“

Advanced Behavior and Design of Steel Structure

Team 6 M11205310 劉映彤 M11205314 張原嘉

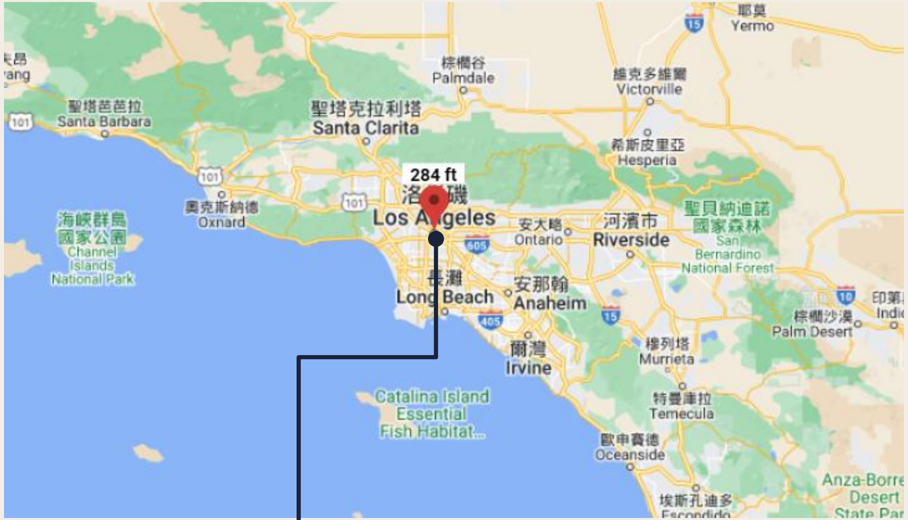
TABLE OF CONTENTS

Model Information

01

Model Information

Design Code: ASCE 7-16



LOCATION

Los Angeles (LA)
(34.051283, -118.246637)

III

RISK CATAGORY

SITE CLASS

D—Stiff Soil

Model Information

Story Height	Span Length	No. of Stories
13 ft	23 ft	10

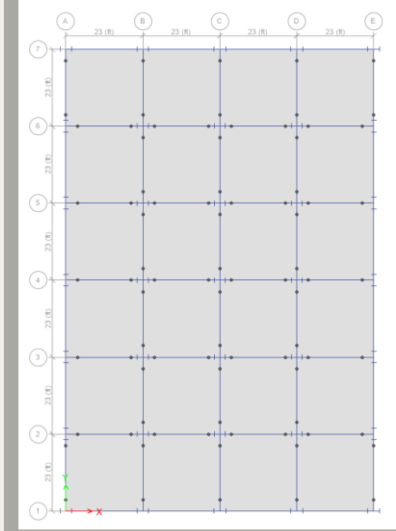
Each floor has a 4×6 span configuration.

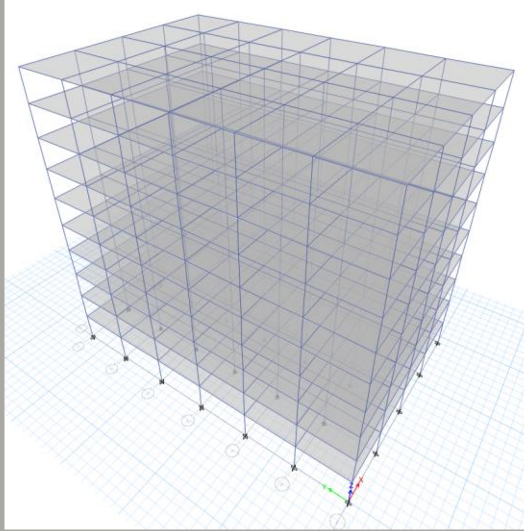
OUTER

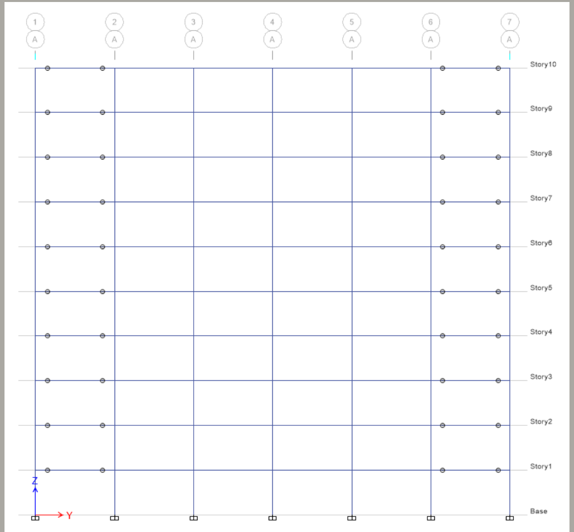
Fixed-end moment-resisting frames (MRF).

