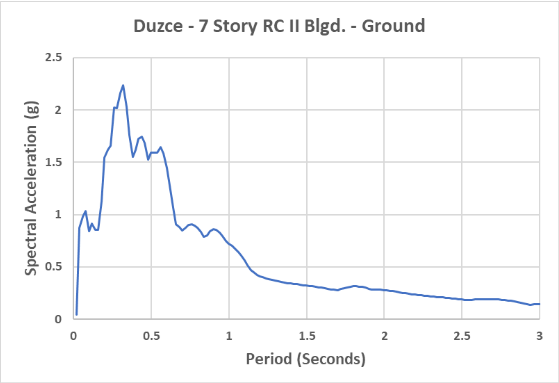
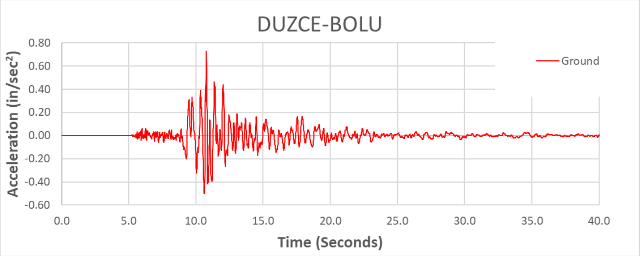
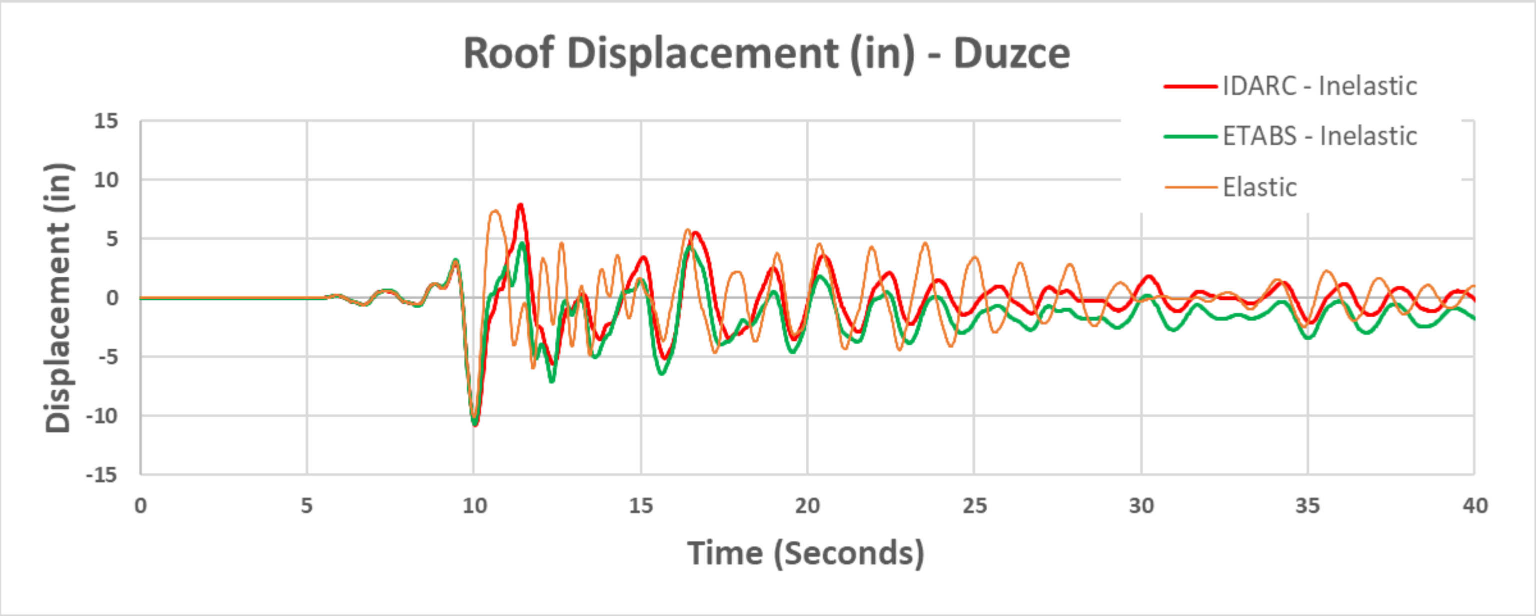
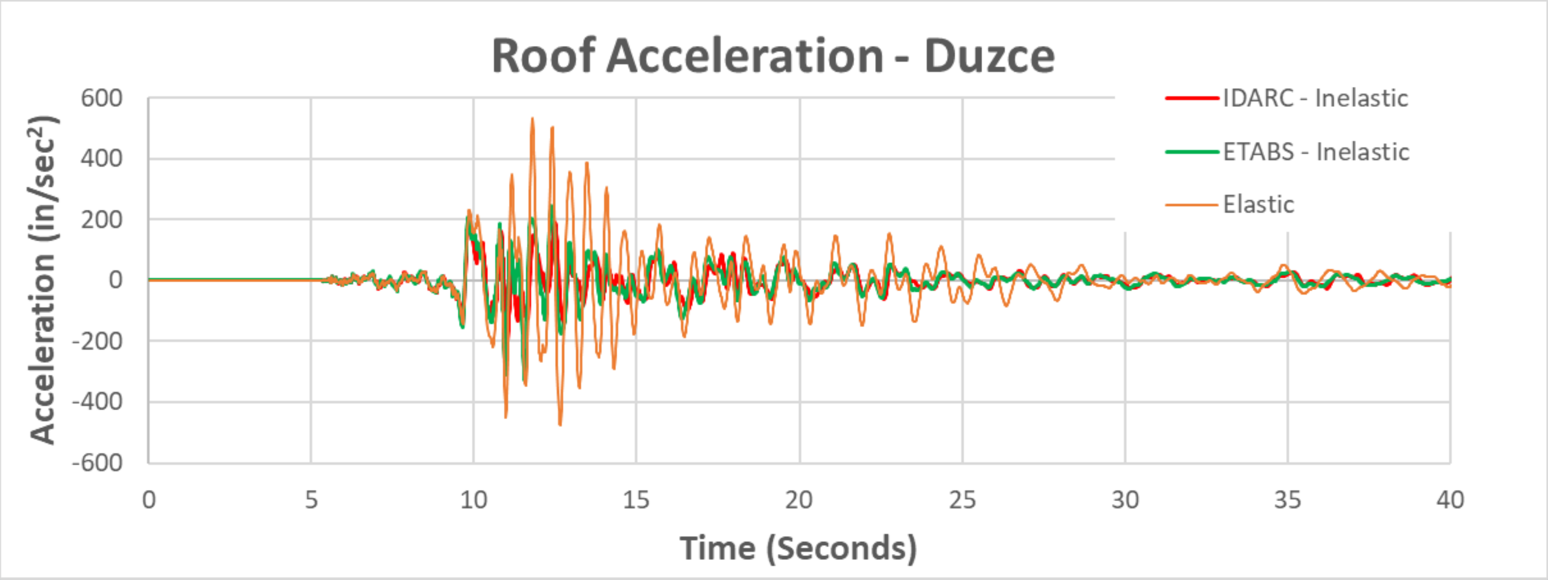
Time History Comparisons – Duzce Bolu

- ***PGA – 0.726g***
- Model 1 (FB)
- 1st Mode Period = 1.45 seconds





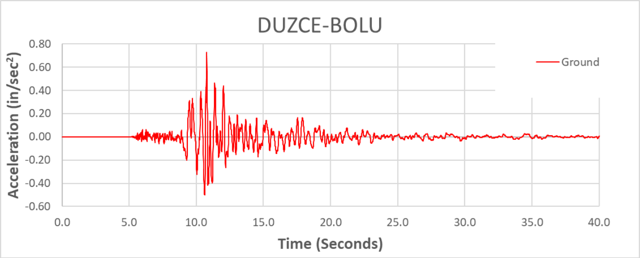


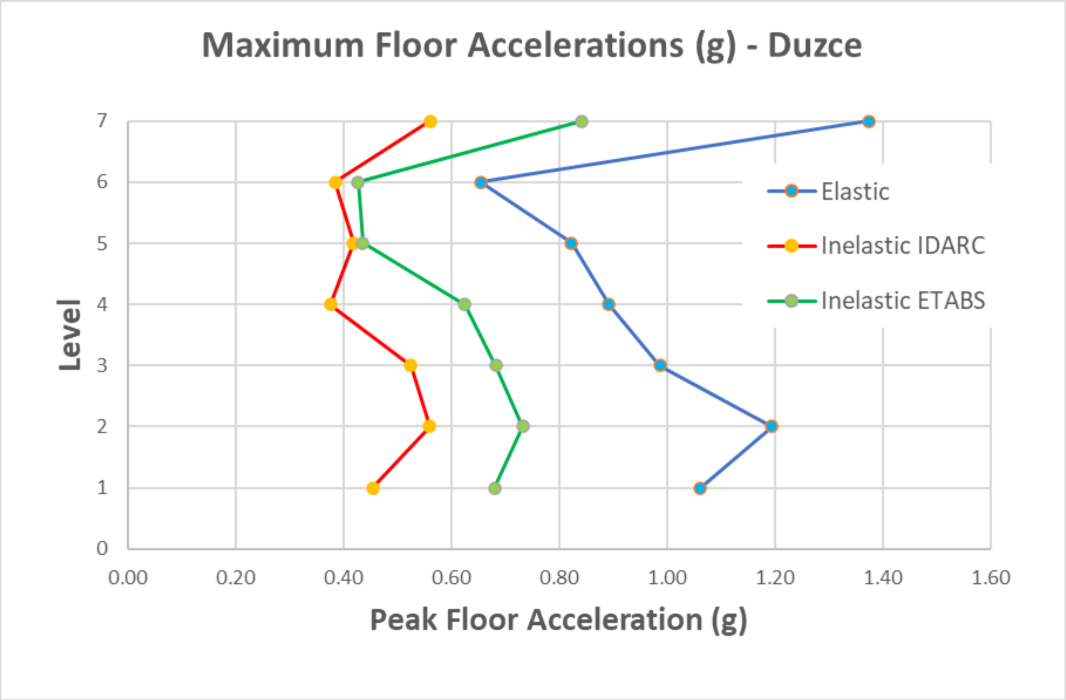


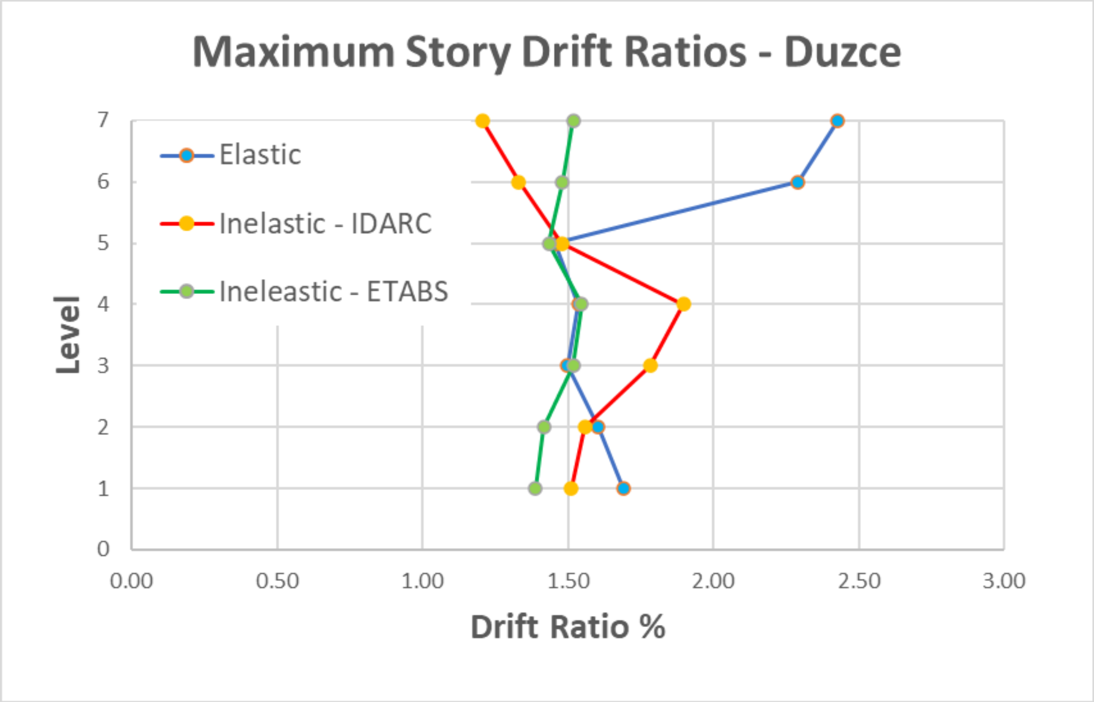
Example 7-Stor

Comparison of Maximum Responses – Duzce Bolu

- ***PGA – 0.726 g***
- Model 1 (FB)
- 1^{st} Mode Period = 1.45 seconds







Example 7-Story Building (Concrete MF)

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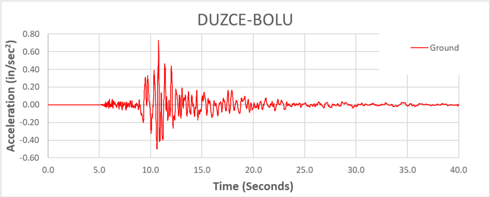
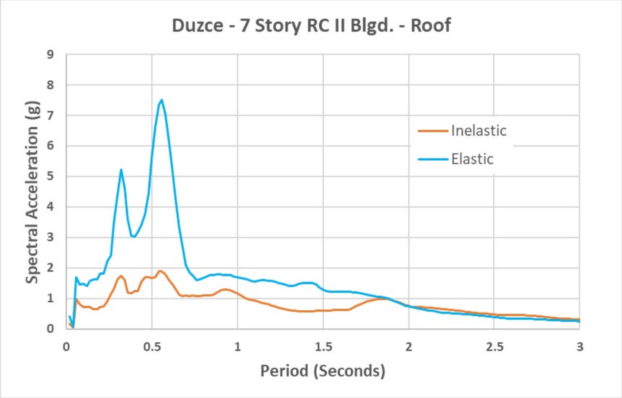
Floor Response Spectrum – Duzce Bolu

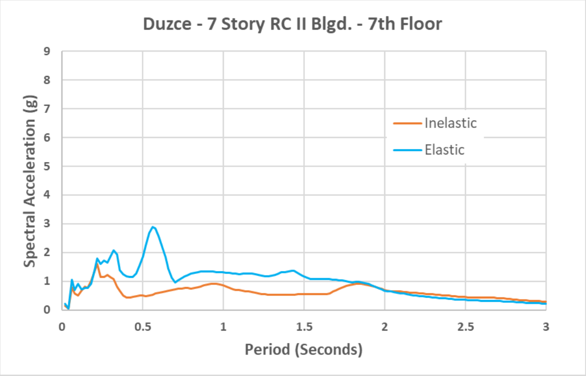
- ***PGA – 0.726 g***

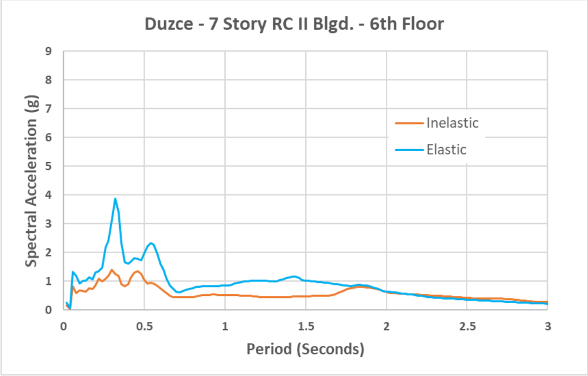
Model 1 (FB)

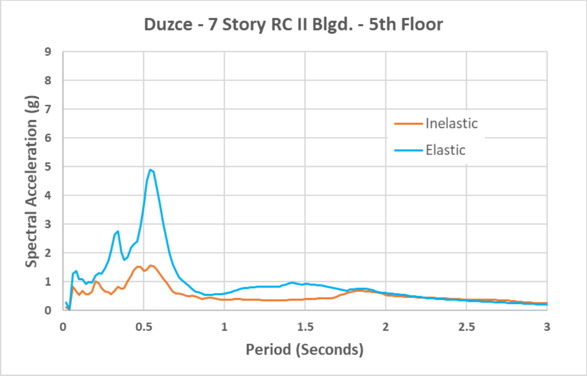
Mode 1 = 1.45 s
Mode 2 = 0.54 s
Mode 3 = 0.28 s

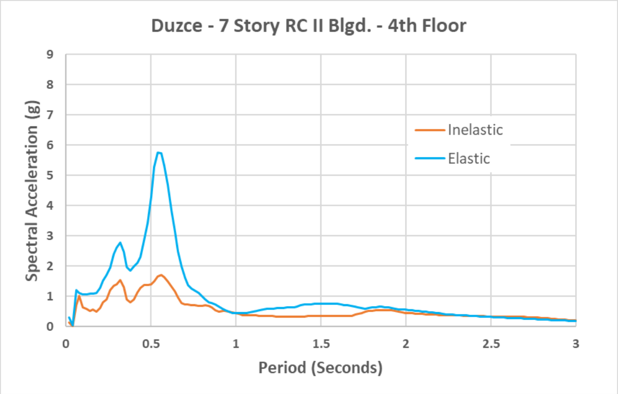


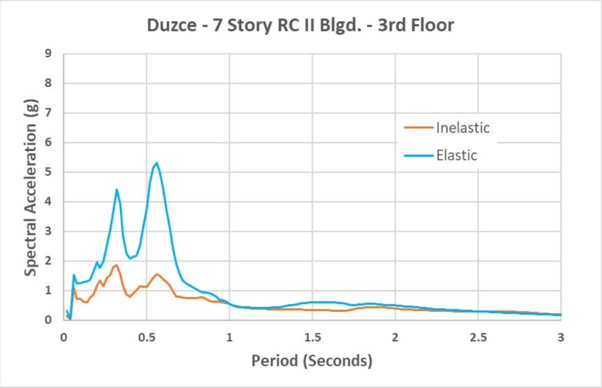


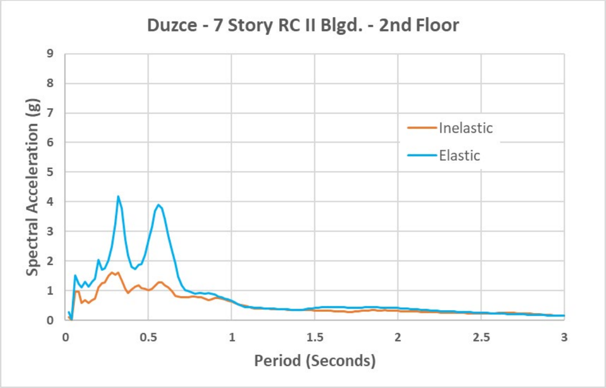


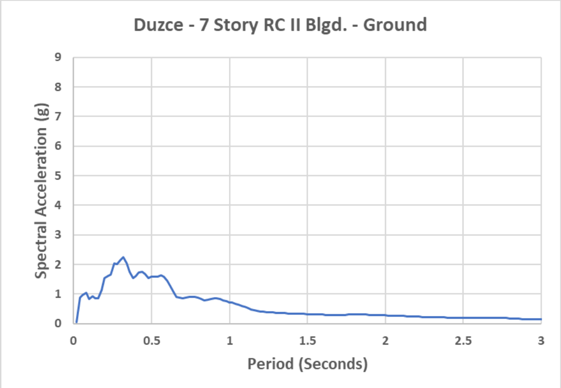








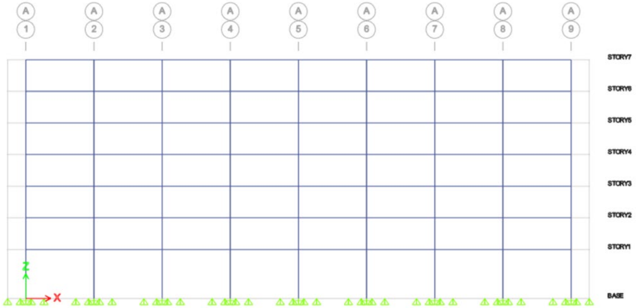


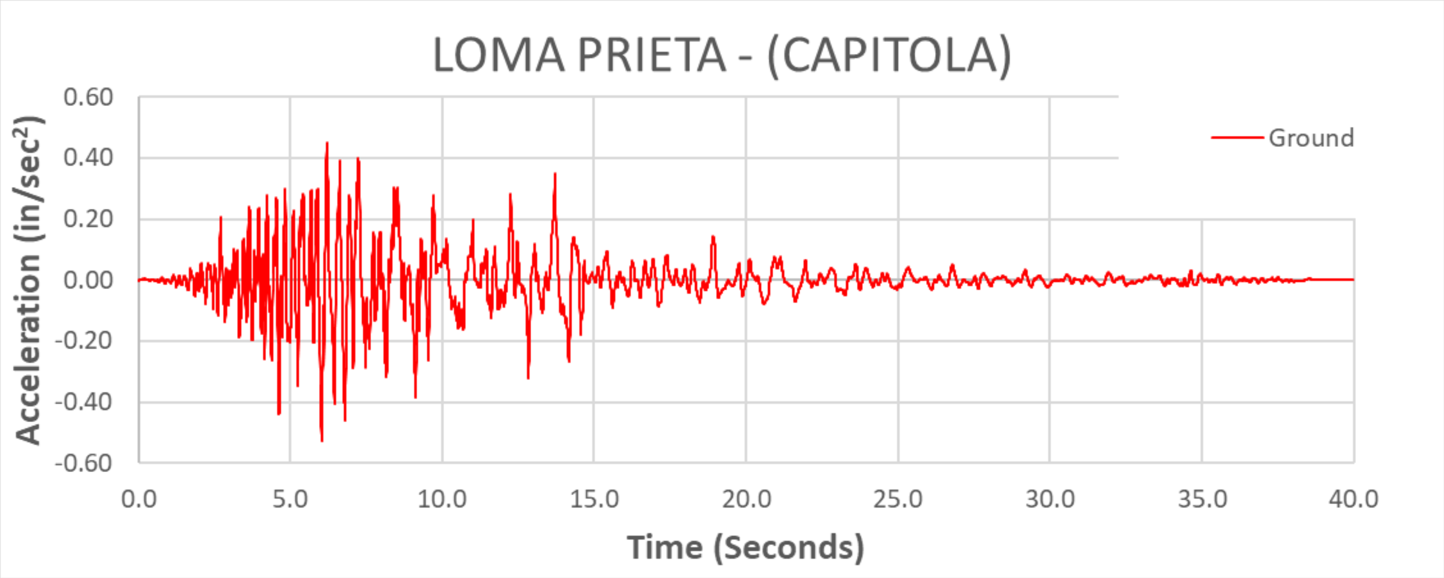


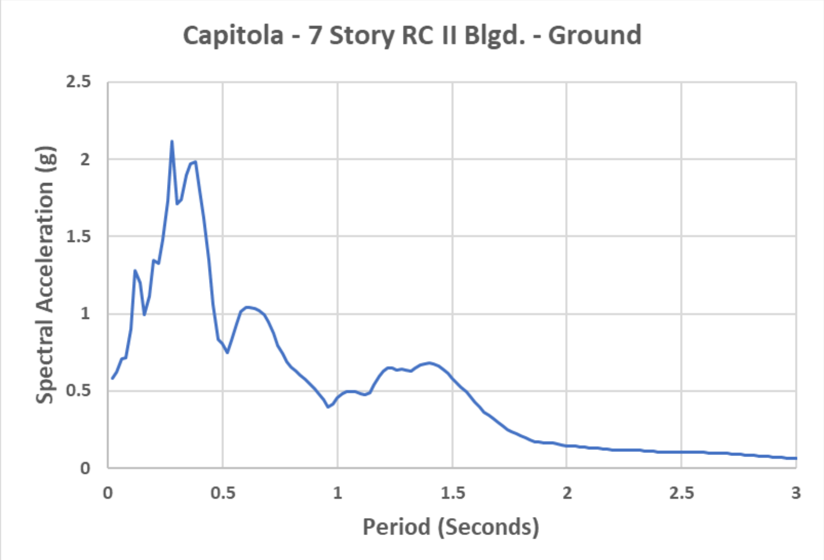
Example 7-Story Building (Concrete MF)

Earthquake Record – Loma Prieta (Capitola)

- *PGA – 0.529g*

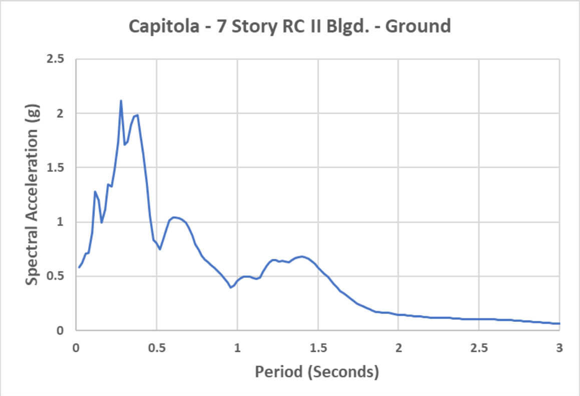


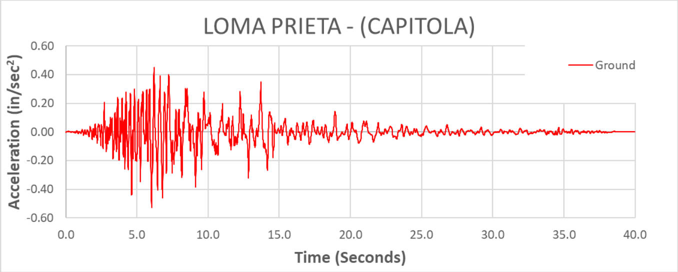


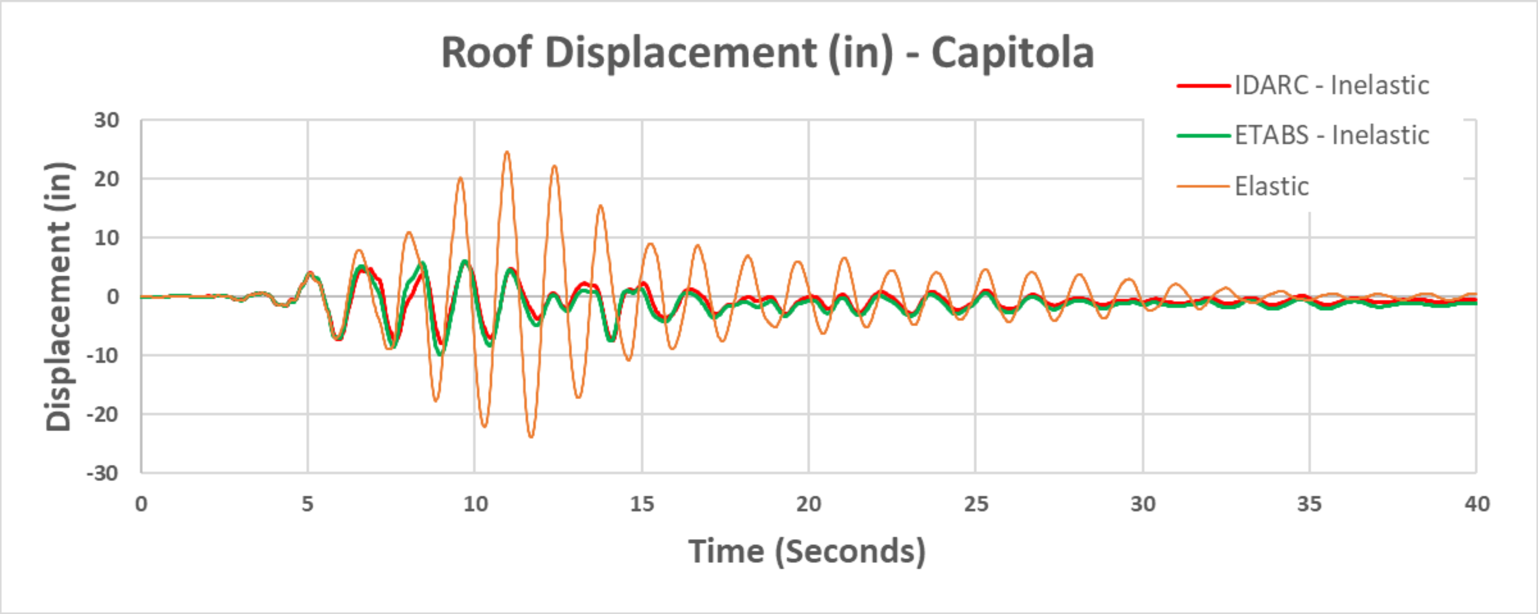


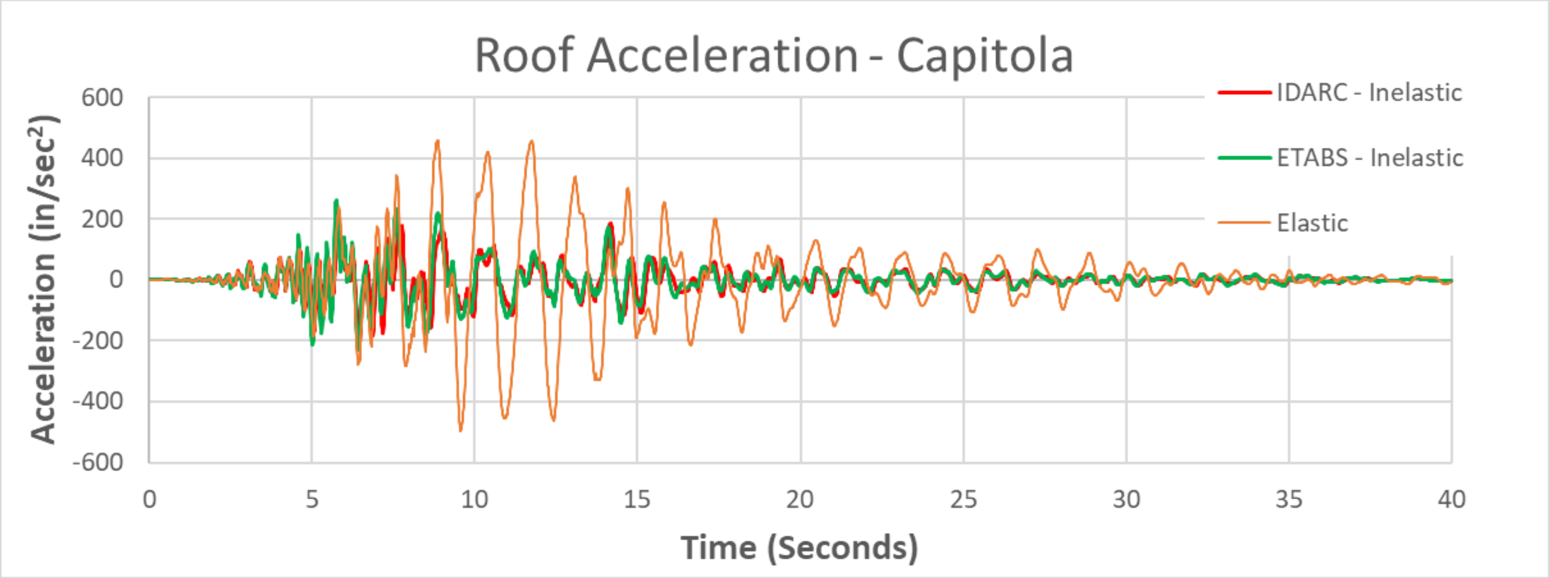
Time History Comparisons – Loma Prieta (Capitola)

- ***PGA – 0.529g***
- Model 1 (FB)
- 1^{st} Mode Period = 1.45 seconds





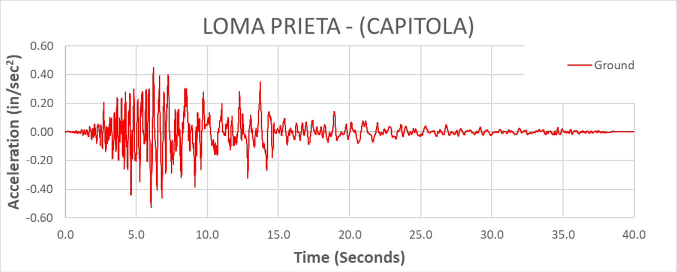


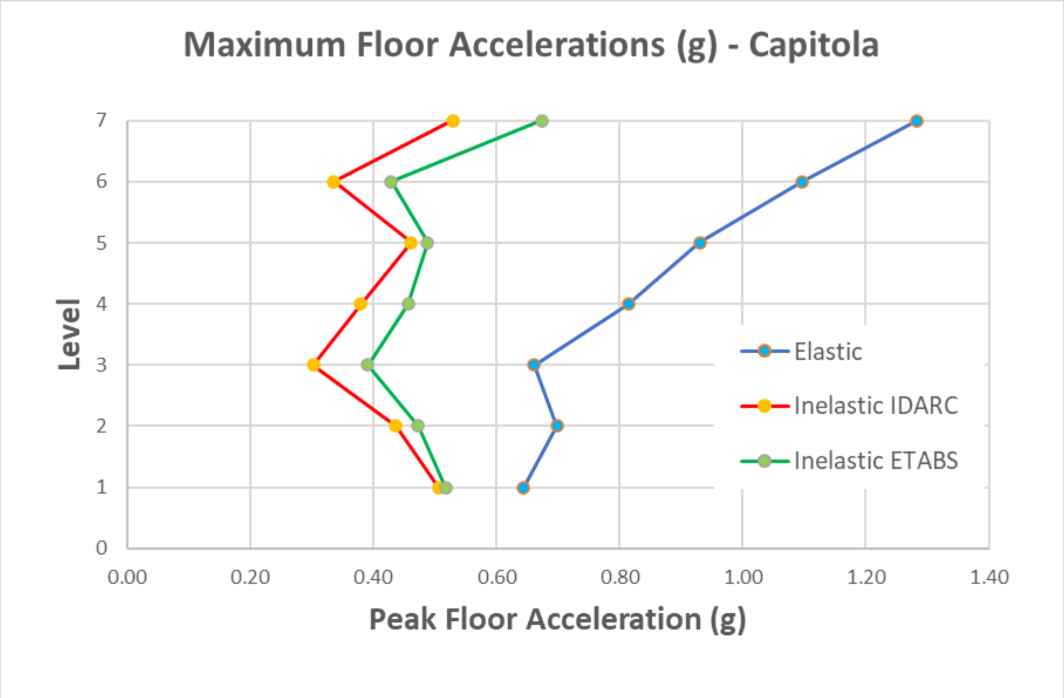


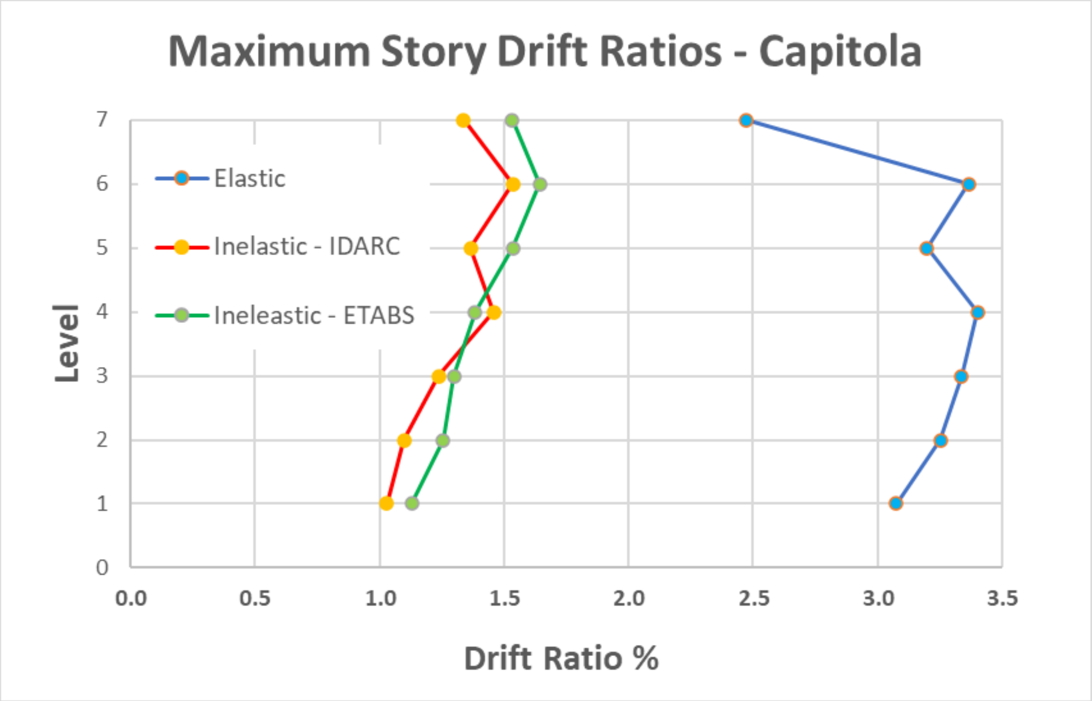
Example 7-Stor

Comparison of Maximum Responses – Loma Prieta (Capitola)

- ***PGA – 0.529 g***
- Model 1 (FB)
- 1^{st} Mode Period = 1.45 seconds







Example 7-Story Building (Concrete MF)

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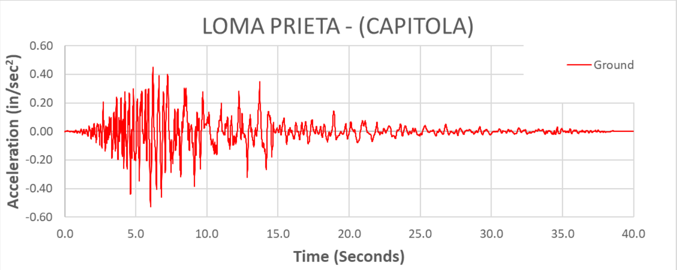
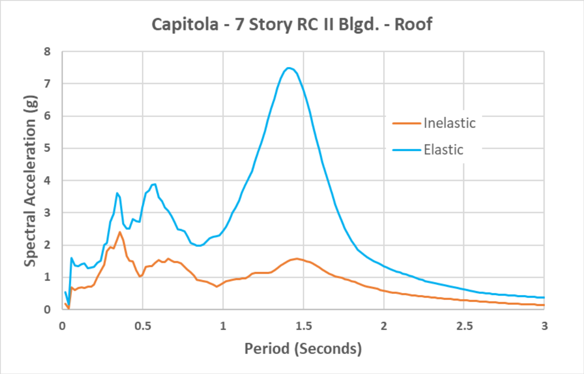
Floor Response Spectrum – Loma Prieta (Capitola)

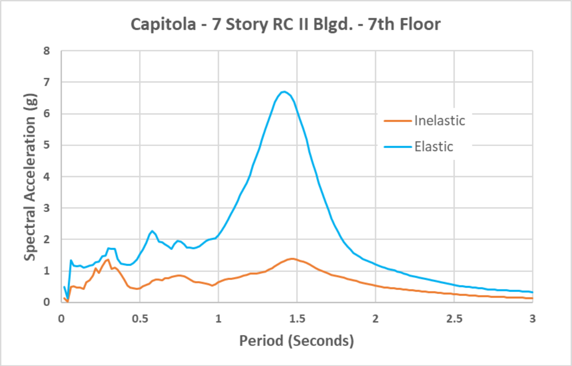
- ***PGA – 0.529 g***

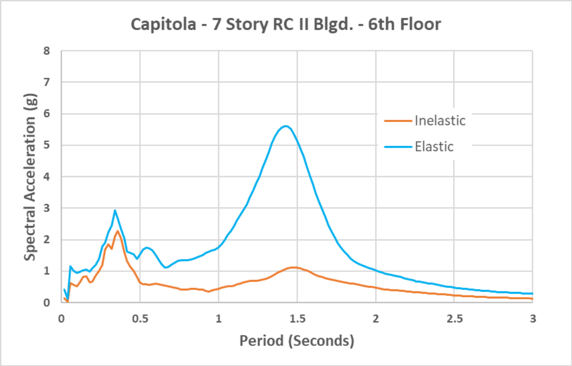
Model 1 (FB)

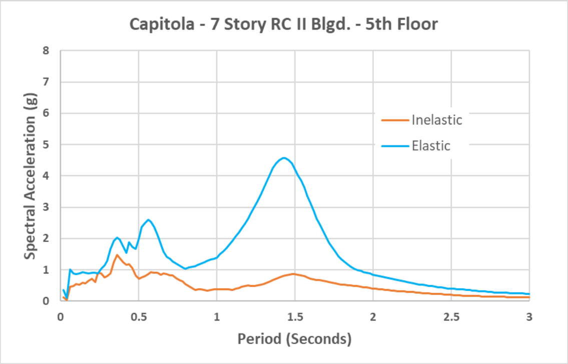
Mode 1 = 1.45 s
Mode 2 = 0.54 s
Mode 3 = 0.28 s

