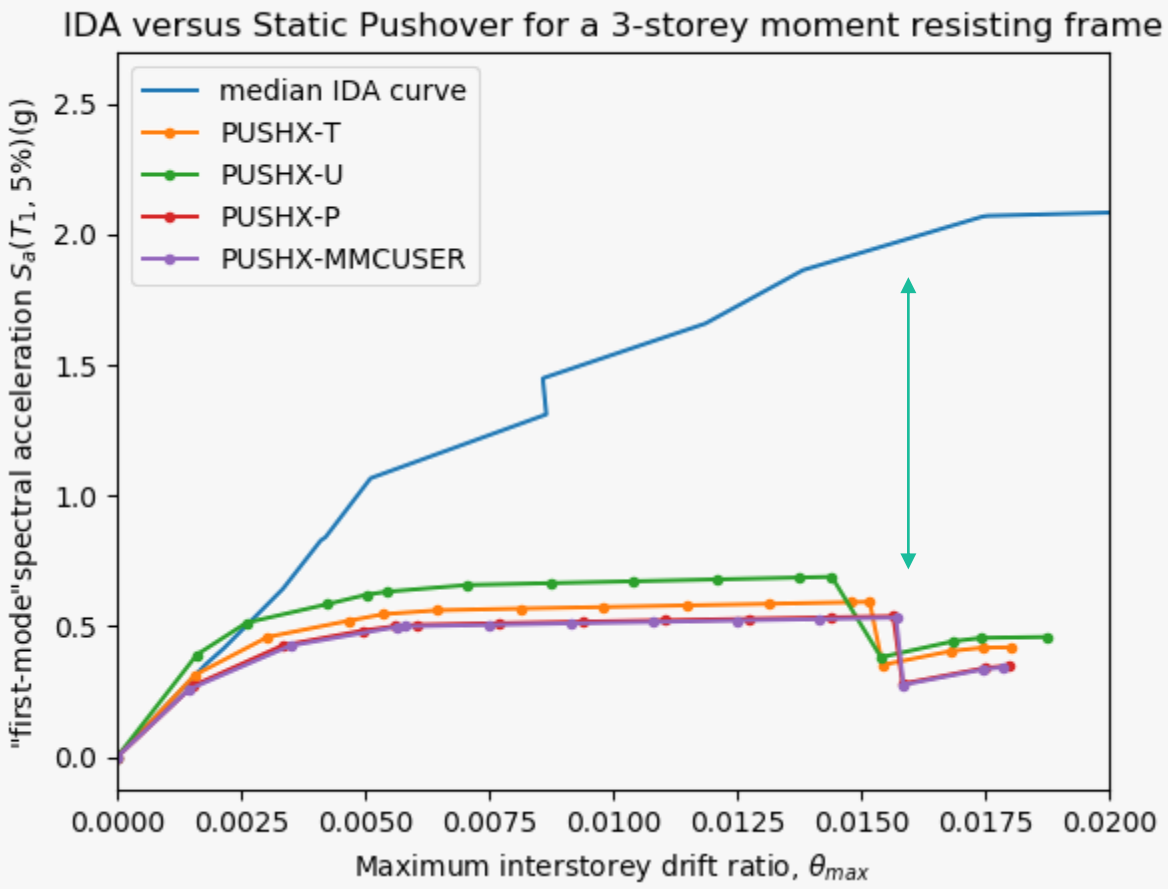
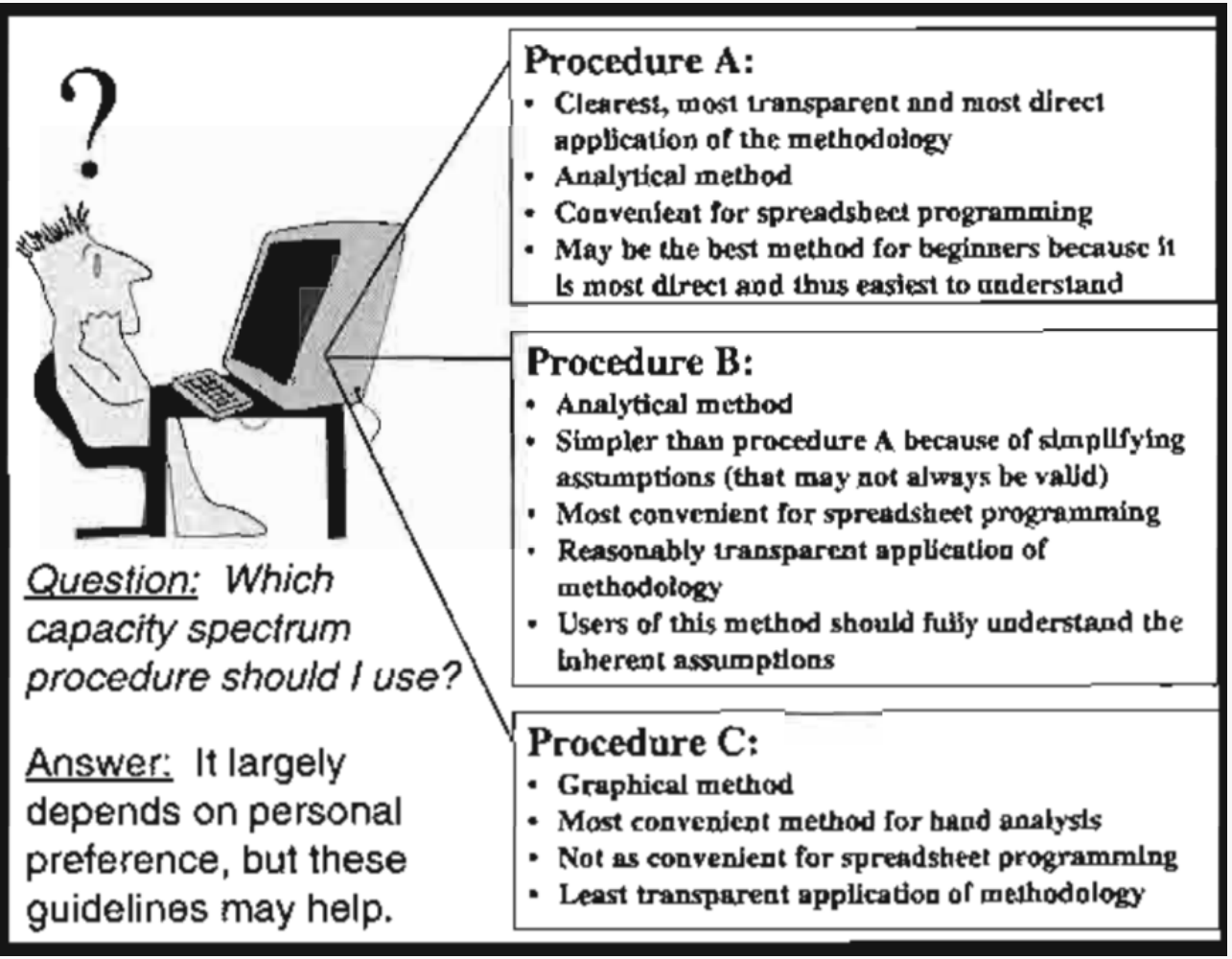
MULTI-CUT REBAR(13)