INTERIOR

Pin-connected gravity frames.







02

Base Shear & Lateral Seismic Force

- *Seismic Parameter*
- *Base Shear*
- *Lateral Seismic Force*

Seismic Parameters

Parameters	Value	Reference
S_S	1.927	By ATC Website
S_1	0.703	By ATC Website
F_a	1	By ATC Website
F_v	1.5	By table 11.4-2, $S_1 \geq 0.5$, Site Class D $F_v = 1.5$
S_{MS}	1.972	By ATC Website
S_{M1}	1.055	By equation $S_{M1} = F_v S_1$
S_{DS}	1.315	By ATC Website
S_{D1}	0.703	By equation $S_{D1} = \frac{2}{3} S_{M1}$
R	8	By ASCE 7-16 , Steel special moment frames
I_e	1.25	By table 1.5-2, Risk category III, Seismic important factor
C_d	5.5	By ASCE 7-16 , Steel special moment frames

Seismic Parameters

$$T_a = C_t h_n^x = 0.028 \times 130^{0.8} = 1.375 \text{ sec}$$

$$T = C_u T_a = 1.4 \times 1.375 = 1.925 \text{ sec}$$

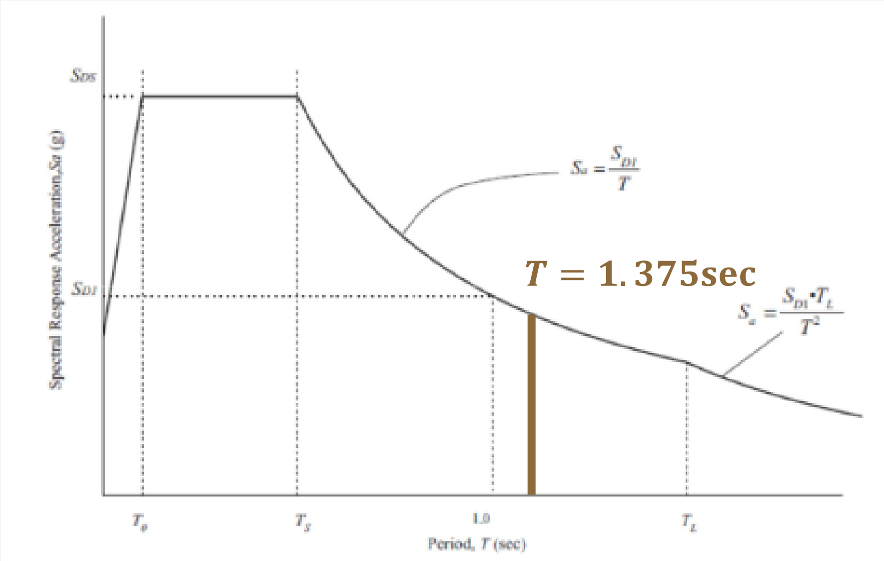
$$T = \min\{1.375, 1.925\} = 1.375 \text{ sec}$$

$$T_s = {}^{S_{D1}}/_{S_{Ds}} = {}^{0.703}/_{1.315} = 0.535 \text{ sec}$$

$$T_L = 8 \text{ sec (From ATC Hazards)}$$

$$T_s < T < T_L$$

$$\rightarrow S_a = {}^{S_{D1}}/_{\mathrm{T}} = {}^{0.703}/_{1.375} = 0.511g$$



1.375 sec

Structural Period (T)

0.511g

Spectral Response Acceleration (S_a)

Lateral Seismic Force

$$C_{vx} = \frac{w_x h_n^k}{\sum_{i=1}^{n} w_i h_n^i}$$

$$V_x = \sum_{i=1}^{n} F_i$$

Story	w_x (kips)	h_x (ft)	$w_x h_n^x$	C_{vx}	$V - F_t$(kips)	F_x(kips)	V_x(kips)
10	1523.520	130.000	1665994.019	0.217	1650.500	532.834	
9	1523.520	117.000	1431846.159	0.186	1650.500	307.480	532.834
8	1523.520	104.000	1208826.134	0.157	1650.500	259.588	840.315
7	1523.520	91.000	997699.023	0.130	1650.500	214.250	1099.902
6	1523.520	78.000	799397.034	0.104	1650.500	171.666	1314.152
5	1523.520	65.000	615089.486	0.080	1650.500	132.087	1485.818
4	1523.520	52.000	446301.870	0.058	1650.500	95.841	1617.904
3	1523.520	39.000	295139.542	0.038	1650.500	63.379	1713.745
2	1523.520	26.000	164775.854	0.021	1650.500	35.385	1777.124
1	1523.520	13.000	60835.690	0.008	1650.500	13.064	1812.509
Base	0.000	0.000	0.000	0.000		0.000	1825.573
Total	15235.200	715.000	7685904.811	1.000		1825.573	14019.877