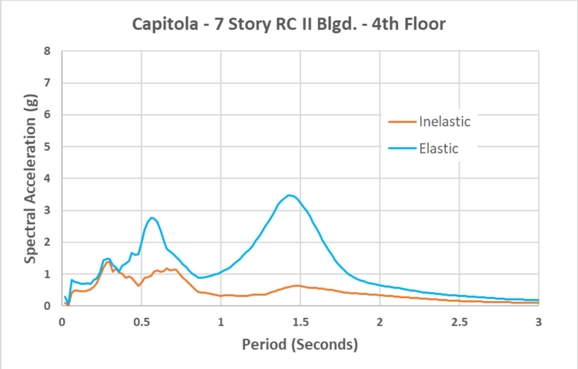


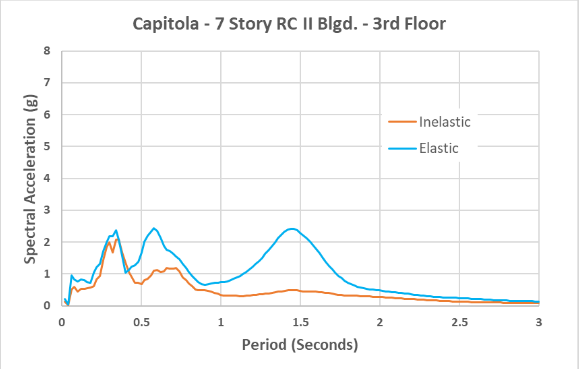


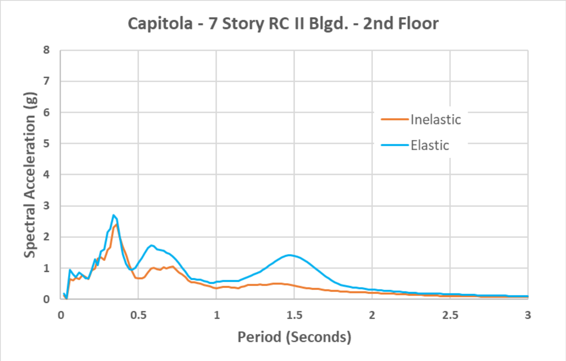


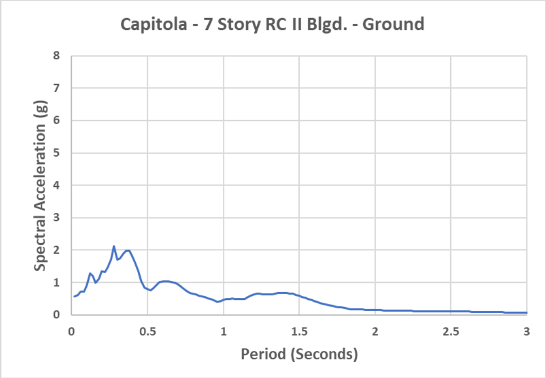






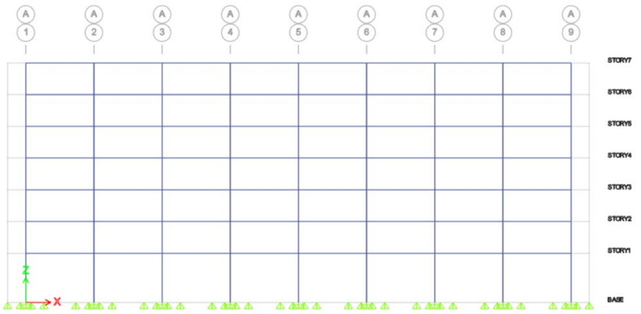


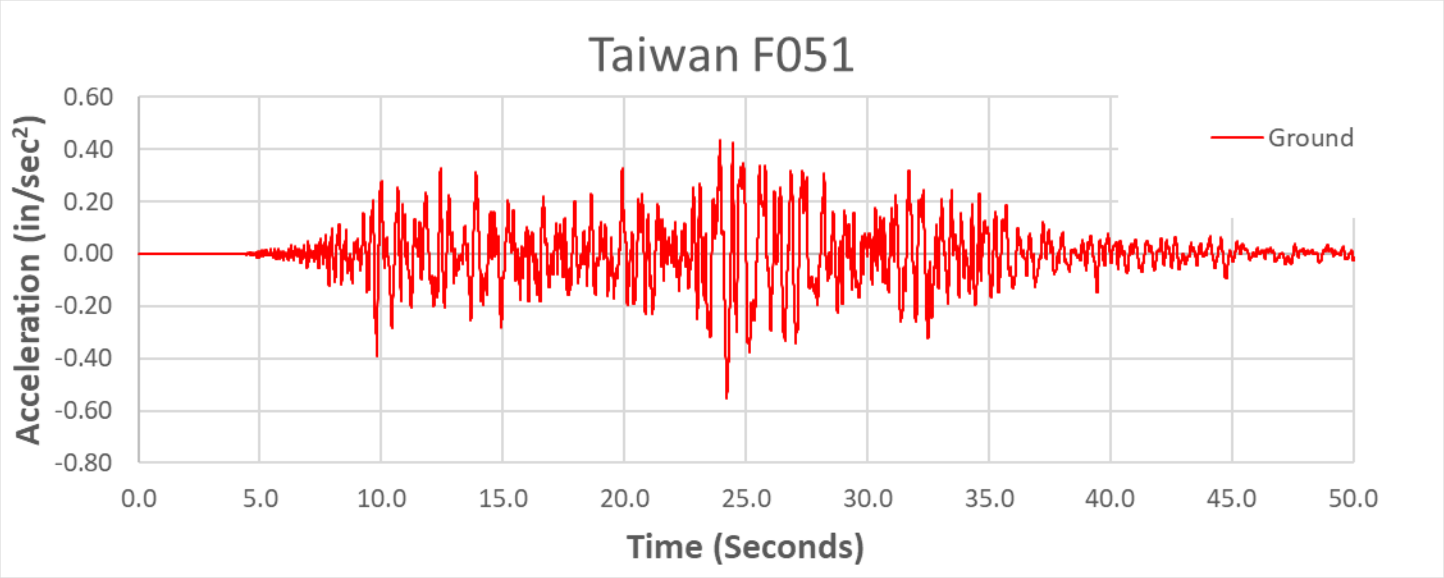


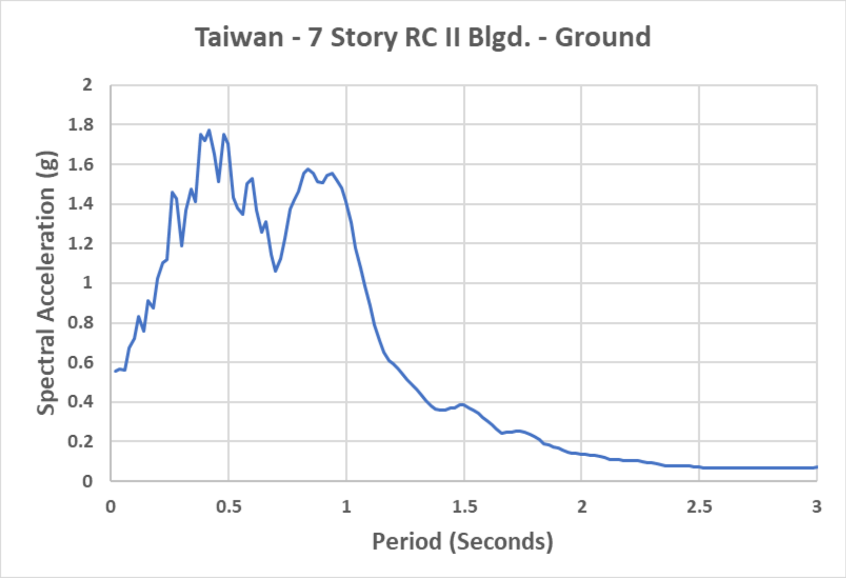


Earthquake Record – Taiwan

- ***PGA – 0.552g***



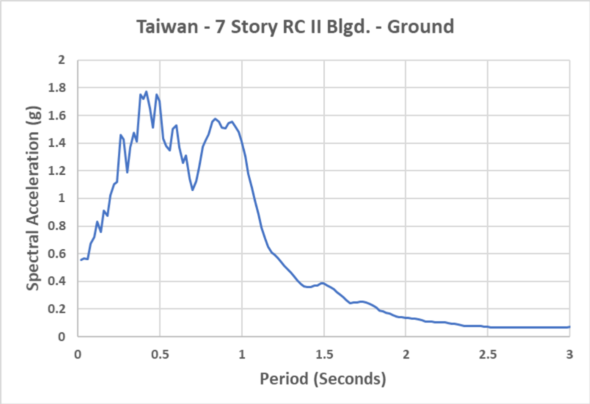


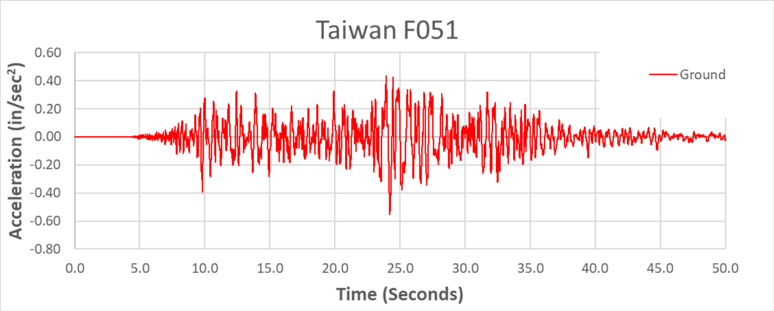


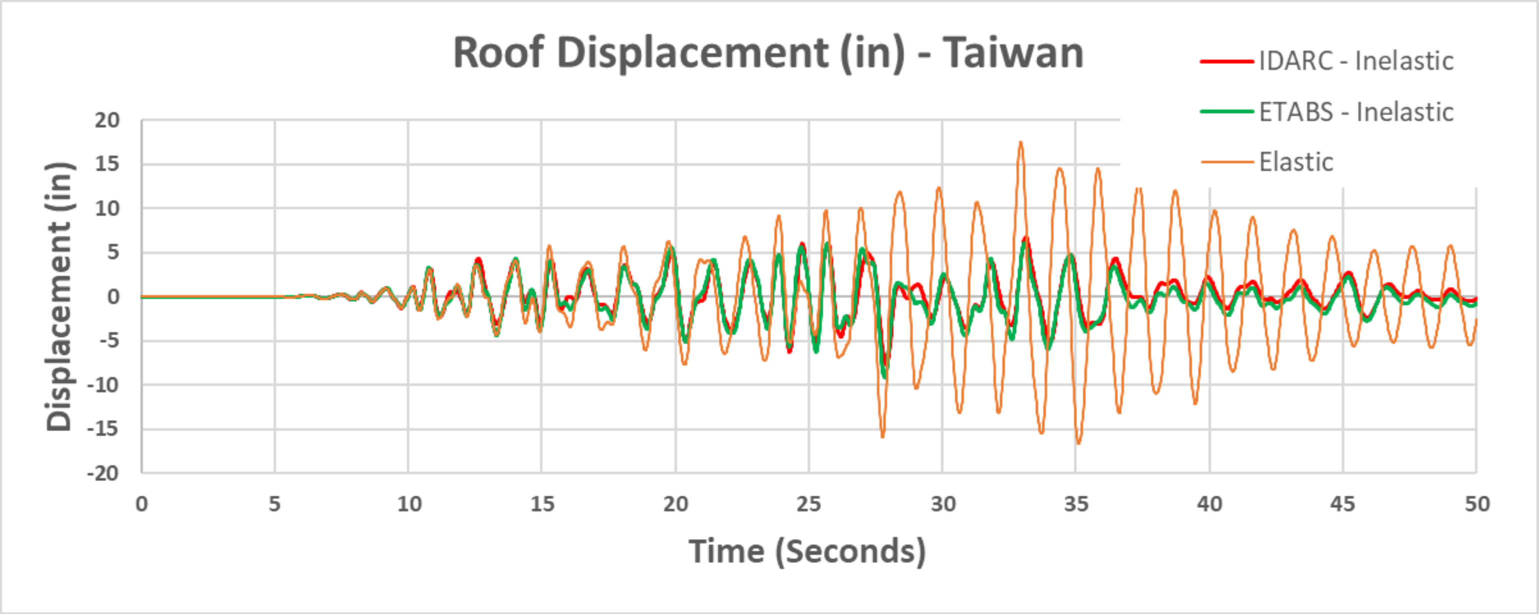
Example 7-Story Building (Concrete MF)

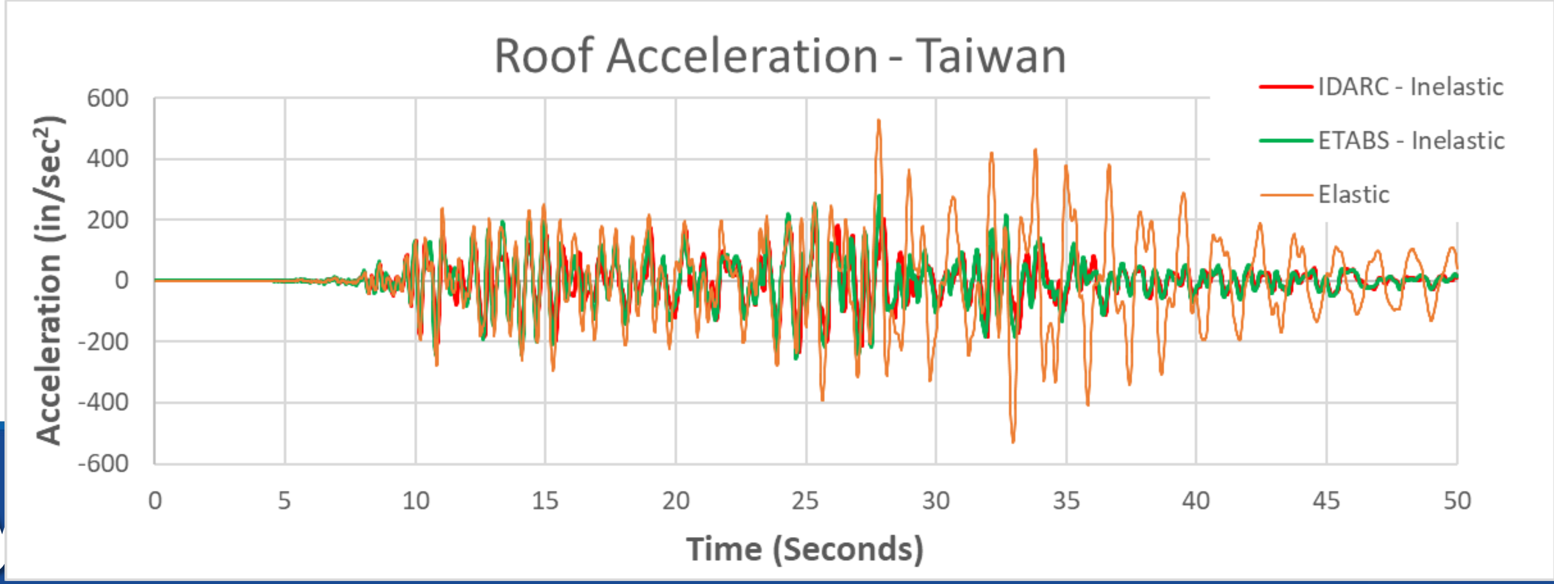
Time History Comparisons – Taiwan

- ***PGA – 0.552g***
- Model 1 (FB)
- 1st Mode Period = 1.45 seconds





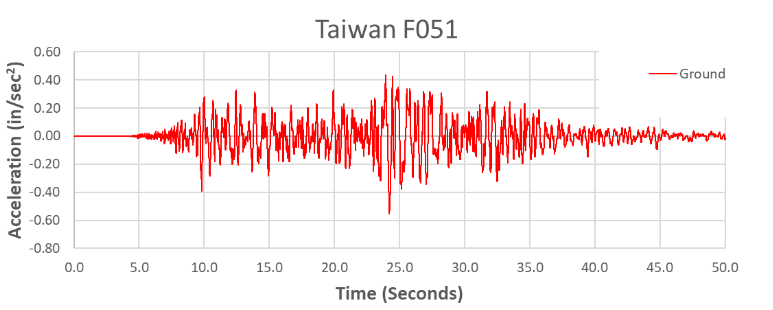


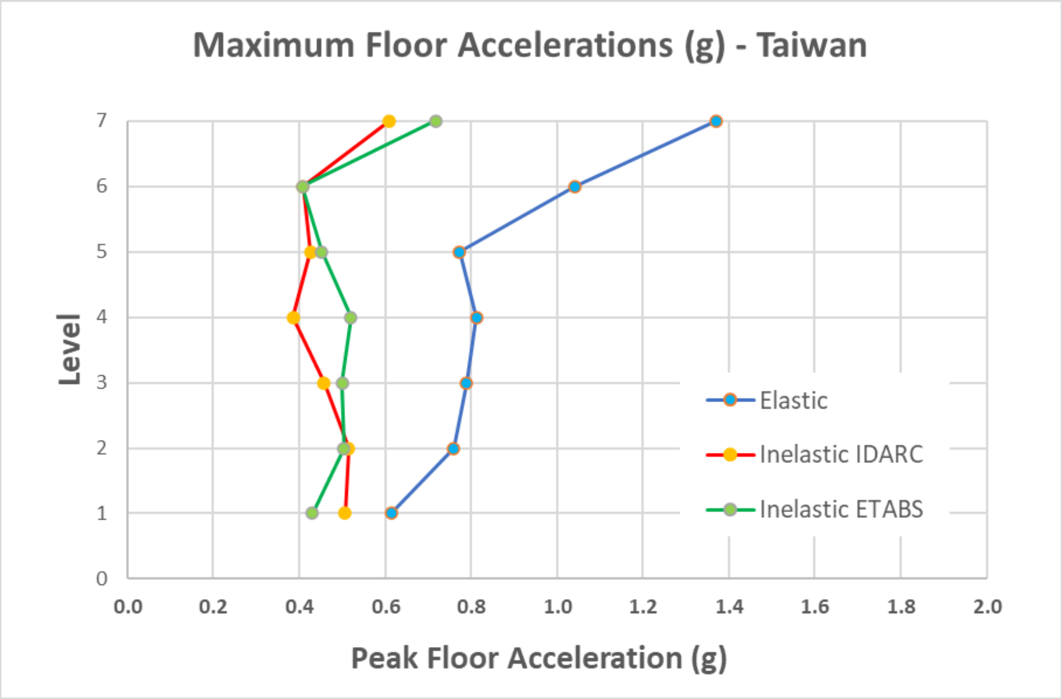


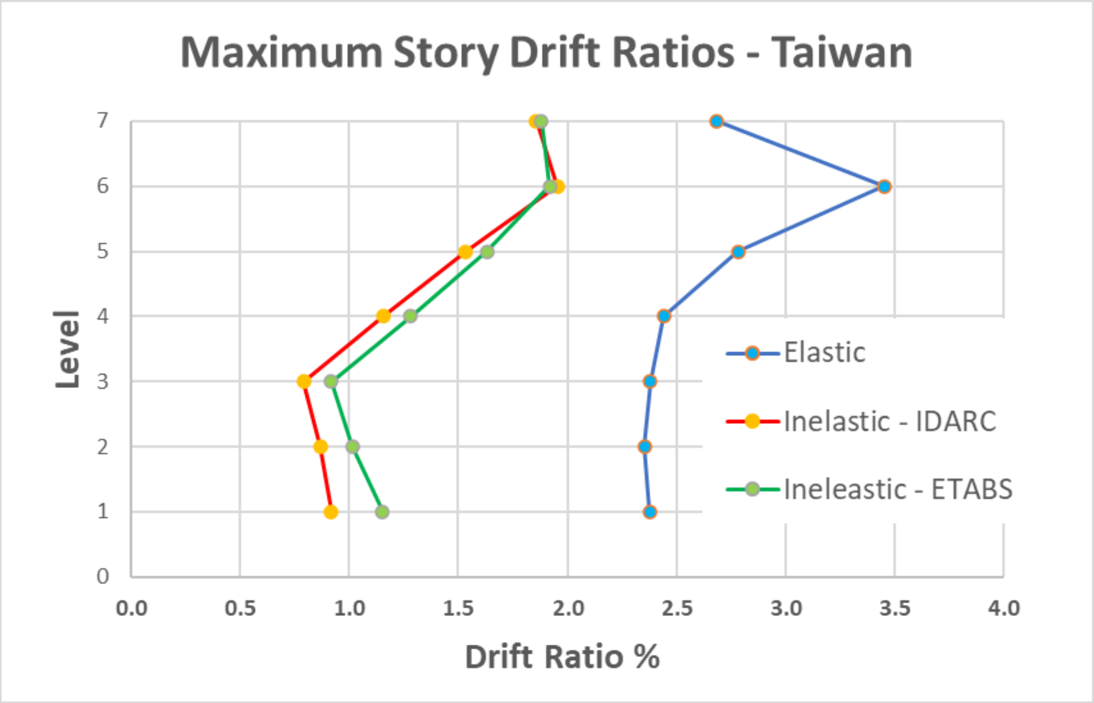
Example 7-Story

Comparison of Maximum Responses – Taiwan

- ***PGA – 0.552 g***
- Model 1 (FB)
- 1^{st} Mode Period = 1.45 seconds







Floor Response Spectrum – Taiwan Earthquake

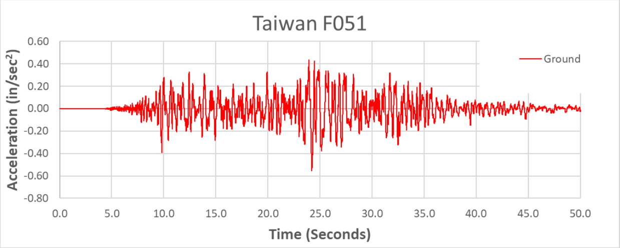
- *PGA – 0.552 g*

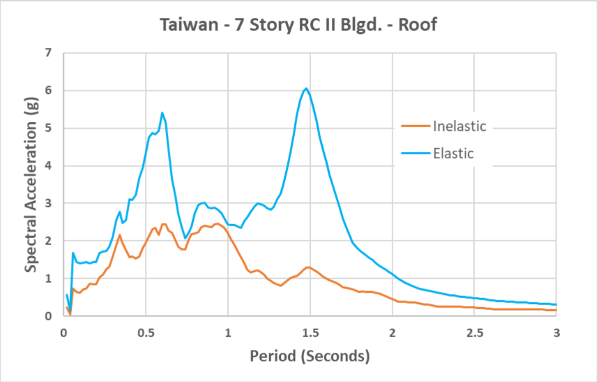
Model 1 (FB)

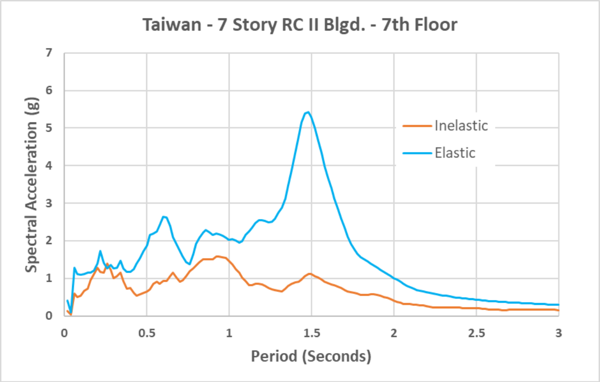
Mode 1 = 1.45 s

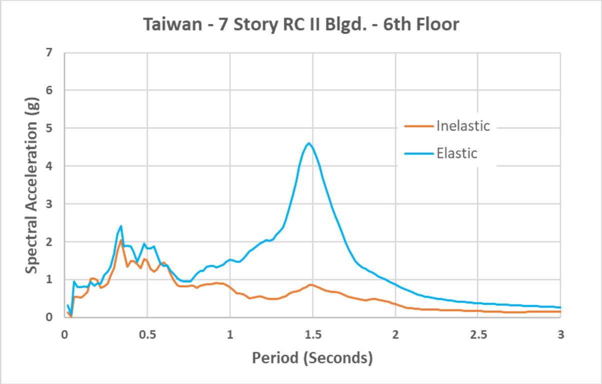
Mode 2 = 0.54 s

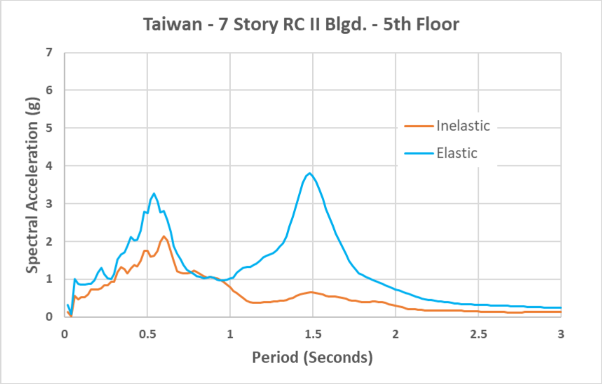
Mode 3 = 0.28 s

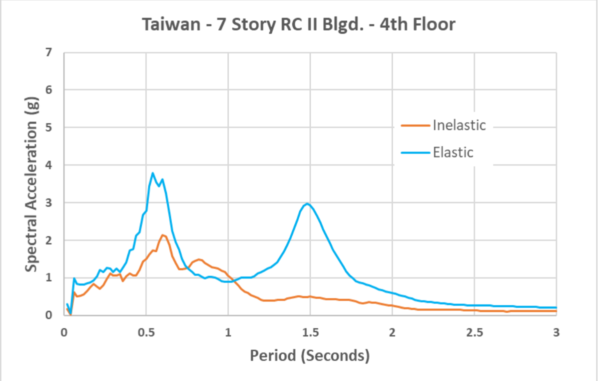


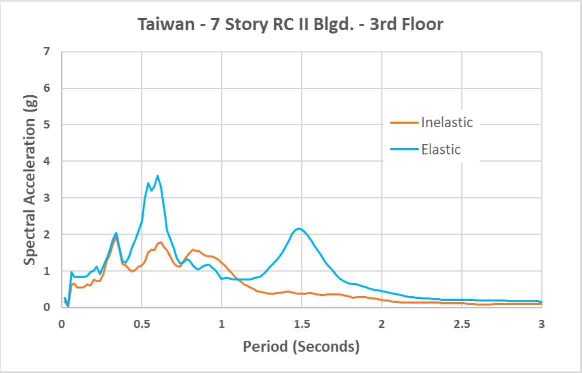


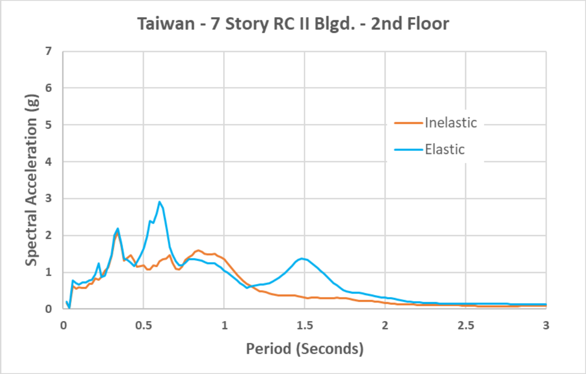


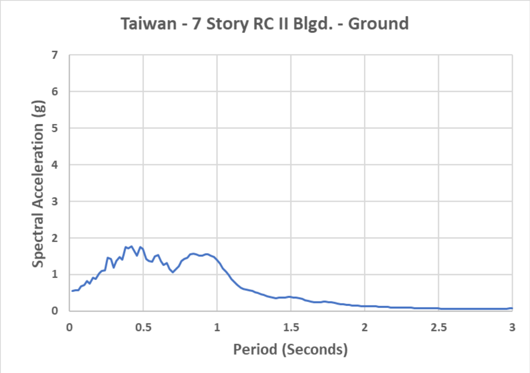












Observations

- *Inter-story drift ratios are within acceptable limits for the EQ records chosen*
- *In most cases inelastic drifts are lower than elastic drifts from the TH analysis*
- *Elastic accelerations are always higher than inelastic acceleration response*
- *Elastic floor response spectra can be significantly higher than the inelastic floor response spectra, resulting in higher force demands on nonstructural components within the building.*

Case Study Example: 7 - Story Concrete SMF on a 1-story Podium

Models and analysis are intended to simulate design for a Special Moment Frame RC-II Building on a stiff extended podium Structure

Goal

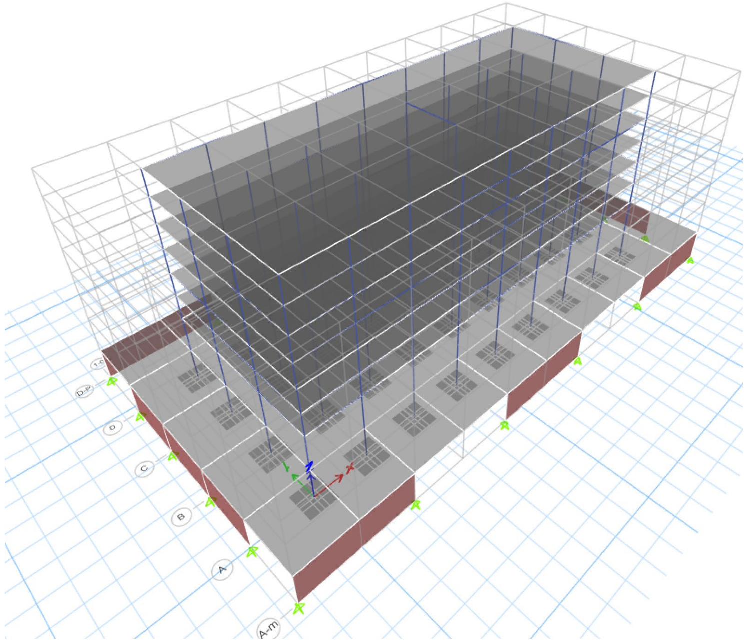
For a building that qualifies for a Two-Stage analysis, do the transfer forces at the podium level need to be amplified by Omega and R_{Upper}/R_{Lower}.

Example: 7 - Story Concrete Special Moment Frame on a Podium

- *Building is a modified version of the 7-story Van Nuys building with the following modifications*

- *General Assumptions - Linear Elastic Properties*
  - *Building modeled on shallow foundations*
  - *Beam and column dimensions modified to satisfy ACI and ASCE 7 strength and drift requirements*
  - *Only Longitudinal direction considered.*
  - *Beam Stiffness = 0.3 EI*
  - *Column Stiffness = 0.3 – 0.5 EI*
  - *No shear failures*
  - *Strong column weak beam satisfied*
  - *Stiff diaphragm and shear walls at first floor*

  - *Building Periods Longitudinal Direction*
    - *Mode 1 = 1.55 second*
    - *Mode 2 = 0.58 seconds*
    - *Mode 3 = 0.32 seconds*



Model 2

Model with Podium at 1st Floor

Example: 7-story Concrete MF + SW@1st floor

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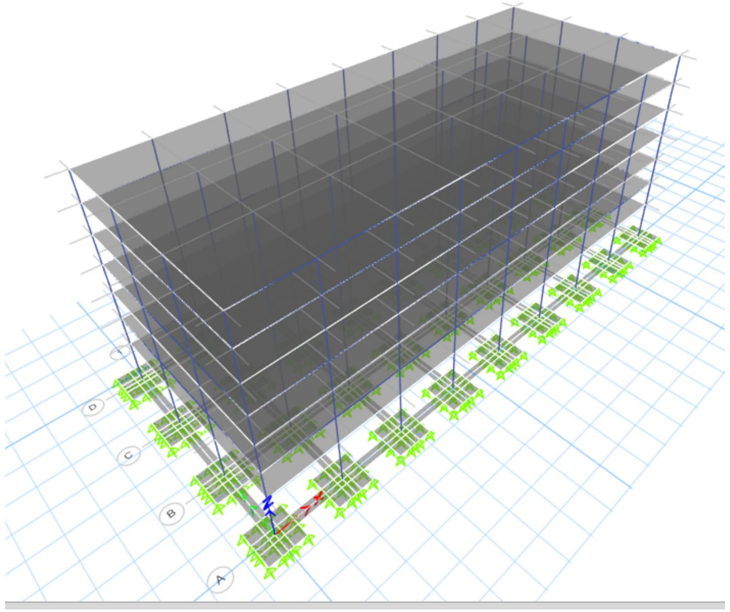
Example: 7 - Story Concrete Special Moment Frame

- *Ground motion data*

  - $S_{DS} = 1.62$
  - $S_{D1} = 0.64g$

Base Shear Calculation

S_{DS}	1.620	g
S_{D1}	0.640	g
C_t	0.016	
h_n	65.7	ft
x	0.9	
C_u	1.40	S_{D1} > 0.4 s
R	8.0	Reinforced Concrete SMRF
I_e	1.0	Risk Category II
$T_{Building}$	1.450	Fixed based period
T_0	0.079	sec
T_s	0.395	sec
T_a	0.69	sec
T	0.97	sec
$\mathbf{C_s}$	**0.08**	
V =	**826**	kips



Model 1

Fixed Base Model

Example 7-Story Building (Concrete MF)

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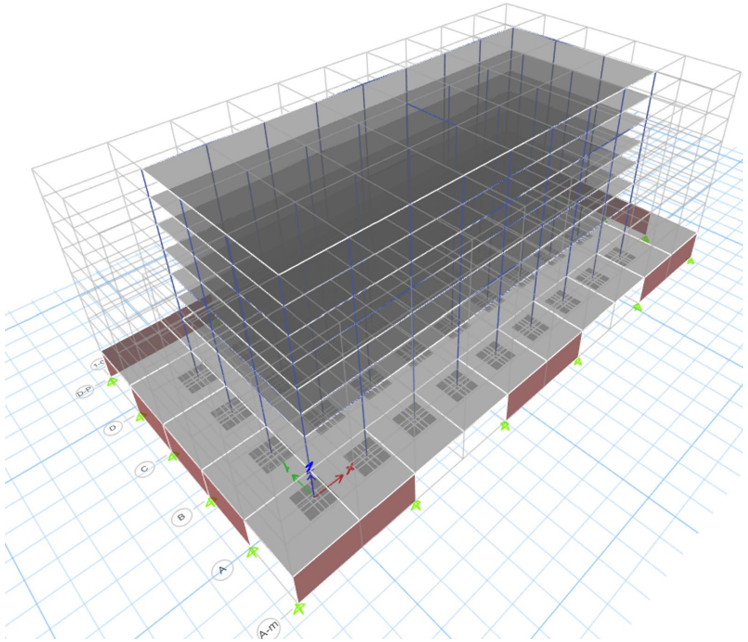
Example: 7 - Story Concrete Special Moment Frame

- ***Ground motion data***
  - $S_{DS} = 1.62$
  - $S_{D1} = 0.64g$

Base Shear Calculation – R_{Upper}

S_{DS}	1.620	g
S_{D1}	0.640	g
C_t	0.016	
h_n	77.7	ft
x	0.9	
C_u	1.40	S_{D1} > 0.4 s
R	8.0	Reinforced Concrete SMRF
I_e	1.0	Risk Category II
$T_{Building}$	1.540	Fixed based period
T_0	0.079	sec
T_s	0.395	sec
T_a	0.80	sec
T	1.13	sec
C_s	**0.07**	

V = **955**



Model 2
Podium Model

Example: 7-story Concrete MF + SW@1st floor

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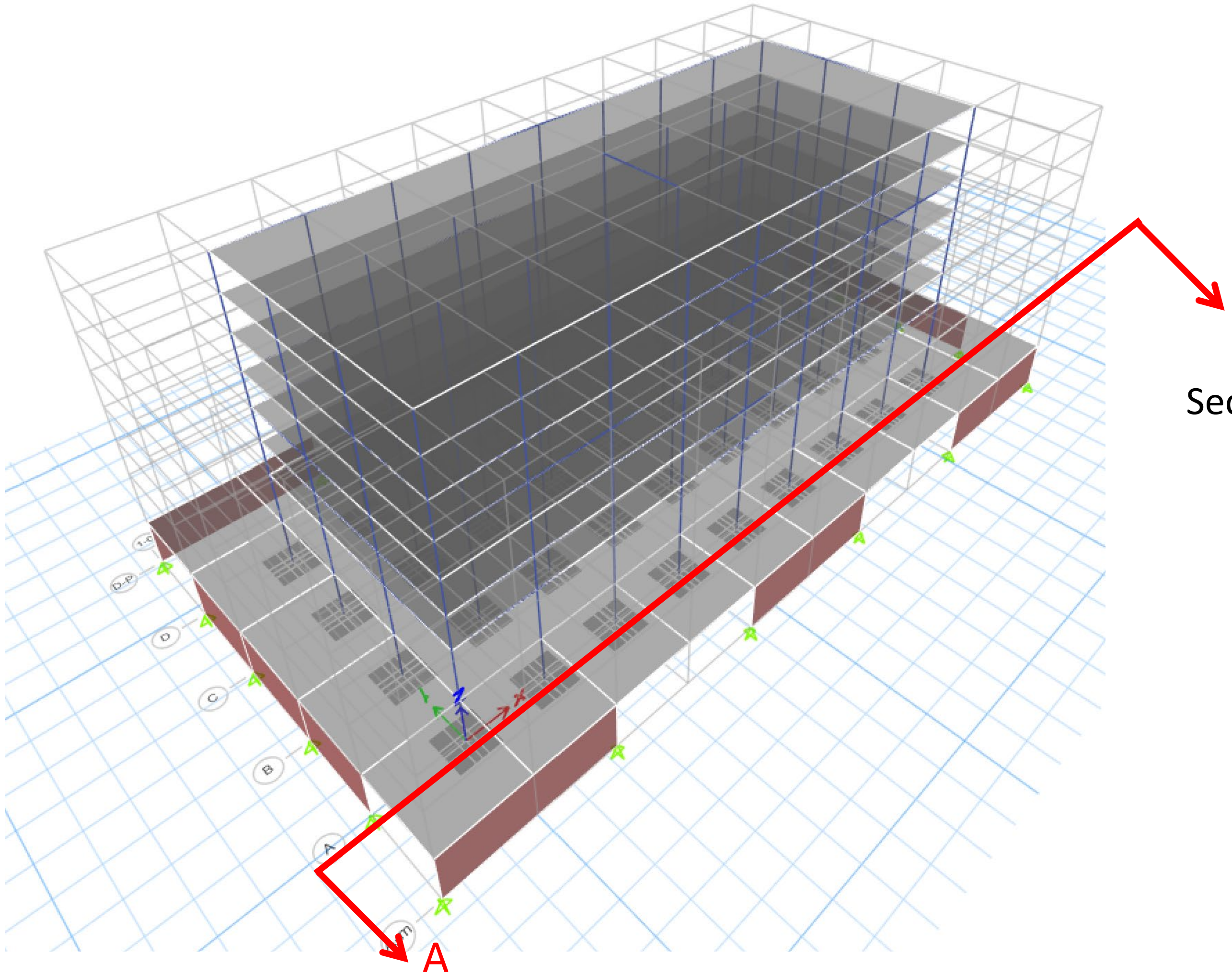
Example: 7 - Story Concrete Special Moment Frame + Podium