Advisor : Prof. K.C.Chang

Presenters : You-Ran Nai



Pushover and IDA too much difference



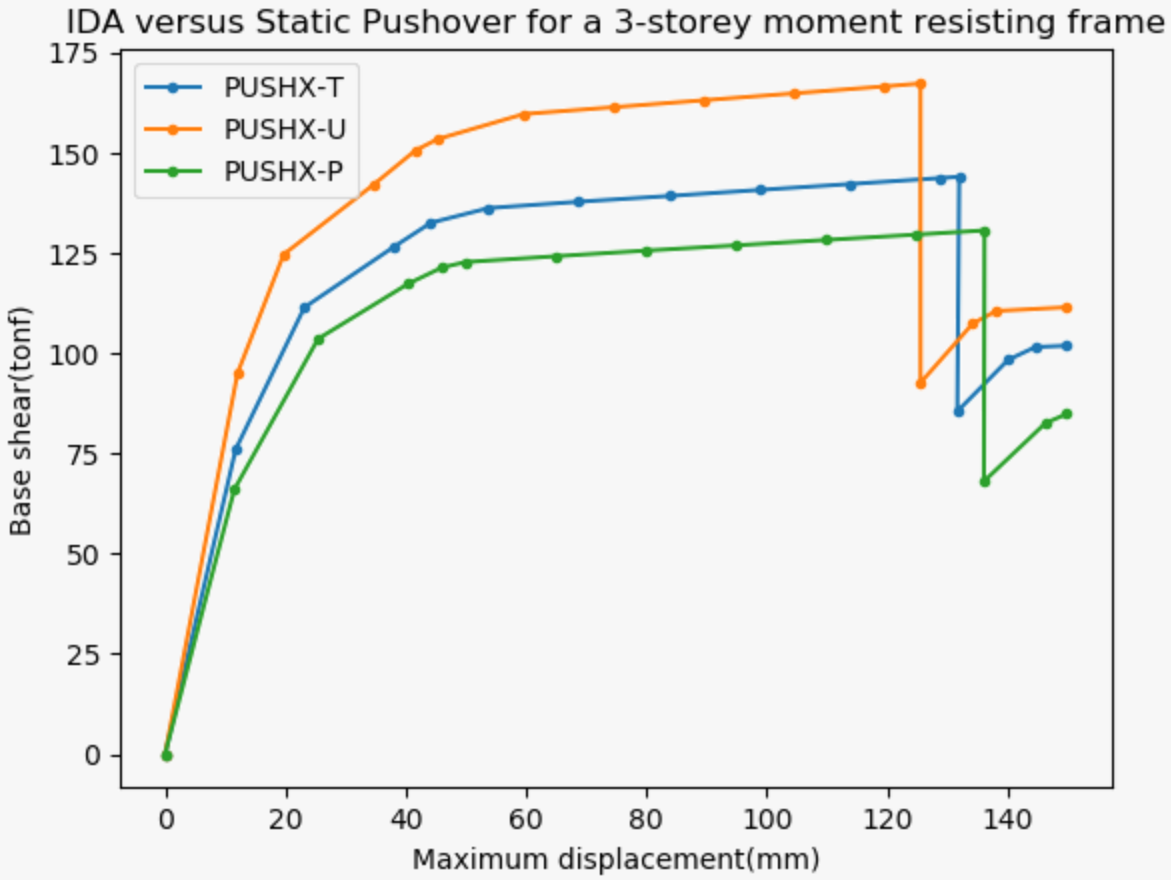
Need to determine C_A, C_V, SR_A, SR_V

Have simplifying assumptions

Convenient for hand analysis

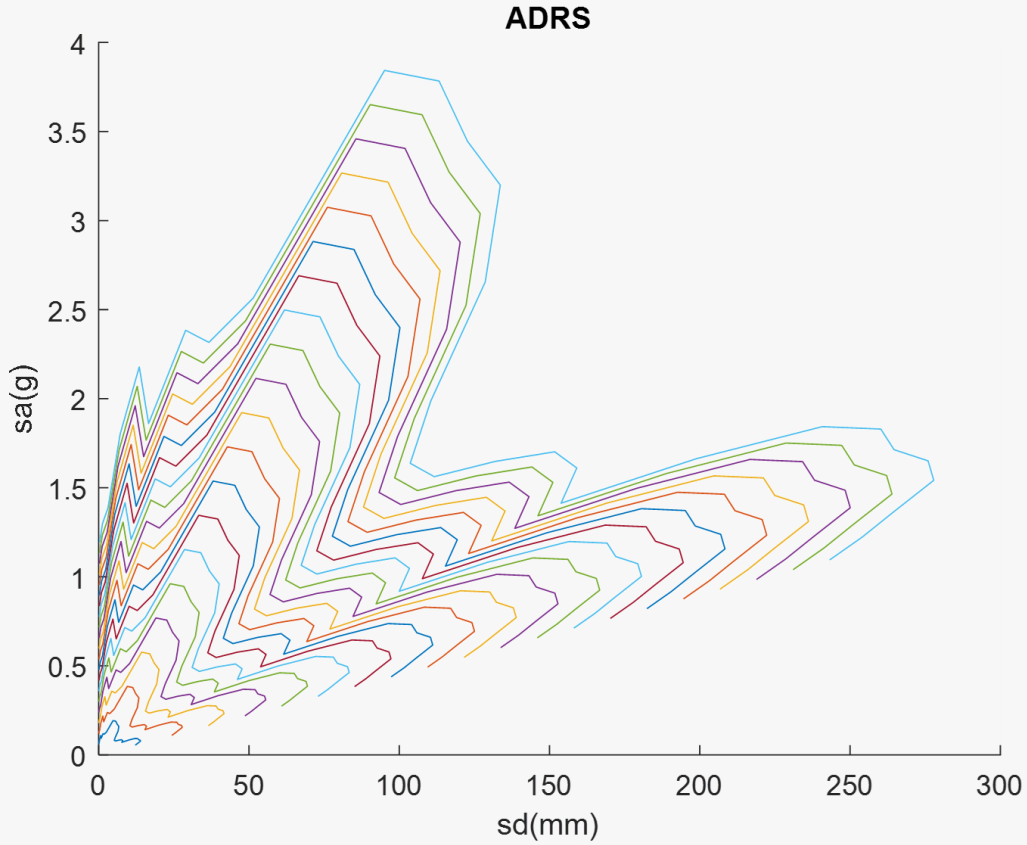
Capacity Curve

load pattern: triangle, uniform, power

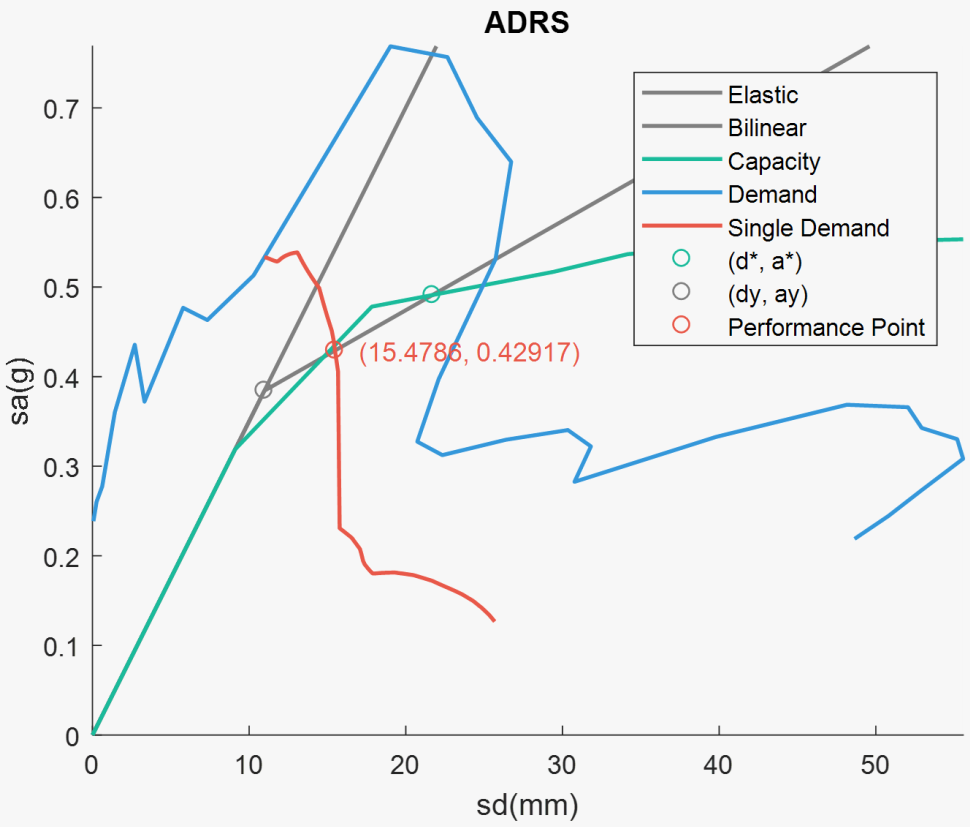


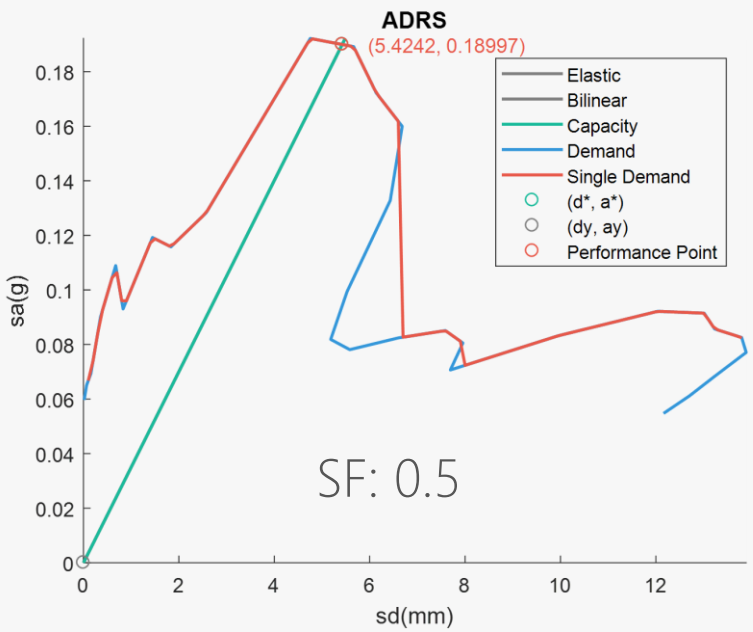
Demand curve

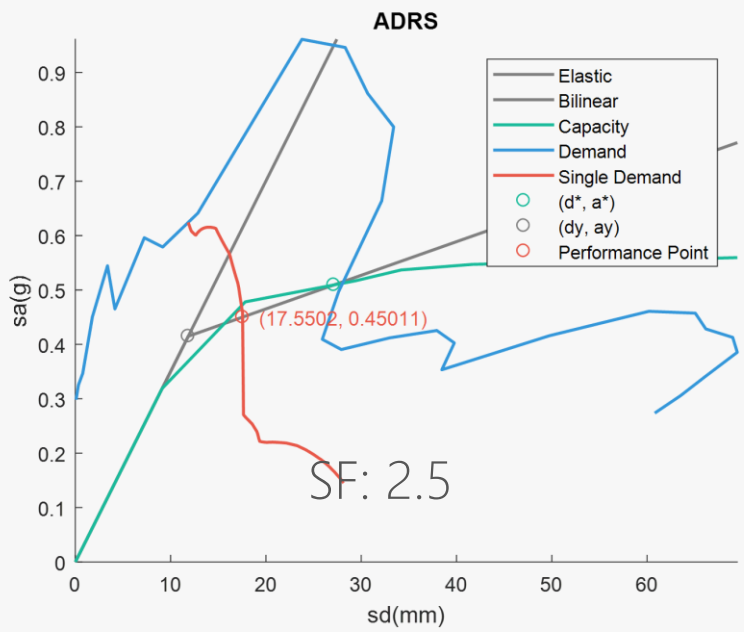
TAP010 scaled factor: 0.5:0.5:10

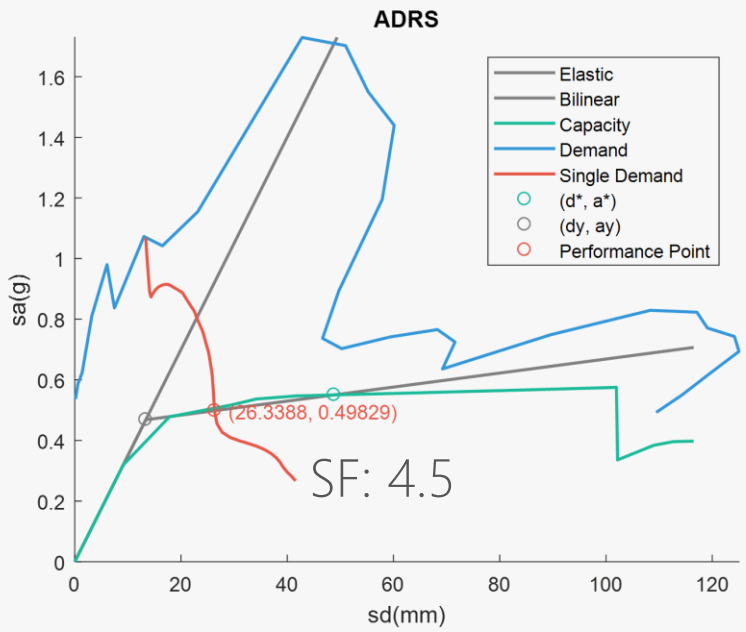


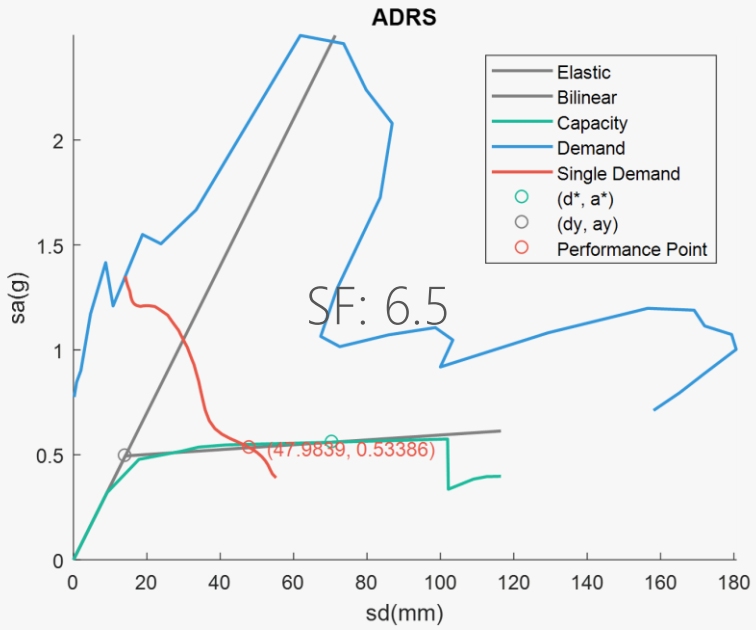
Procedure B

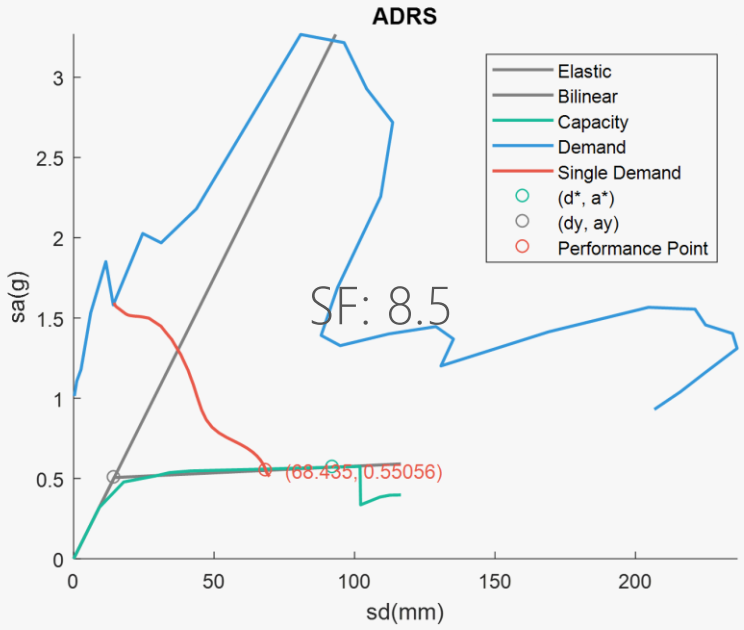

ADRS
Elastic
Bilinear
Capacity
Demand
Single Demand
(d*, a*)
(dy, ay)
Performance Point
(15.4786, 0.42917)
sa(g)
sd(mm)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0
10
20
30
40
50