Lateral Seismic Force

532.834 kips

307.480 kips

259.588 kips

214.250 kips

171.666 kips

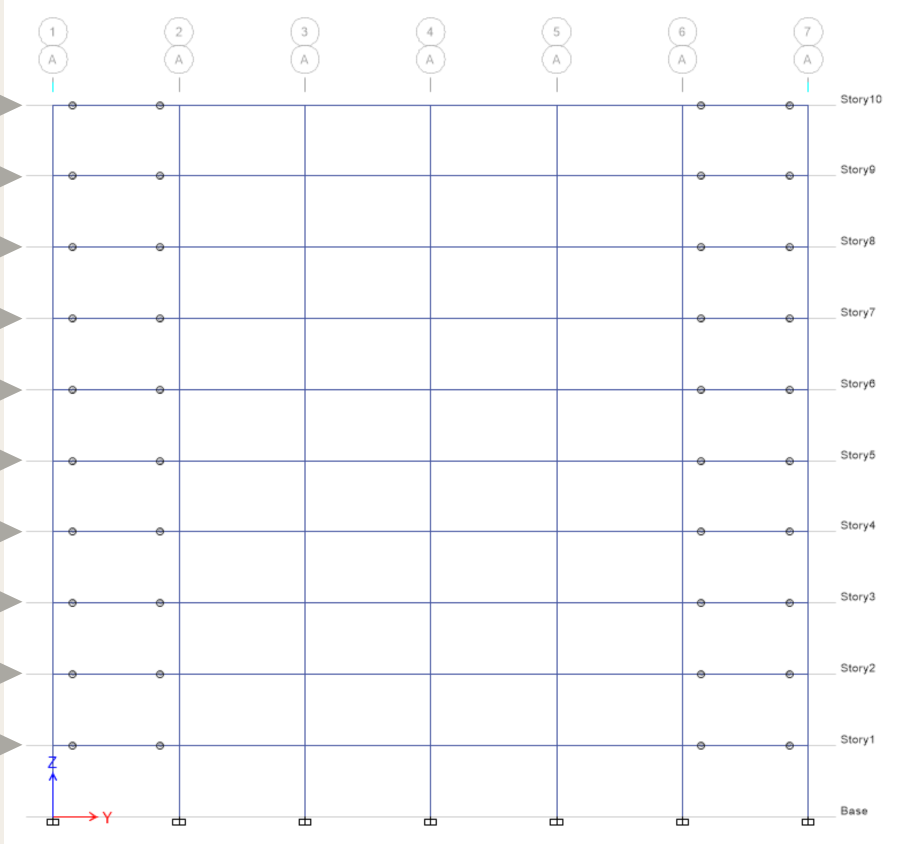
132.087 kips

95.841 kips

63.379 kips

35.385 kips

13.064 kips

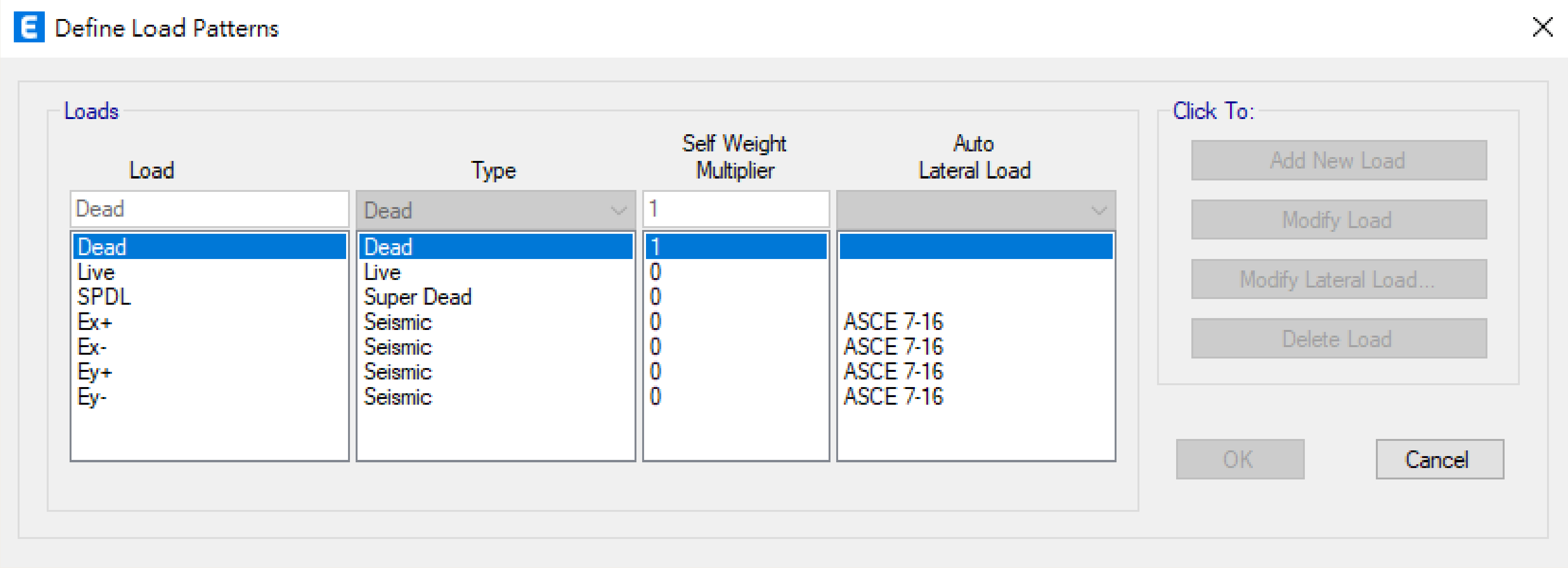


Load Combinations

03

Load Combinations

DL: 120psf, LL: 100psf, SDL: 0psf



Load Combinations

COMBO	Load	COMBO	Load
0	1.4(DL)		
1	1.4(DL + SPDL)		
2	1.2(DL + SPDL) + 1.6LL		
3	1.2(DL + SPDL) + 1.0LL + 1.0Ex+	11	0.9(DL + SPDL) + 1.0LL + 1.0Ex+
4	1.2(DL + SPDL) + 1.0LL + 1.0Ex-	12	0.9(DL + SPDL) + 1.0LL + 1.0Ex-
5	1.2(DL + SPDL) + 1.0LL + 1.0Ey+	13	0.9(DL + SPDL) + 1.0LL + 1.0Ey+
6	1.2(DL + SPDL) + 1.0LL + 1.0Ey-	14	0.9(DL + SPDL) + 1.0LL + 1.0Ey-
7	1.2(DL + SPDL) + 1.0LL - 1.0Ex+	15	0.9(DL + SPDL) + 1.0LL - 1.0Ex+
8	1.2(DL + SPDL) + 1.0LL - 1.0Ex-	16	0.9(DL + SPDL) + 1.0LL - 1.0Ex-