Section Cut A-A at Transfer Diaphragm

Model 2
Podium Model

Example: 7-story Concrete MF + SW@1st floor

Example: 7 - Story Concrete Special Moment Frame + Podium

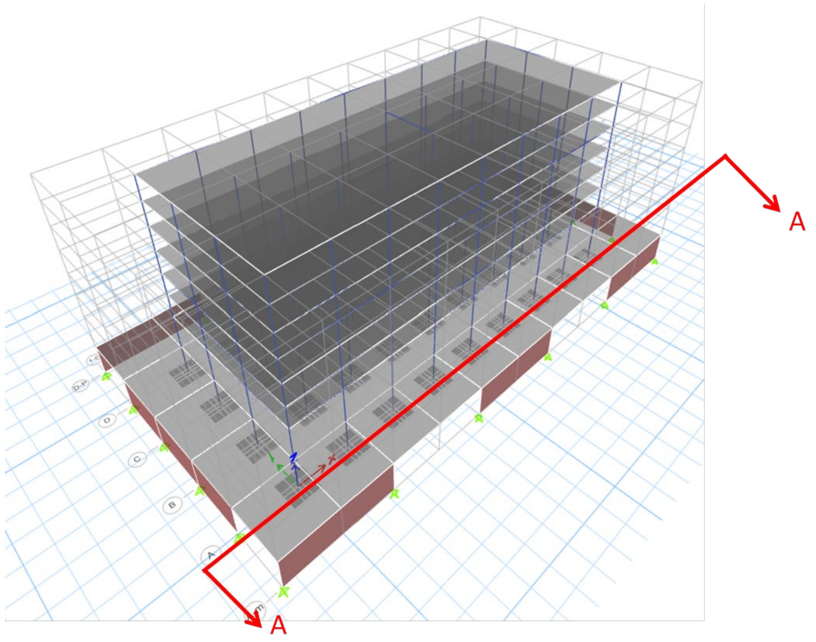
Distribution of Forces – R_{Upper}

Floor	Weight	H_x	$w_x h^k$	C_{vx}	F_x	F_{px}	Max F_{px}	Min F_{px}
7	1341	77.7	407163	0.22	209	209	869	434
6	1381	69	358768	0.19	184	200	895	447
5	1381	60.33	300773	0.16	155	184	895	447
4	1381	51.6	244962	0.13	126	170	895	447
3	1381	42.9	192220	0.10	99	155	895	447
2	1381	34.2	142740	0.08	73	142	895	447
1	1751	25.5	123093	0.07	63	159	1135	567
0	3454	12	90243	0.05	46	245	2238	1119
	13451		1859962		955			

V = **955**

Transfer Force = 909 kips

Podium Inertia Force = 1119 kips



Transfer Diaphragm forces @ A-A

Transfer Dispahragm Shear Without Ω_0	1014 kips
Transfer Diaphragm Shear with R_{upper}/R_{lower}	1166 kips
Transfer Dispahragm Shear With Ω_0	1923 kips
Transfer Diaphragm Shear with R_{upper}/R_{lower} & Ω_0	2378 kips

$R_{upper} = 8$
$R_{lower} = 6$
$\Omega = 3$

Model 2
Podium Model

Example: 7-story Concrete MF + SW@1st floor

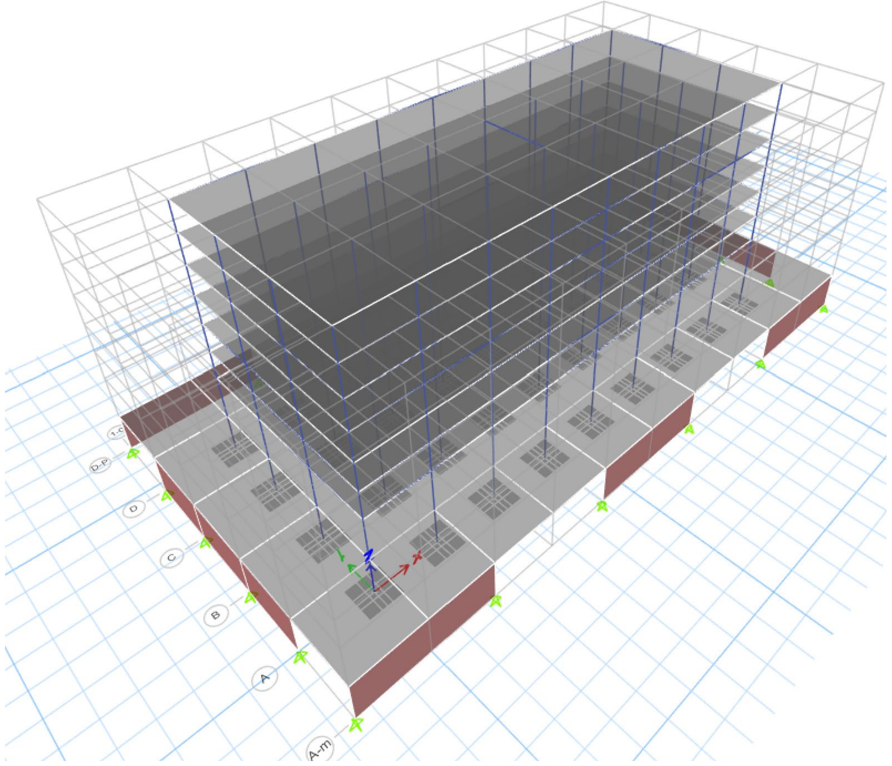
Example: 7 - Story Concrete Special Moment Frame + Podium

- ***Ground motion data***
  - $S_{DS} = 1.62$
  - $S_{D1} = 0.64g$

Base Shear Calculation – R_{lower}

S_{DS}	1.620	g
S_{D1}	0.640	g
C_t	0.020	
h_n	77.7	ft
x	0.8	
C_u	1.40	S_{D1} > 0.4 s
R	6.0	Reinforced Concrete Shear Wall
I_e	1.0	Risk Category II
$T_{Building}$	1.540	Fixed based period
T_0	0.079	sec
T_s	0.395	sec
T_a	0.52	sec
T	0.73	sec
C_s	**0.15**	

V = **1958**



Model 2
Podium Model

Example: 7-story Concrete MF + SW@1st floor

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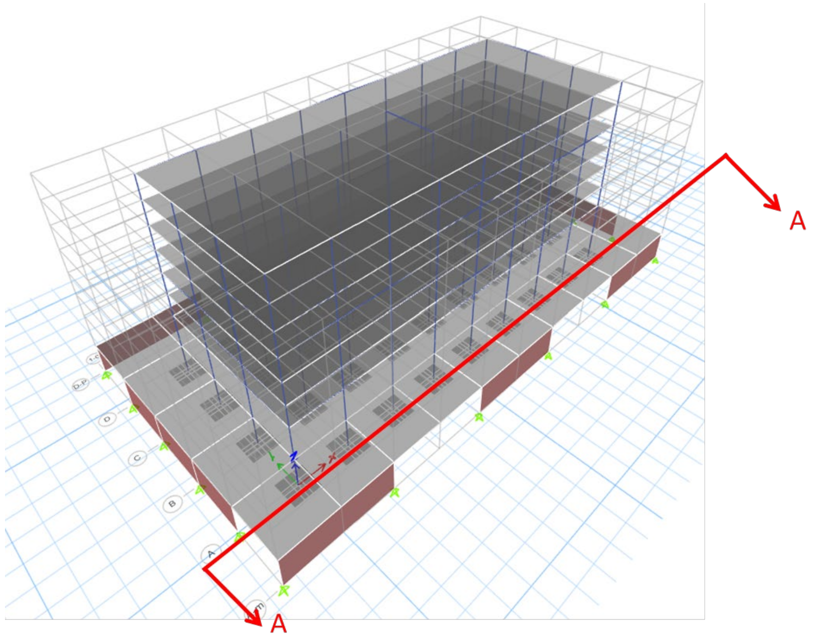
Example: 7 - Story Concrete Special Moment Frame + Podium

Distribution of Forces – R_{Lower}

Floor	Weight	H_x	w_xh^k	C_{vx}	F_x	F_{px}	Max F_{px}	Min F_{px}
7	1341	77.7	172932	0.20	394	394	869	434
6	1381	69	155979	0.18	355	380	895	447
5	1381	60.33	134265	0.16	306	355	895	447
4	1381	51.6	112766	0.13	257	330	895	447
3	1381	42.9	91760	0.11	209	306	895	447
2	1381	34.2	71247	0.08	162	282	895	447
1	1751	25.5	65093	0.08	148	321	1135	567
0	3454	12	55349	0.06	126	503	2238	1119
	13451		859392		1958			

V = **1958**

Transfer Force = 1832 kips
Podium Inertia Force = 1119 kips



Model 2
Podium Model

Transfer Diaphragm forces @ A-A

Transfer Dispahragm Shear Without Ω_0	1475 kips
Transfer Diaphragm Shear with R_{upper}/R_{lower}	1475 kips
Transfer Dispahragm Shear With Ω_0	2849 kips
Transfer Diaphragm Shear with R_{upper}/R_{lower} & Ω_0	2849 kips

$R_{upper} = 6$
$R_{lower} = 6$
$\Omega = 2.5$

Example: 7-story Concrete MF + SW@1st floor

Example: 7 - Story Concrete Special Moment Frame + Podium

- ***Ground motion data***

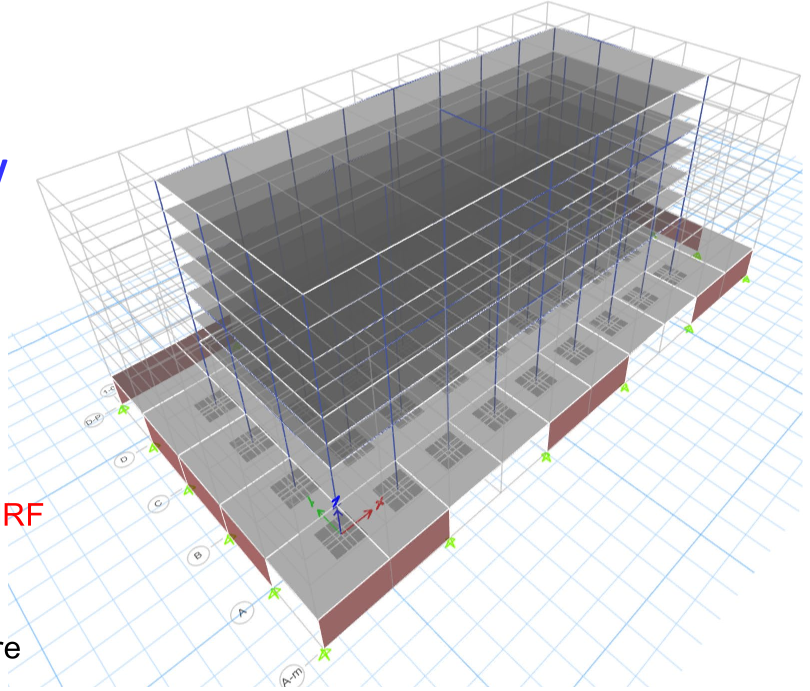
  - $S_{DS} = 1.62$
  - $S_{D1} = 0.64g$

  - ***Total Base Shear Lower***

    $= 826 \times (8/6) + 933 = 2034$ ***kips***

Base Shear Calculation – $R_{\text{lower Only}}$

S_{DS}	1.620	g
S_{D1}	0.640	g
C_t	0.020	
h_n	12.0	ft
x	0.75	
C_u	1.40	S_{D1} > 0.4 s
R	6.0	Reinforced Concrete SMRF
I_e	1.0	Risk Category II
$T_{Building}$	1.540	Fixed based period
Ω_o	2.5	Omega of Upper Structure
T_0	0.079	sec
T_s	0.395	sec
T_a	0.13	sec
T	0.18	sec
C_s	**0.270**	
V =	**933**	



Model 2
Podium Model

Example: 7 - Story Concrete Special Moment Frame + Podium

Diaphragm Force @ Transfer Diaphragm Eq. 12.10-4

Design Parameter		7-story Example + Podium RCMF	7-story Example + Podium RCSW	7-story Example + Podium
Lateral Resisting System		RCMF	RCSW	RCSW
n =		8	8	1
Ω_o =		3	2.5	2.5
S_{DS} =		1.63	1.63	1.63
S_{D1} =		0.64	0.64	0.64
I_e =		1	1	1
h_n =		77	77	12
C_t =		0.016	0.02	0.02
x		0.9	0.75	0.75
T =		0.80	0.52	0.13
C_u =		1.4	1.4	1.4
T_{max} =		1.12	0.73	0.18
R =		8	6	6
Cs =		0.20	0.27	0.27
Cs =		0.07	0.15	0.59
C_s min =		0.07	0.07	0.07
C_s (design) =		0.07	0.15	0.27
$C_{s2}(1)$ =	$(0.15n + 0.25)I_eS_{DS}$ =	2.36	2.36	0.65
$C_{s2}(2)$ =	I_eS_{DS} =	1.63	1.63	1.63
$C_{S2}(3)$ =	$I_eS_{D1}/0.03(n-1) >= 2$	3.05	3.05	0.00
C_{s2} (design) =		1.63	1.63	0.00
z_s =		0.7	1	1
Γ_{m1} =	$1 + z_s/2(1 - 1/n)$ =	1.31	1.44	1.00
Γ_{m2} =	$0.9z_s(1 - 1/n)^2$ =	0.48	0.69	0.00
C_{pn} =	$\sqrt{(\Gamma_{m1}\Omega_0 C_s)^2 + (\Gamma_{m2} C_{s2})^2}$	0.83	1.24	0.679

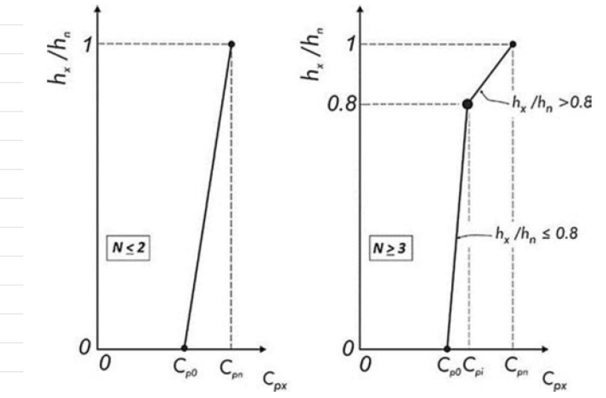


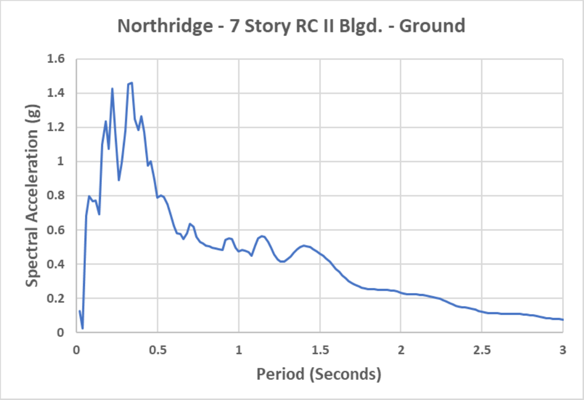
Figure 12.10-2. Calculating the design acceleration coefficient, C_{px}, in buildings with $N \le 2$ and in buildings with $N \ge 3$.

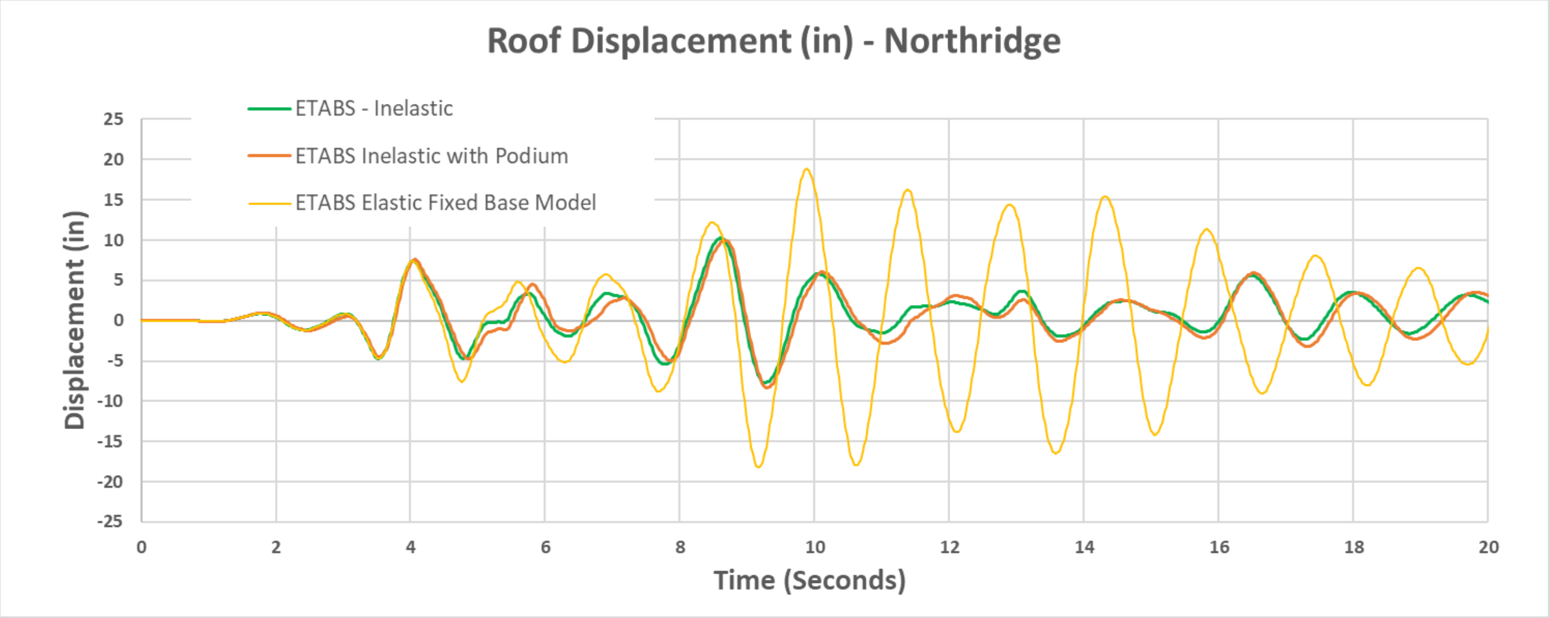
Design Parameter		7-story Example + Podium RCMF	7-story Example + Podium RCSW	7-story Example + Podium
C_{p0} =	$0.4S_{DS}I_e$	0.648	0.648	0.648
C_{pi} =	$0.8C_{p0}$	0.66	0.99	0.54
C_{pi} =	$C_{pi} = 0.9\Gamma_{m1}\Omega_0 C_s$	0.25	0.47	0.61
$C_{pi\ (Design)}$ =	Fig. 12.10-2	0.66	0.99	0.61
Ht of Diap. (ft)		12	12	12
$C_{px\ (Design@L1)}$ =	Design Accel Coefficient	0.651	0.714	0.675
R_s	Table 12.10-1	1.5	1.5	1.5
W_{px}	Weight of Diaphragm	3454	3454	3454
F_{px} (kips)	Diap. Seismic Design Force	1499	1644	1554
F_{px_min} =	$0.2S_{DS}I_eW_{px}$	1119.1	1119.1	1119.1

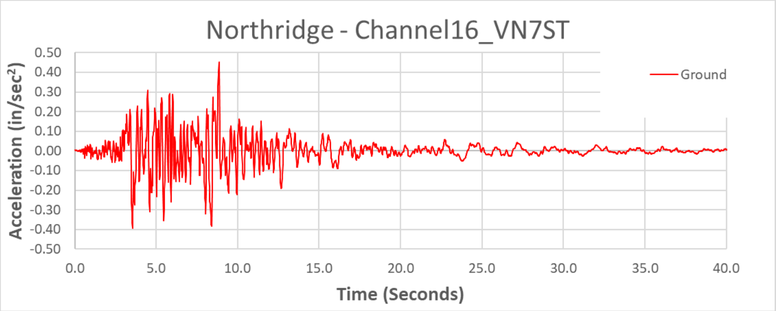
Example: 7-story Concrete MF + SW@1st floor

Time History Comparisons – Northridge (Van Nuys)

- ***PGA – 0.453g***
- Model 1 (7 Story Fixed Base)
- Model 2(Podium at 1st Floor)







Example: 7-story Concrete MF + SW@1st floor

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Time History Comparisons – Northridge (Van Nuys)

- ***PGA – 0.453g***
- Model 1 (7 Story Fixed Base)
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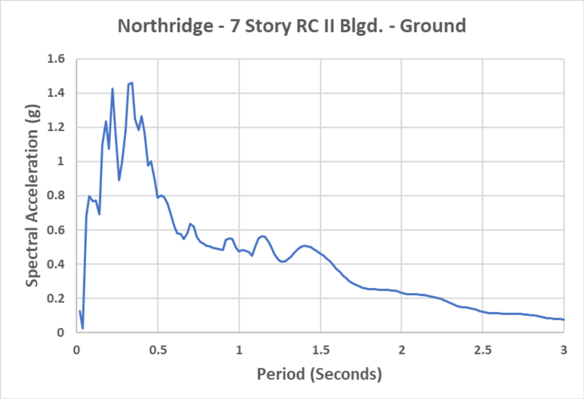
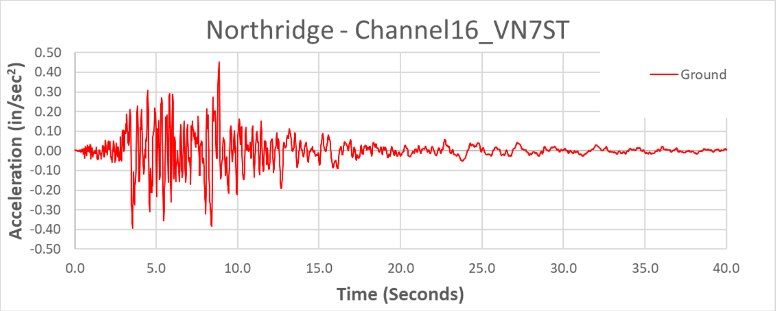
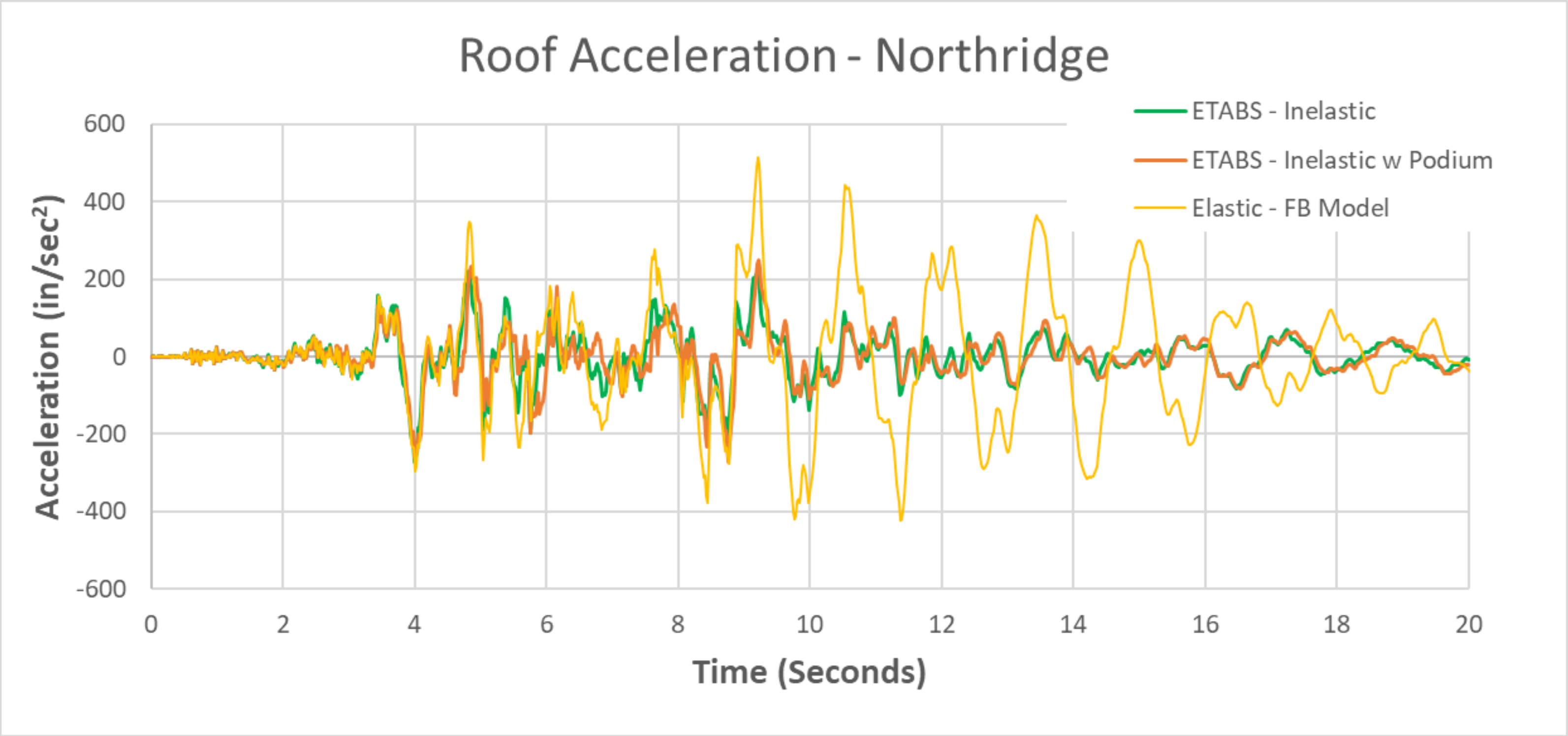
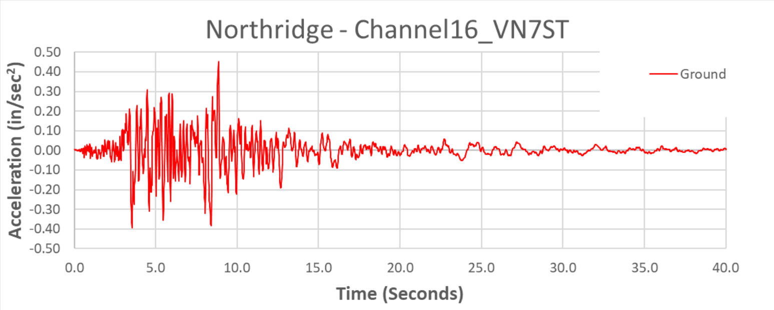


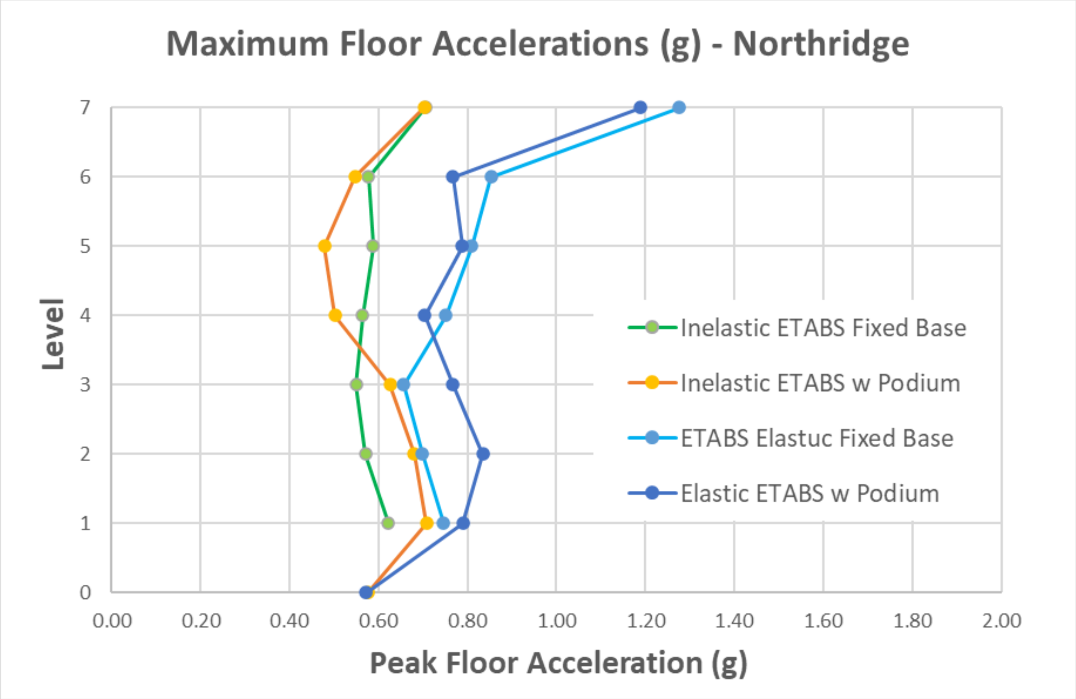


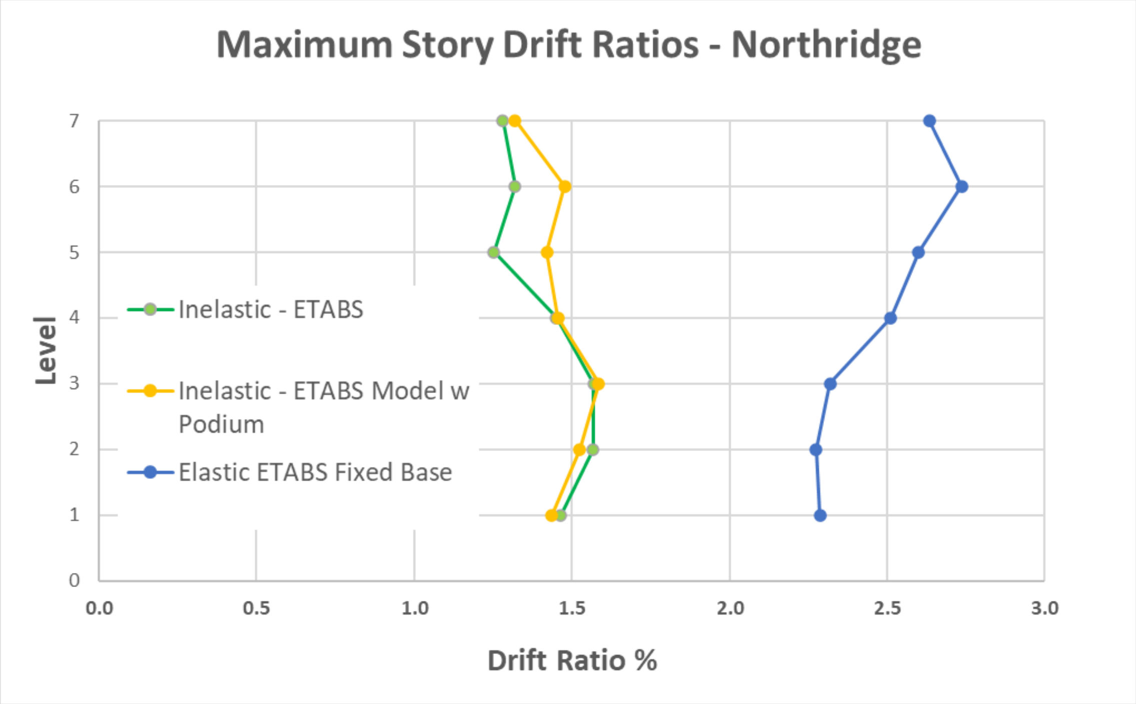


Comparison of Maximum Responses – Northridge (Van Nuys)

- ***PGA – 0.453 g***
- Model 1 (7 Story Fixed Base)
- Model 2(Podium at 1st Floor)







Example: 7-story Concrete MF + SW@1st floor

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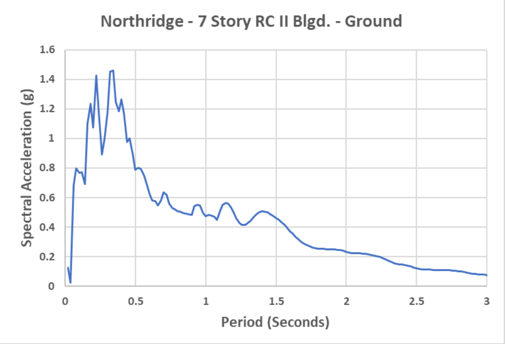
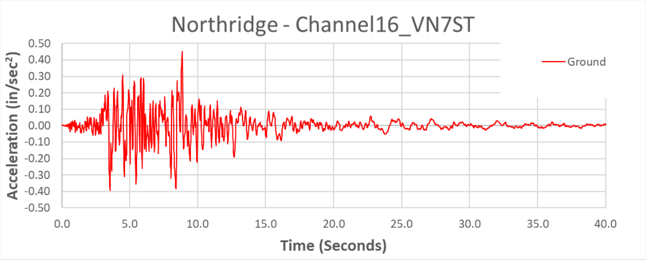
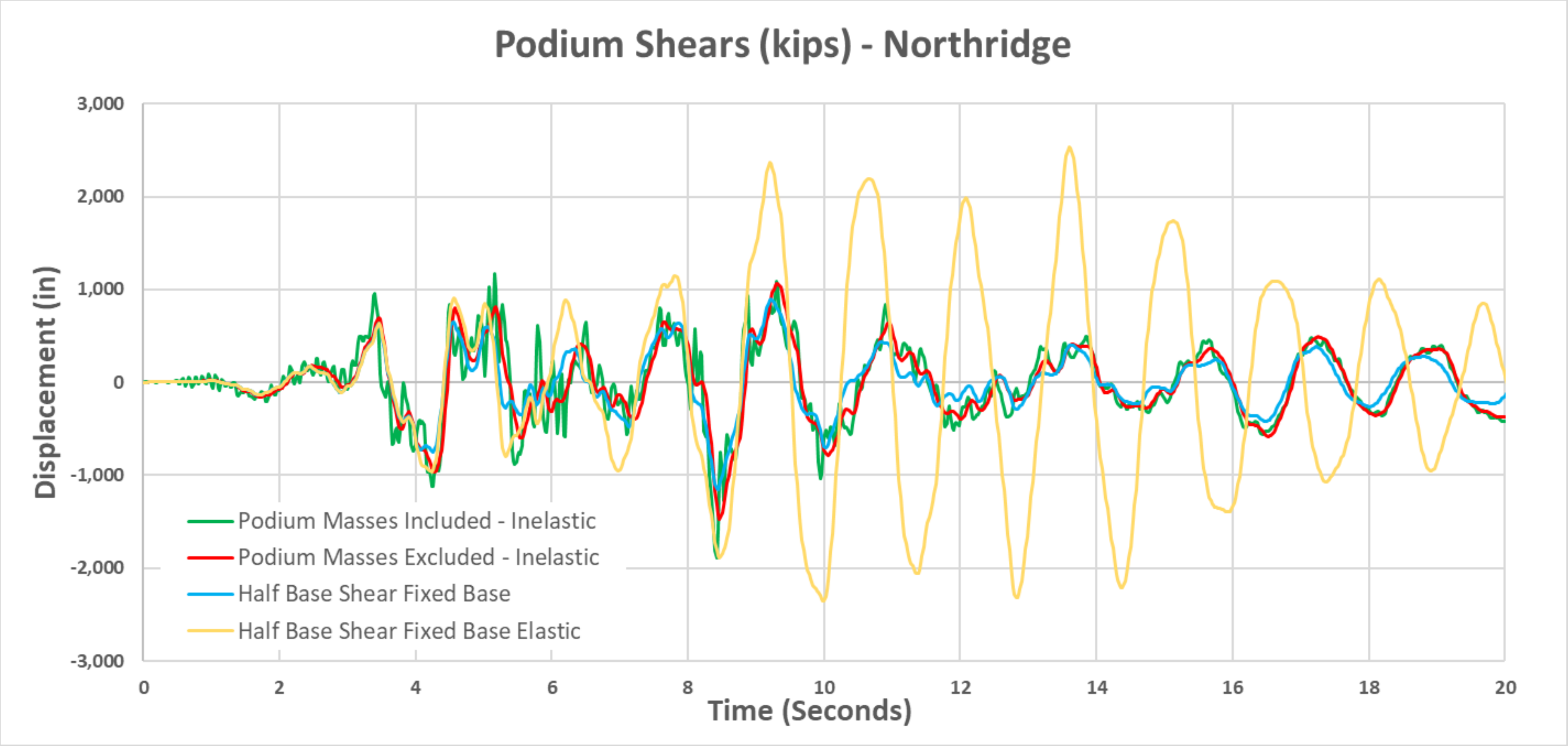
Podium Shear Time History Comparisons – Northridge (Van Nuys)

- ***PGA – 0.453g***
- Model 1 (7 Story Fixed Base)
- Model 2(Podium at 1st Floor)







Example: 7-story Concrete MF + SW@1st floor

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Podium Shear Time History Comparisons – Northridge (Van Nuys)

- ***PGA – 0.453g***
- Model 1 (7 Story Fixed Base)
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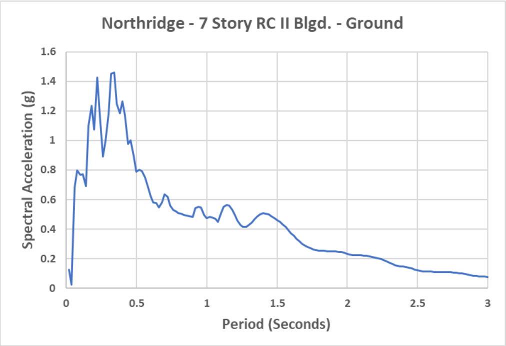

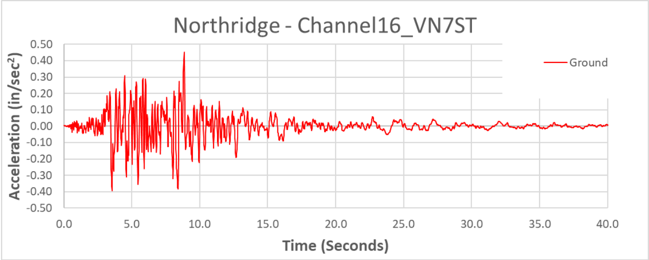

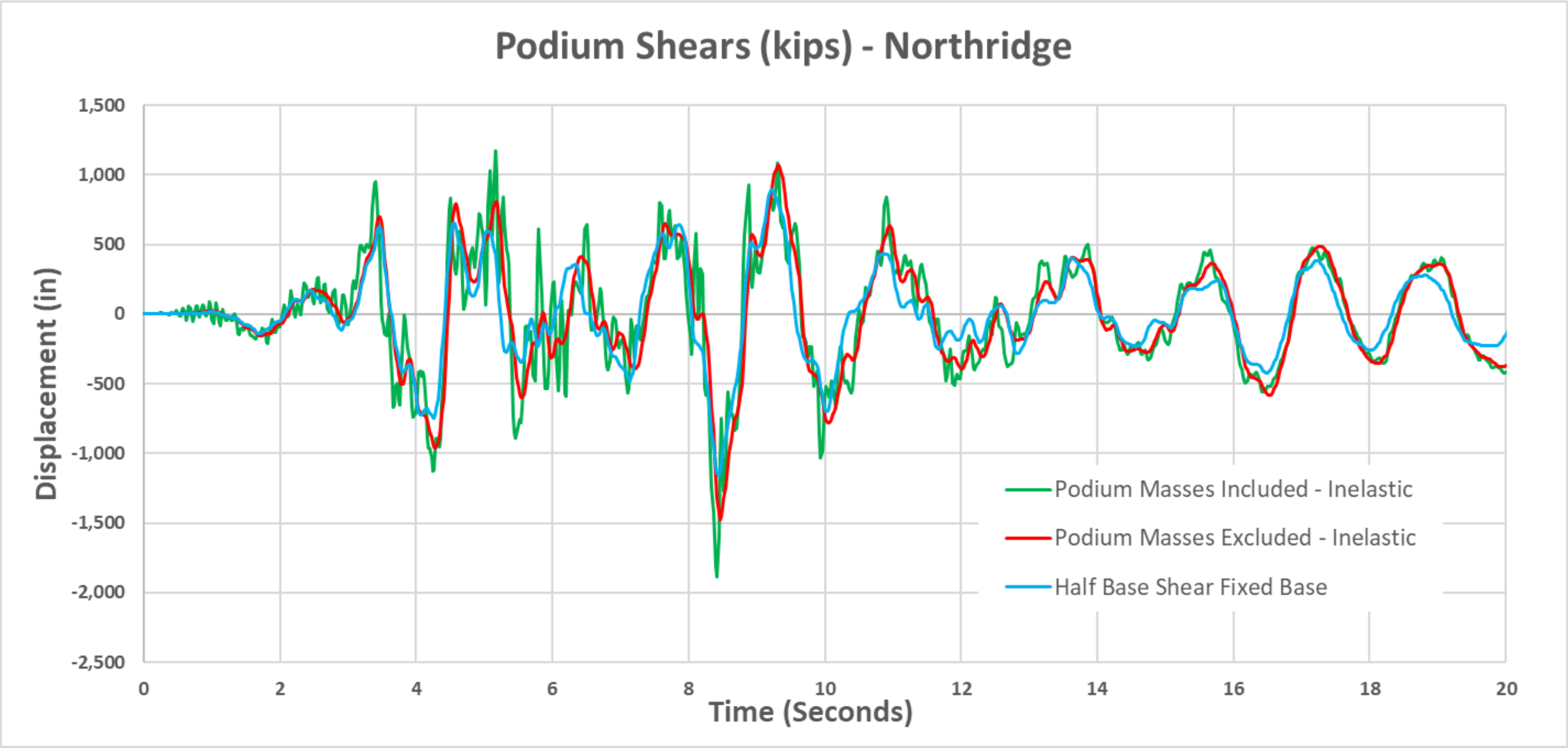

Example: 7-story Concrete MF + SW@1st floor

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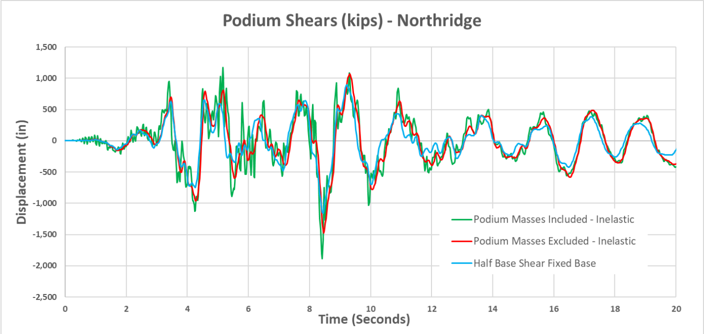
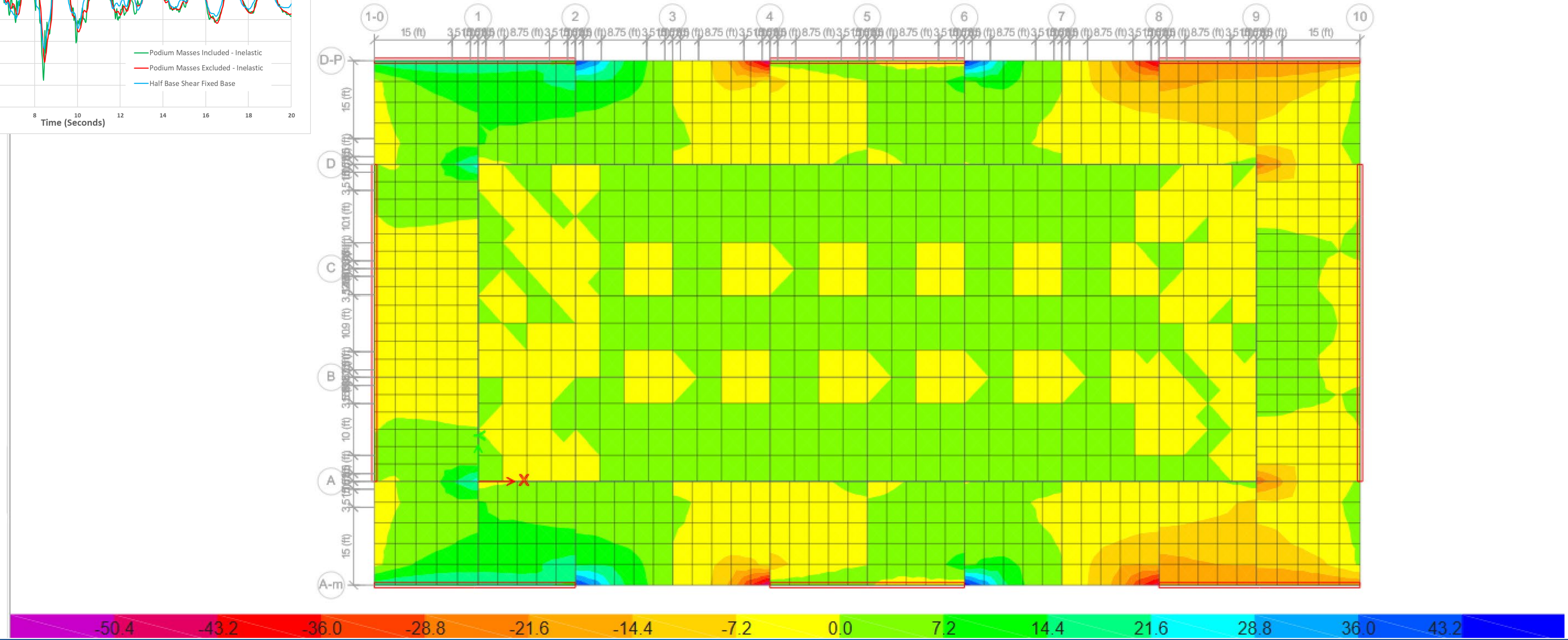
Diaphragm F11 Stresses at Max. Shear 8.42 seconds