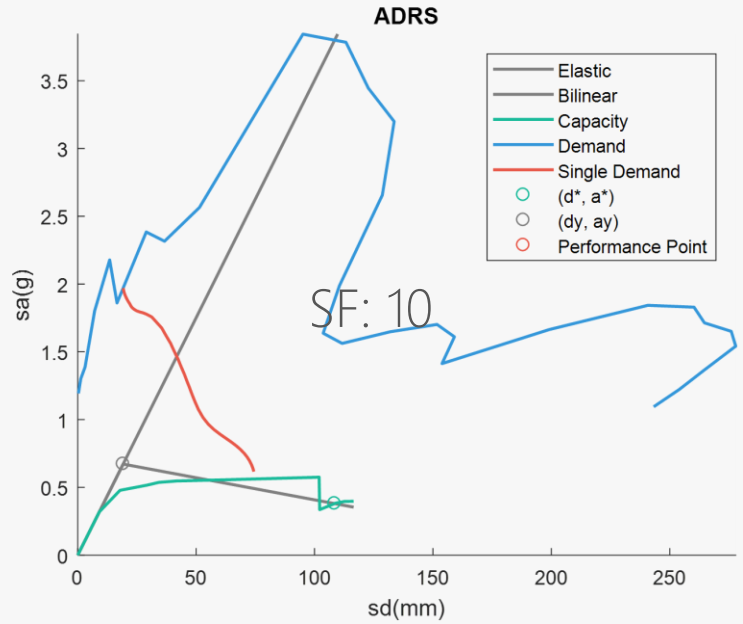

ADRS
(5.4242, 0.18997)
Elastic
Bilinear
Capacity
Demand
Single Demand
(d*, a*)
(dy, ay)
Performance Point
SF: 0.5
sa(g)
sd(mm)


ADRS
(17.5502, 0.45011)
Elastic
Bilinear
Capacity
Demand
Single Demand
(d*, a*)
(dy, ay)
Performance Point
SF: 2.5
sa(g)
sd(mm)

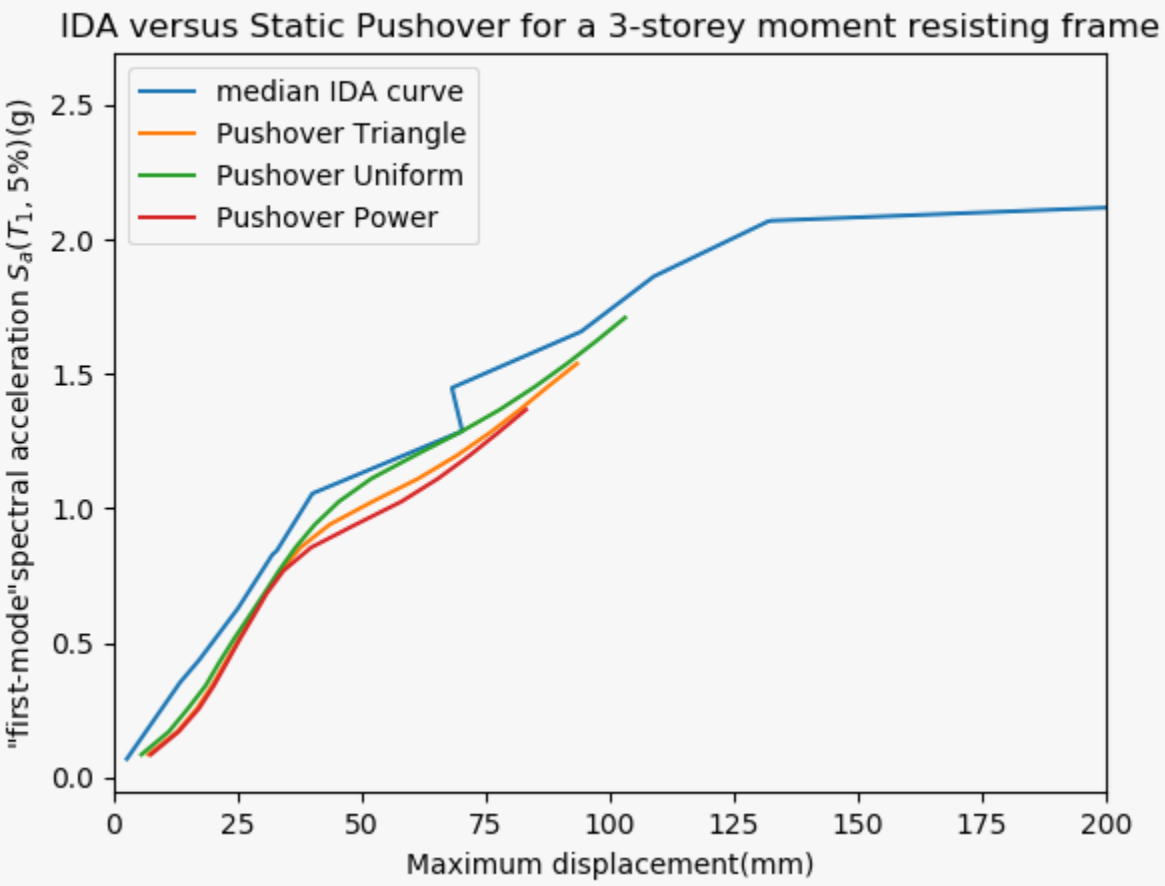

ADRS
(26.3388, 0.49829)
Elastic
Bilinear
Capacity
Demand
Single Demand
(d*, a*)
(dy, ay)
Performance Point
SF: 4.5
sa(g)
sd(mm)


ADRS
(47.9839, 0.53386)
Elastic
Bilinear
Capacity
Demand
Single Demand
(d*, a*)
(dy, ay)
Performance Point
SF: 6.5
sa(g)
sd(mm)

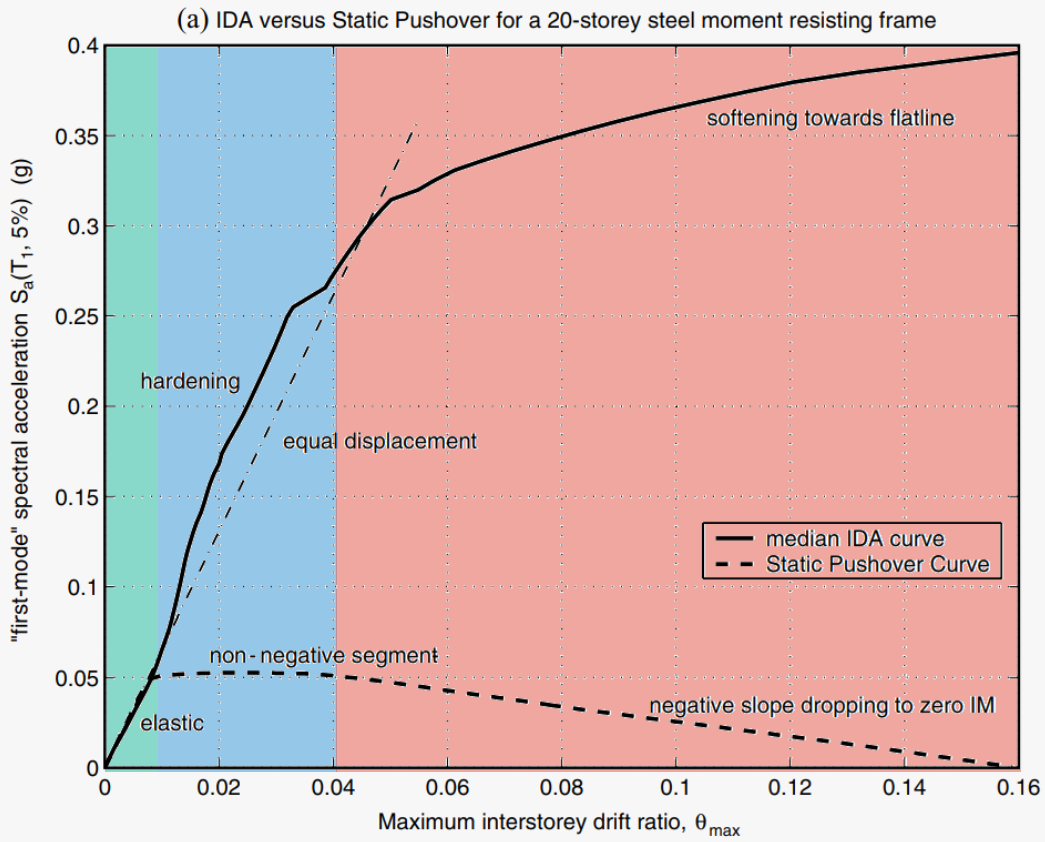

ADRS
(68.435, 0.55056)
Elastic
Bilinear
Capacity
Demand
Single Demand
(d*, a*)
(dy, ay)
Performance Point
SF: 8.5
sa(g)
sd(mm)


ADRS
Elastic
Bilinear
Capacity
Demand
Single Demand
(d*, a*)
(dy, ay)
Performance Point
SF: 10
sa(g)
sd(mm)

Result


IDA versus Static Pushover for a 3-storey moment resisting frame
median IDA curve
Pushover Triangle
Pushover Uniform
Pushover Power
"first-mode"spectral acceleration $S_a(T_1, 5\%)$(g)
0.0
0.5
1.0
1.5
2.0
2.5
0
25
50
75
100
125
150
175
200
Maximum displacement(mm)