9	1.2(DL + SPDL) + 1.0LL - 1.0Ey+	17	0.9(DL + SPDL) + 1.0LL - 1.0Ey+
10	1.2(DL + SPDL) + 1.0LL - 1.0Ey-	18	0.9(DL + SPDL) + 1.0LL - 1.0Ey-

Section Selection

“

04

Section Selection

Fixed-end moment-resisting frames (MRF).

Story	Beam (in.)	Stress Ratio	Column (in.)	Ext. Col.	Int. Col.
				Stress Ratio	
10	BH 36x18x1.3x1.75	0.056~0.090	BH 36x30x1.5x2.4	0.049~0.057	0.075~0.085
9		0.100~0.135		0.062~0.067	0.090~0.099
8		0.154~0.183		0.078~0.088	0.130~0.136
7		0.204~0.231		0.097~0.111	0.165~0.170
6		0.248~0.272		0.123~0.140	0.195~0.197
5		0.283~0.304	BH 36x32x1.5x2.4	0.208~0.233	0.204~0.205
4		0.307~0.326		0.265~0.295	0.222~0.224
3		0.314~0.337		0.325~0.359	0.239~0.244
2		0.299~0.326		0.383~0.422	0.259~0.268
1		0.236~0.262		0.431~0.475	0.298~0.303

Section Selection

Pin-connected gravity frames.