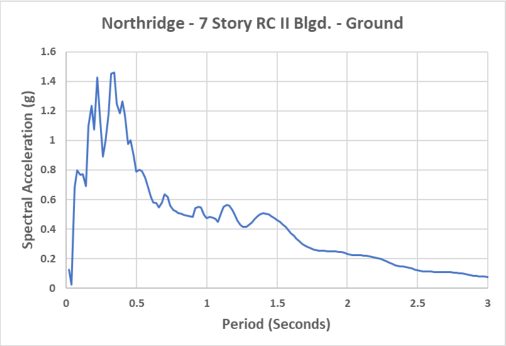


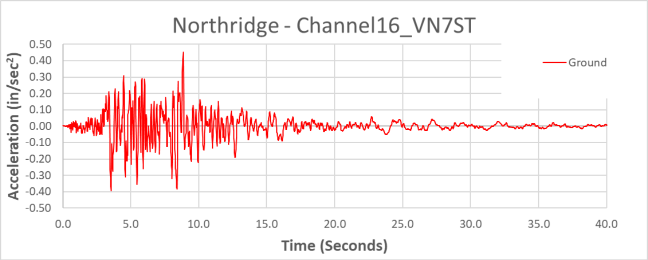


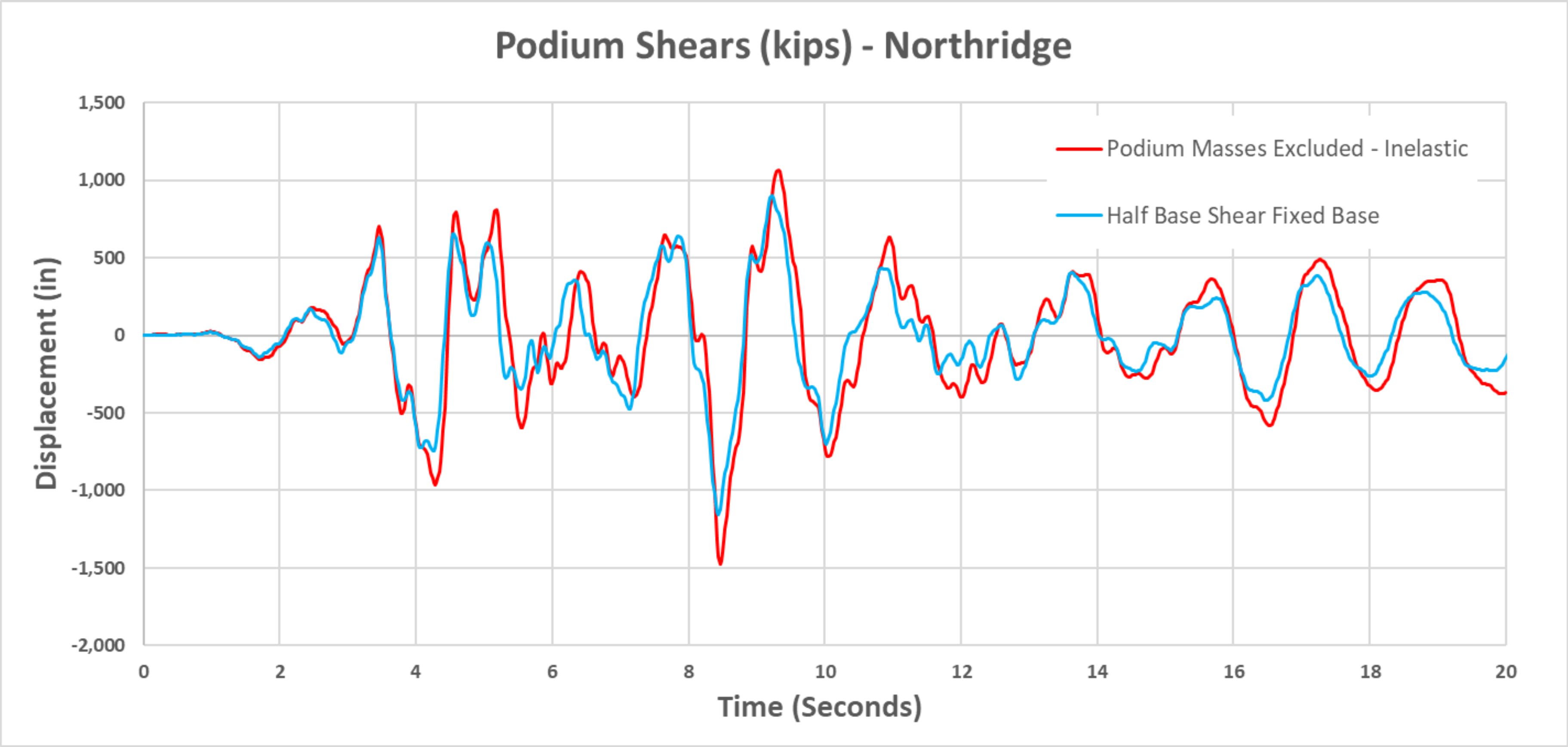
Example: 7-story Concrete MF + SW@1st floor

Podium Shear Time History Comparisons – Northridge (Van Nuys)

- ***PGA – 0.453g***
- Model 1 (7 Story Fixed Base)
- Model 2(Podium at 1st Floor)







Example: 7-story Concrete MF + SW@1st floor

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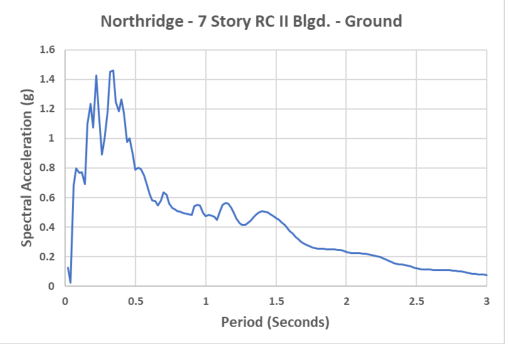
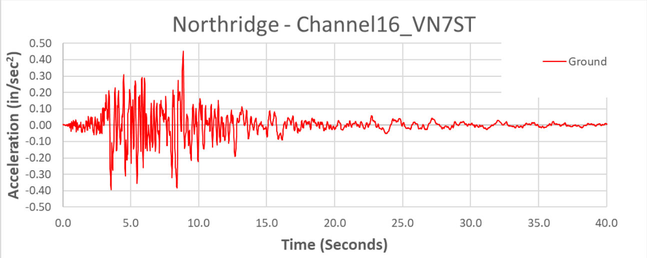
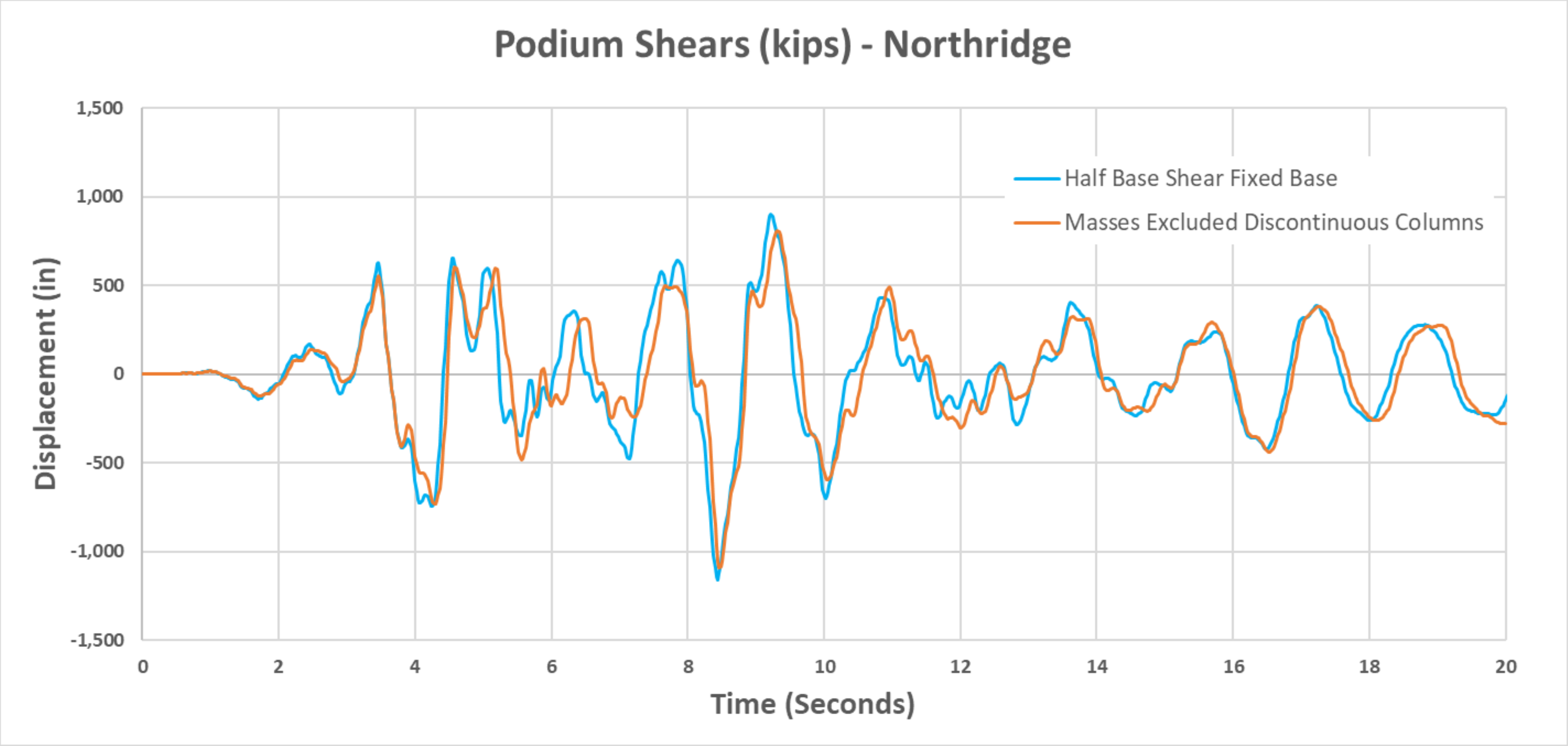
Podium Shear Time History Comparisons – Northridge (Van Nuys)

- ***PGA – 0.453g***
- Model 1 (7 Story Fixed Base)
- Model 2(Podium at 1st Floor)







Example: 7-story Concrete MF + SW@1st floor

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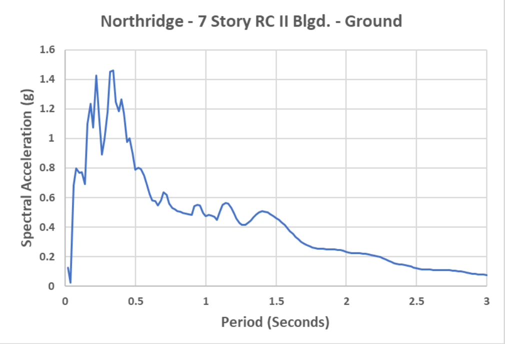
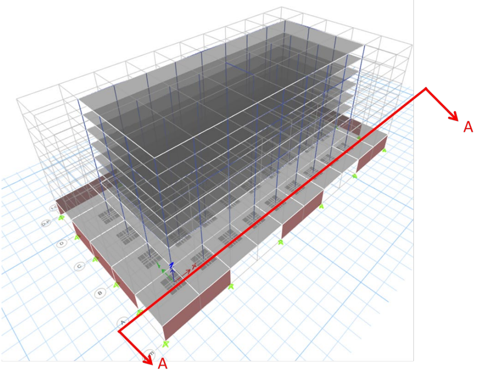
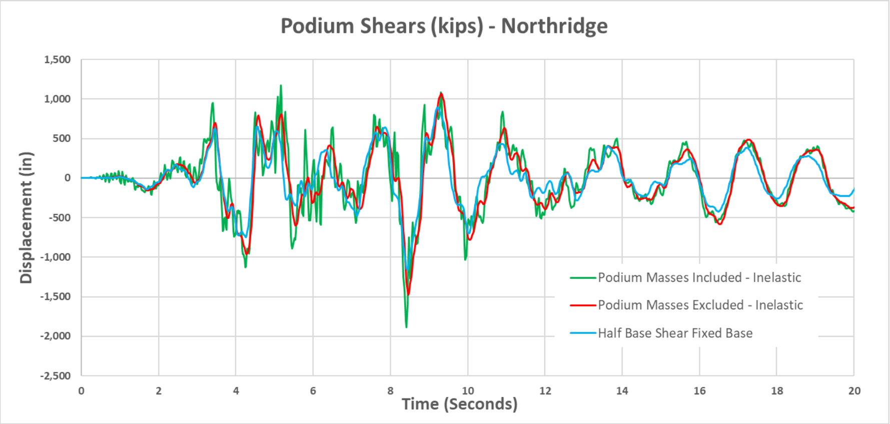
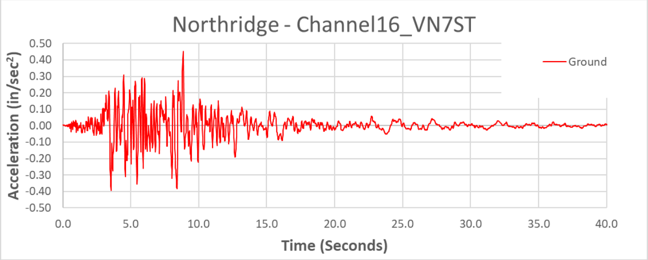
Podium Shear Time History Comparisons – Northridge (Van Nuys)

- ***PGA – 0.453g***
- Model 1 (7 Story Fixed Base)
- Model 2(Podium at 1st Floor)







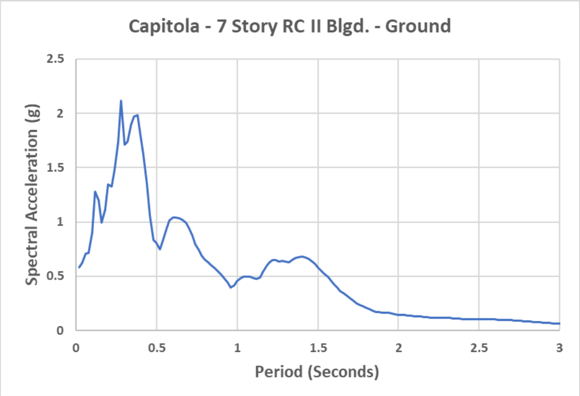


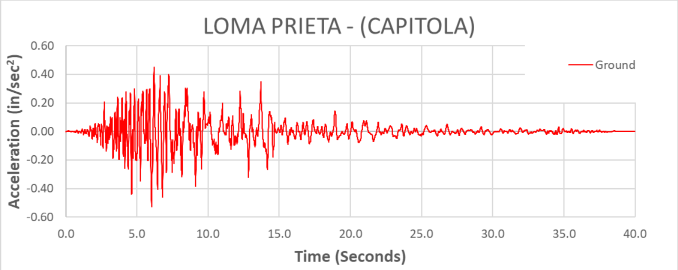
Maximum Podium Shears (Northridge) - Kips	
Podium Mass Included (Time History)	1889
Podium Mass Excluded (Time History)	1472
Podium Mass Excluded Discontinuous Columns (Time History)	1092
Half Base Shear Fixed Base - Inelastic(No Podium) (Time History)	1157
Half Base Shear Fixed Base - Elastic(No Podium) (Time History)	2532
Shear corresponding to Upper Structure Properties from model (ELF)	520
Half base shear corresponding to FB Upper Structure (ELF)	413

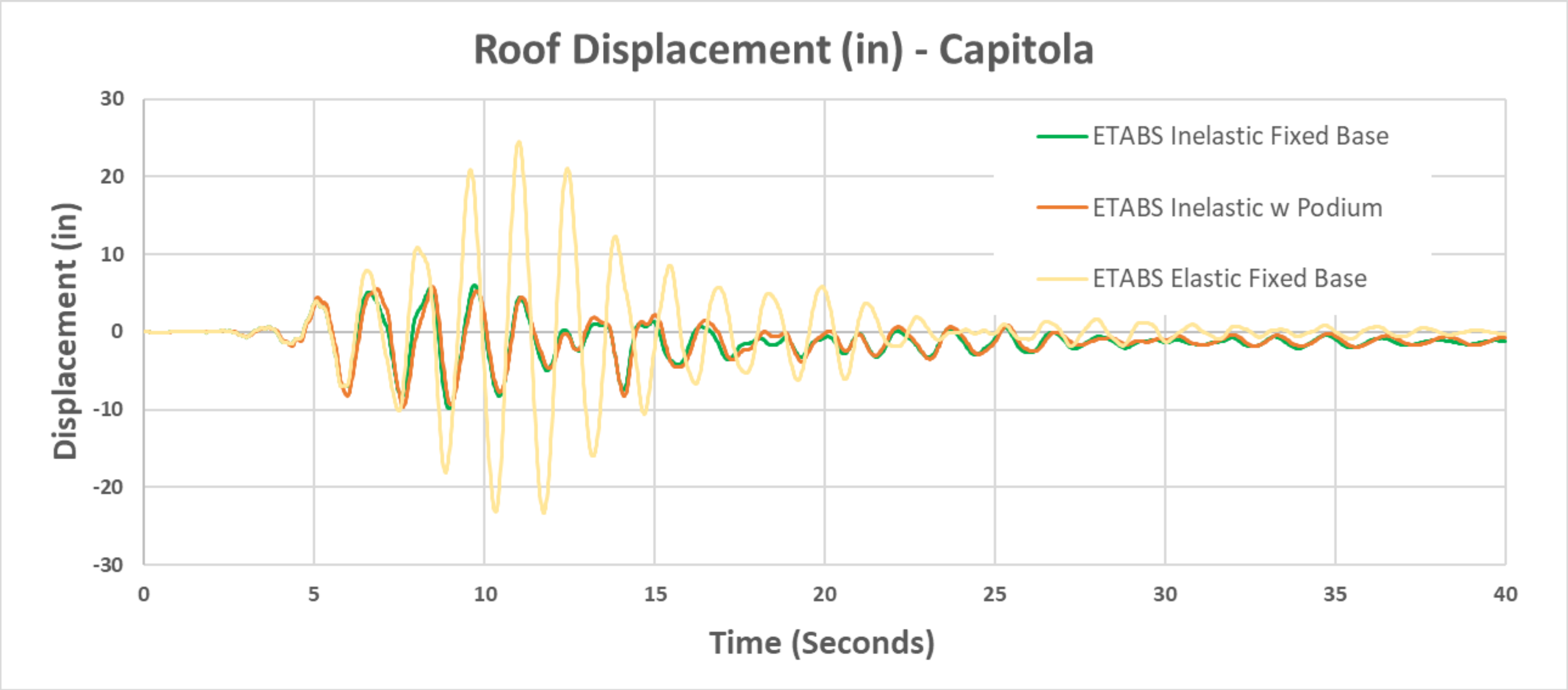
Example: 7-story Concrete MF + SW@1st floor

Time History Comparisons – Loma Prieta (Capitola)

- ***PGA – 0.529g***
- Model 1 (7 Story Fixed Base)
- Model 2(Podium at 1st Floor)



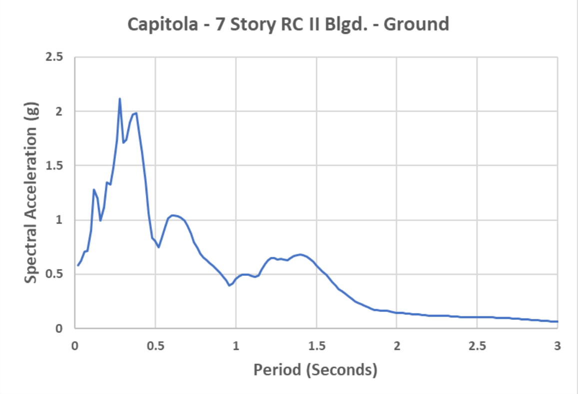


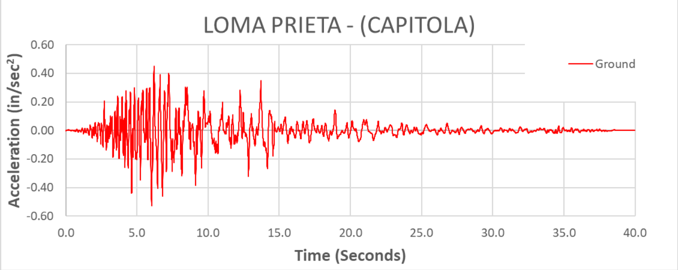


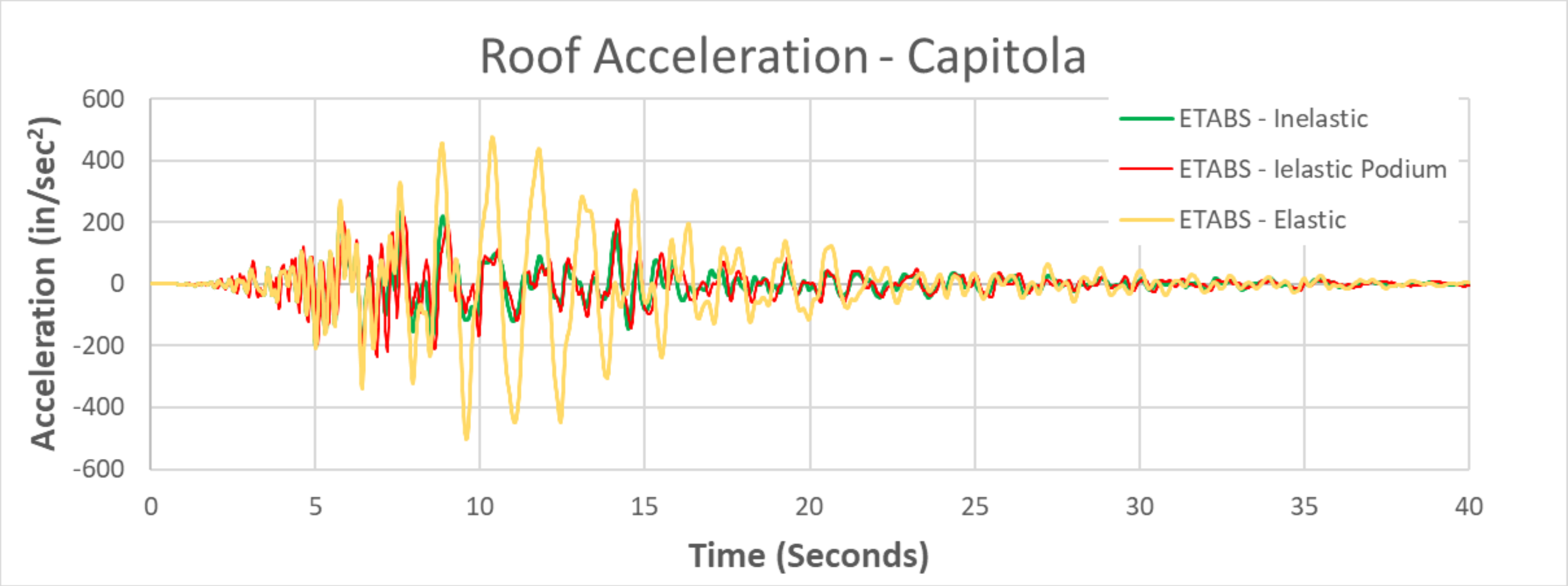
Example: 7-story Concrete MF + SW@1st floor

Time History Comparisons – Loma Prieta (Capitola)

- ***PGA – 0.529g***
- Model 1 (7 Story Fixed Base)
- Model 2(Podium at 1st Floor)





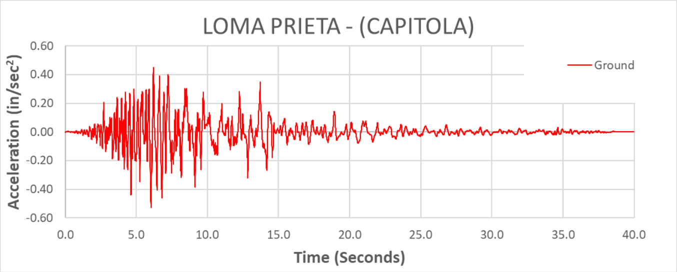


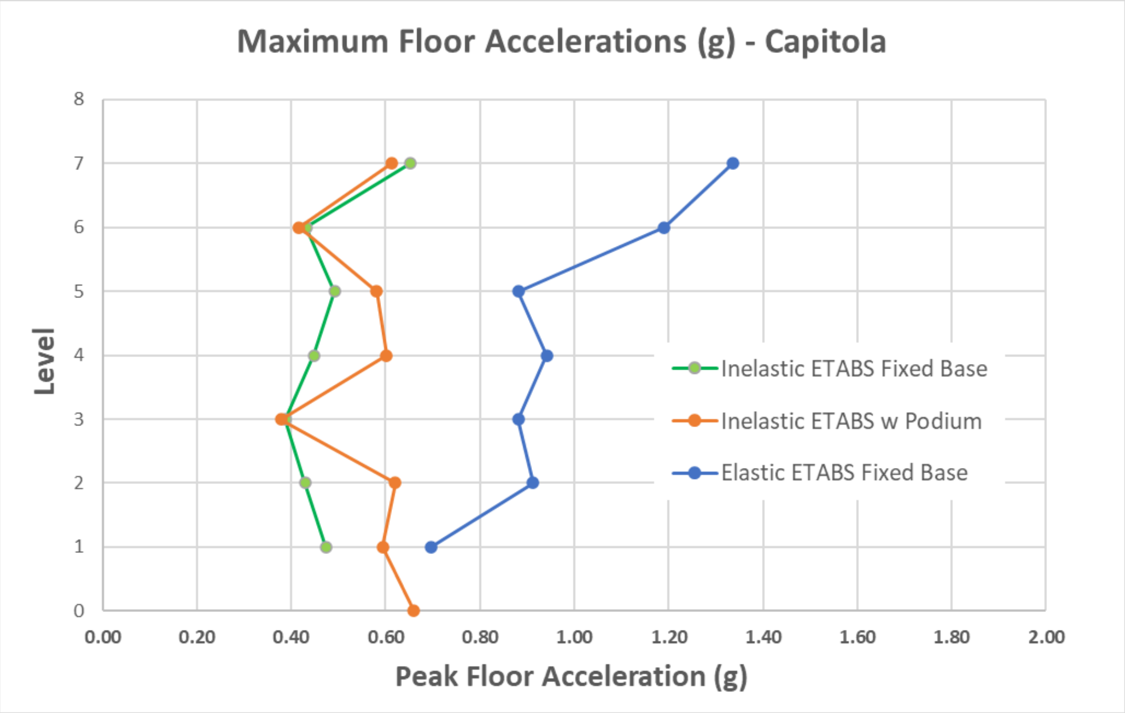
Example: 7-story Concrete MF + SW@1st floor

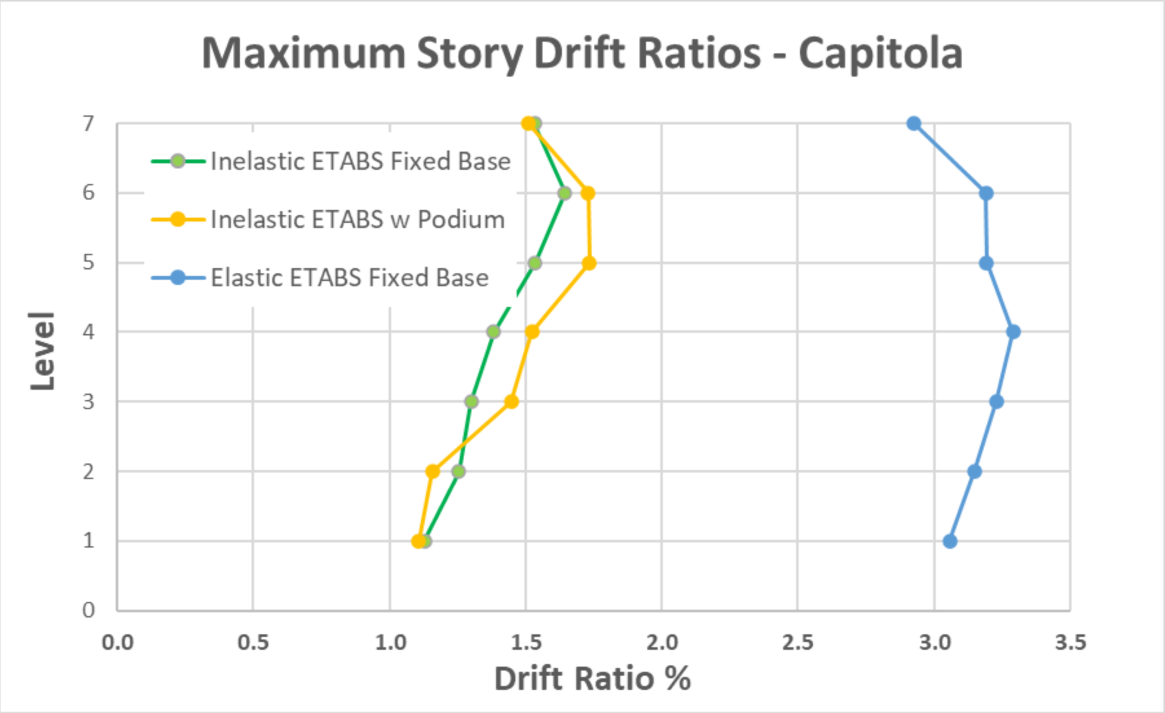
Department of Health Care Access and Information

Comparison of Maximum Responses – Loma Prieta (Capitola)

- ***PGA – 0.529 g***
- Model 1 (7 Story Fixed Base)
- Model 2(Podium at 1st Floor)





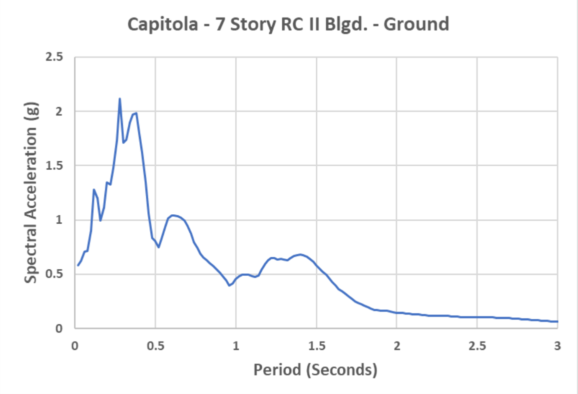


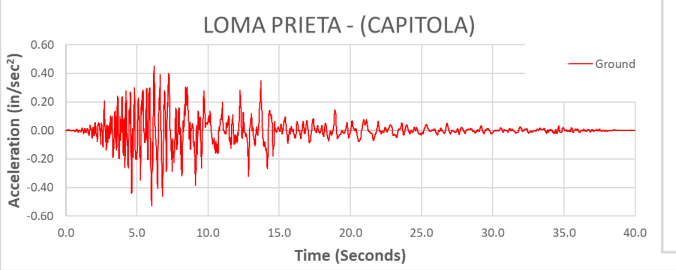
Example: 7-story Concrete MF + SW@1st floor

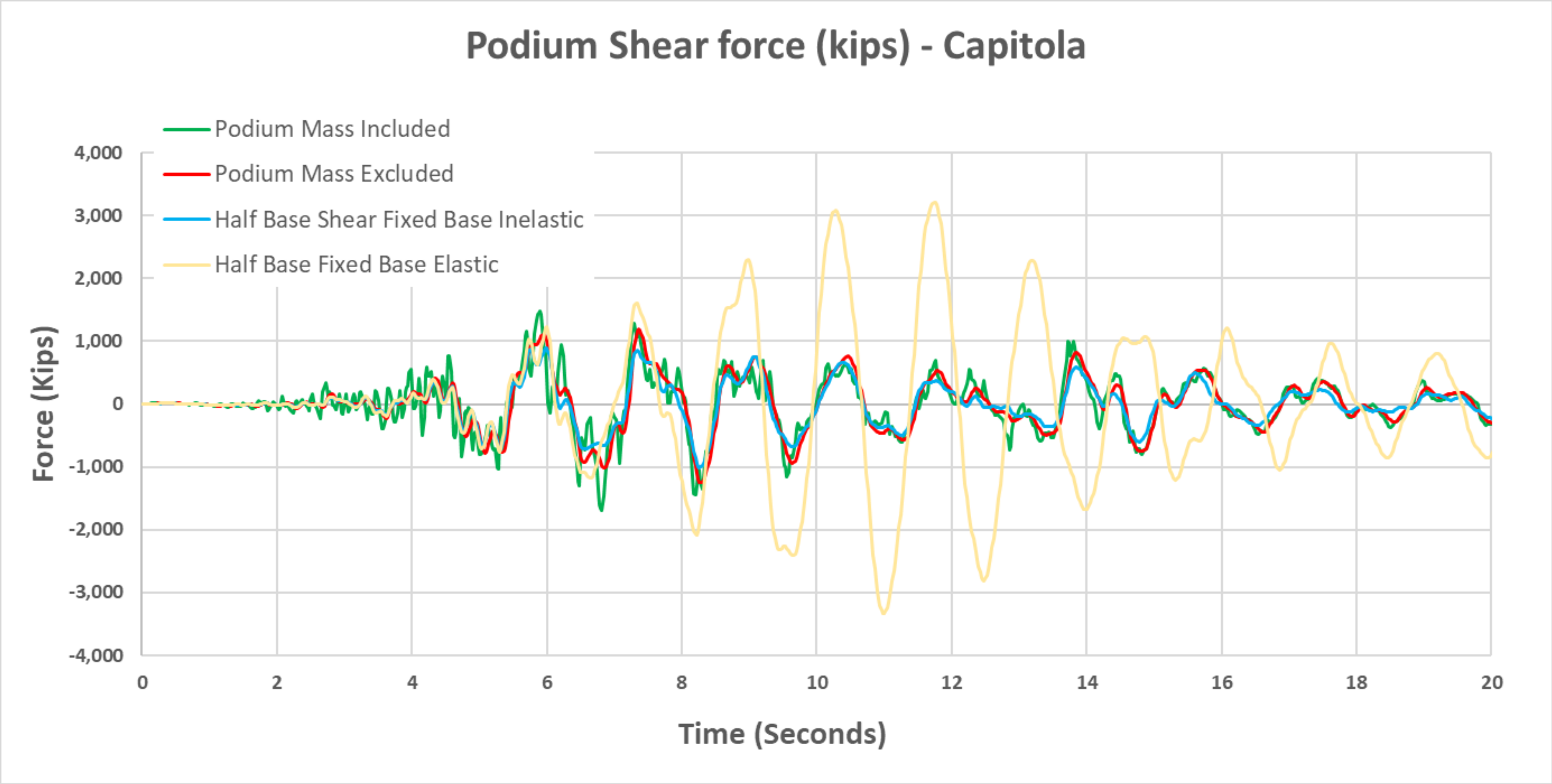
HCAI Department of Health Care Access and Information

Podium Shear Time History Comparisons – Loma Prieta (Capitola)

- ***PGA – 0.529g***
- Model 1 (7 Story Fixed Base)
- Model 2(Podium at 1st Floor)







Example: 7-story Concrete MF + SW@1st floor

HCAi Department of Health Care Access and Information

Podium Shear Time History Comparisons – Loma Prieta (Capitola)

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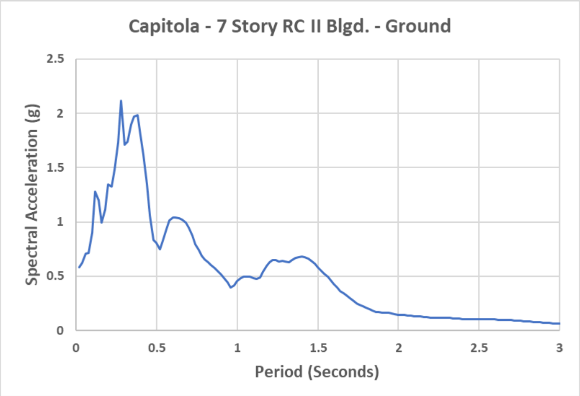