NON-LINEAR SPO



ELASTIC

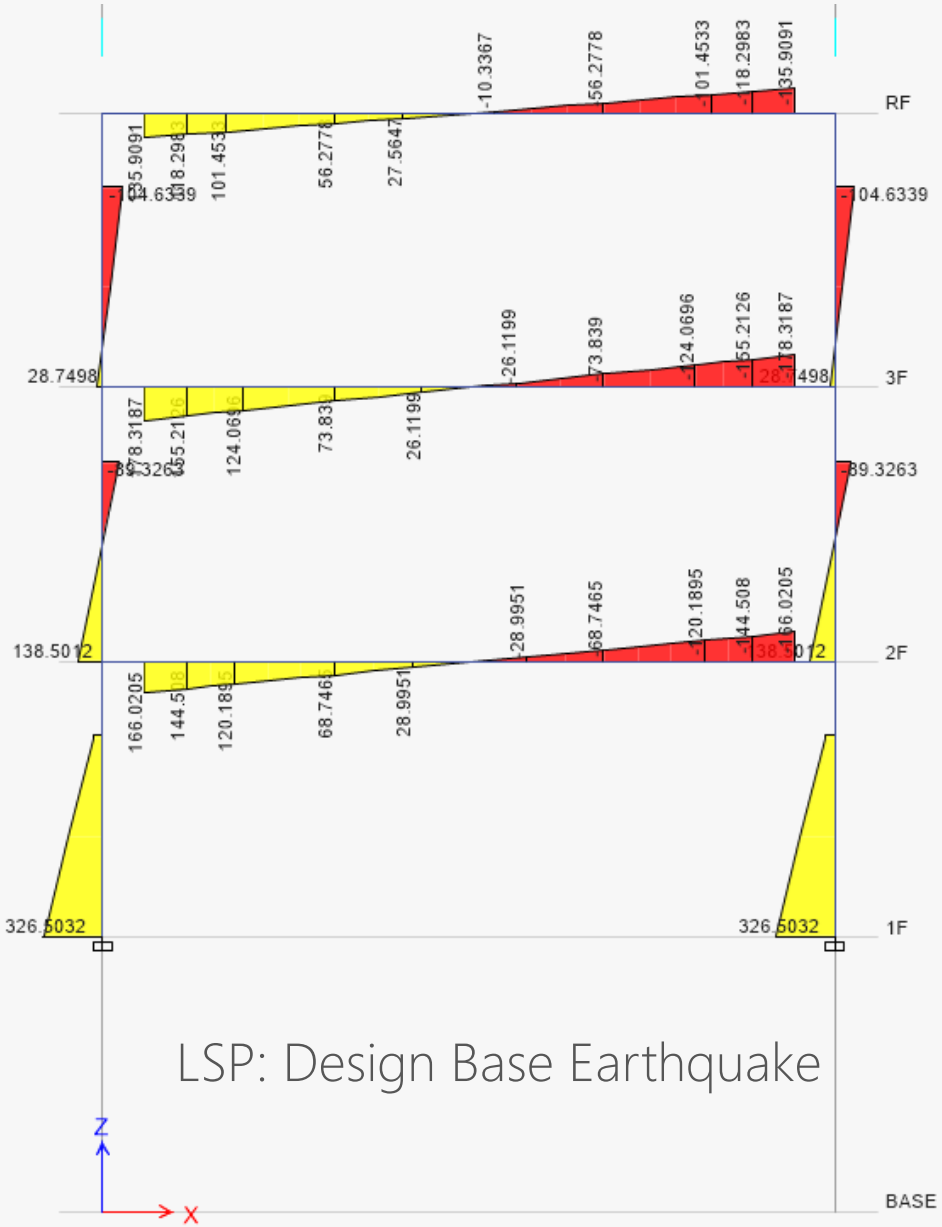
➔ MATCH

NON-NEGATIVE

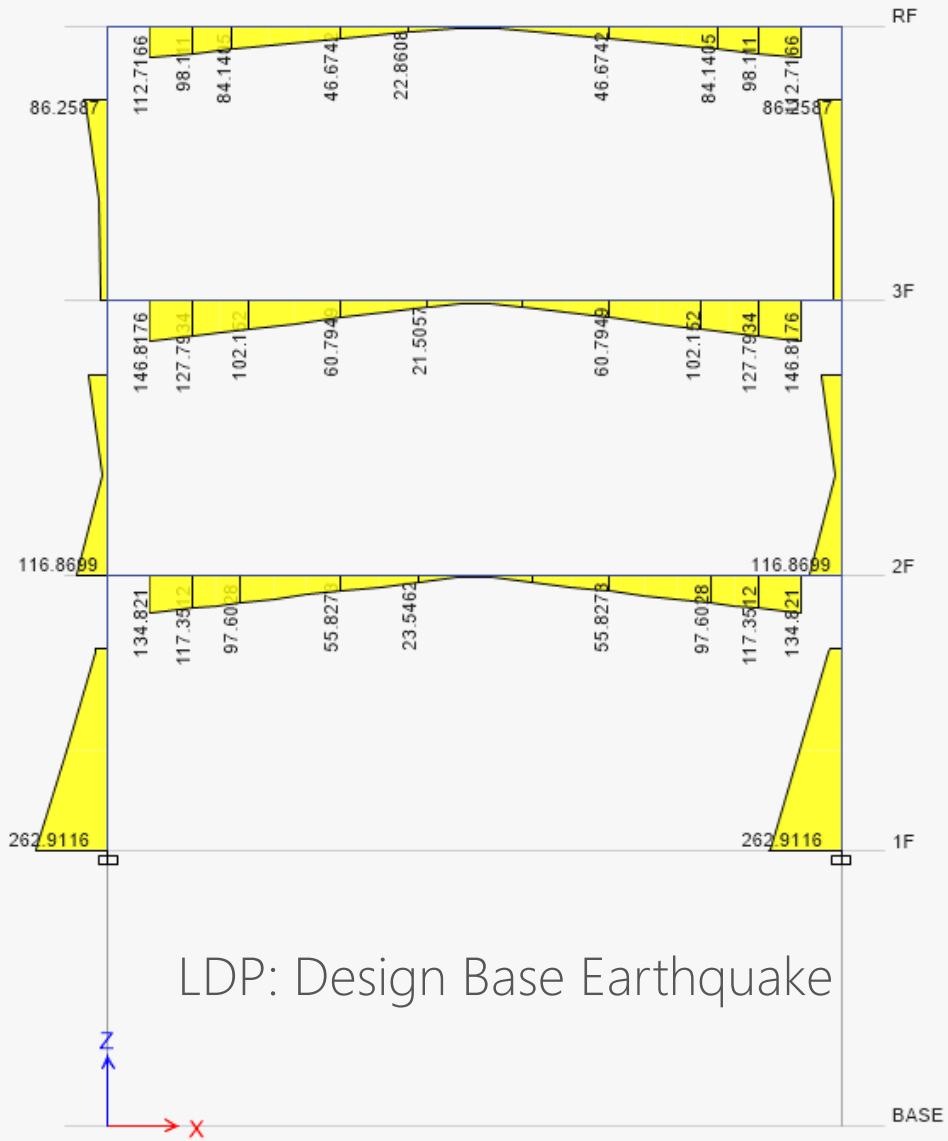
➔ EQUAL DISPLACEMENT

NEGATIVE

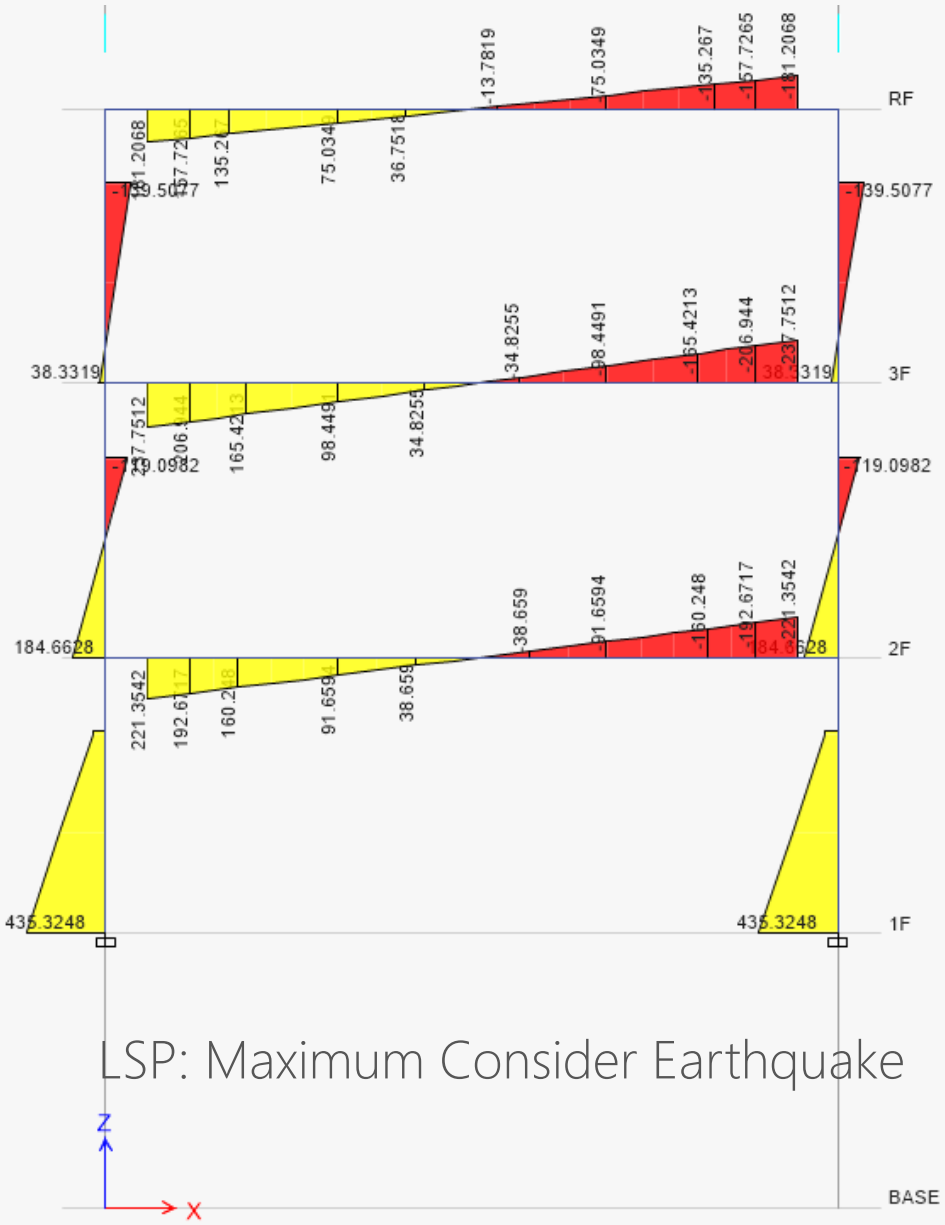
➔ SOFTENING



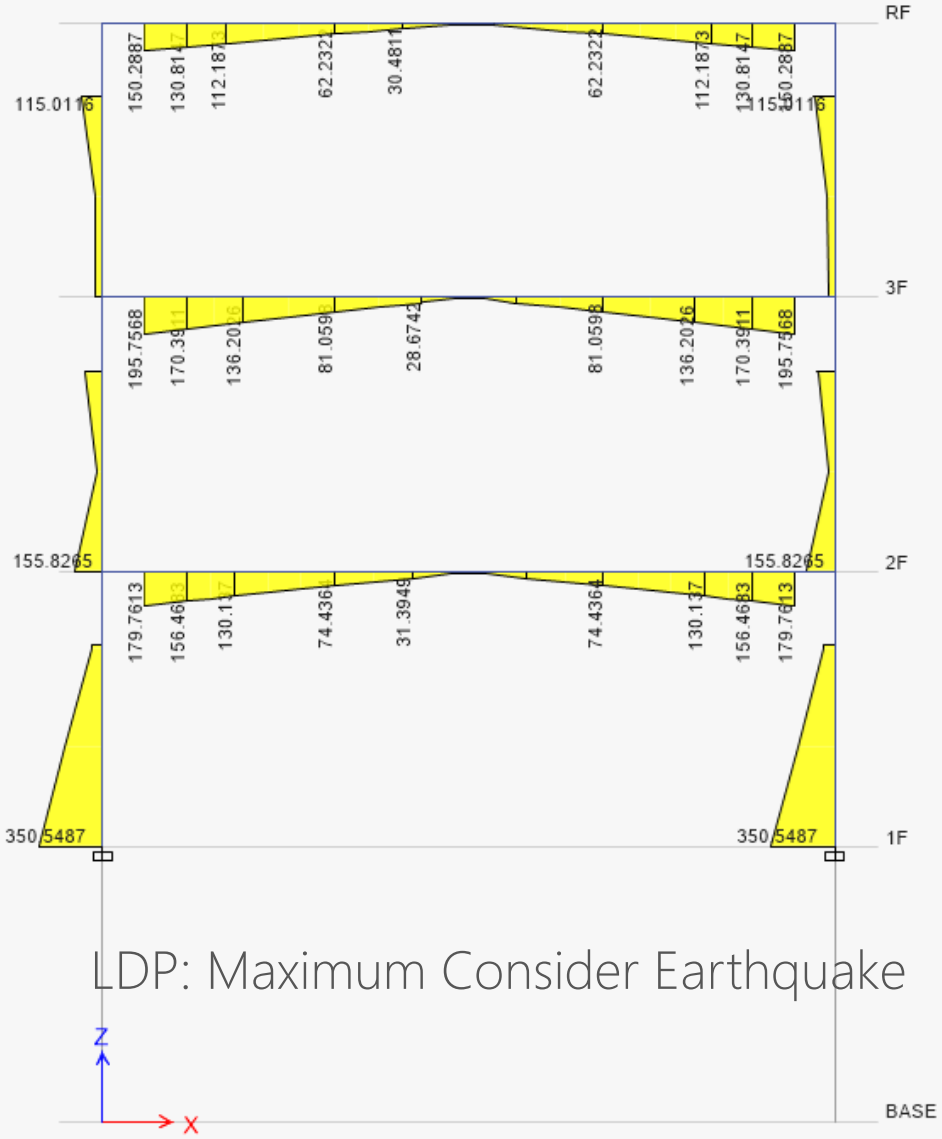
LSP: Design Base Earthquake



LDP: Design Base Earthquake



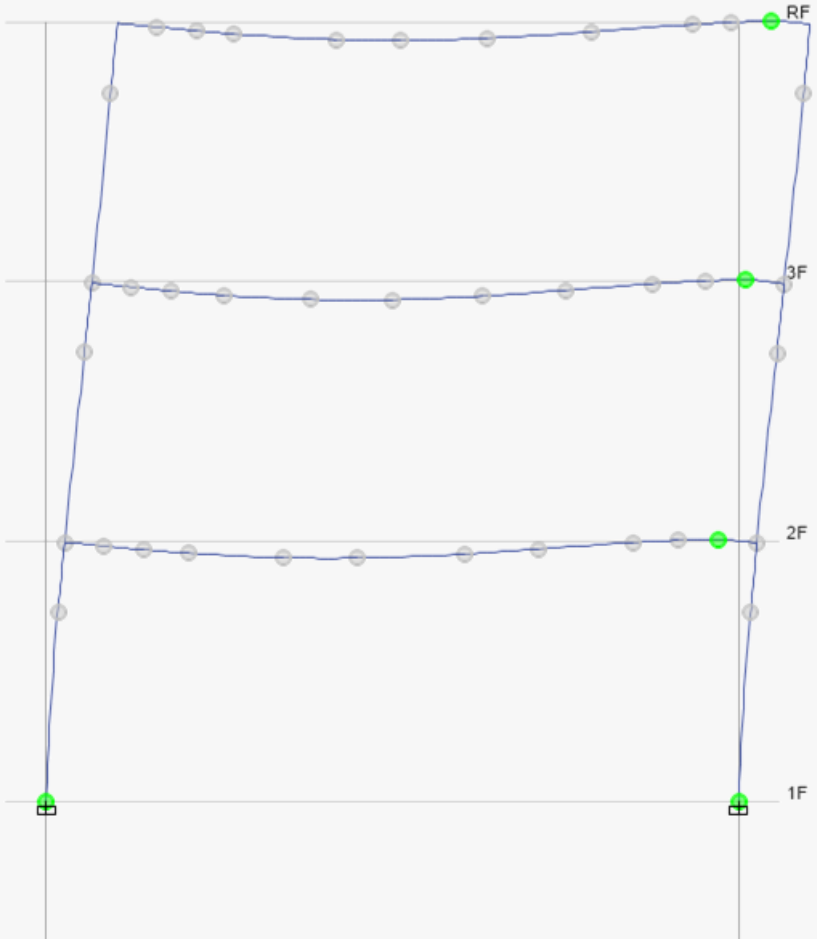
LSP: Maximum Consider Earthquake



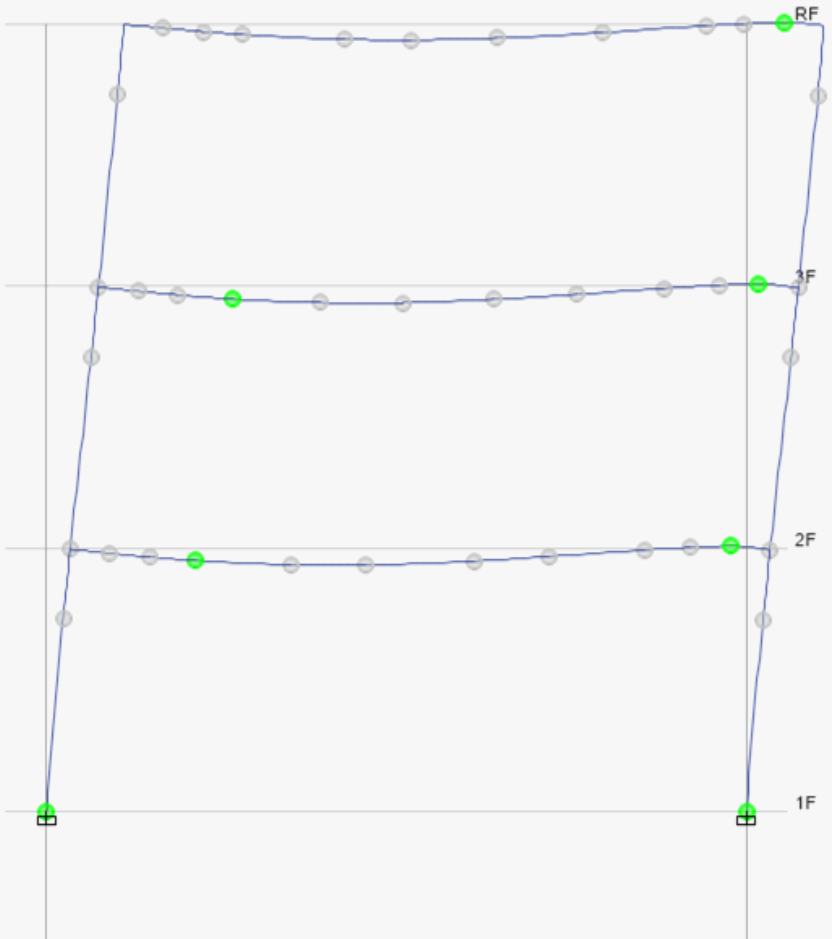
LDP: Maximum Consider Earthquake

Nonlinear Static Procedure

Design

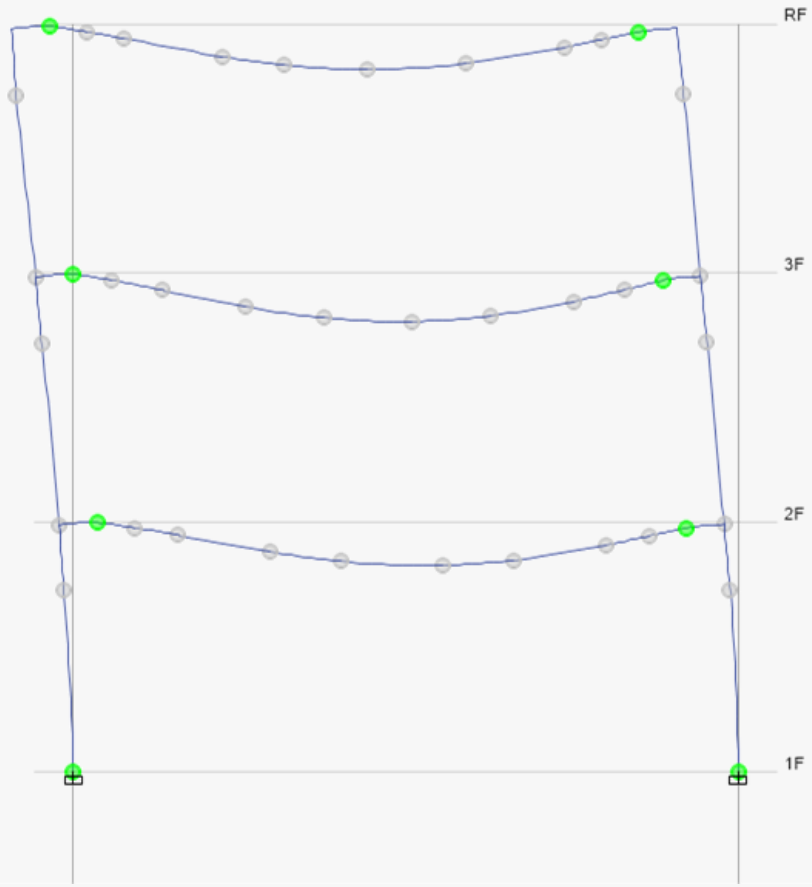


Maximum

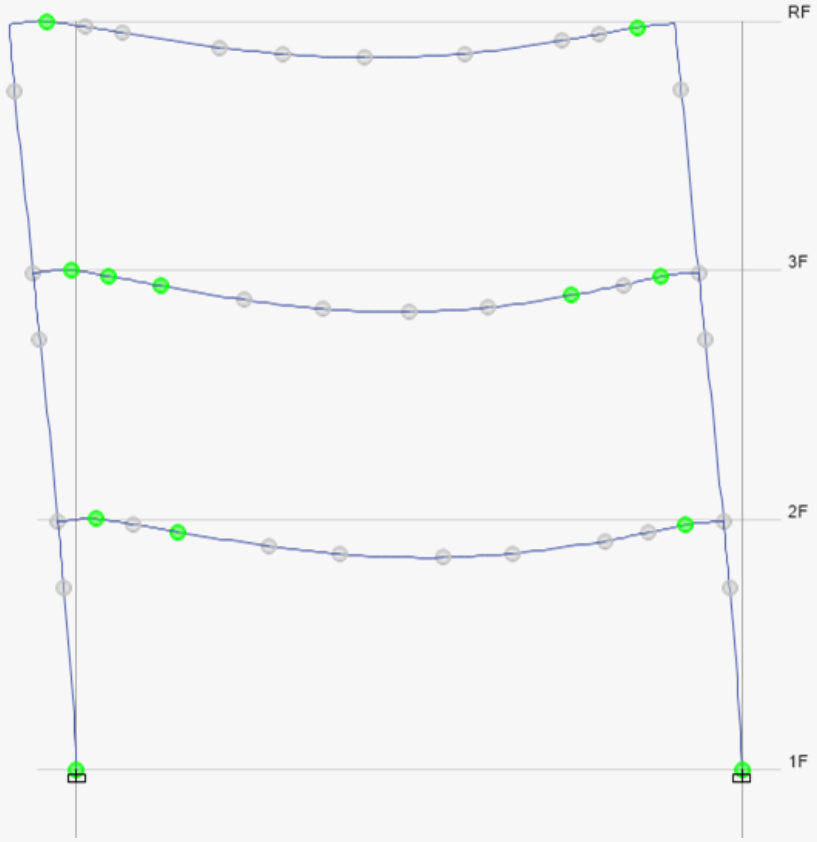


Nonlinear Dynamic Procedure

Design



Maximum



Story	Frame/Wall	Load Case/Combo	R3 Plastic	Hinge State	Hinge Status
2F	C1	NSPMAXIMUM-U Max	0.002761	B to C	A to IO
2F	C2	NSPMAXIMUM-U Max	0.002659	B to C	A to IO
2F	C1	NSPMAXIMUM-T Max	0.002015	B to C	A to IO
2F	C2	NSPMAXIMUM-T Max	0.001918	B to C	A to IO
3F	B19	NSPMAXIMUM-T Max	0.001089	B to C	A to IO
2F	B4	NSPMAXIMUM-U Max	0.00106	B to C	A to IO
3F	B19	NSPMAXIMUM-U Max	0.000613	B to C	A to IO
2F	B4	NSPMAXIMUM-T Max	0.000539	B to C	A to IO
3F	B19	FEMA TAP032 Maximum Max	0.000376	B to C	A to IO
2F	C1	NSPDESIGN-U Max	0.000258	B to C	A to IO
2F	C2	NSPDESIGN-U Max	0.000248	B to C	A to IO
3F	B19	FEMA TAP010 Maximum Max	0.000247	B to C	A to IO
3F	B24	FEMA TAP010 Maximum Max	0.000226	B to C	A to IO
2F	B4	FEMA TAP032 Maximum Max	0.000154	B to C	A to IO
2F	B9	FEMA TAP010 Maximum Max	0.00015	B to C	A to IO
3F	B24	FEMA TAP032 Maximum Max	0.000147	B to C	A to IO
3F	B19	FEMA TAP052 Maximum Max	0.000139	B to C	A to IO
3F	B24	FEMA TAP052 Maximum Max	0.000131	B to C	A to IO
2F	C1	FEMA TAP032 Maximum Max	0.000097	B to C	A to IO