Story	Beam	Stress Ratio	Column	Stress Ratio
10	W 12x136	0.131 ~ 0.204	W 12x336	0.046 ~ 0.061
9		0.129 ~ 0.202		0.075 ~ 0.084
8		0.129 ~ 0.202		0.107 ~ 0.116
7		0.129 ~ 0.201		0.225 ~ 0.232
6		0.129 ~ 0.200		0.279 ~ 0.286
5		0.128 ~ 0.200	W 14x370	0.305 ~ 0.312
4		0.128 ~ 0.200		0.355 ~ 0.361
3		0.128 ~ 0.199		0.406 ~ 0.412
2		0.128 ~ 0.199		0.462 ~ 0.472
1		0.128 ~ 0.198		0.506 ~ 0.522

According to AISC 341-16 Table D1.1 highly ductile members

Width-Thickness Ratio Inspection

	Beam	Column
Flange	$\frac{b_f}{2t_f} \leq 0.32\sqrt{\frac{E}{R_y F_y}} = 0.32\sqrt{\frac{29000}{(1.1)(50)}} = 7.348$	
Web	For $C_a = 0 \leq 0.114$ $\frac{h_w}{t_w} \leq 2.57\sqrt{\frac{E}{R_y F_y}}(1 - 1.04C_a)$ $\rightarrow \frac{h_w}{t_w} \leq 59.013$	For $C_a = \frac{P_u}{\emptyset_c P_y} \leq 0.114$ $\frac{h_w}{t_w} \leq 2.57\sqrt{\frac{E}{R_y F_y}}(1 - 1.04C_a)$ $\rightarrow \frac{h_w}{t_w} \leq 59.013(1 - 1.04C_a)$ For $C_a = \frac{P_u}{\emptyset_c P_y} > 0.114$ $0.88\sqrt{\frac{E}{R_y F_y}}(2.68 - C_a) \geq 1.57\sqrt{\frac{E}{R_y F_y}}$ $\rightarrow 20.207(2.68 - C_a) \geq 36.051$

Width-Thickness Ratio Inspection

		Beam				Column	
		Flange		Web		Flange	
Story		$\frac{b_f}{2t_f}$	Upper Limit	$\frac{h_w}{t_w}$	Upper Limit	$\frac{b_f}{2t_f}$	Upper Limit
MRF	6-10F	5.142	7.348	25.00	59.013	6.670	7.348
	1-5F	5.142	7.348	25.00	59.013	6.250	7.348
Gravity Frame	6-10F	4.960	7.348	13.79	59.013	2.263	7.348
	1-5F	4.960	7.348	13.79	59.013	3.101	7.348
			PASS!		*PASS!*		*PASS!*

Column web inspection of MRF

Story	P_u	$\frac{P_u}{\phi_c P_y}$	Compare with 0.114	$\frac{h_w}{t_w}$	$0.88\sqrt{\frac{E}{R_y F_y}}\left(2.68 - \frac{P_u}{\phi_c P_y}\right)$	Upper/ Lower Limit	
10	130.52	0.013	Less	20.800		58.210	PASS!
9	284.54	0.030	Less	20.800		57.160	PASS!
8	465.81	0.049	Less	20.800		56.000	PASS!
7	672.54	0.071	Less	20.800		54.650	PASS!
6	901.21	0.095	Less	20.800		53.180	PASS!
5	1148.57	0.115	Greater		51.810	36.051	PASS!
4	1408.74	0.142	Greater		51.260	36.051	PASS!
3	1676.59	0.169	Greater		50.720	36.051	PASS!
2	1941.36	0.195	Greater		50.190	36.051	PASS!
1	2173.67	0.219	Greater		49.710	36.051	PASS!

Column web inspection of gravity frames

Story	P_u	$\frac{P_u}{\phi_c P_y}$	Compare with 0.114	$\frac{h_w}{t_w}$	$0.88\sqrt{\frac{E}{R_y F_y}}\left(2.68-\frac{P_u}{\phi_c P_y}\right)$	Upper/ Lower Limit	
10	243.04	0.049	Less	6.110		56.000	*PASS!*
9	485.71	0.099	Less	6.110		52.930	*PASS!*
8	728.05	0.148	Greater		51.140	36.051	*PASS!*
7	969.86	0.198	Greater		50.130	36.051	*PASS!*
6	1212.6	0.247	Greater		49.140	36.051	*PASS!*
5	1456.15	0.269	Greater		48.700	36.051	*PASS!*
4	1700.11	0.315	Greater		47.770	36.051	*PASS!*
3	1944.94	0.360	Greater		46.860	36.051	*PASS!*
2	2196.97	0.407	Greater		45.910	36.051	*PASS!*
1	2452.24	0.454	Greater		44.960	36.051	*PASS!*