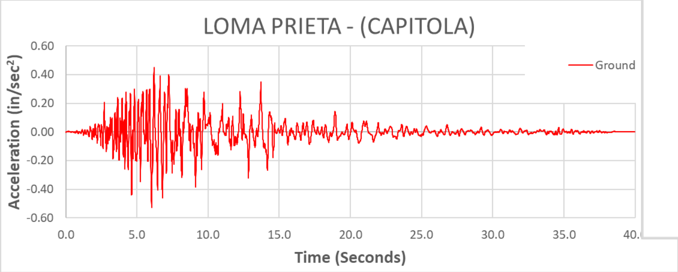

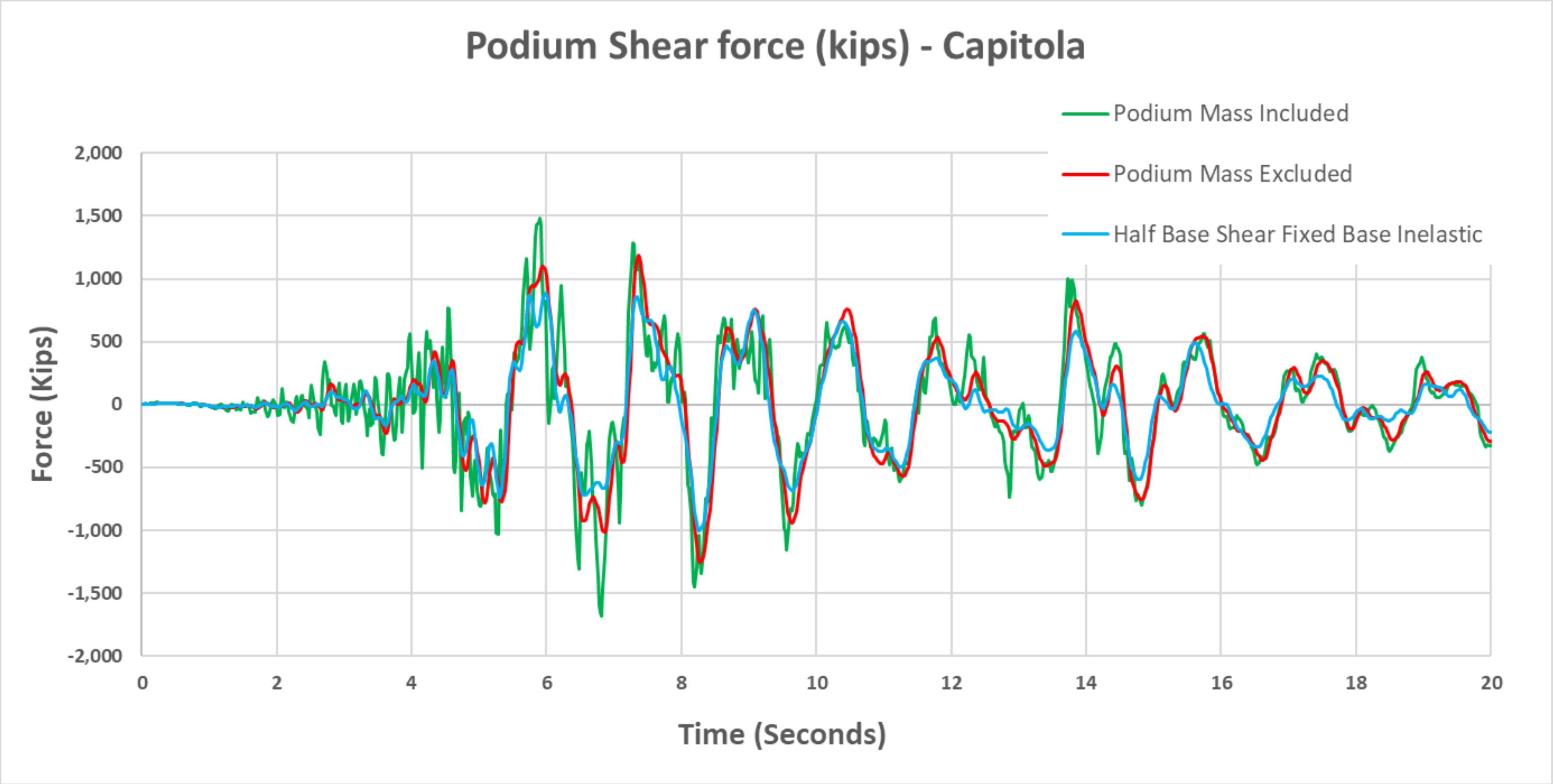

Example: 7-story Concrete MF + SW@1st floor

HCAi Department of Health Care Access and Information

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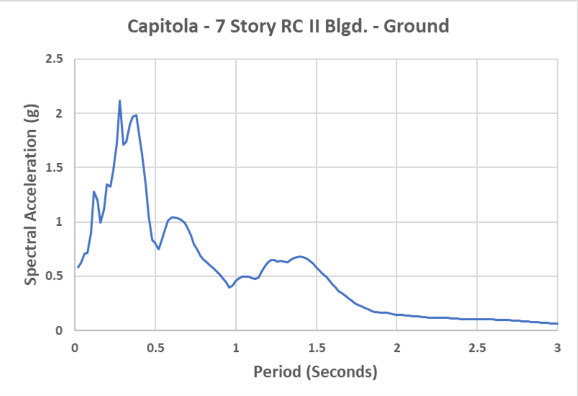

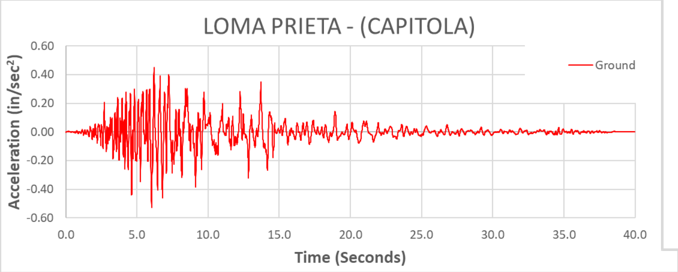

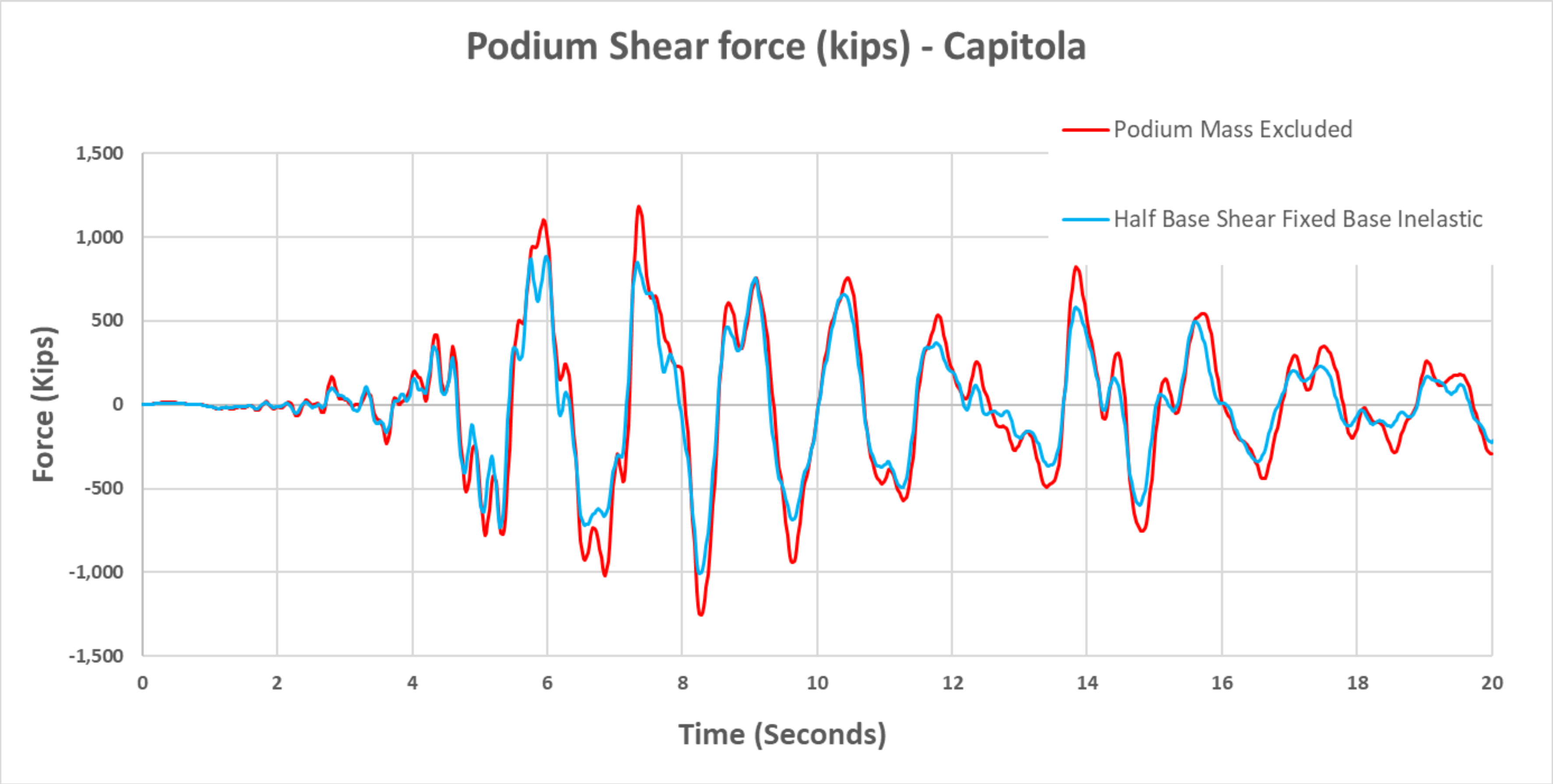

Example: 7-story Concrete MF + SW@1st floor

HCAI Department of Health Care Access and Information

Podium Shear Time History Comparisons – Loma Prieta (Capitola)

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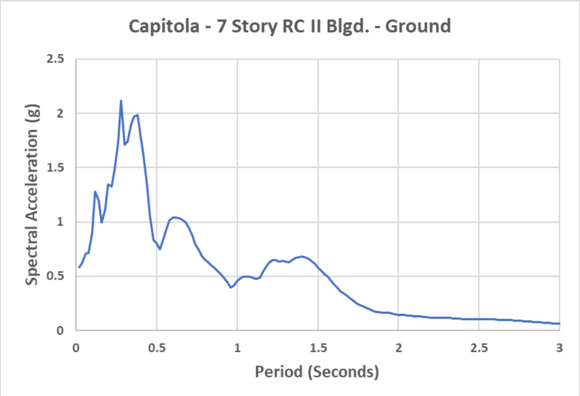

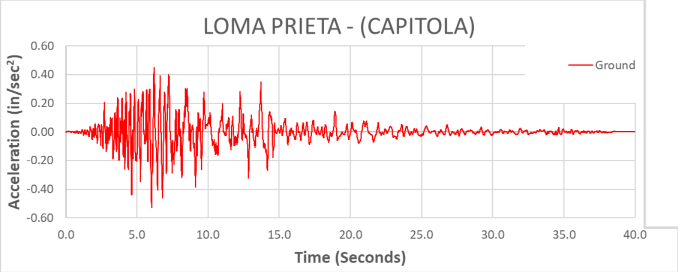

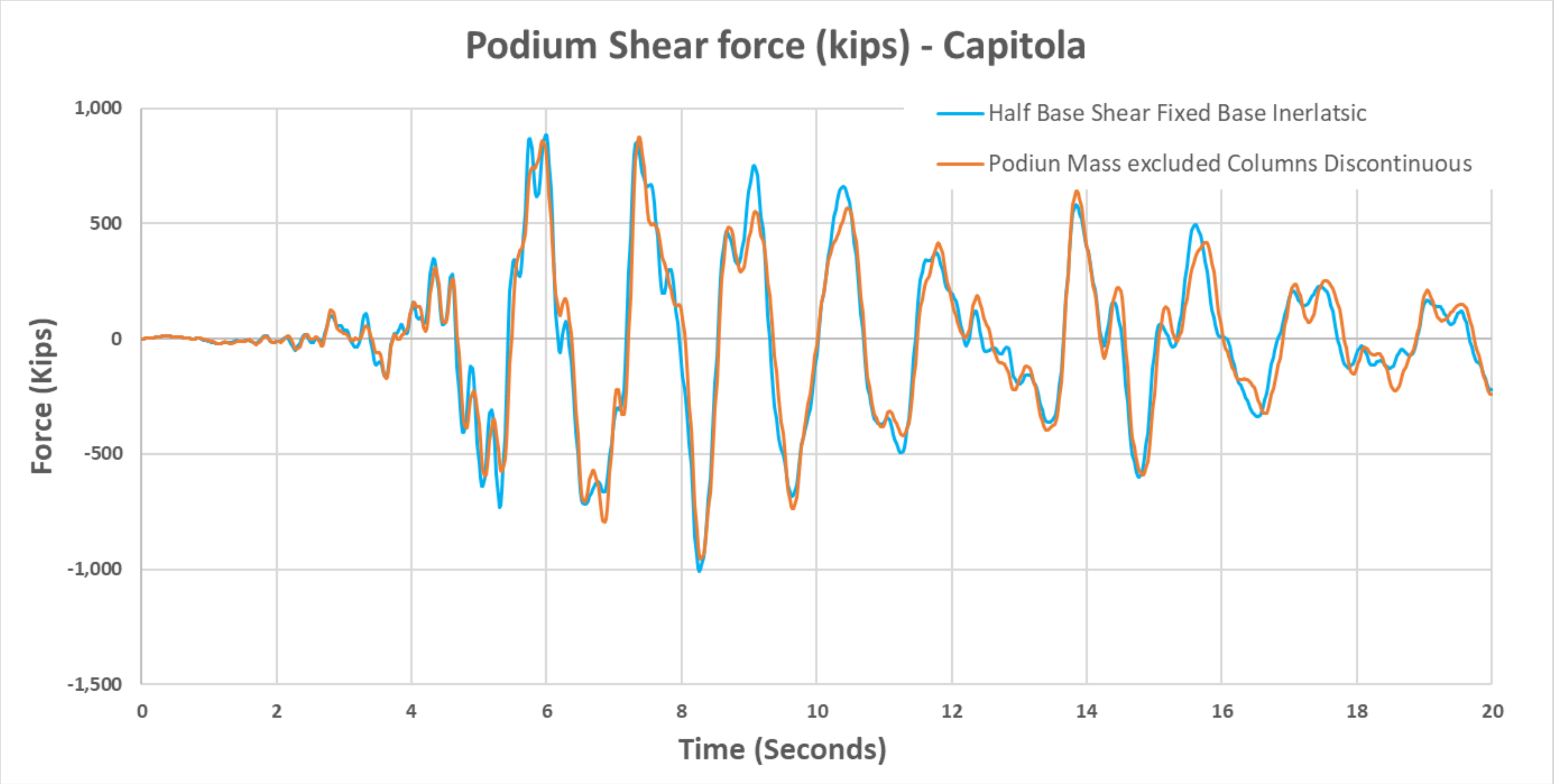

Example: 7-story Concrete MF + SW@1st floor

HCAI Department of Health Care Access and Information

Podium Shear Time History Comparisons – Loma Prieta (Capitola)

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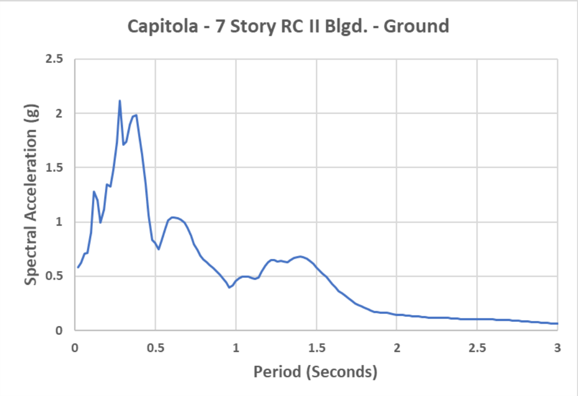
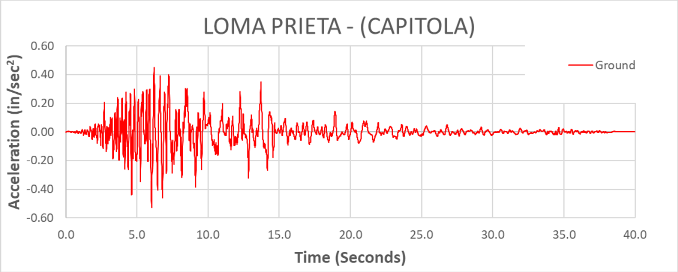
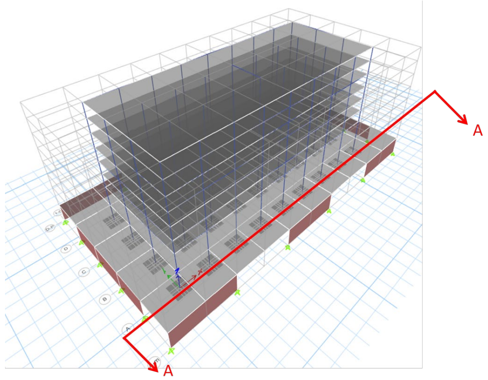
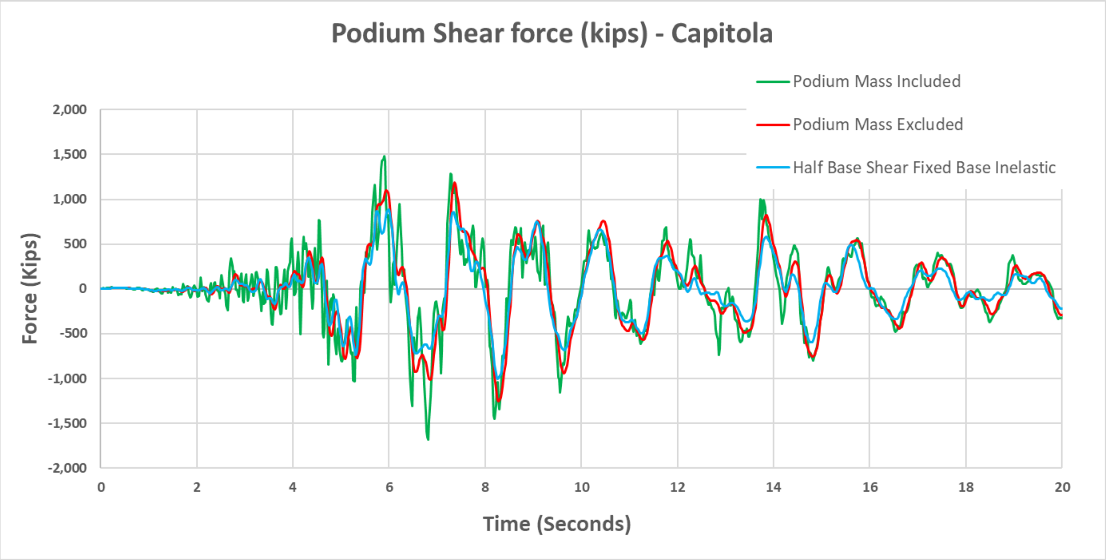








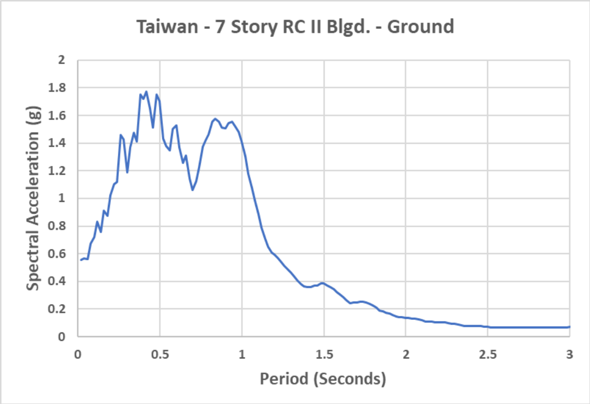
Maximum Podium Shears (Capitola) - Kips	
Podium Mass Included	1611
Podium Mass Excluded	1253
Podium Mass Excluded Discontinuous Columns	954
Half Base Shear Fixed Base - Inelastic(No Podium)	1085
Half Base Shear Fixed Base - Elastic(No Podium)	2750

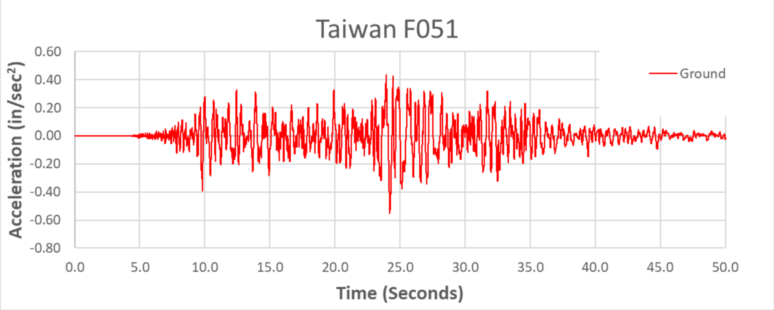
Example: 7-story Concrete MF + SW@1st floor

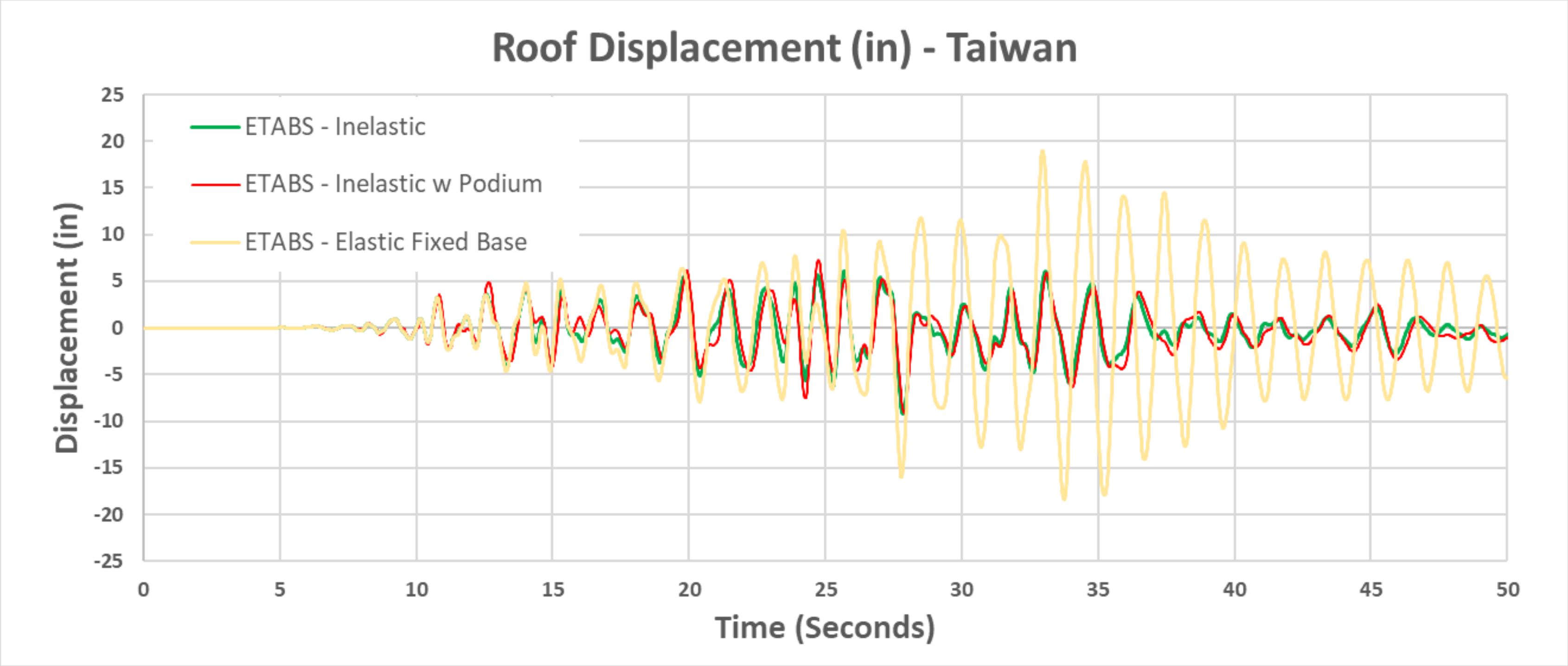
HCAI Department of Health Care Access and Information

Time History Comparisons – Taiwan

- ***PGA – 0.552g***
- Model 1 (7 Story Fixed Base)
- Model 2(Podium at 1st Floor)





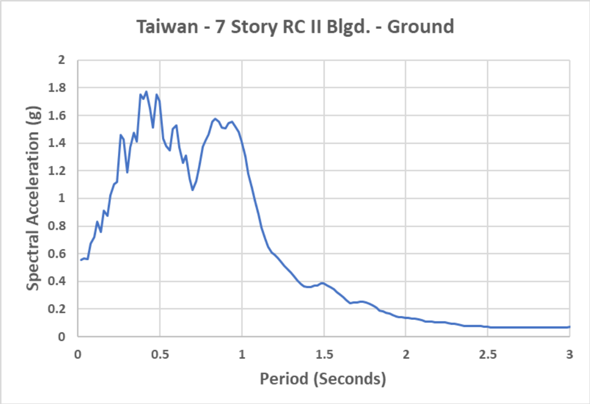


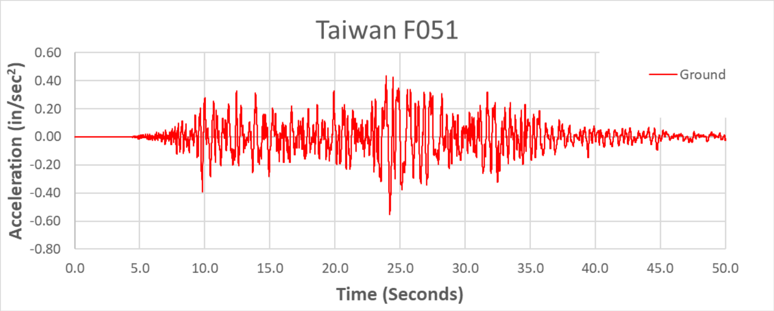
Example: 7-story Concrete MF + SW@1st floor

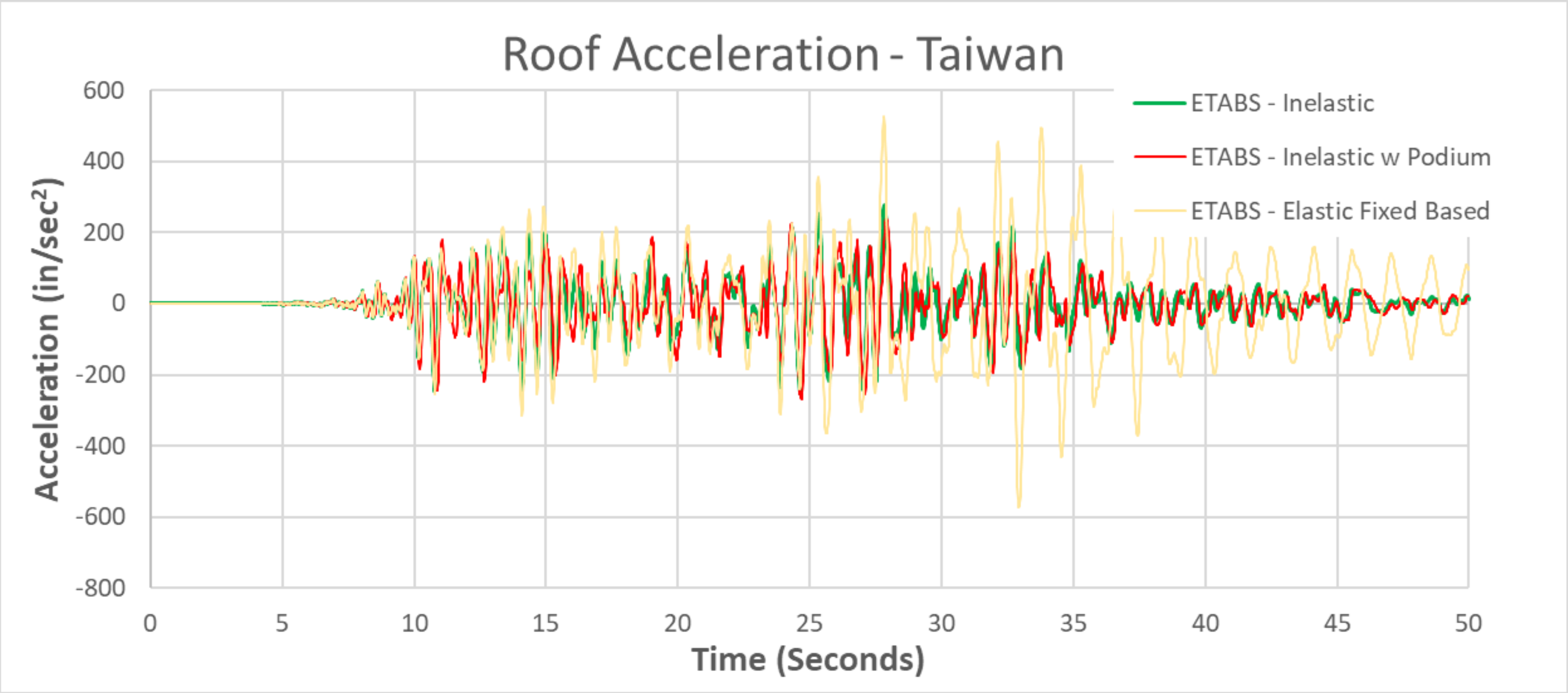
HCAI Department of Health Care Access and Information

Time History Comparisons – Taiwan

- ***PGA – 0.552g***
- Model 1 (7 Story Fixed Base)
- Model 2(Podium at 1st Floor)





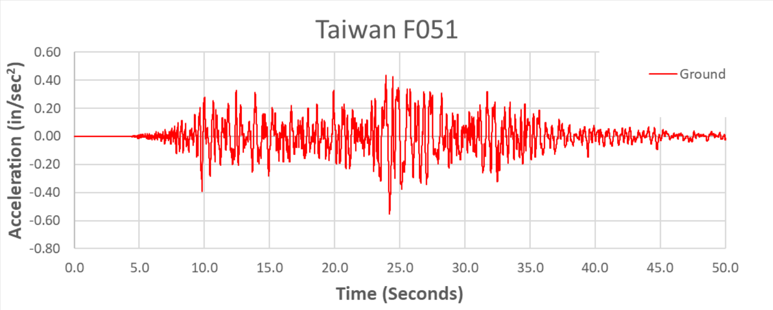


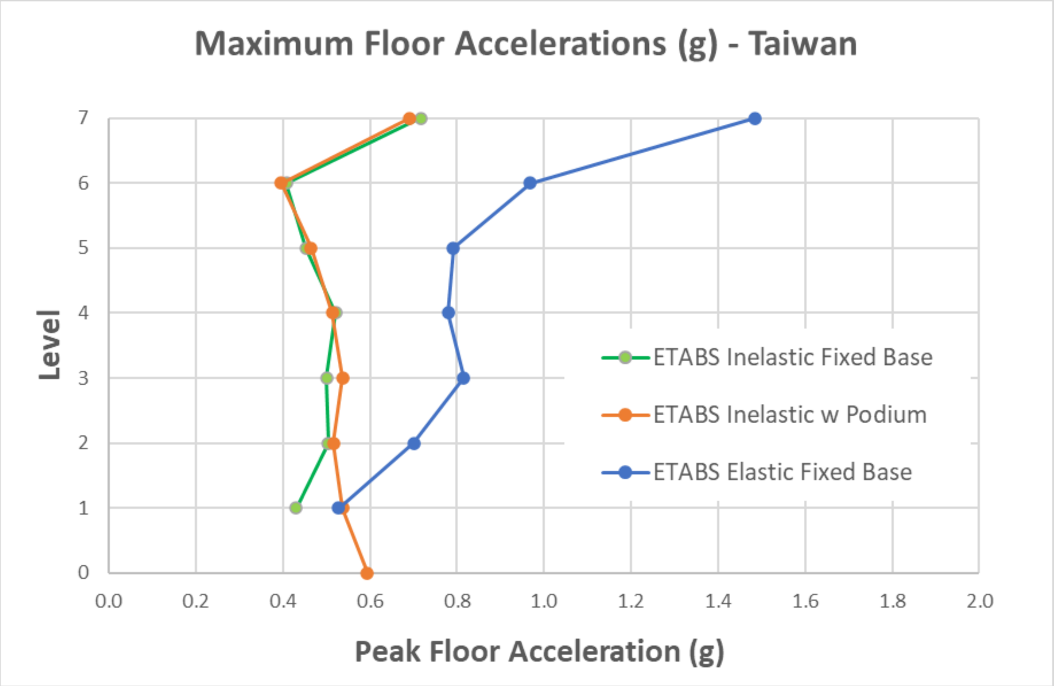
Example: 7-story Concrete MF + SW@1st floor

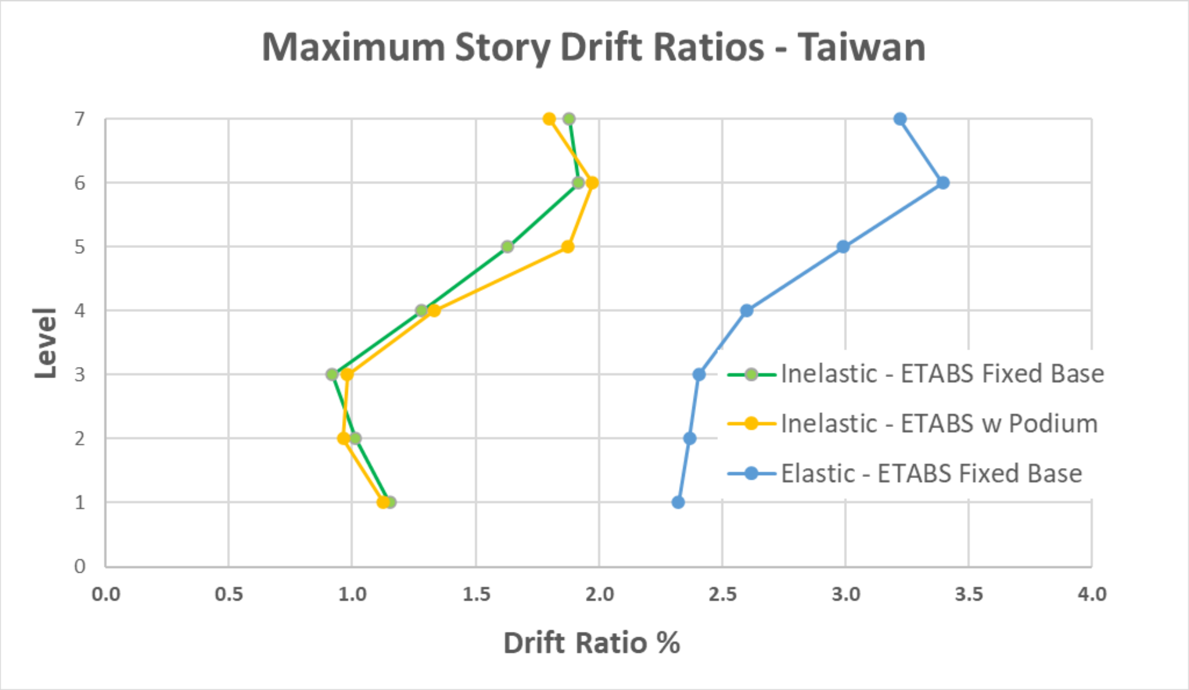
HCAi Department of Health Care Access and Information

Comparison of Maximum Responses – Taiwan

- ***PGA – 0.552 g***
- Model 1 (7 Story Fixed Base)
- Model 2(Podium at 1st Floor)





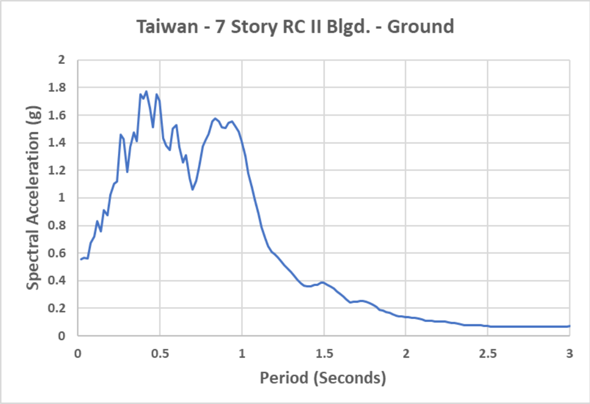


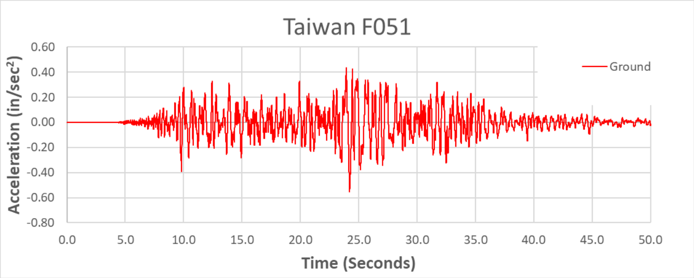
Example: 7-story Concrete MF + SW@1st floor

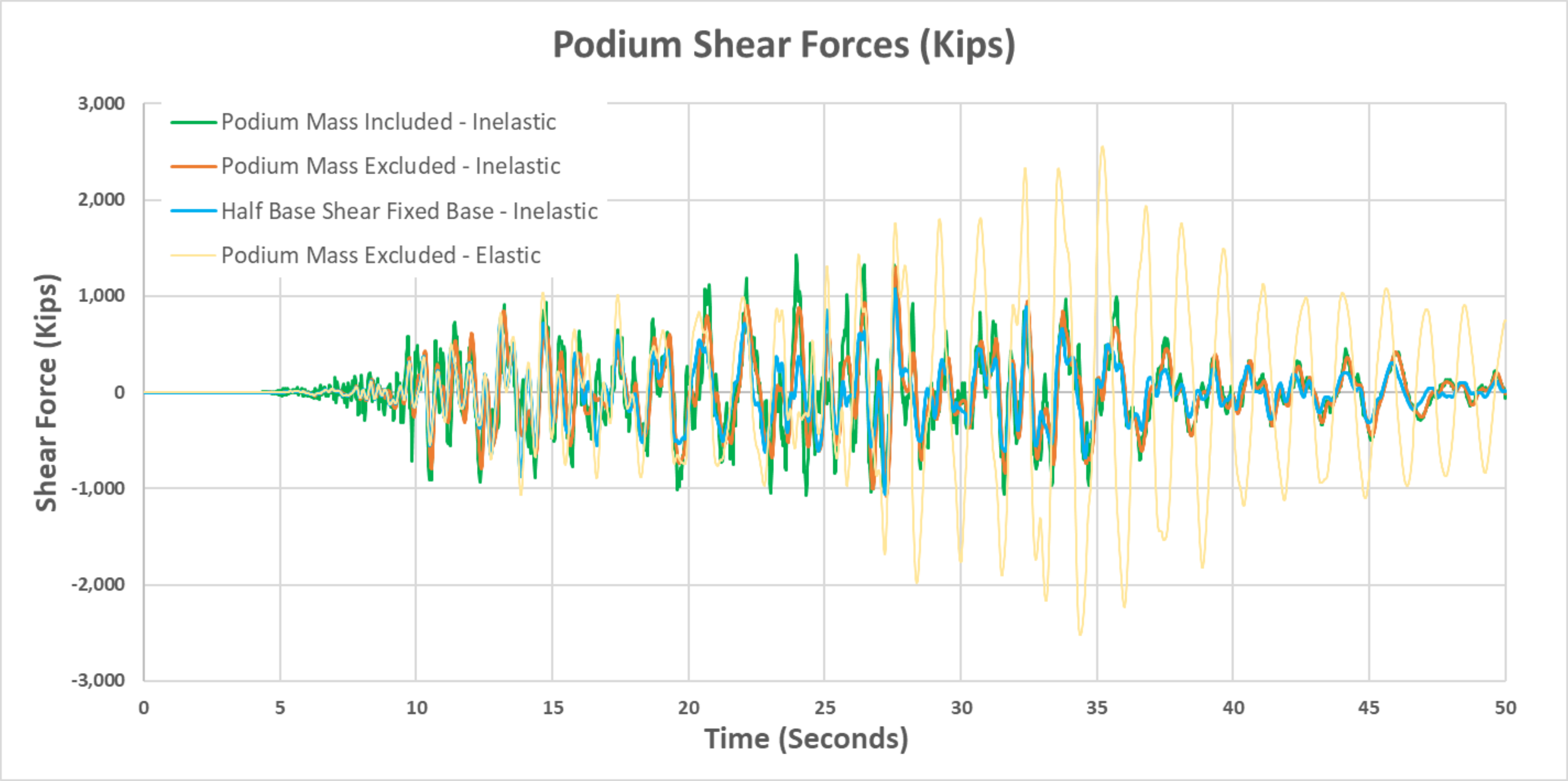
HCAI Department of Health Care Access and Information