2F	B4	FEMA TAP010 Maximum Max	0.000097	B to C	A to IO
3F	B18	FEMA TAP032 Maximum Max	0.00009	B to C	A to IO
3F	B10	FEMA TAP010 Maximum Max	0.000065	B to C	A to IO
2F	B10	FEMA TAP010 Maximum Max	0.000047	B to C	A to IO
2F	C1	FEMA TAP052 Maximum Max	0.000032	B to C	A to IO
3F	B10	FEMA TAP052 Maximum Max	0.000027	B to C	A to IO
2F	B3	FEMA TAP032 Maximum Max	0.000023	B to C	A to IO
3F	B18	FEMA TAP052 Maximum Max	0.000021	B to C	A to IO
3F	B18	FEMA TAP010 Maximum Max	0.000018	B to C	A to IO
3F	B10	FEMA TAP032 Maximum Max	0.000009	B to C	A to IO
2F	B9	FEMA TAP052 Maximum Max	0.000006	B to C	A to IO
2F	B9	FEMA TAP032 Maximum Max	0.000003	B to C	A to IO

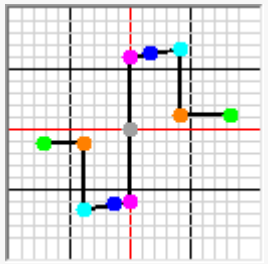


Table 9-2 Reinforced Concrete Special Moment Frame Archetype Structural Design Properties

Archetype ID	No. of Stories	Key Archetype Design Parameters						
		Framing (Gravity Loads)	Seismic Design Criteria					$S_{MT}(T)$ [g]
			SDC	*R*	*T* [sec]	T_1 [sec]	*V/W* [g]	
Performance Group No. PG-5 (Short Period, 20' Bay Width Configuration)								
2069	1	P	D_{max}	8	0.26	0.71	0.125	1.50
2064	2	P	D_{max}	8	0.45	0.66	0.125	1.50
--	3	P	D_{max}	8	0.63	--	0.119	1.43
Performance Group No. PG-6 (Long Period, 20' Bay Width Configuration)								
1003	4	P	D_{max}	8	0.81	1.12	0.092	1.11
1011	8	P	D_{max}	8	1.49	1.71	0.050	0.60
5013	12	P	D_{max}	8	2.13	2.01	0.035	0.42
5020	20	P	D_{max}	8	3.36	2.63	0.022	0.27
Performance Group No. PG-1 (Short Period, 20' Bay Width Configuration)								
2061	1	S	D_{max}	8	0.26	0.42	0.125	1.50
1001	2	S	D_{max}	8	0.45	0.63	0.125	1.50
--	3	S	D_{max}	8	0.63	--	0.119	1.43
Performance Group No. PG-3 (Long Period, 20' Bay Width Configuration)								