“

05

Section Inspection

- *Strong Column and Weak Beam*

Strong Column/Weak Beam Inspection

$$\frac{\sum M^*{}_{pc}}{\sum M^*{}_{pc}} > 1.0$$

Story		$M^*{}_{pc}$ (kip · in)	$M^*{}_{pb}$ (kip · in)	$M^*{}_{pc}/M^*{}_{pc}$	
MRF	6-10F	252125~274615	215933	1.167~1.271	*PASS!*
	1-5F	238504~268739	215933	1.104~1.244	*PASS!*
Gravity Frame	6-10F	45513~57336	30491	1.492~1.880	*PASS!*
	1-5F	40483~53935	30605	1.322~1.762	*PASS!*

“

06

Design Details

- *Width-Thickness Ratio Inspection*
- *Doubler Plate*
- *Continuity Plate*
- *Connection Size*

Doubler Plate

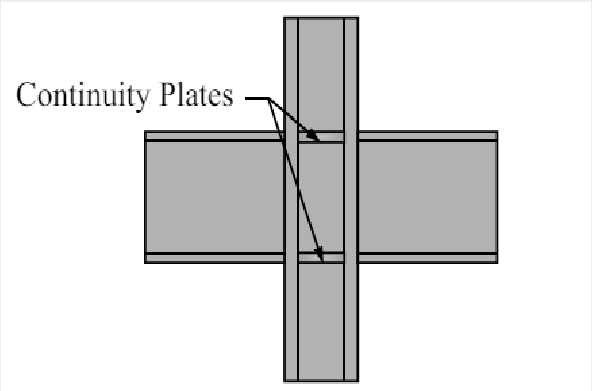
Story		R_u (kips)	R_v (kips)	t_p (in.)	Doubler Plate (in.)	Lower Limit $\frac{d_z + w_z}{90}$	
MRF	6-10F	4192.271	2052.000	3.481	1.981	0.707	*PASS!*
	1-5F	4192.271	2080.800	3.454	1.954	0.707	*PASS!*
Gravity Frame	6-10F	2169.962	1685.664	2.740	0.960	0.242	*PASS!*
	1-5F	2169.227	1675.544	2.578	0.918	0.260	*PASS!*

Continuity Plate

$$t_{cf} = 2.4\text{in.} < \frac{b_{bf}}{6} = \frac{18}{6} = 3\text{in.}$$

Story		$\frac{b_{bf}-t_{cw}}{2}$ Lower Limit	$\frac{b_{cf}-t_{cw}}{2}$ Upper Limit	Design Width	
MRF	6-10F	8.25	14.25	9	*PASS!*
	1-5F	8.25	15.25	9	*PASS!*

Story		Lower Limit $0.5t_{bf}$	Lower Limit $0.75t_{bf}$	Design Thickness	
MRF 1-10F	Int.		1.312	1.5	*PASS!*
	Ext.	0.875		0.9	*PASS!*

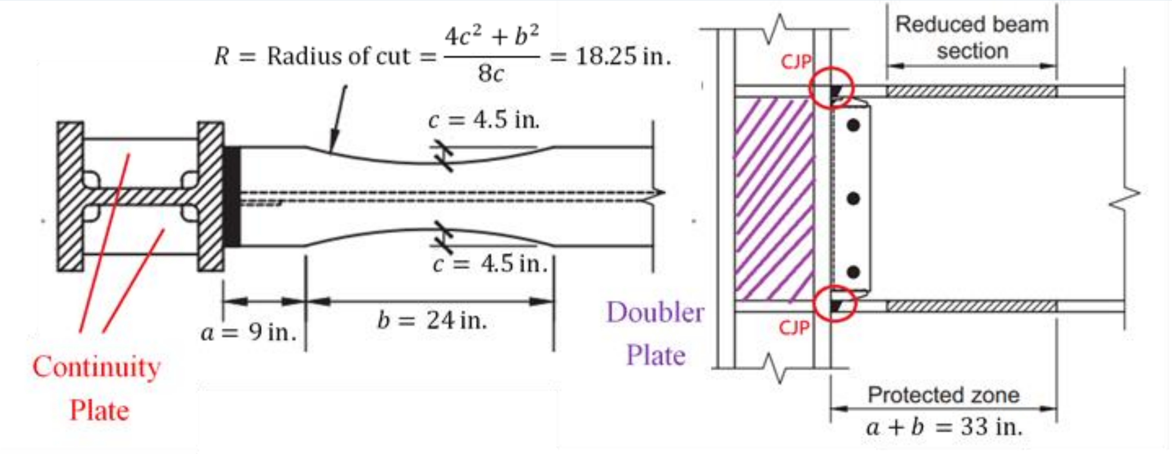


Design Configuration:

Story		Width (in.)	Thickness (in.)	Full Depth (in.)	
MRF 1-10F	Int.	9	1.5	31.2	*Two plates*
	Ext.	9	0.9	31.2	*Two plates*

Connection Size

Reduced Beam Section, RBS



Limitations

Beam:

1. Beam Depth = 36in. ≦ 36in. *PASS!*
2. Beam flange thickness = 1.75 in. ≦ 1.75in. *PASS!*
3. The clear span-to-depth ratio = 7.661 in. ≧ 7in. *PASS!*

Column:

1. Column Depth = 36in. ≦ 36in. *PASS!*

Width-to-thickness ratios:
Satisfy the requirements of AISC code *PASS!*

Selection: a = 9 in., b = 24 in., c = 4.5 in.

RBS Size:

$0.5b_{bf}$ =9 ≦ a ≦ $0.75b_{bf}$ =13.5 *PASS!*
0.65d =23.5 ≦ b ≦ 0.85d =30.6 *PASS!*
$0.1b_{bf}$ =1.8 ≦ c ≦ $0.25b_{bf}$ =4.5 *PASS!*

Modal Analysis

07

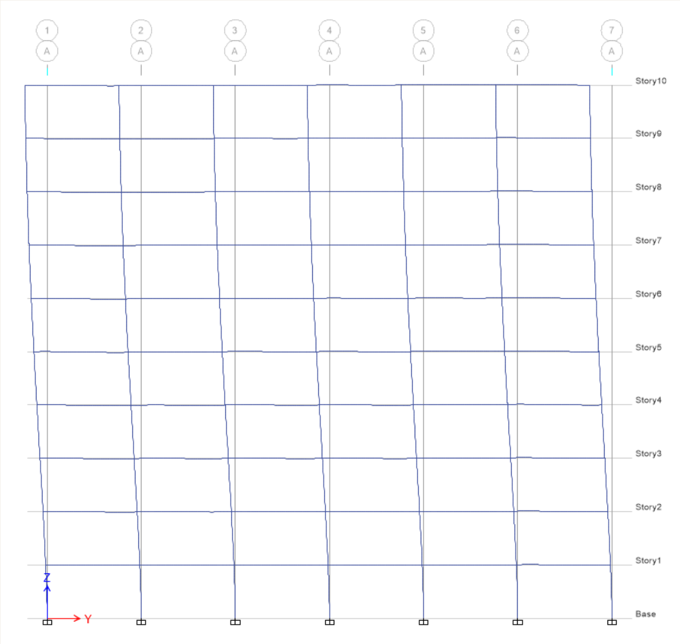
- *Structural Period*
- *Structural Mode*

Structural Period

$$T = 1.187 \text{ sec} < C_u T_a = 1.4 \times 1.375 = 1.925 \text{ sec}$$ *PASS!*

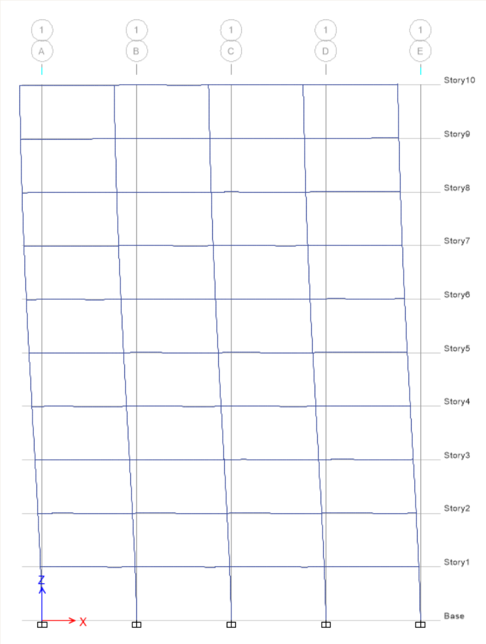
Case	Mode	Period (sec)	Frequency (cyc/sec)	CircFreq (rad/sec)	Eigenvalue (rad²/sec²)
Modal	1	1.187	0.842	5.293	28.079
Modal	2	1.185	0.844	5.304	28.137
Modal	3	0.755	1.324	8.320	69.213