Podium Shear Time History Comparisons – Taiwan

- ***PGA – 0.552g***
- Model 1 (7 Story Fixed Base)
- Model 2(Podium at 1st Floor)







Example: 7-story Concrete MF + SW@1st floor

HCAi Department of Health Care Access and Information

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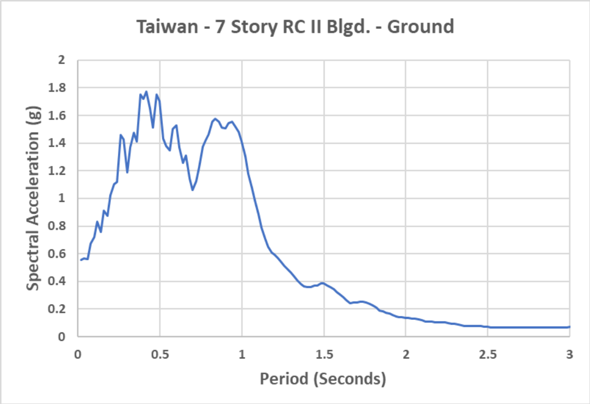

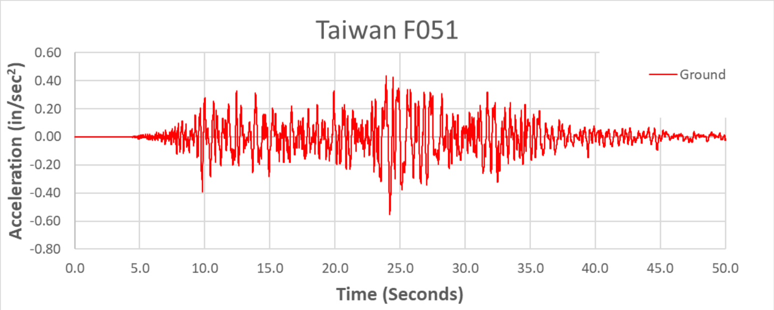

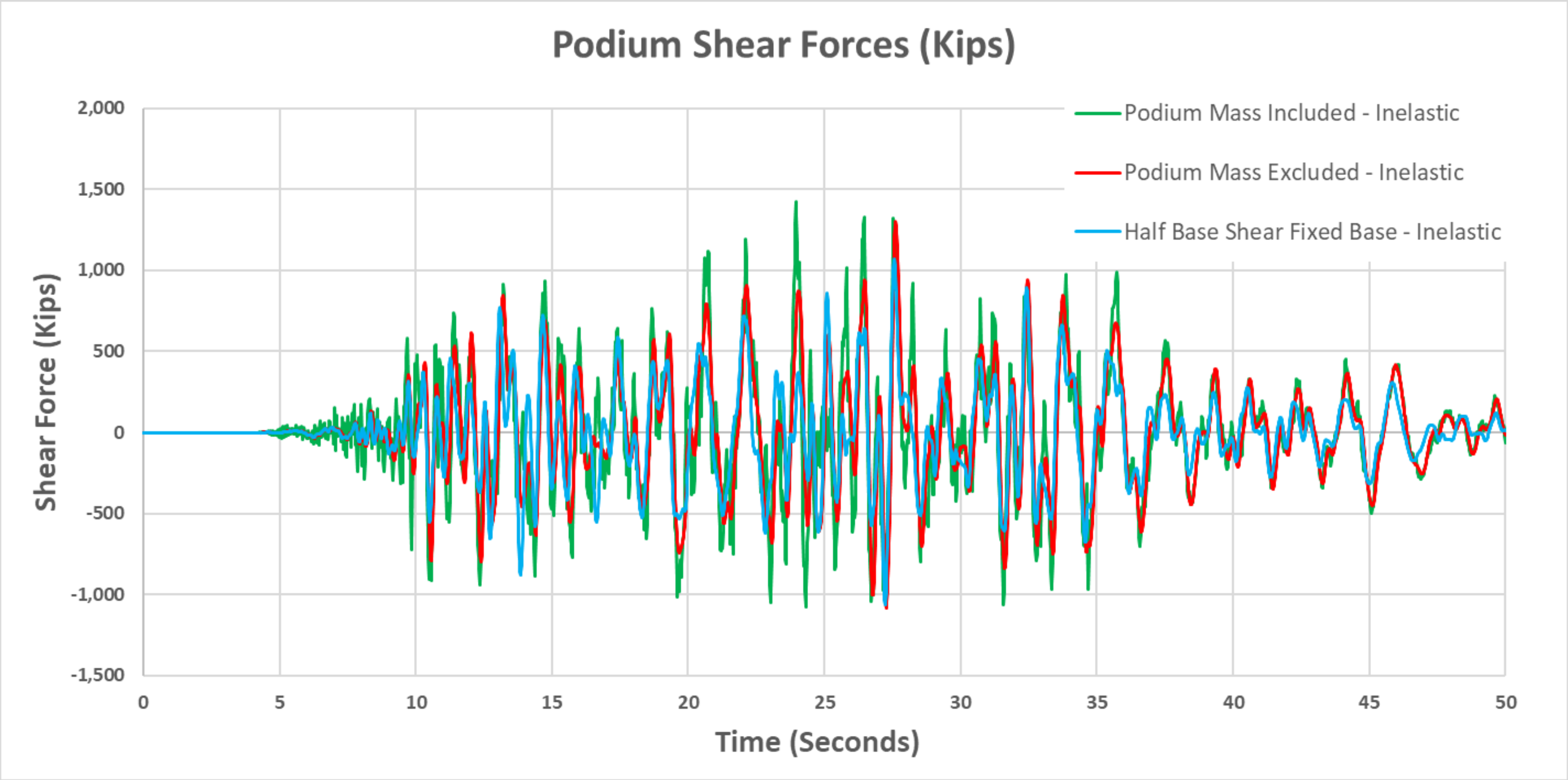

Example: 7-story Concrete MF + SW@1st floor

HCAI Department of Health Care Access and Information

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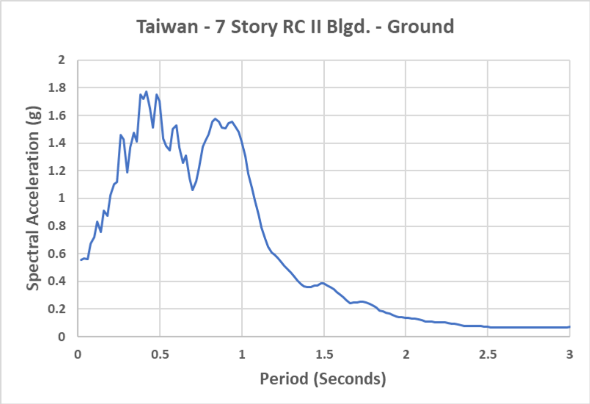

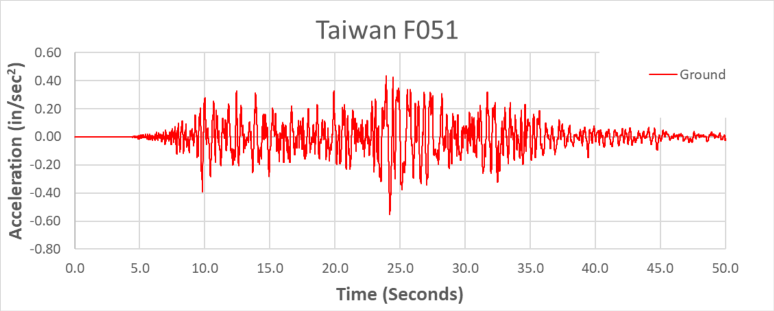

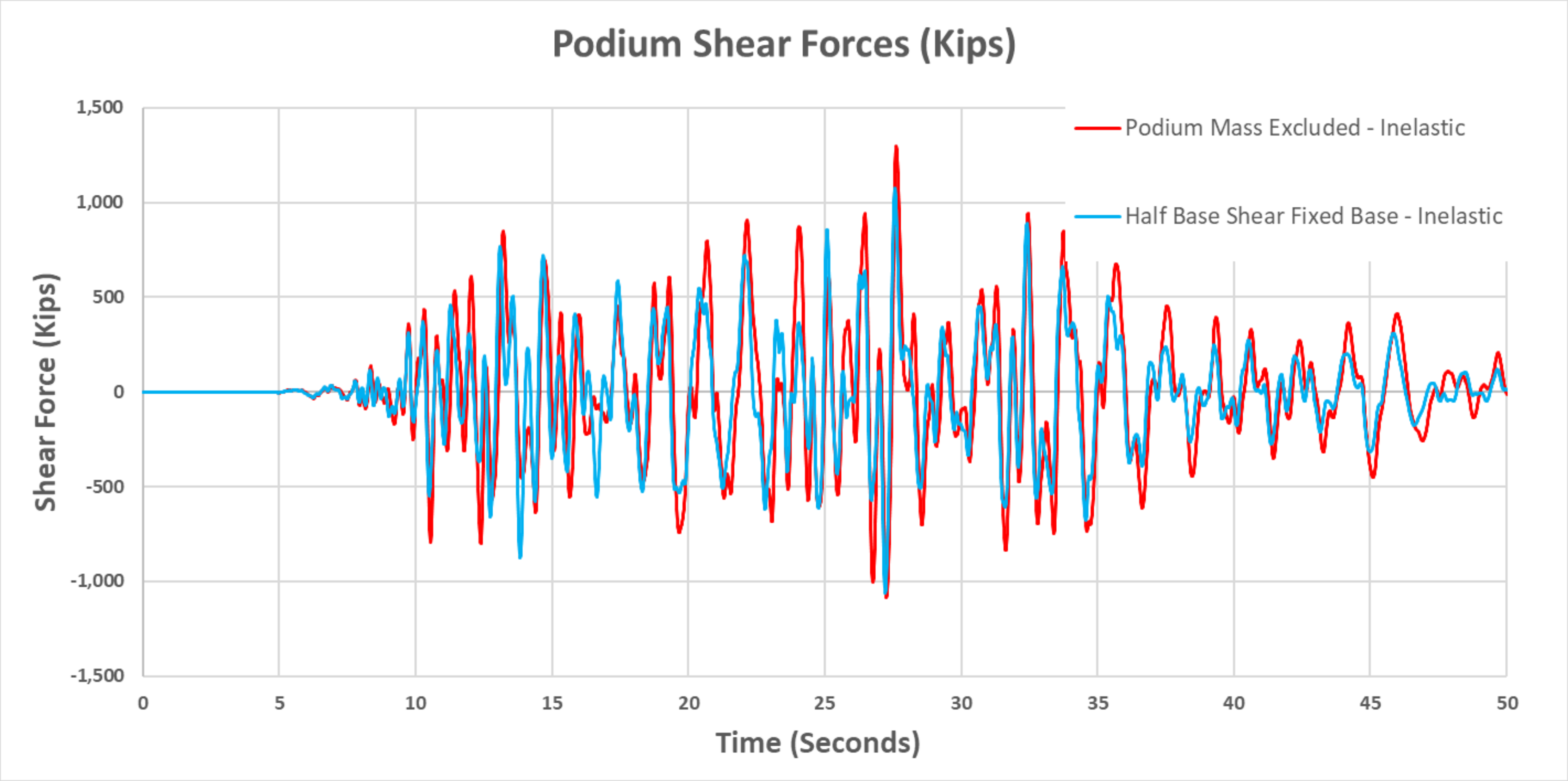

Example: 7-story Concrete MF + SW@1st floor

HCAi Department of Health Care Access and Information

Podium Shear Time History Comparisons – Taiwan

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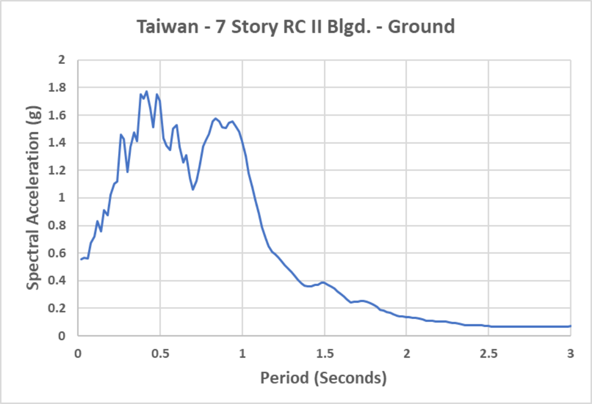

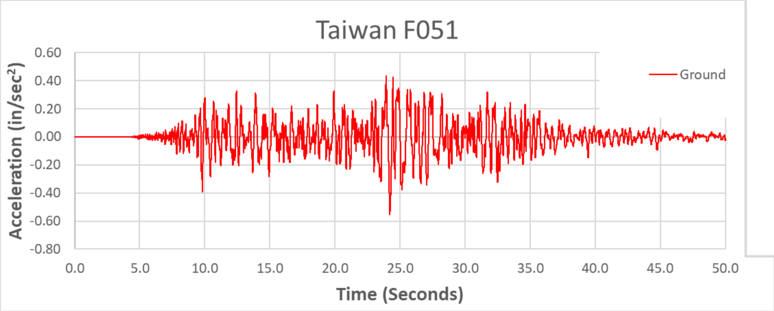

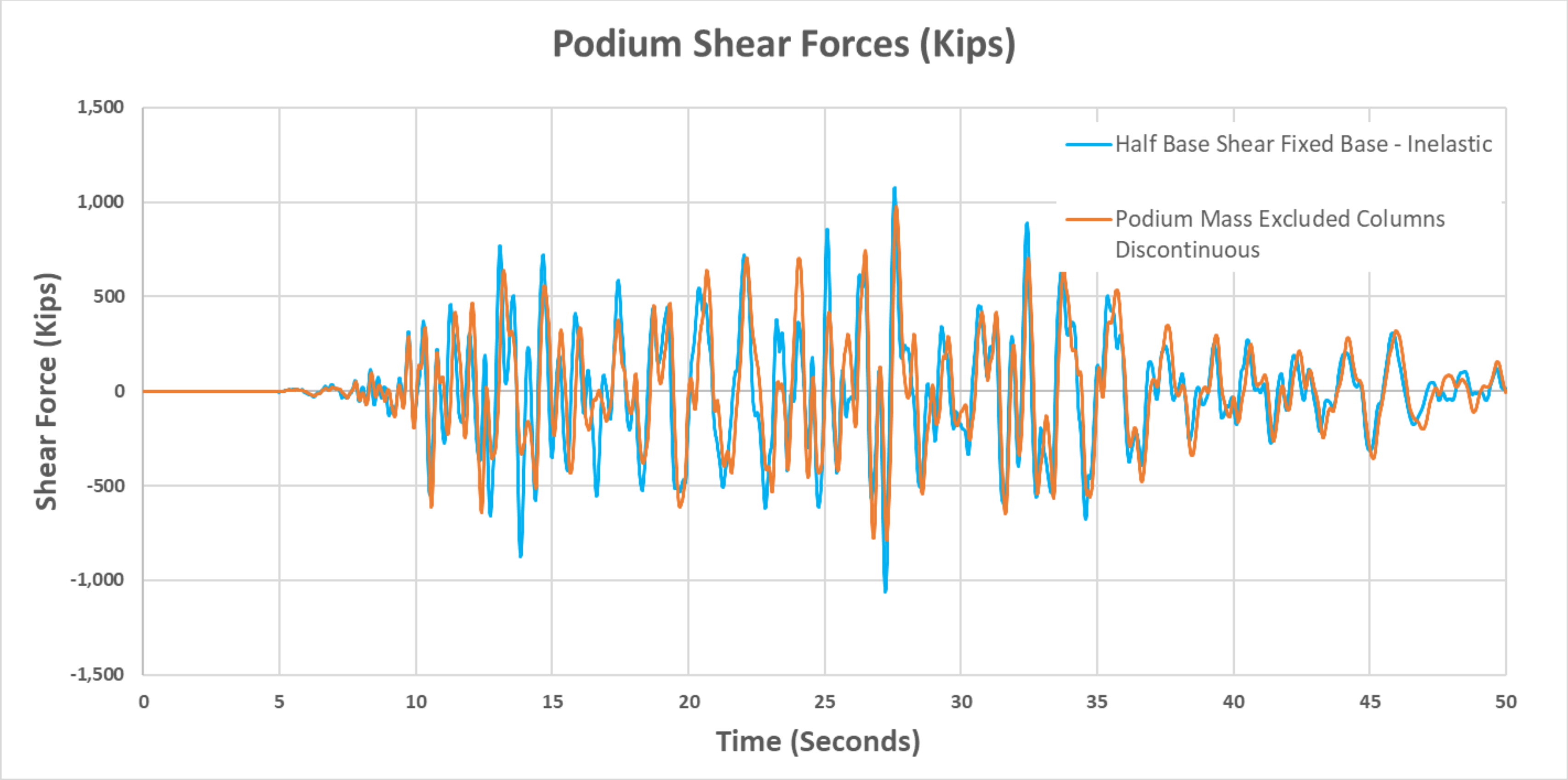

Example: 7-story Concrete MF + SW@1st floor

HCAi Department of Health Care Access and Information

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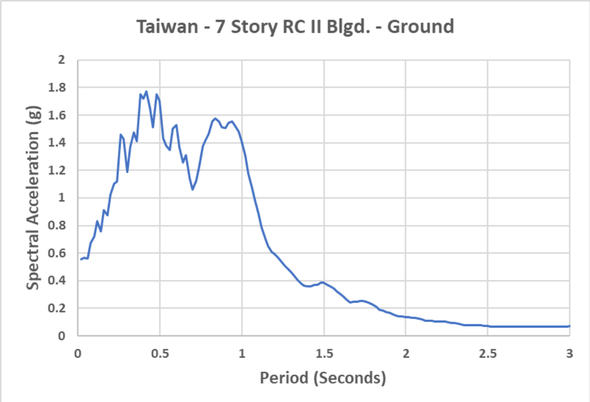
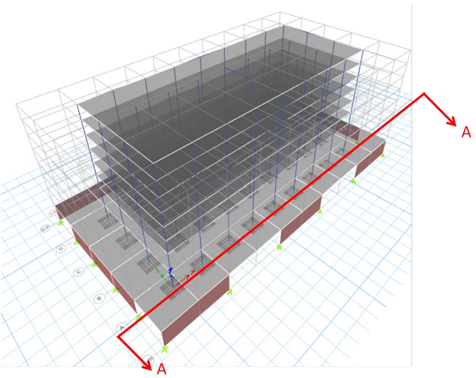
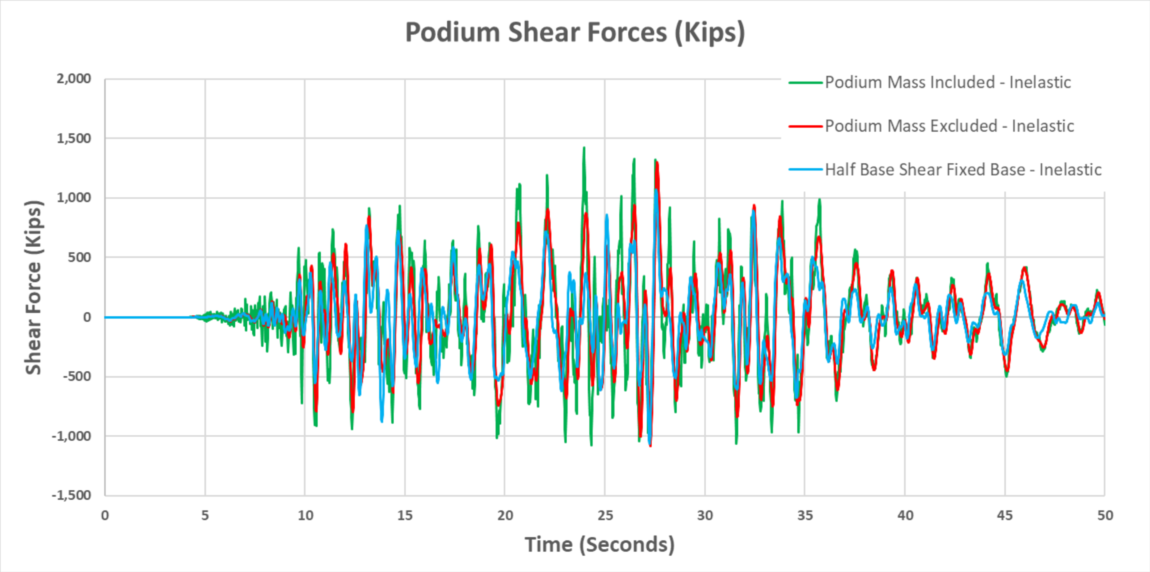
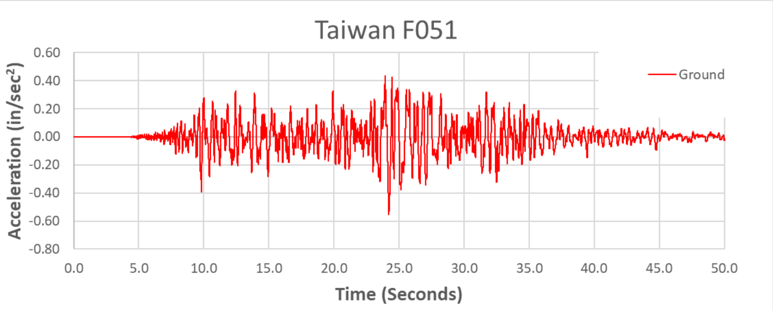






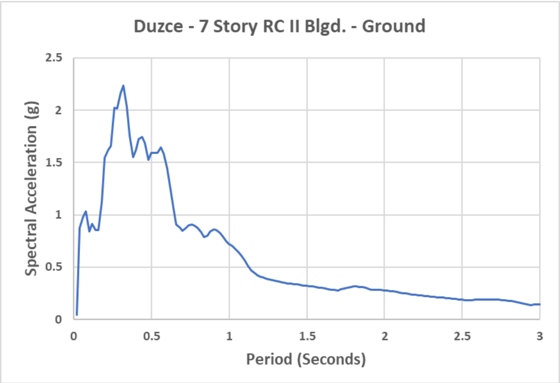


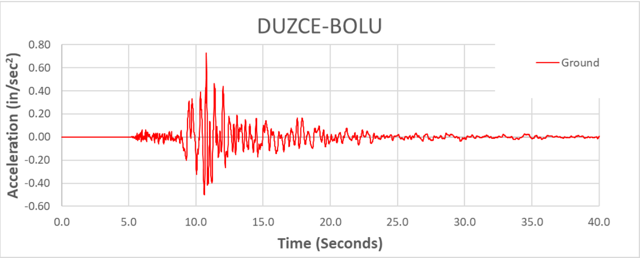
Maximum Podium Shears (Taiwan) - Kips	
Podium Mass Included	1425
Podium Mass Excluded	1300
Podium Mass Excluded Discontinuous Columns	976
Half Base Shear Fixed Base - Inelastic(No Podium)	1073
Half Base Shear Fixed Base - Elastic(No Podium)	2554

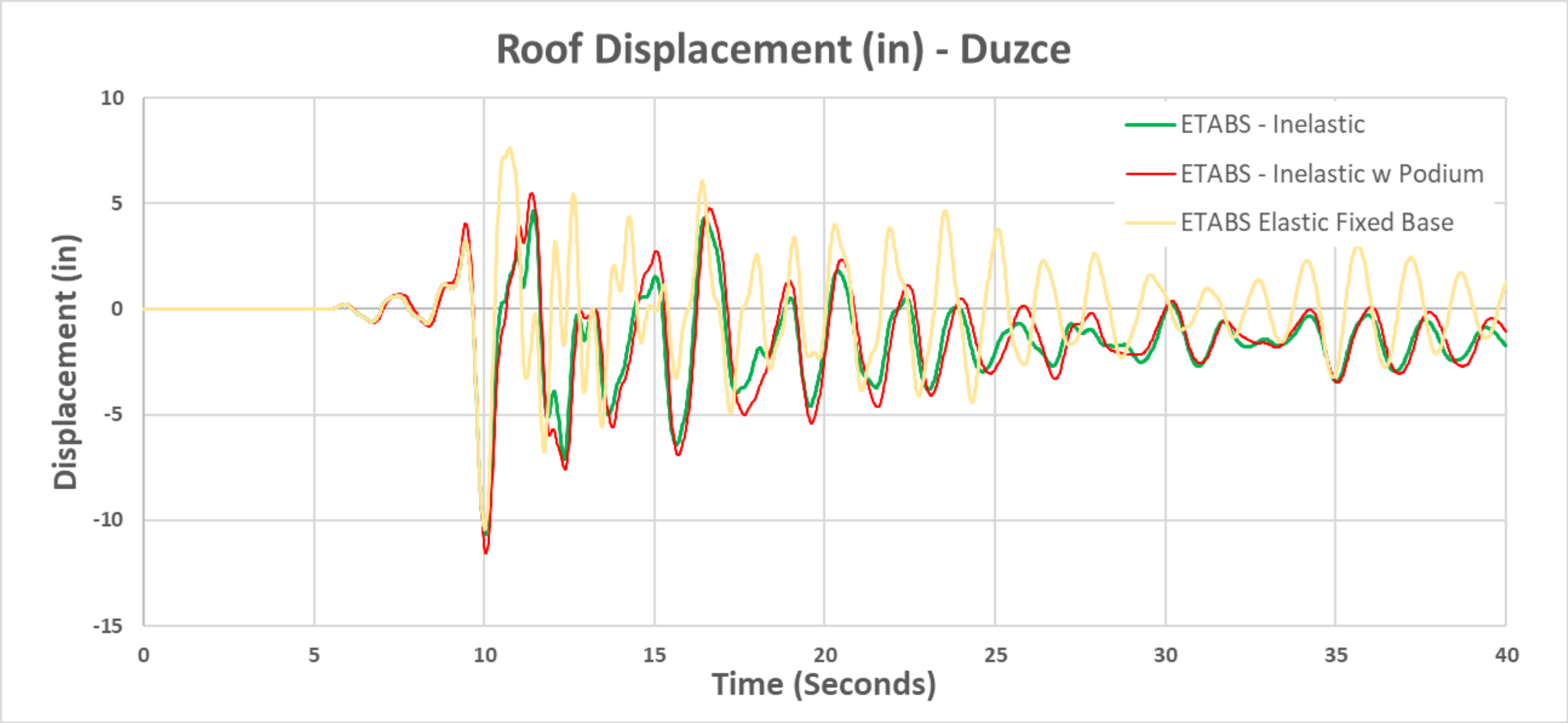
Example: 7-story Concrete MF + SW@1st floor

Time History Comparisons – Duzce Bolu

- ***PGA – 0.726g***
- Model 1 (7 Story Fixed Base)
- Model 2(Podium at 1st Floor)







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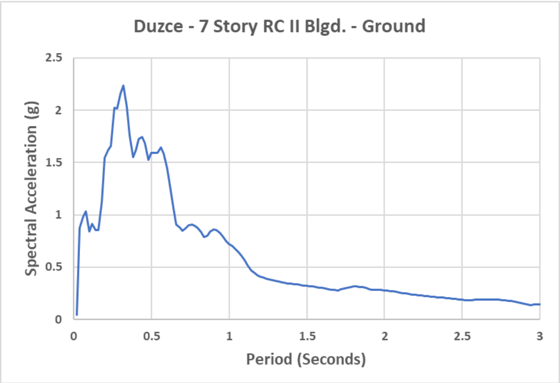

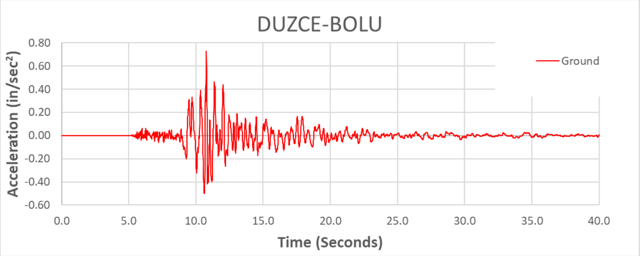

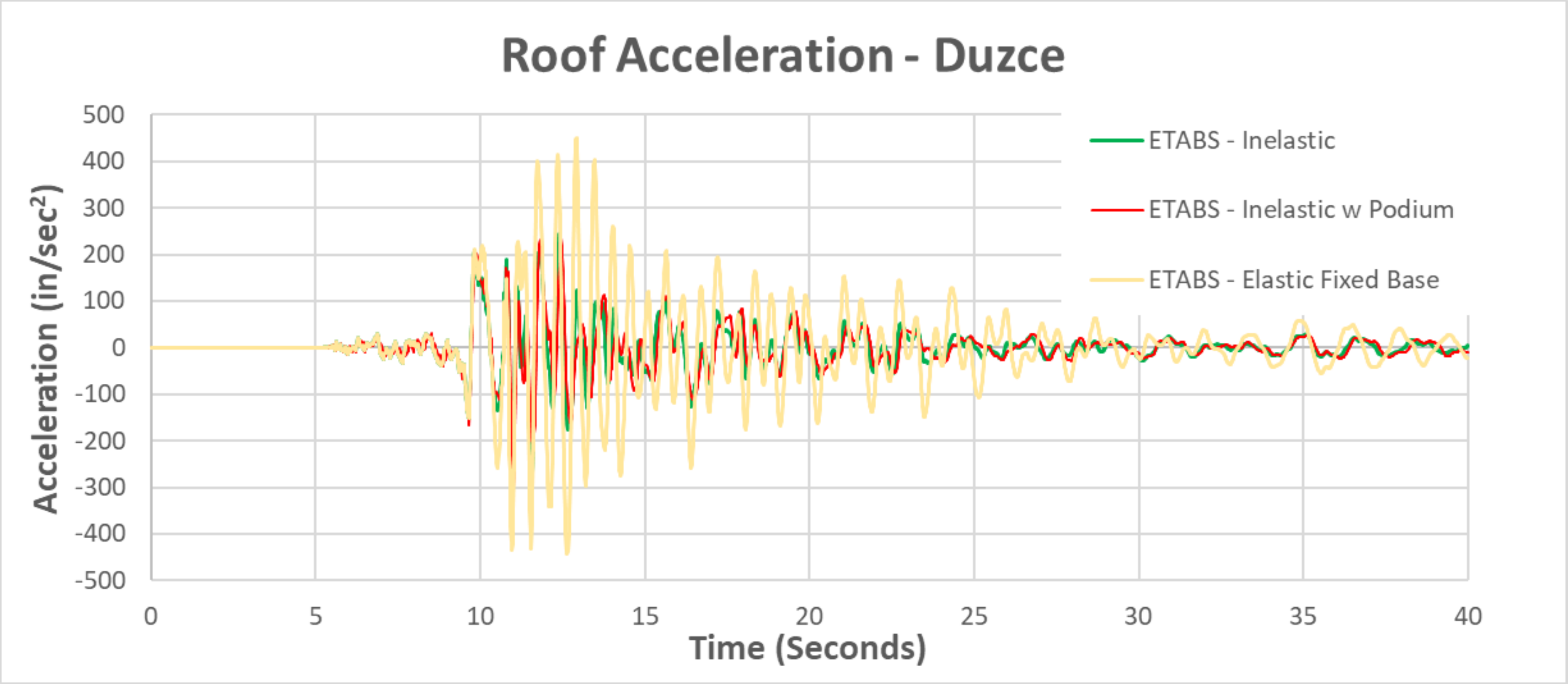

Example: 7-story Concrete MF + SW@1st floor

Comparison of Maximum Responses – Duzce Bolu

- ***PGA – 0.726 g***
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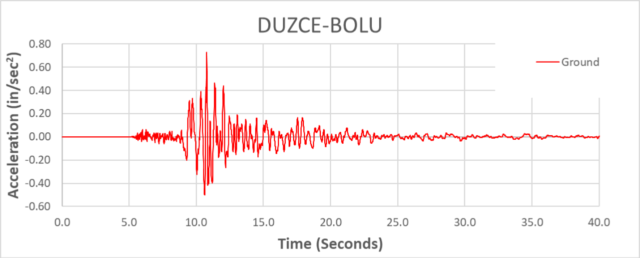
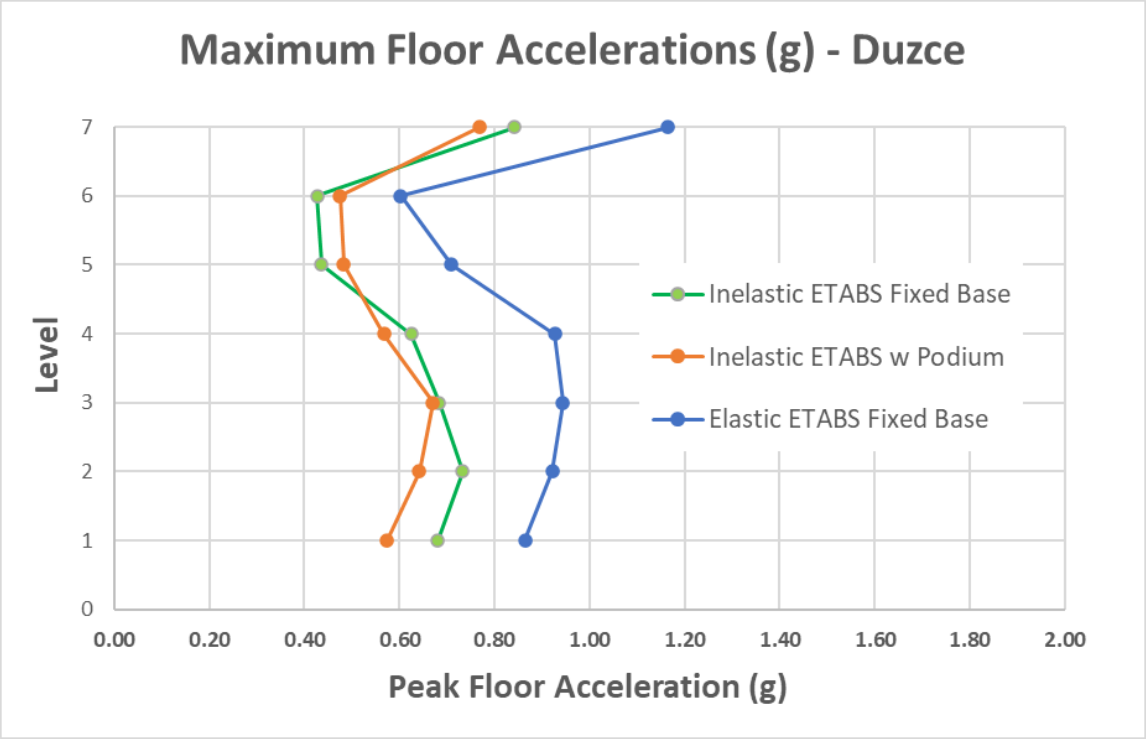
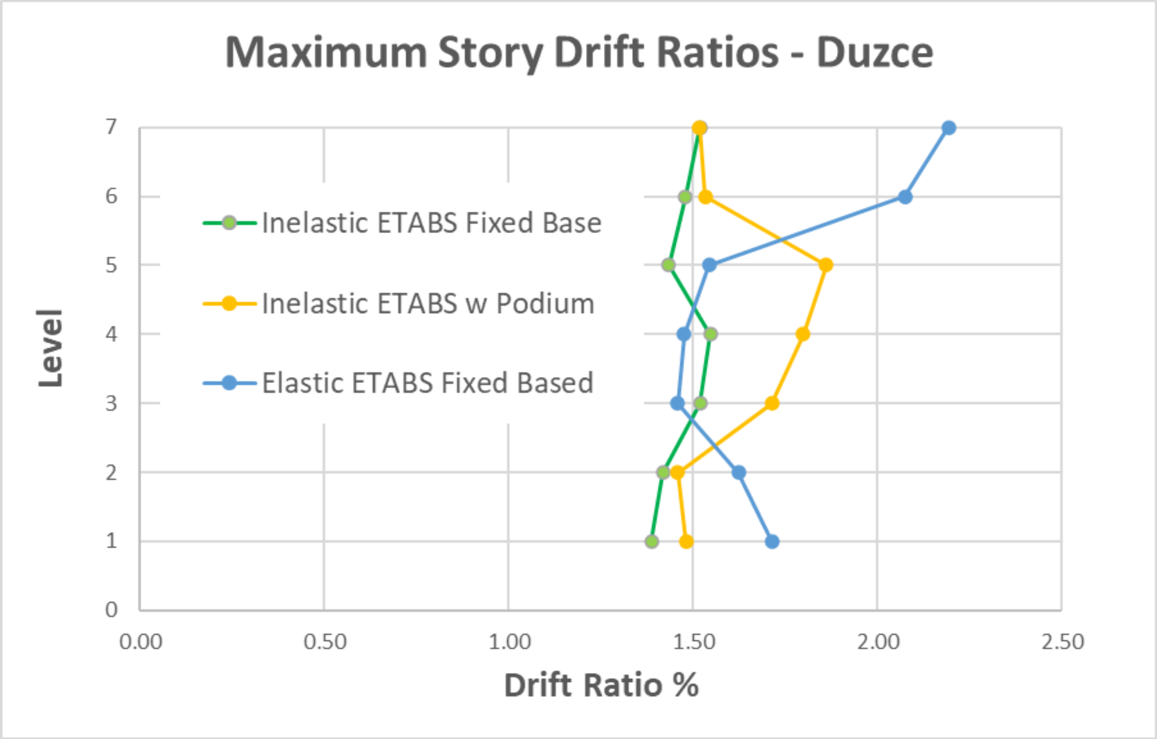
- Model 2(Podium at 1st Floor)







Example: 7-story Concrete MF + SW@1st floor

Podium Shears Time History Comparisons – Duzce Bolu

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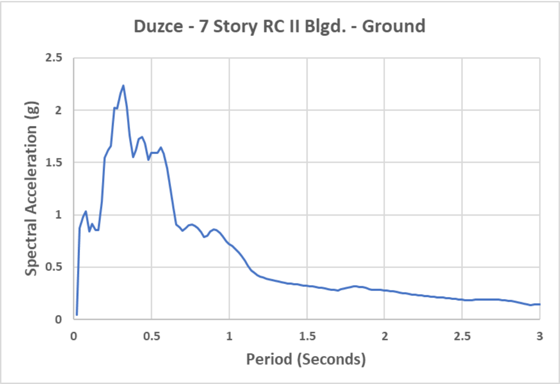