1008	4	S	D_{max}	8	0.81	0.94	0.092	1.11
1012	8	S	D_{max}	8	1.49	1.80	0.050	0.60
5014	12	S	D_{max}	8	2.13	2.14	0.035	0.42
5021	20	S	D_{max}	8	3.36	2.36	0.022	0.27
Selected Archetypes - Performance Group Nos. PG-4 and PG-8 (20' Bay Width)								
6011	8	P	D_{min}	8	1.60	3.00	0.013	0.15
6013	12	P	D_{min}	8	2.28	3.35	0.010	0.10
6020	20	P	D_{min}	8	3.60	4.08	0.010	0.065
6021	20	S	D_{min}	8	3.60	4.03	0.010	0.065
Selected Archetypes - Performance Group Nos. PG-10 and PG-14 (30' Bay Width)								
1009	4	P-30	D_{max}	8	1.03	1.16	0.092	1.03
1010	4	S-30	D_{max}	8	1.03	0.86	0.092	1.03

Table 9-9 Structural Design Properties for Reinforced Concrete Special Moment Frame Archetypes Redesigned Considering a Minimum Base Shear Requirement

Archetype ID	No. of Stories	Key Archetype Design Parameters						
		Framing (Gravity Loads)	Seismic Design Criteria					$S_{MT}(T)$ [g]
			SDC	R_{eff}[1]	*T* [sec]	T_1 [sec]	*V/W* [g]	
Re-Designed Archetypes - Performance Group No. PG-6 (Long Period, 20' Bay Width)								
1013	12	P	D_{max}	6.4	2.13	2.01	0.044	0.42
1020	20	P	D_{max}	4.1	3.36	2.63	0.044	0.27
Re-Designed Archetypes - Performance Group No. PG-3 (Long Period, 20' Bay Width)								
1014	12	S	D_{max}	6.4	2.13	2.14	0.044	0.42
1021	20	S	D_{max}	4.1	3.36	2.36	0.044	0.27
Re-Designed Archetypes - Performance Group No. PG-4, PG-8 (Long Period, 20' Bays)								
4011	8	P	D_{min}	5.8	1.6	3.00	0.017	0.15
4013	12	P	D_{min}	6.6	2.28	3.35	0.017	0.10
4020	20	P	D_{min}	4.2	3.6	4.08	0.017	0.065
4021	20	S	D_{min}	8.0	3.6	4.03	0.017	0.065

Space frame

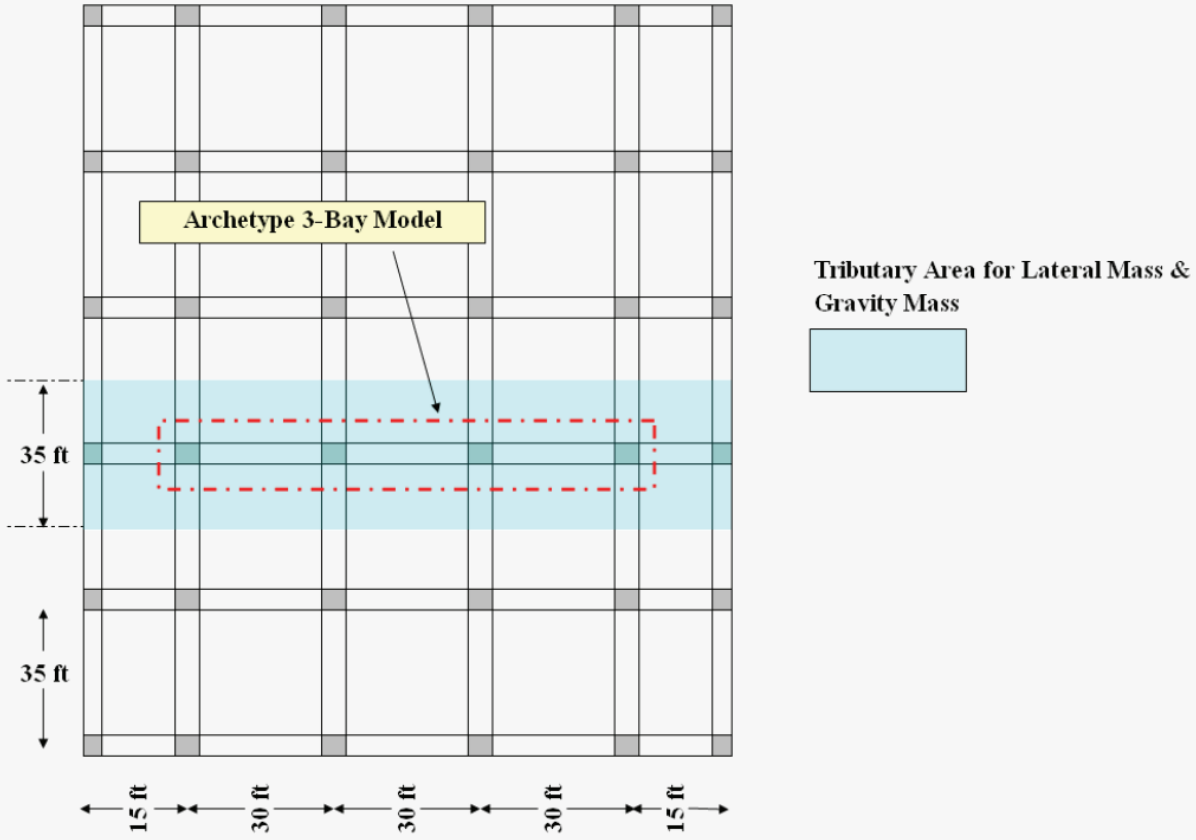


Figure 9-9 High gravity (space frame) layout.

Perimeter frame

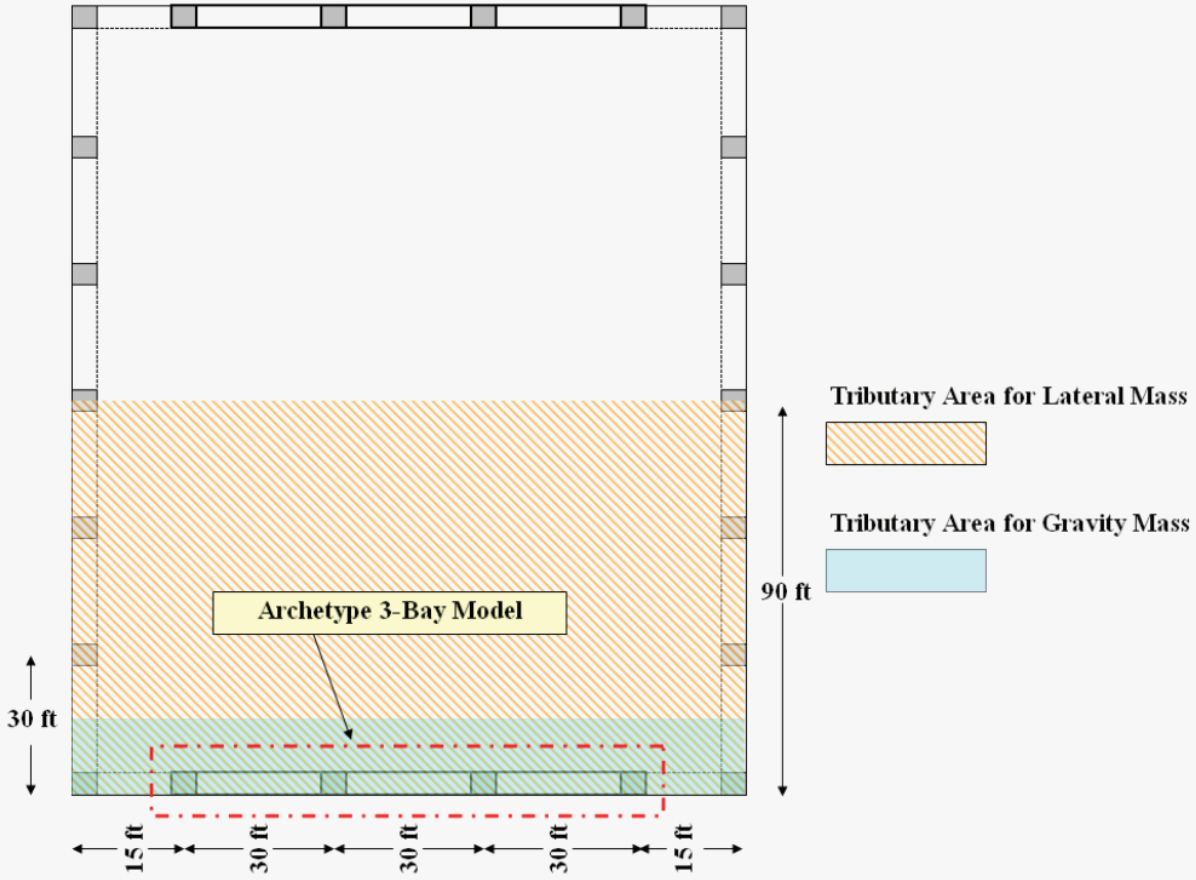


Figure 9-10 Low gravity (perimeter frame) layout. Interior (gravity) columns are not shown for clarity.

Table 9-2 Reinforced Concrete Special Moment Frame Archetype Structural Design Properties

Archetype ID	No. of Stories	Key Archetype Design Parameters						
		Framing (Gravity Loads)	Seismic Design Criteria					$S_{MT}(T)$ [g]
			SDC	*R*	*T* [sec]	T_1 [sec]	*V/W* [g]	
Performance Group No. PG-5 (Short Period, 20' Bay Width Configuration)								
2069	1	P	D_{max}	8	0.26	0.71	0.125	1.50
2064	2	P	D_{max}	8	0.45	0.66	0.125	1.50
--	3	P	D_{max}	8	0.63	--	0.119	1.43
Performance Group No. PG-6 (Long Period, 20' Bay Width Configuration)								
1003	4	P	D_{max}	8	0.81	1.12	0.092	1.11
1011	8	P	D_{max}	8	1.49	1.71	0.050	0.60
5013	12	P	D_{max}	8	2.13	2.01	0.035	0.42
5020	20	P	D_{max}	8	3.36	2.63	0.022	0.27
Performance Group No. PG-1 (Short Period, 20' Bay Width Configuration)								
2061	1	S	D_{max}	8	0.26	0.42	0.125	1.50
1001	2	S	D_{max}	8	0.45	0.63	0.125	1.50
--	3	S	D_{max}	8	0.63	--	0.119	1.43
Performance Group No. PG-3 (Long Period, 20' Bay Width Configuration)								
1008	4	S	D_{max}	8	0.81	0.94	0.092	1.11
1012	8	S	D_{max}	8	1.49	1.80	0.050	0.60
5014	12	S	D_{max}	8	2.13	2.14	0.035	0.42
5021	20	S	D_{max}	8	3.36	2.36	0.022	0.27
Selected Archetypes - Performance Group Nos. PG-4 and PG-8 (20' Bay Width)								
6011	8	P	D_{min}	8	1.60	3.00	0.013	0.15
6013	12	P	D_{min}	8	2.28	3.35	0.010	0.10
6020	20	P	D_{min}	8	3.60	4.08	0.010	0.065
6021	20	S	D_{min}	8	3.60	4.03	0.010	0.065
Selected Archetypes - Performance Group Nos. PG-10 and PG-14 (30' Bay Width)								
1009	4	P-30	D_{max}	8	1.03	1.16	0.092	1.03
1010	4	S-30	D_{max}	8	1.03	0.86	0.092	1.03

Table 9-9 Structural Design Properties for Reinforced Concrete Special Moment Frame Archetypes Redesigned Considering a Minimum Base Shear Requirement

Archetype ID	No. of Stories	Key Archetype Design Parameters						
		Framing (Gravity Loads)	Seismic Design Criteria					$S_{MT}(T)$ [g]
			SDC	R_{eff}[1]	*T* [sec]	T_1 [sec]	*V/W* [g]	
Re-Designed Archetypes - Performance Group No. PG-6 (Long Period, 20' Bay Width)								
1013	12	P	D_{max}	6.4	2.13	2.01	0.044	0.42
1020	20	P	D_{max}	4.1	3.36	2.63	0.044	0.27
Re-Designed Archetypes - Performance Group No. PG-3 (Long Period, 20' Bay Width)								
1014	12	S	D_{max}	6.4	2.13	2.14	0.044	0.42
1021	20	S	D_{max}	4.1	3.36	2.36	0.044	0.27
Re-Designed Archetypes - Performance Group No. PG-4, PG-8 (Long Period, 20' Bays)								
4011	8	P	D_{min}	5.8	1.6	3.00	0.017	0.15
4013	12	P	D_{min}	6.6	2.28	3.35	0.017	0.10
4020	20	P	D_{min}	4.2	3.6	4.08	0.017	0.065
4021	20	S	D_{min}	8.0	3.6	4.03	0.017	0.065

Building Type: Special RC Frame, designed per 2003 IBC

Building Design ID: 1008

Number of Stories: 4

Fundamental Period (sec): 0.94

SUMMARY OF DESIGN DECISIONS AND WHAT CONTROLLED DESIGN

Initial member sizes (beam depths, column dimensions) were determined mostly by minimum size requirements and column-beam compatibility. Joint shear requirements dictated beam depths. The beams' negative strengths were controlled by force demands, particularly lateral forces, while their positive strengths were dictated by the minimum positive to negative strength ratio. Column strengths were determined by strong-column weak-beam (SCWB) ratios. Beam stirrups were controlled by shear capacity design. The column stirrups were controlled by both the shear capacity design and the confinement requirements.

Building Type: Special RC Frame, designed per 2003 IBC

Building Design ID: 1012

Number of Stories: 8

Fundamental Period (sec): 1.80

SUMMARY OF DESIGN DECISIONS AND WHAT CONTROLLED DESIGN

Initial member sizes (beam depths, column dimensions) were determined by joint shear requirements. Beam strengths were controlled by force demands, particularly lateral forces. Column strengths were determined by strong-column weak-beam (SCWB) ratios. Column concrete was stepped up to 6.0 ksi in all stories to meet joint shear requirements. Beam stirrups were controlled by shear capacity design. The column stirrups were controlled by both the shear capacity design and the confinement requirements.

Building Type: Special RC Frame, designed per 2003 IBC

Building Design ID: 1010

Number of Stories: 4

Fundamental Period (sec): 0.86

SUMMARY OF DESIGN DECISIONS AND WHAT CONTROLLED DESIGN

Initial member sizes (beam depths, column dimensions) were determined by joint shear requirements. Beam strengths were controlled by force demands, particularly lateral forces. Column strengths were determined by strong-column weak-beam (SCWB) ratios. Beam stirrups were controlled by shear capacity design. The column stirrups were controlled by both the shear capacity design and the confinement requirements.

Design Documentation (1 of 2)

Floor 5				24	30	0.0072	0.0116	0.0032	5.0			24	30	0.0072	0.0116	0.0032	5.0			24	30	0.0072	0.0116	0.0032	5.0
Story 4	h (in) =	30								30								30								30
	b (in) =	30								30								30								30
	ρ_{tot} =	0.0108								0.0110								0.0110								0.0108
	ρ_{sh} =	0.0065								0.0065								0.0065								0.0065
	s (in) =	4.0								4.0								4.0								4.0
Floor 4				24	30	0.0069	0.0132	0.0034	5.0			24	30	0.0069	0.0132	0.0034	5.0			24	30	0.0069	0.0132	0.0034	5.0
Story 3	h (in) =	30								30								30								30
	b (in) =	30								30								30								30
	ρ_{tot} =	0.0108								0.0160								0.0160								0.0108
	ρ_{sh} =	0.0065								0.0065								0.0065								0.0065
	s (in) =	4.0								4.0								4.0								4.0
Floor 3				30	30	0.0050	0.0100	0.0023	5.5			30	30	0.0050	0.0100	0.0023	5.5			30	30	0.0050	0.0100	0.0023	5.5
Story 2	h (in) =	30								30								30								30
	b (in) =	30								30								30								30
	ρ_{tot} =	0.0133								0.0158								0.0158								0.0133
	ρ_{sh} =	0.0065								0.0065								0.0065								0.0065
	s (in) =	4.0								4.0								4.0								4.0
Floor 2				30	30	0.0054	0.0110	0.0025	5.0			30	30	0.0054	0.0110	0.0025	5.0			30	30	0.0054	0.0110	0.0025	5.0
Story 1	h (in) =	30		h (in) =		ρ =	ρ' =	ρ_{sh} =	s (in) =	30		h (in) =		ρ =	ρ' =	ρ_{sh} =	s (in) =	30		h (in) =		ρ =	ρ' =	ρ_{sh} =	s (in) =	30
	b (in) =	30		b (in) =						30		b (in) =						30		b (in) =						30
	ρ_{tot} =	0.0133								0.0160								0.0160								0.0133
	ρ_{sh} =	0.0065								0.0065								0.0065								0.0065
	s (in) =	4.0								4.0								4.0								4.0