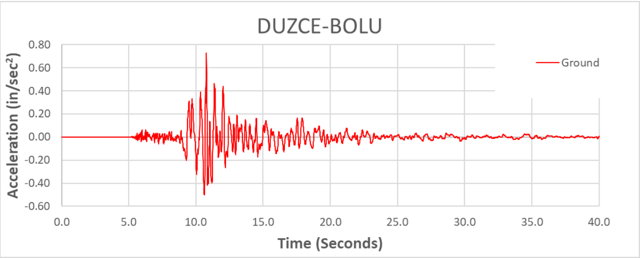

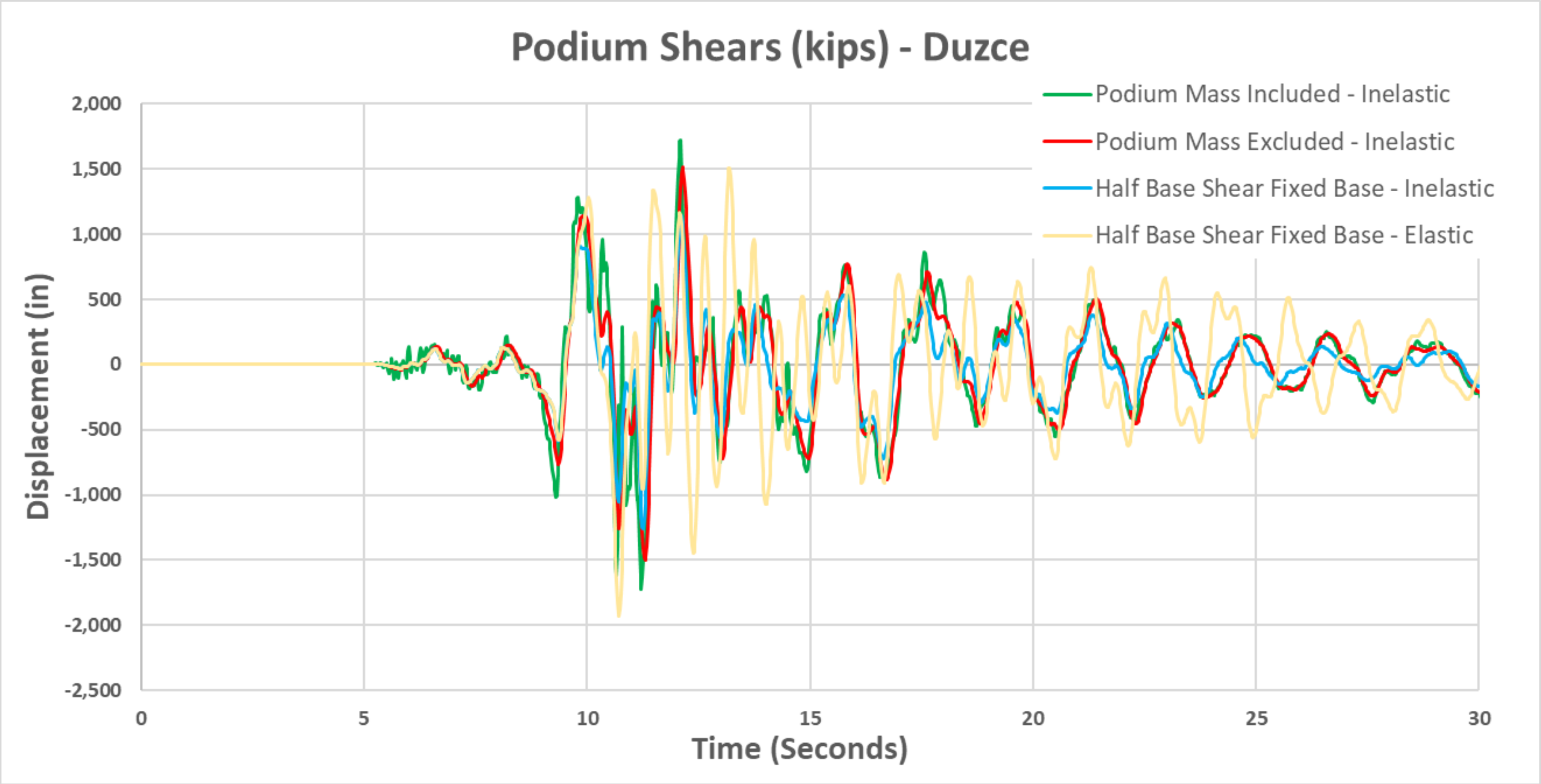

Example: 7-story Concrete MF + SW@1st floor

HCAi Department of Health Care Access and Information

Podium Shear Time History Comparisons – Duzce Bolu

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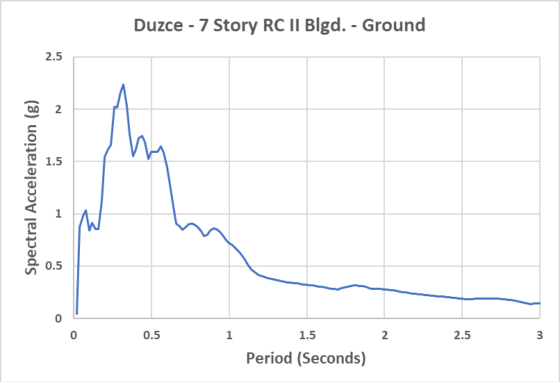

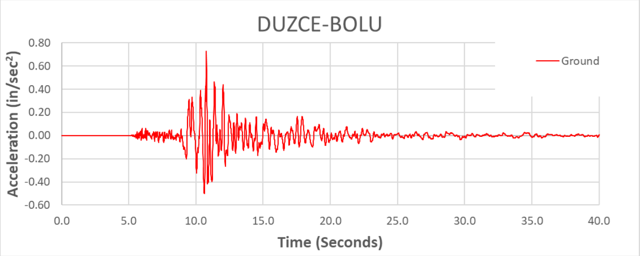

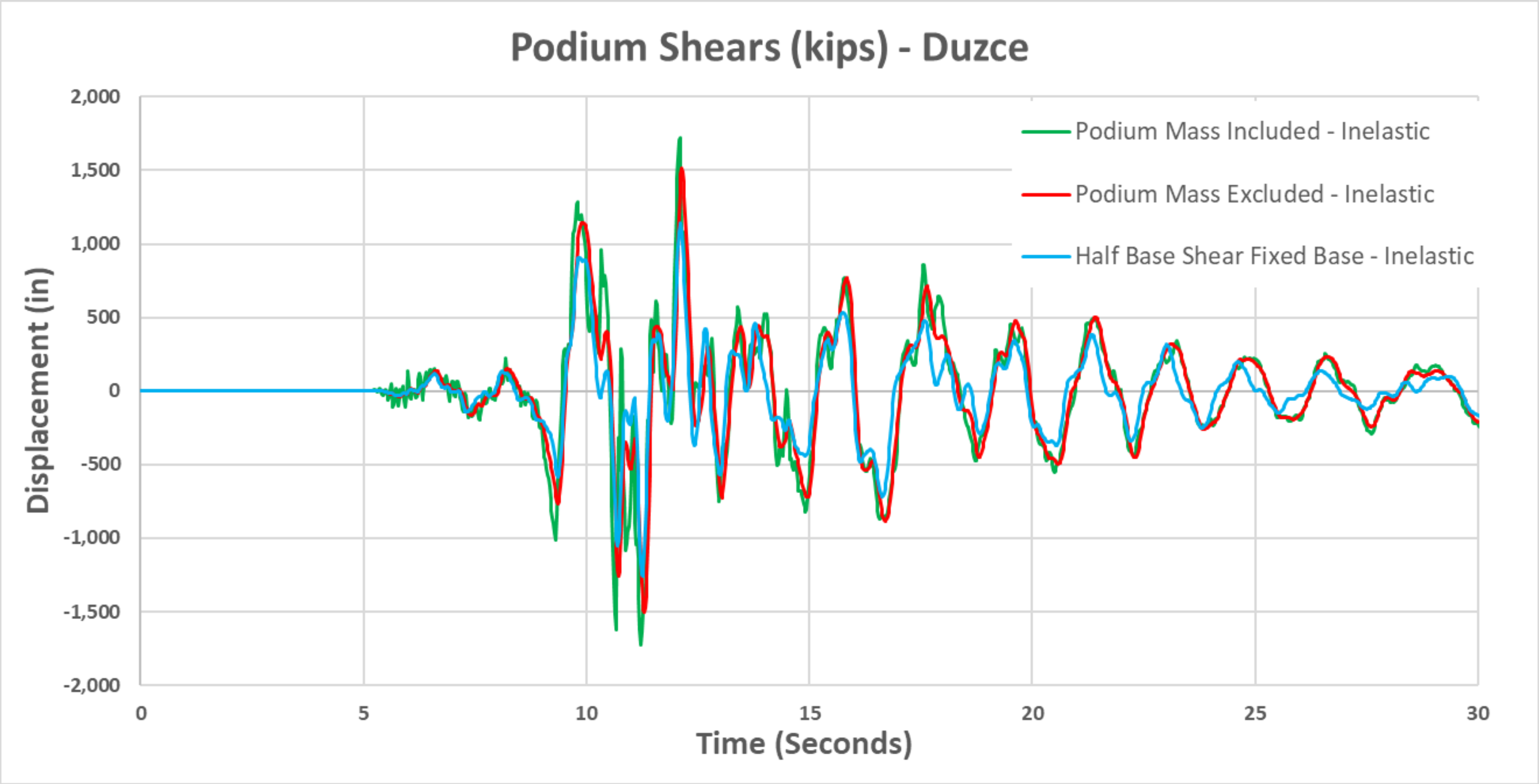

Example: 7-story Concrete MF + SW@1st floor

Podium Shear Time History Comparisons – Duzce Bolu

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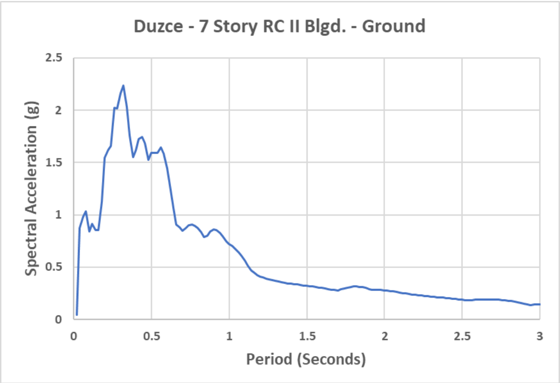

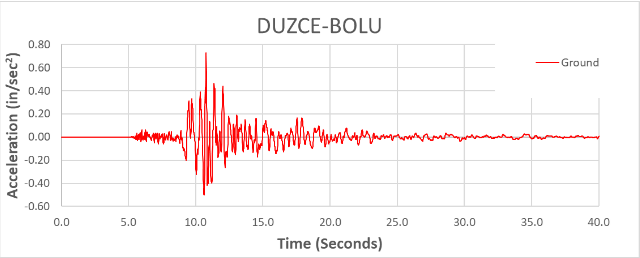

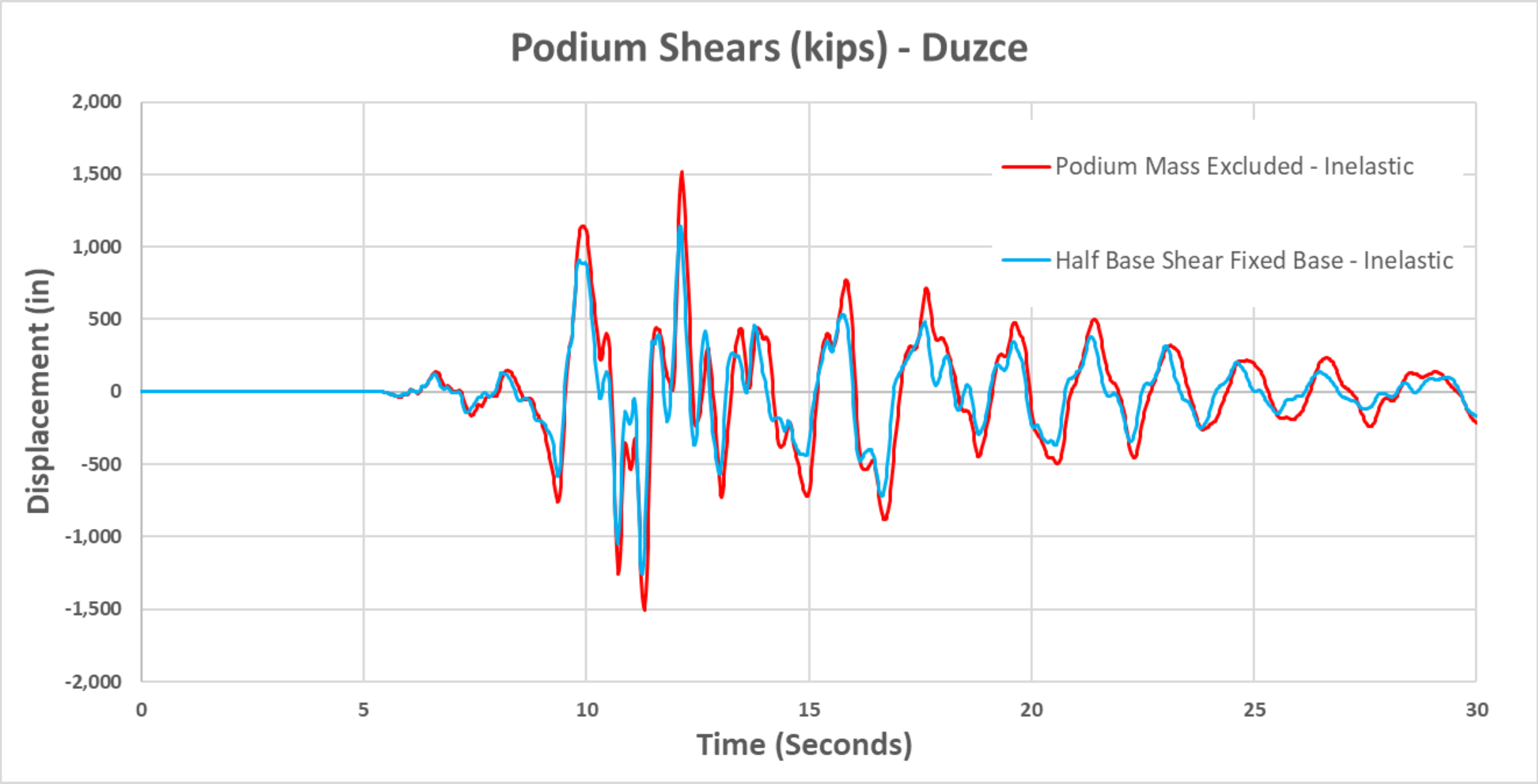

Example: 7-story Concrete MF + SW@1st floor

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Podium Shear Time History Comparisons – Duzce Bolu

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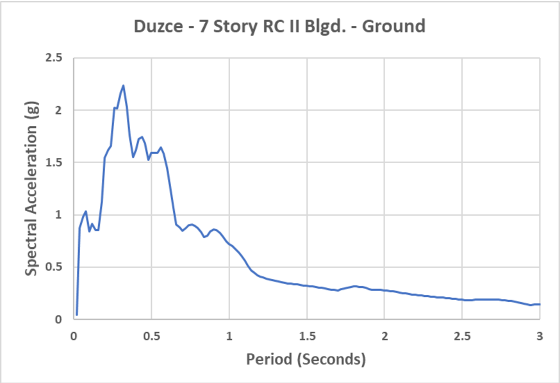
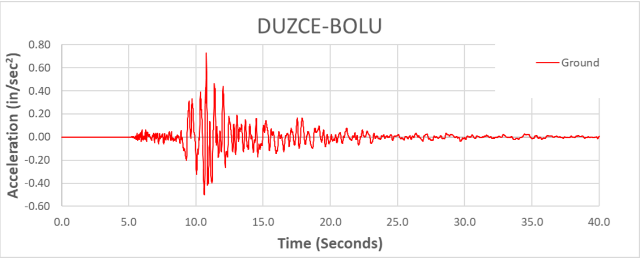
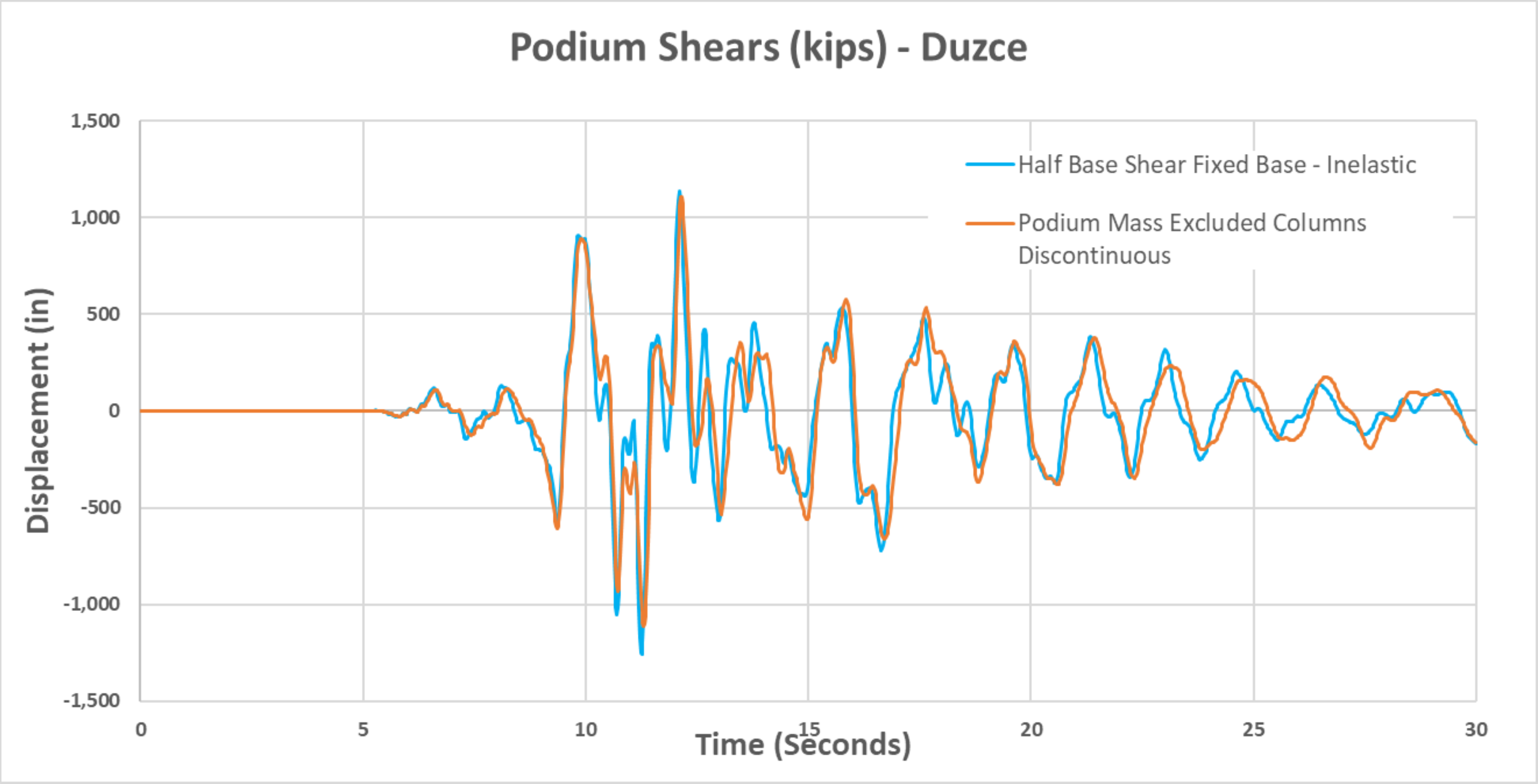
- Model 1 (7 Story Fixed Base)
- Model 2(Podium at 1st Floor)



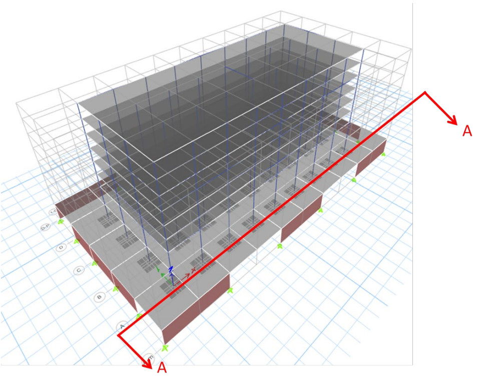


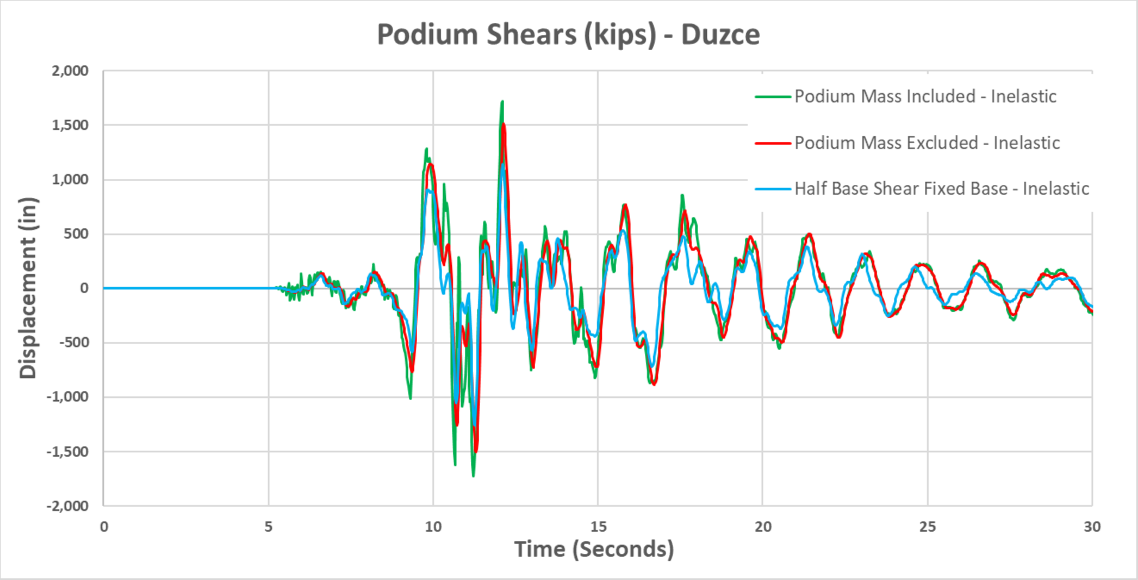


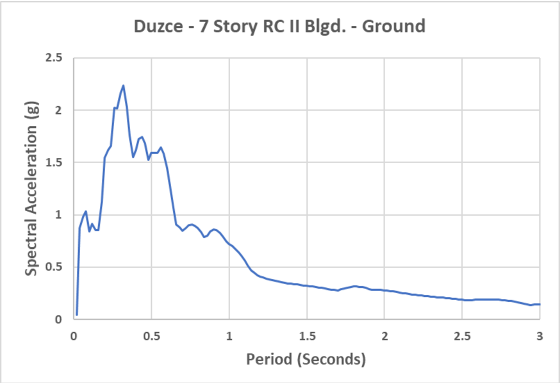
Example: 7-story Concrete MF + SW@1st floor

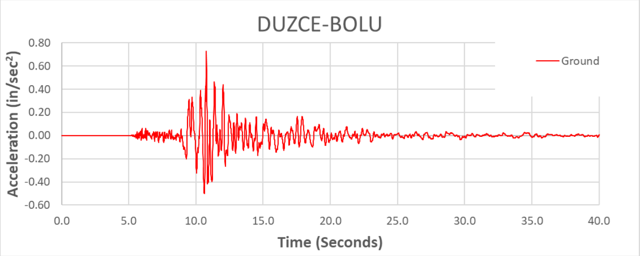
Podium Shear Time History Comparisons – Duzce Bolu

- ***PGA – 0.726g***
- Model 1 (7 Story Fixed Base)
- Model 2(Podium at 1st Floor)









Maximum Podium Shears (Duzce) - Kips	
Podium Mass Included	1725
Podium Mass Excluded	1515
Podium Mass Excluded Discontinuous Columns	1115
Half Base Shear Fixed Base - Inelastic(No Podium)	1255
Half Base Shear Fixed Base - Elastic(No Podium)	1933

Example: 7-story Concrete MF + SW@1st floor

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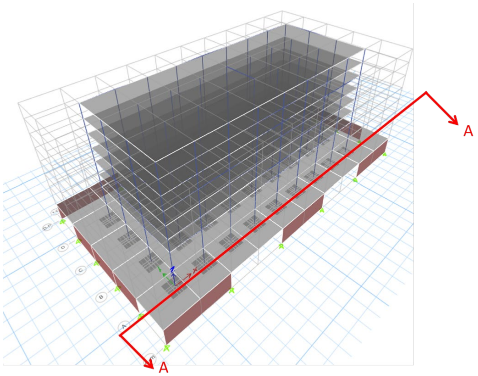
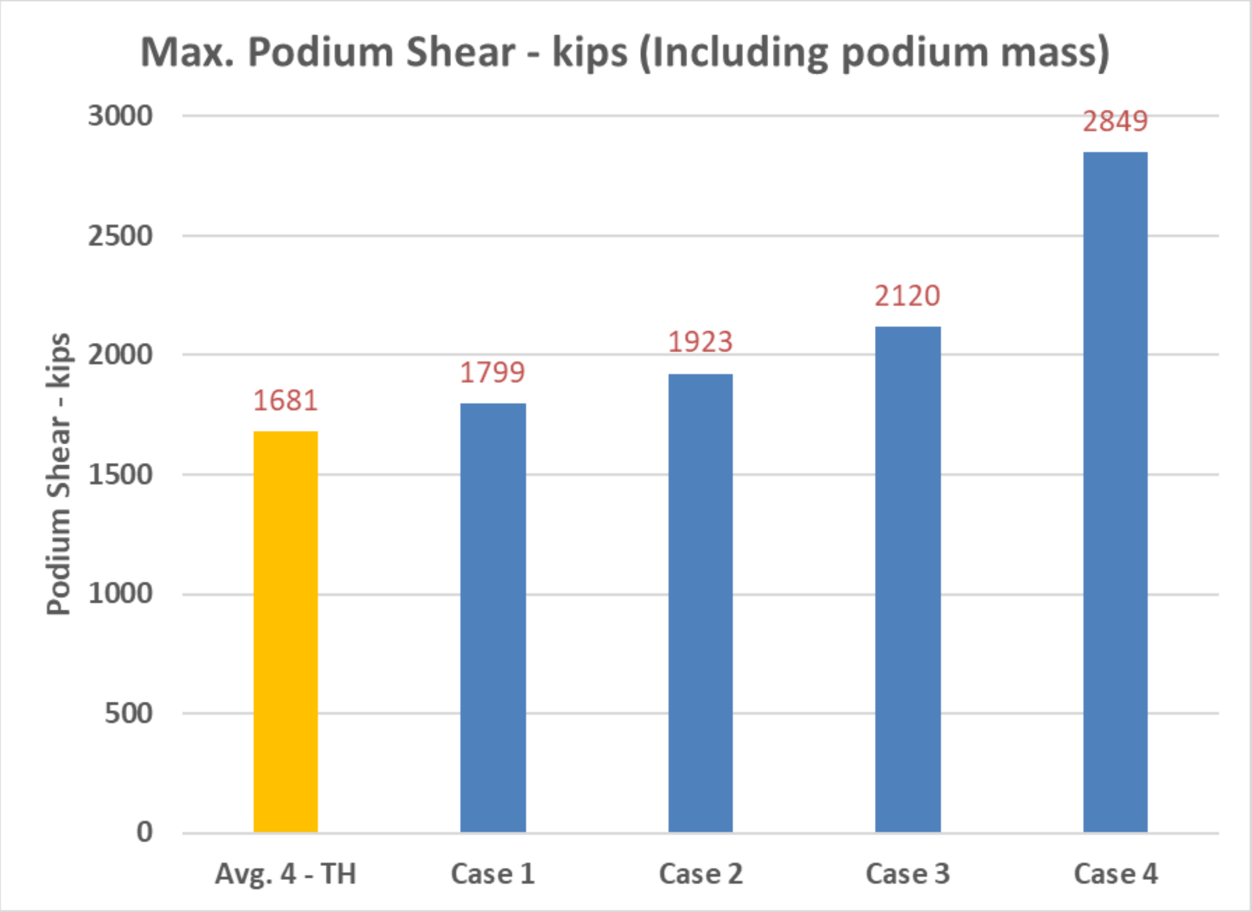
Summary of Diaphragm Transfer Forces, w/Podium Masses

- Model 1 (7 Story Fixed Base)
- Model 2(Podium at 1st Floor)





Avg. 4-TH: Average Max Diaph shears from the 4 eqk TH w/podium mass inc.

Case 1: R, Ω & Period from Upper (ELF: Fixed Base no podium)

826/2*3 + 1119/2 = 1799

Case 2: R, Ω & Period from Upper (ELF: Fixed Base with Podium)

909/2*3 + 1119/2 = 1923

Case 3: R, Ω & Period from Upper (Forces: Massless Podium Model)

520*3 + 1119/2 = 2120

Case 4: R, Ω & Period from Lower (ELF: Fixed Base Lower)

1832/2*2.5 + 1119/2 = 2849

Example: 7-story Concrete MF + SW@1st floor

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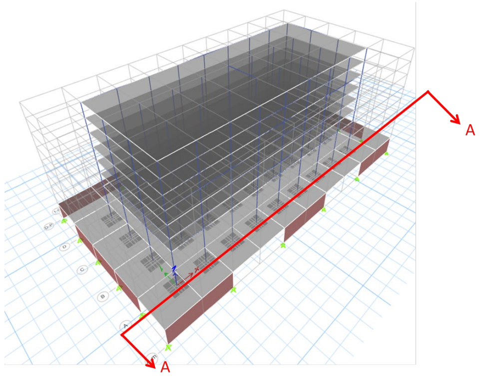
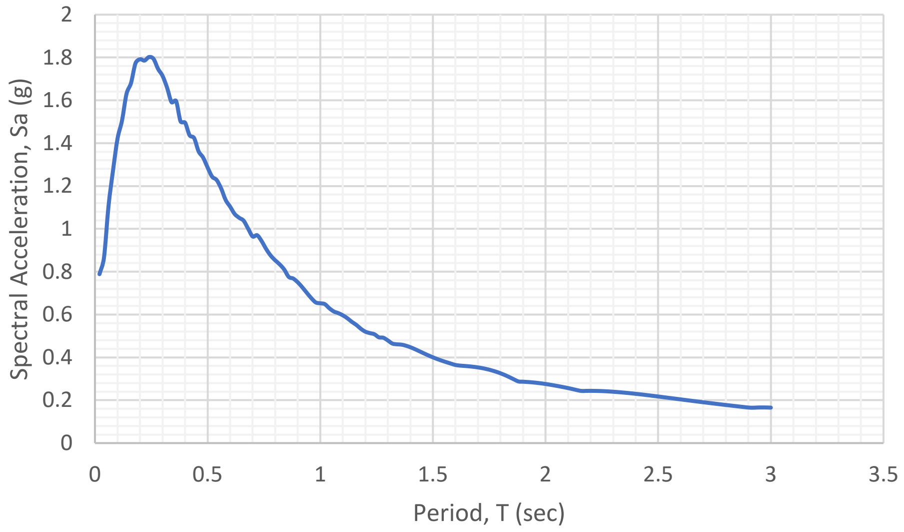
Podium Shear Time History Summary

- *7 Spectrally Matched Time Histories*

Max Podium Shears (Spectrally Match 7 TH) - Kips	
Christchurch	1806
Loma Prieta Sratoga Station	2131
Duzce	1968
Tabas	1971
Elcentro Imp Valley	2073
Darfield	2093
ChiChi	1825.1

Average = 1981 k





Example: 7-story Concrete MF + SW@1st floor

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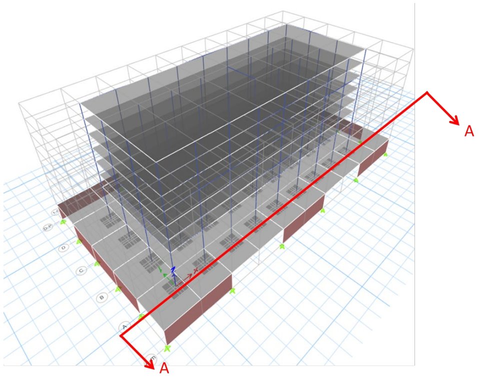
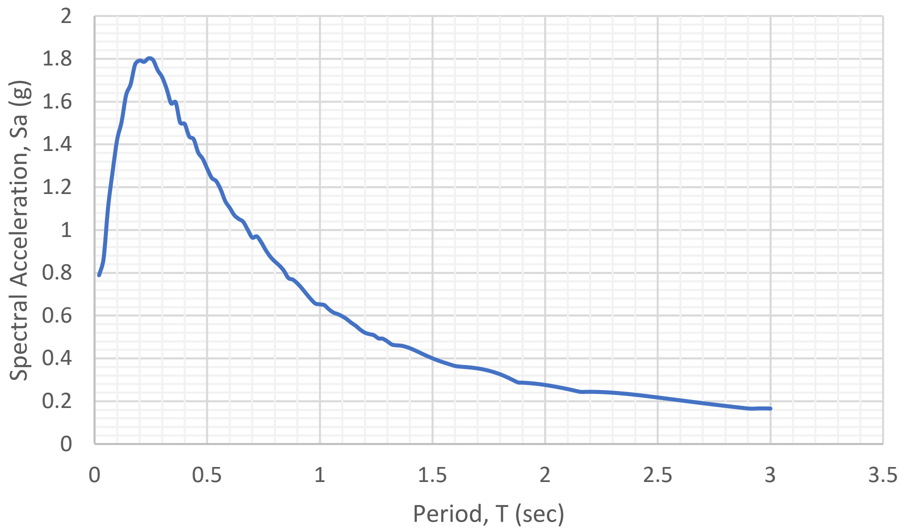
Podium Shear Time History Summary

- *7 Spectrally Matched Time Histories*

Max Podium Shears (Spectrally Match 7 TH) - Kips Area Spring supports all elements	
Christchurch	1642
Loma Prieta Sratoga Station	1959
Duzce	1879
Tabas	1962
Elcentro Imp Valley	1974
Darfield	2014
ChiChi	1611

Average = 1863 k





Example: 7-story Concrete MF + SW@1st floor

Example: 7 - Story Concrete Special Moment Frame + Podium

Diaphragm Force @ Transfer Diaphragm Eq. 12.10-4

Design Parameter		7-story Example + Podium RCMF	7-story Example + Podium RCSW	7-story Example + Podium
Lateral Resisting System		RCMF	RCSW	RCSW
n =		8	8	1
Ω_o =		3	2.5	2.5
S_{DS} =		1.63	1.63	1.63
S_{D1} =		0.64	0.64	0.64
I_e =		1	1	1
h_n =		77	77	12
C_t =		0.016	0.02	0.02
x		0.9	0.75	0.75
T =		0.80	0.52	0.13
C_u =		1.4	1.4	1.4
T_{max} =		1.12	0.73	0.18
R =		8	6	6
Cs =		0.20	0.27	0.27
Cs =		0.07	0.15	0.59
C_s min =		0.07	0.07	0.07
C_s (design) =		0.07	0.15	0.27
$C_{s2}(1)$ =	$(0.15n + 0.25)I_eS_{DS}$ =	2.36	2.36	0.65
$C_{s2}(2)$ =	I_eS_{DS} =	1.63	1.63	1.63
$C_{s2}(3)$ =	$I_eS_{D1}/0.03(n-1) >= 2$	3.05	3.05	0.00
C_{s2} (design) =		1.63	1.63	0.00
z_s =		0.7	1	1
Γ_{m1} =	$1 + z_s/2(1 - 1/n)$ =	1.31	1.44	1.00
Γ_{m2} =	$0.9z_s(1 - 1/n)^2$ =	0.48	0.69	0.00
C_{pn} =	$\sqrt{(\Gamma_{m1}\Omega_0 C_s)^2 + (\Gamma_{m2} C_{s2})^2}$	0.83	1.24	0.679

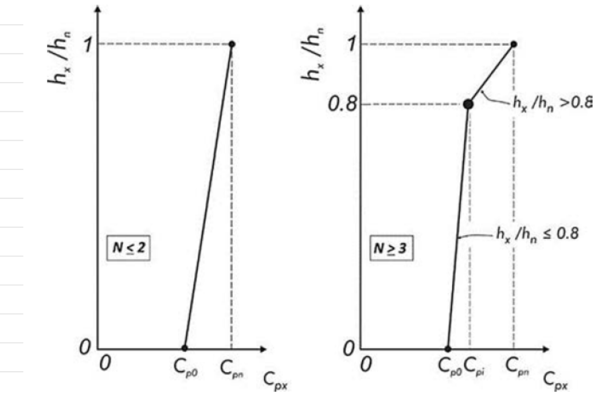


Figure 12.10-2. Calculating the design acceleration coefficient, C_{px}, in buildings with $N \le 2$ and in buildings with $N \ge 3$.

Design Parameter		7-story Example + Podium RCMF	7-story Example + Podium RCSW	7-story Example + Podium
C_{p0} =	$0.4S_{DS}I_e$	0.648	0.648	0.648
C_{pi} =	$0.8C_{p0}$	0.66	0.99	0.54
C_{pi} =	$C_{pi} = 0.9\Gamma_{m1}\Omega_0 C_s$	0.25	0.47	0.61
$C_{pi\,(Design)}$ =	Fig. 12.10-2	0.66	0.99	0.61
Ht of Diap. (ft)		12	12	12
$C_{px\,(Design@L1)}$ =	Design Accel Coefficient	0.651	0.714	0.675
R_s	Table 12.10-1	1.5	1.5	1.5
W_{px}	Weight of Diaphragm	3454	3454	3454
F_{px} (kips)	Diap. Seismic Design Force	1499	1644	1554
F_{px_min} =	$0.2S_{DS}I_eW_{px}$	1119.1	1119.1	1119.1

Example: 7-story Concrete MF + SW@1st floor

Example: 7 - Story Concrete Special Moment Frame + Podium

Diaphragm Force @ Transfer Diaphragm Eq. 12.10-4

Design Parameter		7-story Example + Podium RCMF	7-story Example + Podium RCSW	7-story Example + Podium
Lateral Resisting System		RCMF	RCSW	RCSW
n =		8	8	1
Ω_o =		3	2.5	2.5
S_{DS} =		1.62	1.62	1.62
S_{D1} =		0.64	0.64	0.64
I_e =		1	1	1
h_n =		77	77	12
C_t =		0.016	0.02	0.02
x		0.9	0.75	0.75
T =		0.80	0.52	0.13
C_u =		1.4	1.4	1.4
T_{max} =		1.12	0.73	0.18
R =		8	5	5
Cs =		0.20	0.32	0.32
Cs =		0.07	0.18	0.71
C_s min =		0.07	0.07	0.07
C_s (design) =		0.07	0.18	0.32
$C_{s2}(1)$ =	$(0.15n + 0.25)I_eS_{DS}$ =	2.35	2.35	0.65
$C_{s2}(2)$ =	I_eS_{DS} =	1.62	1.62	1.62
$C_{s2}(3)$ =	$I_eS_{D1}/0.03(n-1) >= 2$	3.05	3.05	0.00
C_{s2} (design) =		1.62	1.62	0.00
z_s =		0.7	1	1
Γ_{m1} =	$1 + z_s/2(1 - 1/n)$ =	1.31	1.44	1.00
Γ_{m2} =	$0.9z_s(1 - 1/n)^2$ =	0.48	0.69	0.00
C_{pn} =	$\sqrt{(\Gamma_{m1}\Omega_0 C_s)^2 + (\Gamma_{m2} C_{s2})^2}$	0.83	1.28	0.810

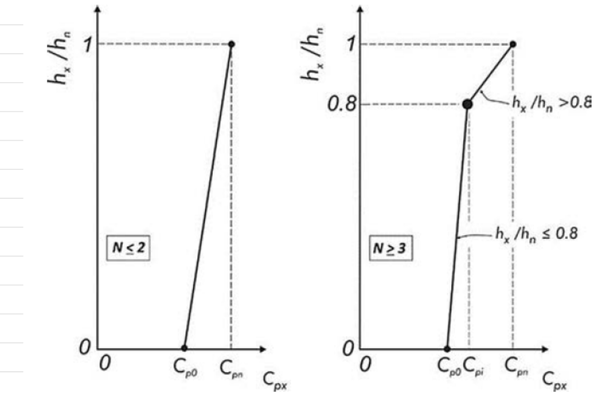


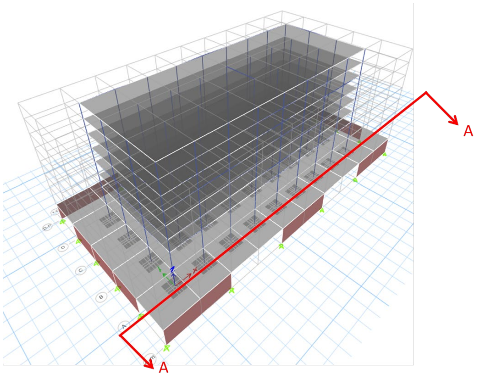
Figure 12.10-2. Calculating the design acceleration coefficient, C_{px}, in buildings with $N \le 2$ and in buildings with $N \ge 3$.

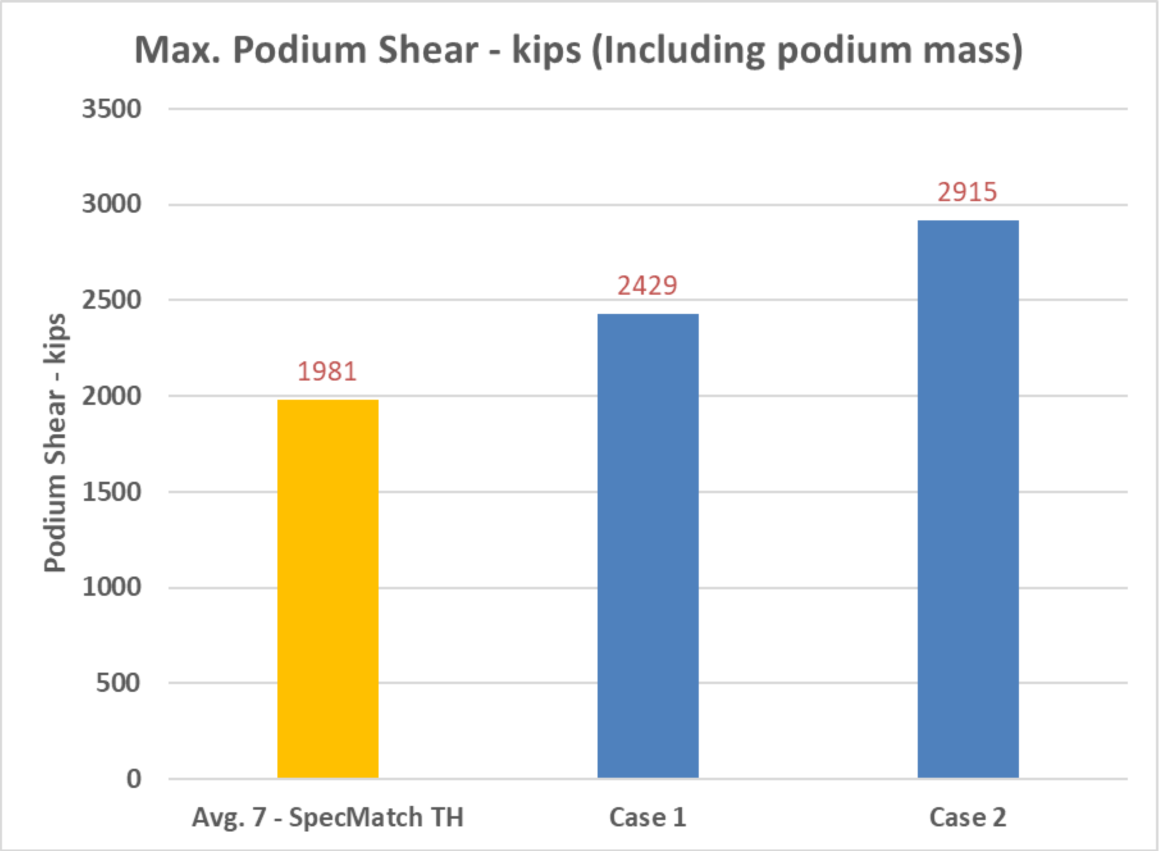
Design Parameter		7-story Example + Podium RCMF	7-story Example + Podium RCSW	7-story Example + Podium
C_{p0} =	$0.4S_{DS}I_e$	0.648	0.648	0.648
C_{pi} =	$0.8C_{p0}$	0.66	1.03	0.65
C_{pi} =	$C_{pi} = 0.9\Gamma_{m1}\Omega_0 C_s$	0.25	0.57	0.73
$C_{pi\,(Design)}$ =	Fig. 12.10-2	0.66	1.03	0.73
Ht of Diap. (ft)		12	12	12
$C_{px\,(Design@L1)}$ =	Design Accel Coefficient	0.651	0.722	0.810
R_s	Table 12.10-1	1.5	1.5	1.5
W_{px}	Weight of Diaphragm	3454	3454	3454
F_{px} (kips)	Diap. Seismic Design Force	1499	1662	1865
F_{px_min} =	$0.2S_{DS}I_eW_{px}$	1119.1	1119.1	1119.1

Example: 7-story Concrete MF + SW@1st floor

Summary of Diaphragm Transfer Forces, w/Podium Masses

- Model 1 (7 Story Fixed Base)
- Model 2(Podium at 1st Floor)





Avg. 7-Spec. Matched TH: Average Max Diaph shears w/podium mass inc.

Case 1: R, Ω & Period from Upper x R_{upper}/R_{lower}(ELF: Fixed Base no podium)

826/2*3*(8/6) + 1554/2 = 2429

Case 2: R, Ω & Period from Upper x R_{upper}/R_{lower}(ELF: Fixed Base no podium)

826/2*3*(8/5) + 1865/2 = 2915

Observations

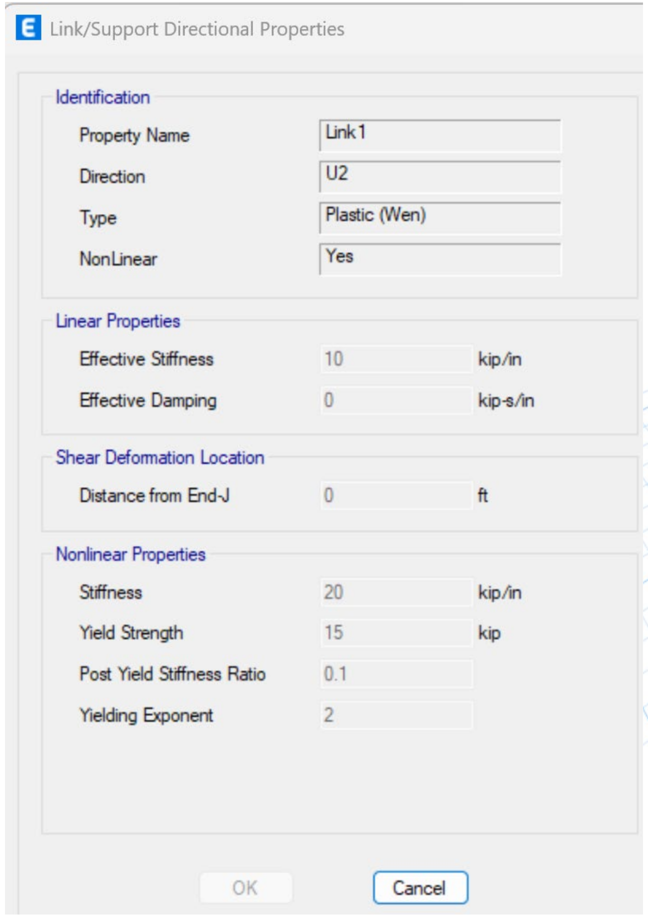
- *Inherent diaphragm shears were earthquake dependent*
- *Transfer forces at the diaphragm exceeded the maximum base shear delivered by the superstructure even when the mass at the diaphragm level was excluded*
- *Transfer forces were lower than the maximum base shear from a fixed base superstructure when the columns were discontinued at the transfer diaphragm level. No backstay effect*
- *The assumption that there is an amplification of R_{upper}/R_{lower} in addition to the maximum force delivered by the superstructure is not substantiated.*
- *Two stage analysis is a reasonable assumption, for the design of the upper structure if two stage criteria is satisfied.*

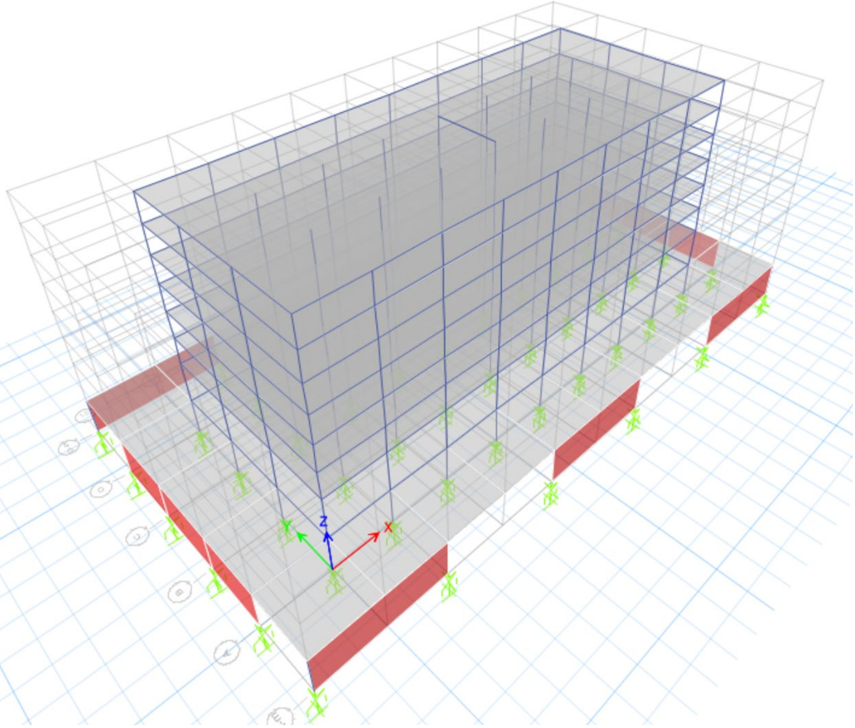
Recommendations

- *Transfer force amplification by Omega appears to be warranted (Analysis assumed an elastic lower structure which is conservative).*
- *Transfer diaphragms need not be designed for transfer forces greater than the upper bound capacity of the vertical elements of the lower structure.*
- *Analytical model should include all gravity and lateral forces resisting vertical elements in a combined model, upper and lower structure and transfer diaphragms should be designed to accommodate the shear amplification due to load reversals at the transfer diaphragm level.*
- *Collectors and connections should be designed stronger than the body of the diaphragm.*

Example: 7 - Story Concrete Special Moment Frame on a Stiff Podium with Base Isolators modeled with a Bouc-Wen hysteretic model

- *All foundation column and pin based wall supports are replaced with nonlinear isolators of the type Plastic (Wen) in ETABS*
- *Lateral Isolator Properties* →
- *Building Periods*
  - *Mode 1 = 2.44 second*
  - *Mode 2 = 0.85 seconds*
  - *Mode 3 = 0.47 seconds*



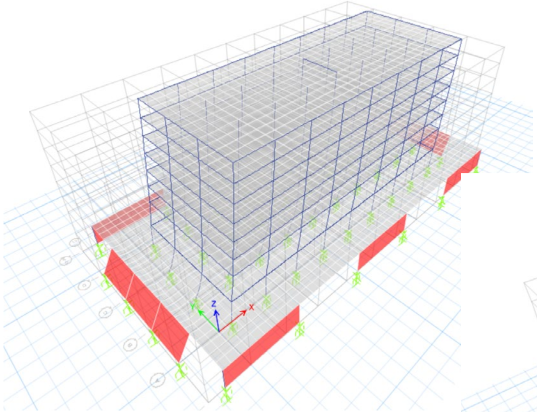


Model 2

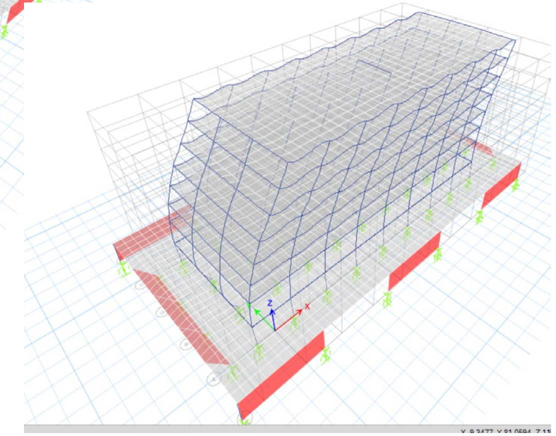
Model with Podium at 1st Floor on Isolators

Example: 7 - Story Concrete Special Moment Frame on a Podium with Base Isolators modeled with a Bouc-Wen hysteretic model

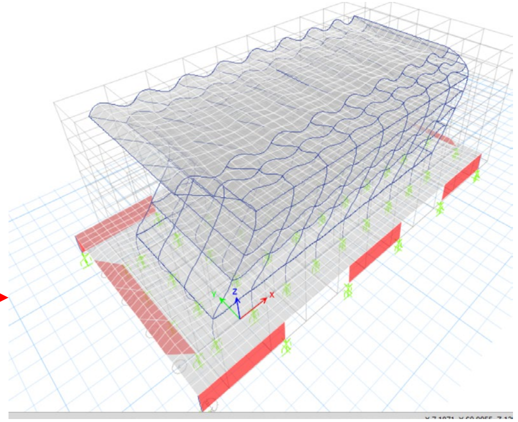
- *Building Periods translational longitudinal direction*
  - *Mode 1 = 2.44 seconds*



  - *Mode 2 = 0.85 seconds*



  - *Mode 3 = 0.47 seconds*



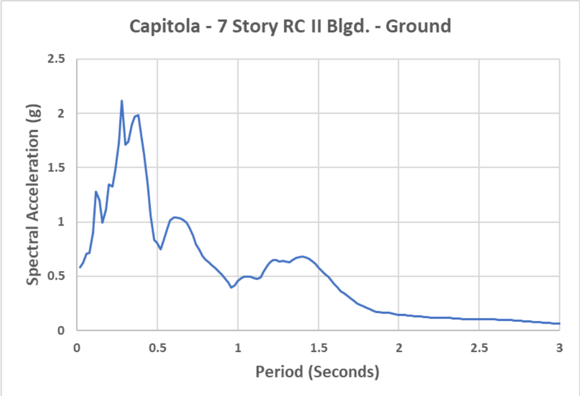
Model 2
Model with Podium at 1st Floor on Isolators

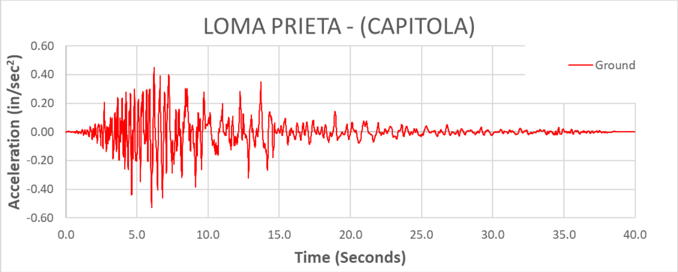
Example: 7-story Concrete MF + SW@1st floor

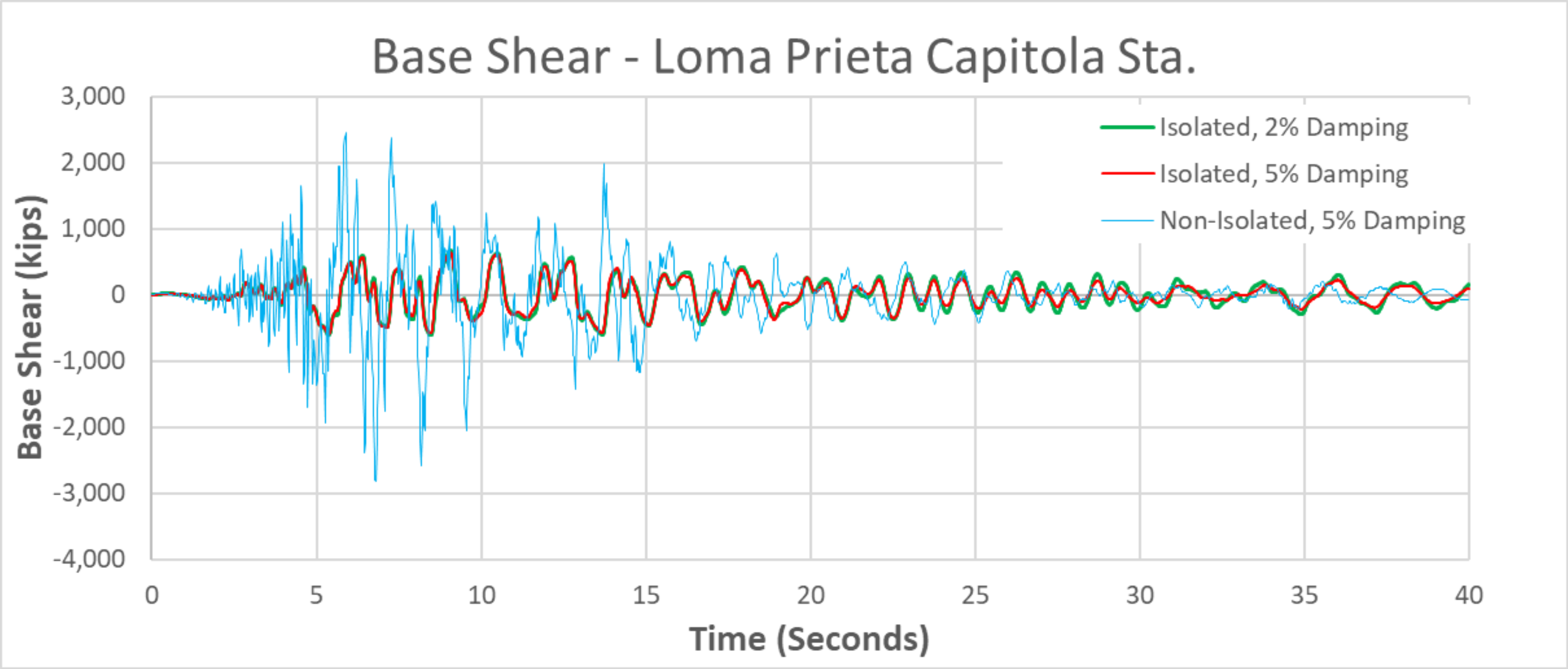
HCAI Department of Health Care Access and Information

Podium Shear Time History Comparisons – Loma Prieta (Capitola)

- ***PGA – 0.529g***
- Model 1 (Podium at 1st Floor Pin Base)
- Model 2(Podium at 1st Floor, Isolators)





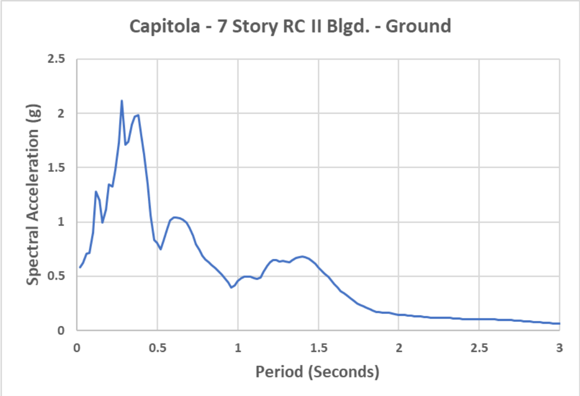


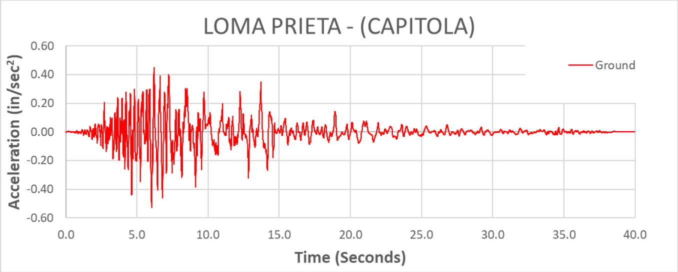
Example: 7-story Concrete MF + SW@1st floor

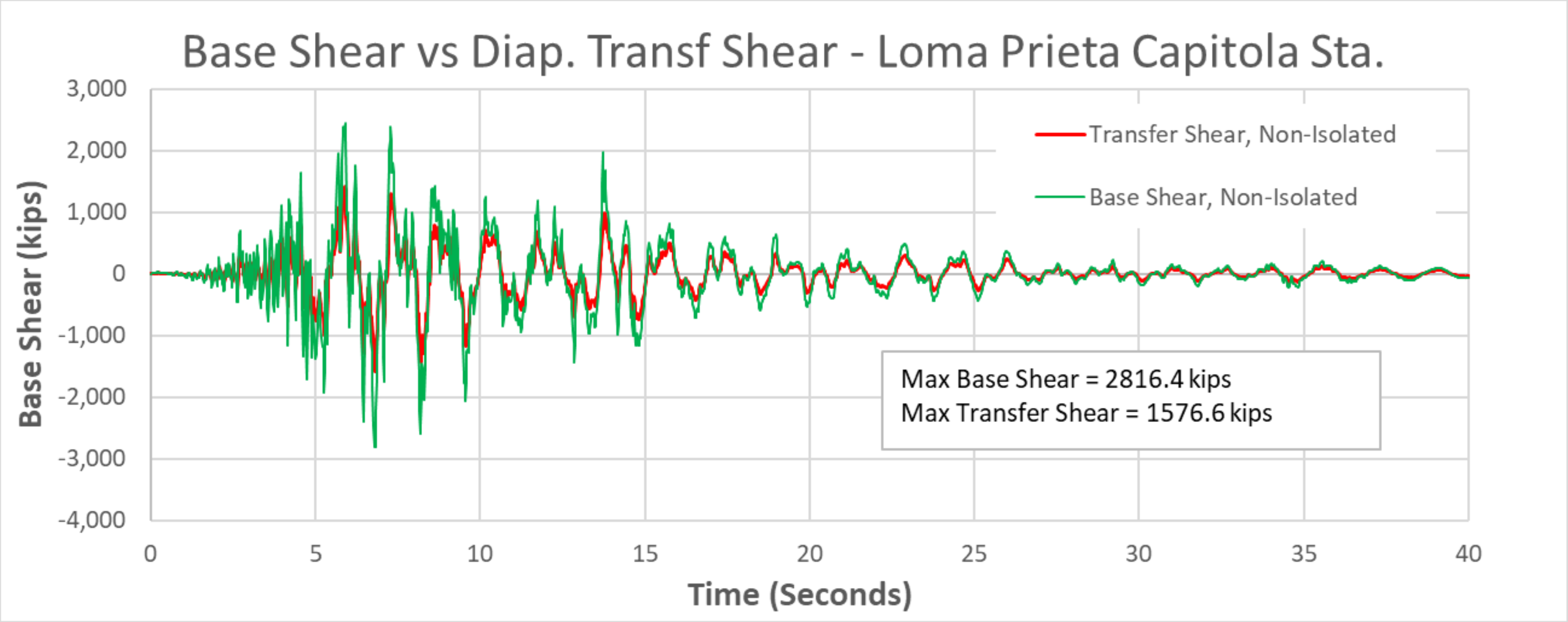
HCAi Department of Health Care Access and Information

Podium Shear Time History Comparisons – Loma Prieta (Capitola)

- ***PGA – 0.529g***
- Model 1 (Podium at 1st Floor Pin Base)
- Model 2(Podium at 1st Floor, Isolators)





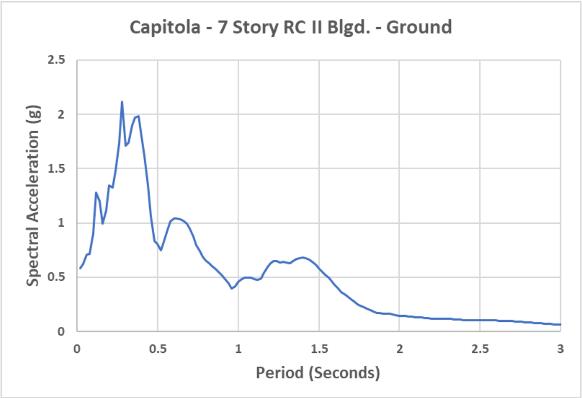


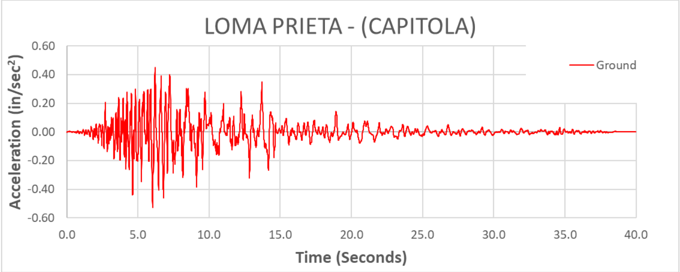
Example: 7-story Concrete MF + SW@1st floor

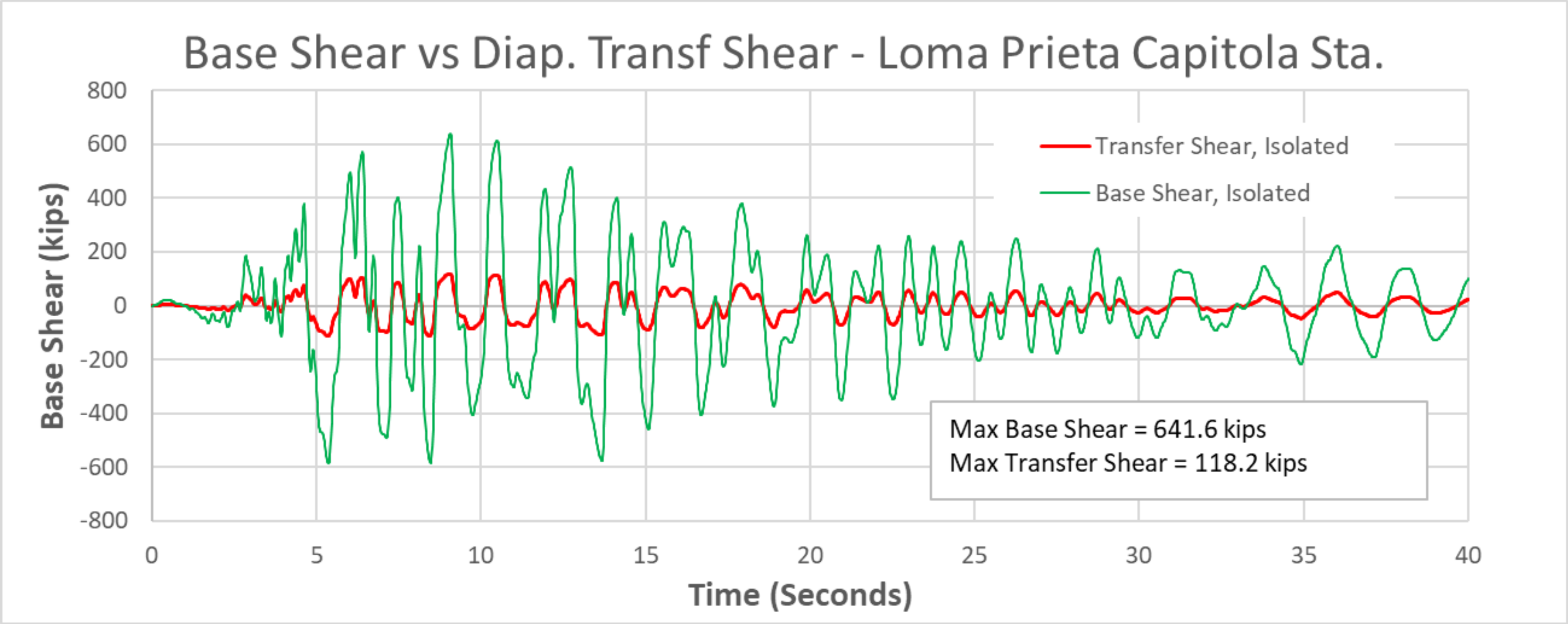
HCAI Department of Health Care Access and Information

Podium Shear Time History Comparisons – Loma Prieta (Capitola)

- ***PGA – 0.529g***
- Model 1 (Podium at 1st Floor Pin Base)
- Model 2(Podium at 1st Floor, Isolators)





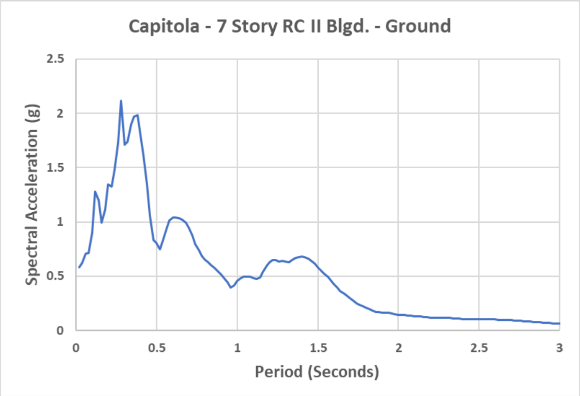


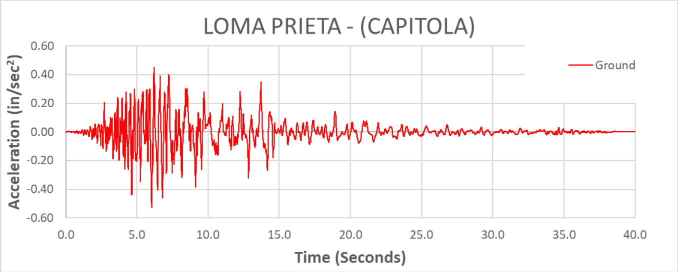
Example: 7-story Concrete MF + SW@1st floor

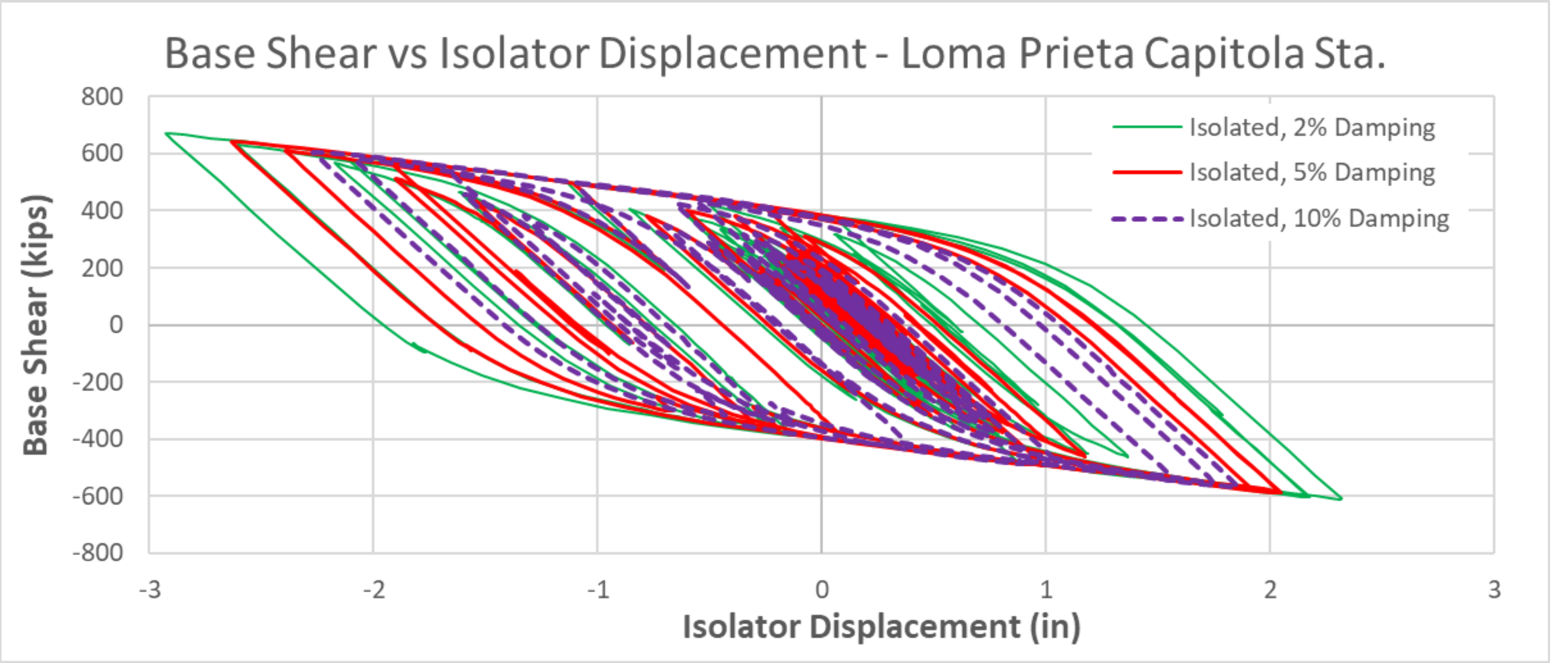
Department of Health Care Access and Information

Podium Shear Time History Comparisons – Loma Prieta (Capitola)

- ***PGA – 0.529g***
- Model 2(Podium at 1st Floor, Isolators)





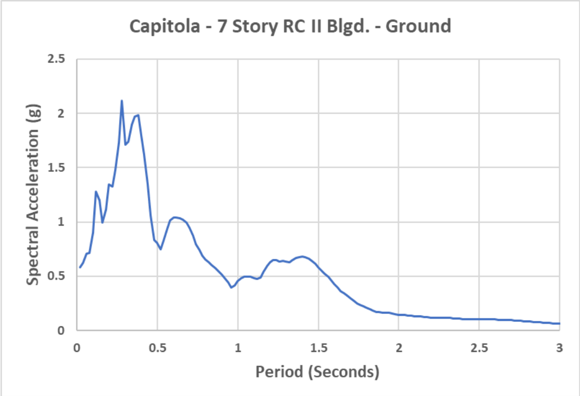


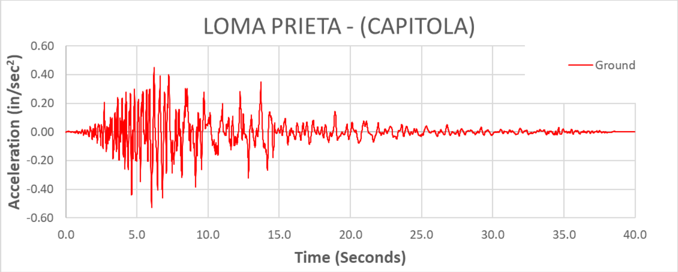
Example: 7-story Concrete MF + SW@1st floor

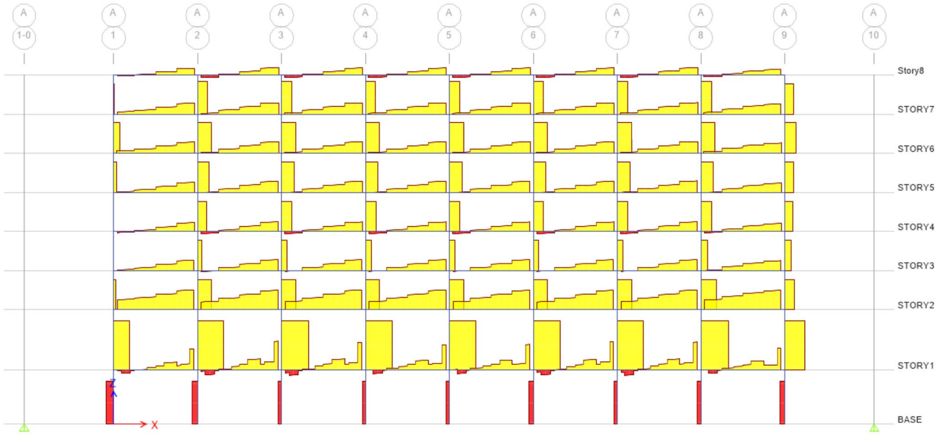
Department of Health Care Access and Information

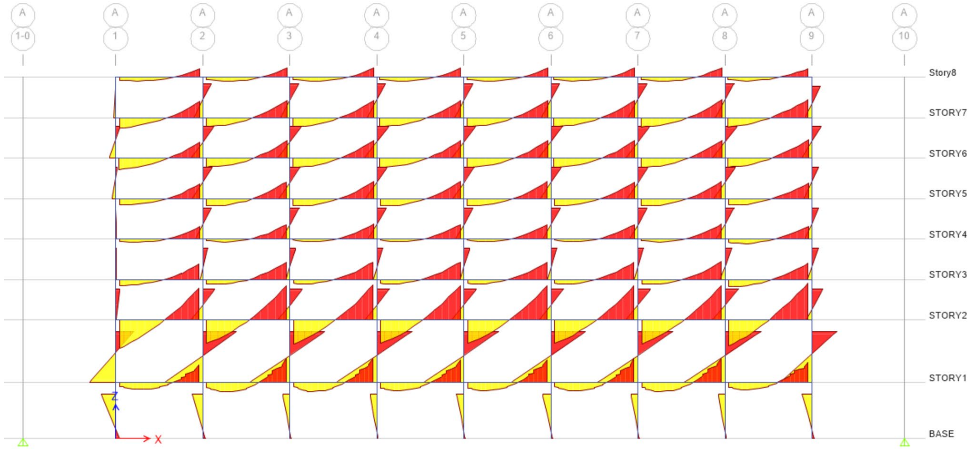
Moments and Shears @ Max. Base Shear – Loma Prieta (Capitola)

- ***PGA – 0.529g***
- Model 1(Podium at 1st Floor, non isolated)
- Moment and Shear @ 6.78 sec.







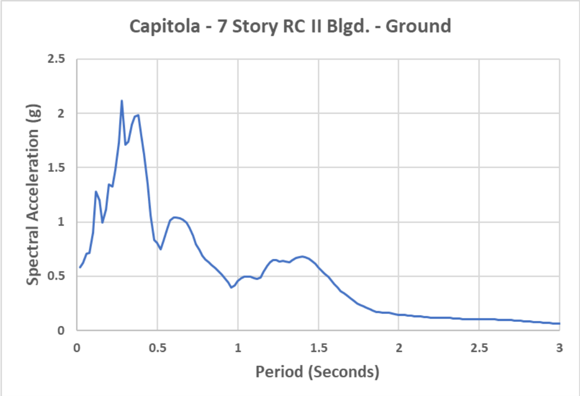


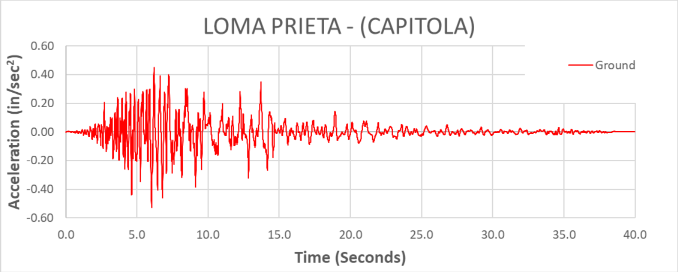
Example: 7-story Concrete MF + SW@1st floor

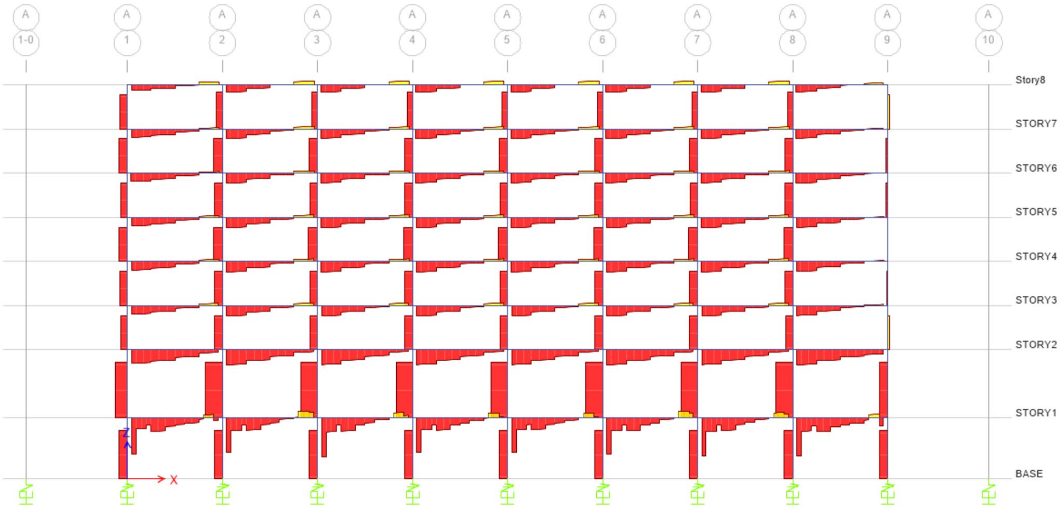
HCAi Department of Health Care Access and Information

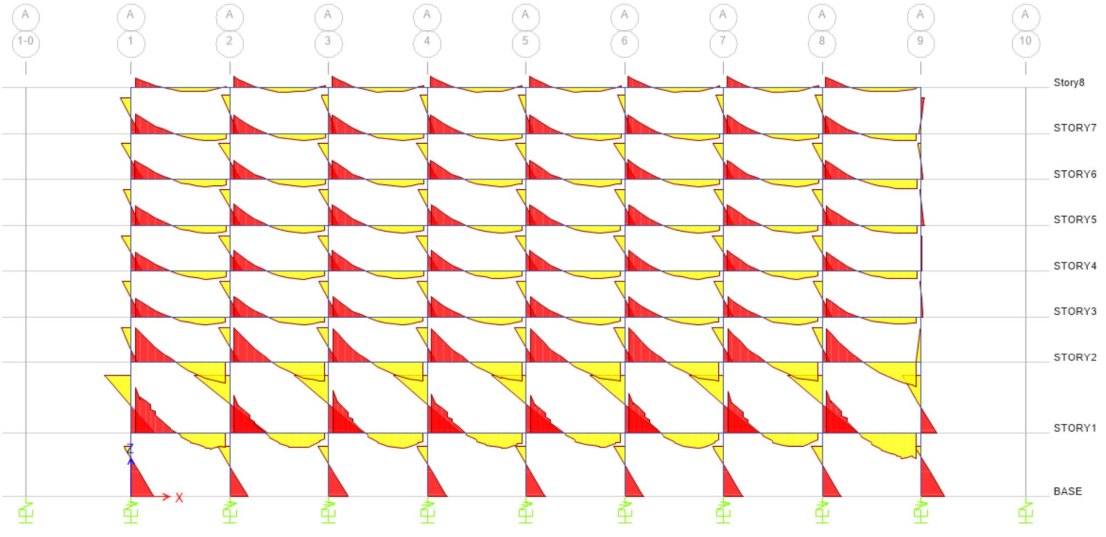
Moments and Shears @ Max. Base Shear – Loma Prieta (Capitola)

- ***PGA – 0.529g***
- Model 2(Podium at 1st Floor, Isolated)
- Moment and Shear @ 9.1 sec.









Example: 7-story Concrete MF + SW@1st floor

Department of Health Care Access and Information