13 feet

15 feet

30 feet

Design base shear =	0.092 g,	193 k	
f'_c beams =	5.0 ksi	$f'_{c,cols,upper}$ =	5.0 ksi
$f_{y,rebar,nom.}$ =	60 ksi	$f'_{c,cols,lower}$ =	5.0 ksi

Design Documentation (2 of 2)

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Modeling Documentation (1 of 1)

| | | |

Table 5-1A Summary of Mapped Values of Short-Period Spectral Acceleration, Site Coefficients and Design Parameters for Seismic Design Categories B, C, and D

Seismic Design Category		Maximum Considered Earthquake			Design
Maximum	Minimum	S_S (g)	F_a	S_{MS} (g)	S_{DS} (g)
D		1.5	1.0	1.5	1.0
C	D	0.55	1.36	0.75	0.50
B	C	0.33	1.53	0.50	0.33
	B	0.156	1.6	0.25	0.167

Table 5-1B Summary of Mapped Values of 1-Second Spectral Acceleration, Site Coefficients and Design Parameters for Seismic Design Categories B, C, and D

Seismic Design Category		Maximum Considered Earthquake			Design
Maximum	Minimum	S_1 (g)	F_v	S_{M1} (g)	S_{D1} (g)
D		0.60[1]	1.50	0.90	0.60
C	D	0.132	2.28	0.30	0.20
B	C	0.083	2.4	0.20	0.133
	B	0.042	2.4	0.10	0.067

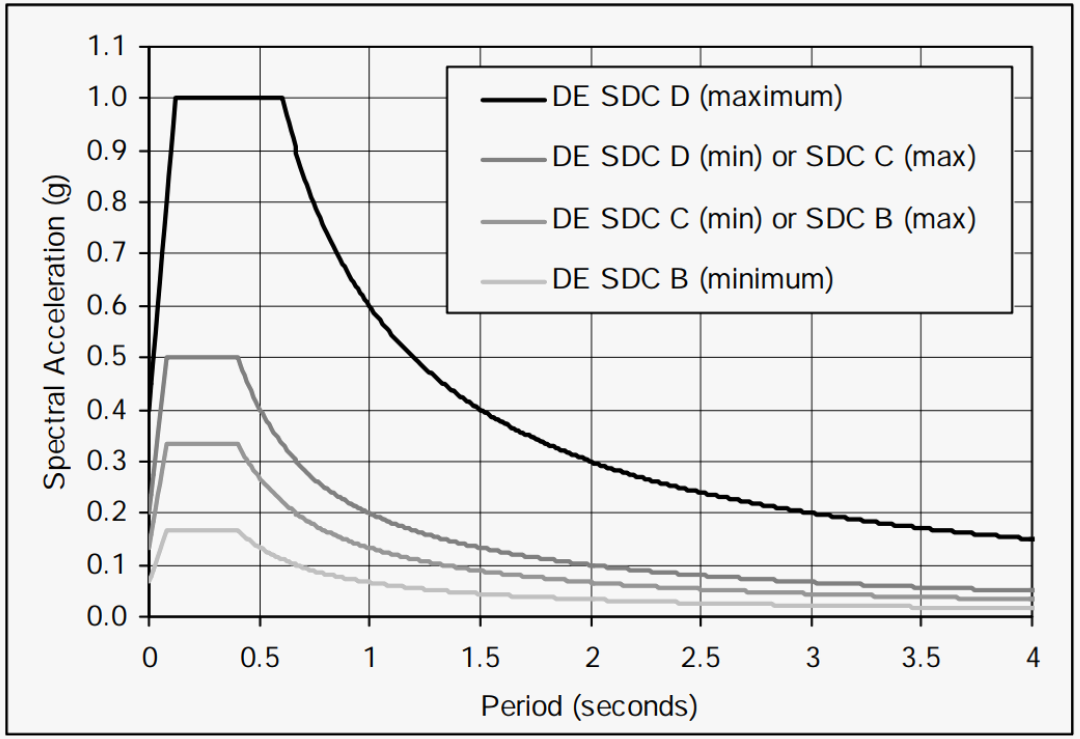

Figure 5-2 Plots of design earthquake (DE) response spectral accelerations used for design of Seismic Design Category D, C and B structure archetypes, respectively.

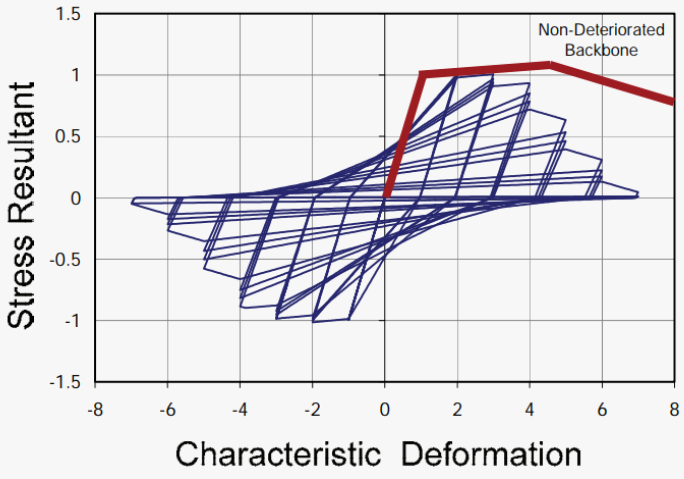

Figure 5-5 Idealized inelastic hysteretic response of structural components with cyclic strength and stiffness degradation.

Table A-4A Summary of Earthquake Event and Recording Station Data for the Far-Field Record Set

ID No.	Earthquake			Recording Station	
	M	Year	Name	Name	Owner
1	6.7	1994	Northridge	Beverly Hills - Mulhol	USC
2	6.7	1994	Northridge	Canyon Country-WLC	USC
3	7.1	1999	Duzce, Turkey	Bolu	ERD
4	7.1	1999	Hector Mine	Hector	SCSN
5	6.5	1979	Imperial Valley	Delta	UNAMUCSD
6	6.5	1979	Imperial Valley	El Centro Array #11	USGS
7	6.9	1995	Kobe, Japan	Nishi-Akashi	CUE
8	6.9	1995	Kobe, Japan	Shin-Osaka	CUE
9	7.5	1999	Kocaeli, Turkey	Duzce	ERD
10	7.5	1999	Kocaeli, Turkey	Arcelik	KOERI
11	7.3	1992	Landers	Yermo Fire Station	CDMG
12	7.3	1992	Landers	Coolwater	SCE
13	6.9	1989	Loma Prieta	Capitola	CDMG
14	6.9	1989	Loma Prieta	Gilroy Array #3	CDMG
15	7.4	1990	Manjil, Iran	Abbar	BHRC
16	6.5	1987	Superstition Hills	El Centro Imp. Co.	CDMG
17	6.5	1987	Superstition Hills	Poe Road (temp)	USGS
18	7.0	1992	Cape Mendocino	Rio Dell Overpass	CDMG
19	7.6	1999	Chi-Chi, Taiwan	CHY101	CWB
20	7.6	1999	Chi-Chi, Taiwan	TCU045	CWB
21	6.6	1971	San Fernando	LA - Hollywood Stor	CDMG
22	6.5	1976	Friuli, Italy	Tolmezzo	--

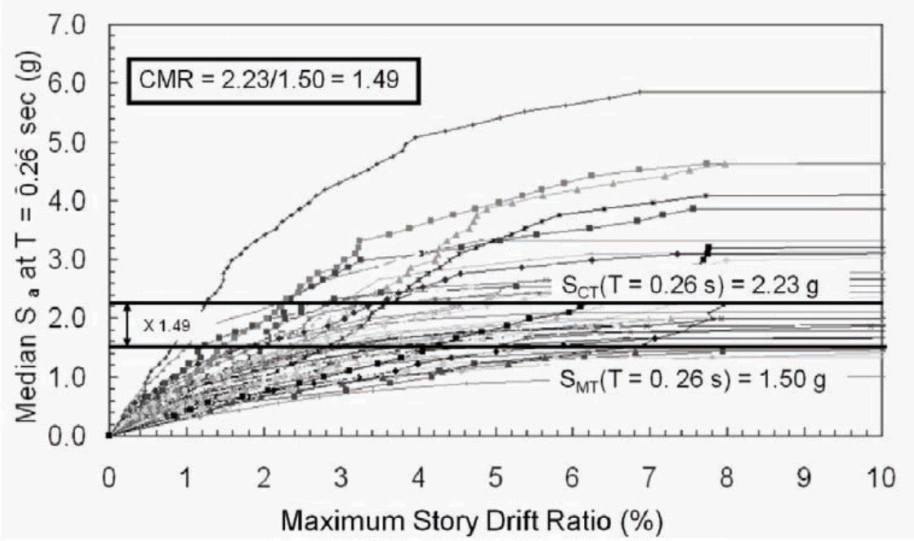

Figure 9-19 Results of incremental dynamic analysis to collapse for the two-story wood light-frame archetype (Archetype ID 5).

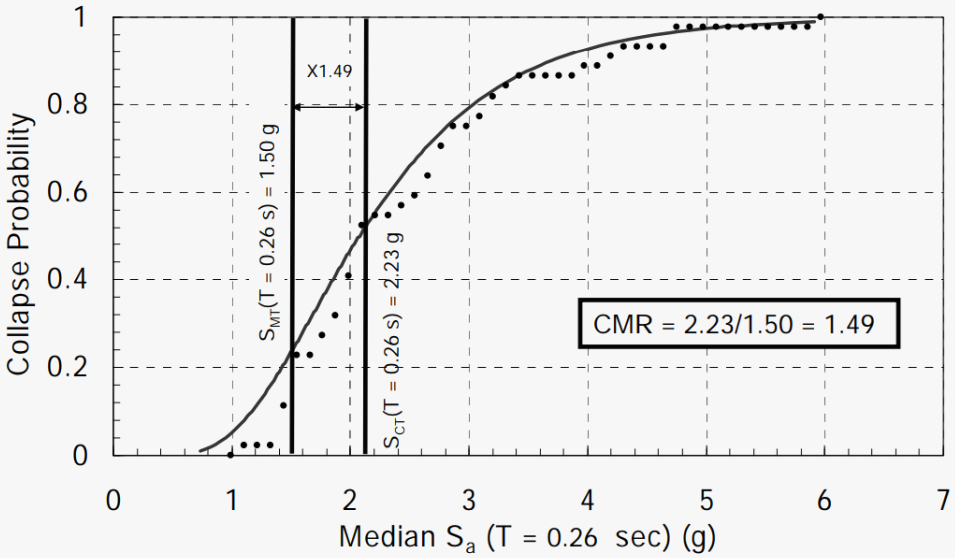

Figure 9-20 Collapse fragility curve for the two-story wood light-frame archetype (Archetype ID 5).

Roadmap

Nonlinear Hinge Program: To Use In Complex Structure

Simulate Model: 2-D 3 story ➔ FEMA P695 Model? ➔ Actual Model (from corporation)