Structural Mode



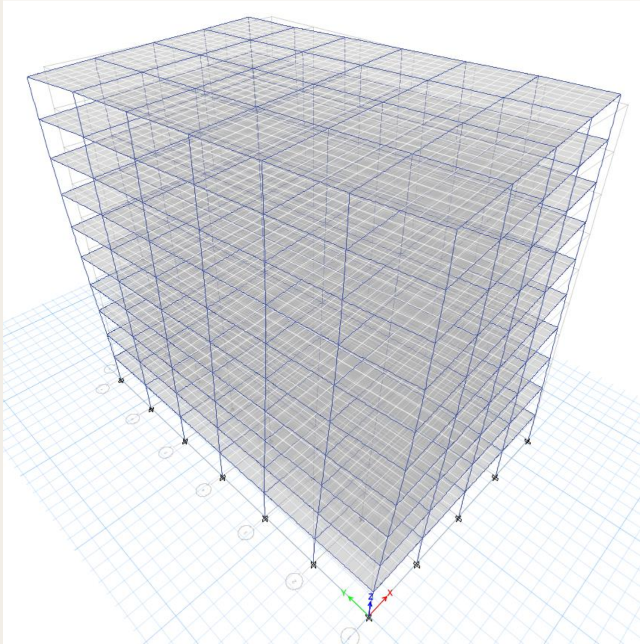
Mode 1

Y Direction



Mode 2

X Direction



Mode 3

Torsion

“

08

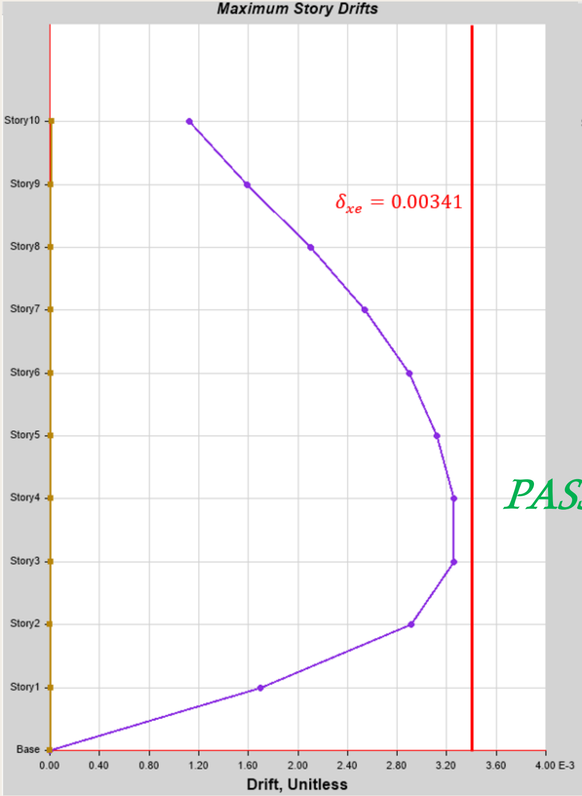
Story Drifts

“ Story Drifts

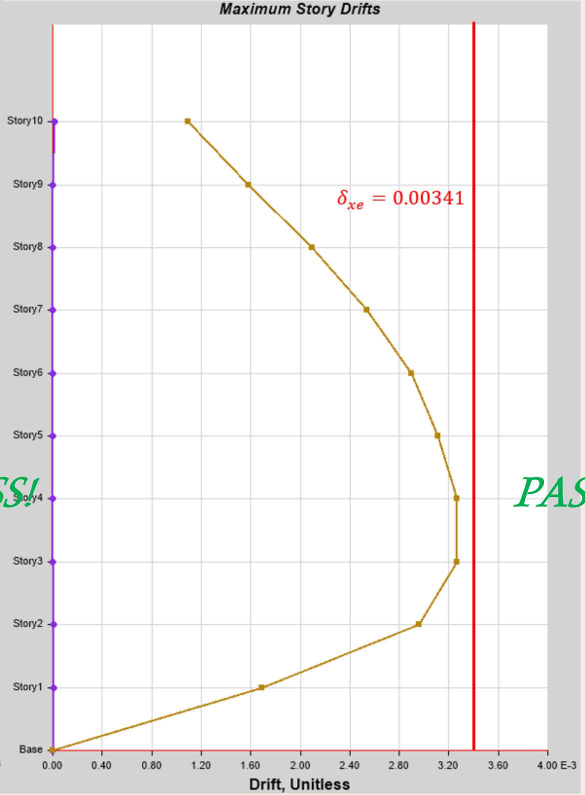
$$\delta_{ANA} \le \delta_{xe} = \frac{I_e \delta_x}{C_d} = 0.00341$$

The maximum inter-story drifts both occur on the fourth floor.

X Direction



PASS!



PASS!

Y Direction

Nonlinear PUSHOVER Analysis

09

- *PUSHOVER Curve*
- *Story Drifts*
- *Plastic Hinge Distribution*

PUSHOVER Curve

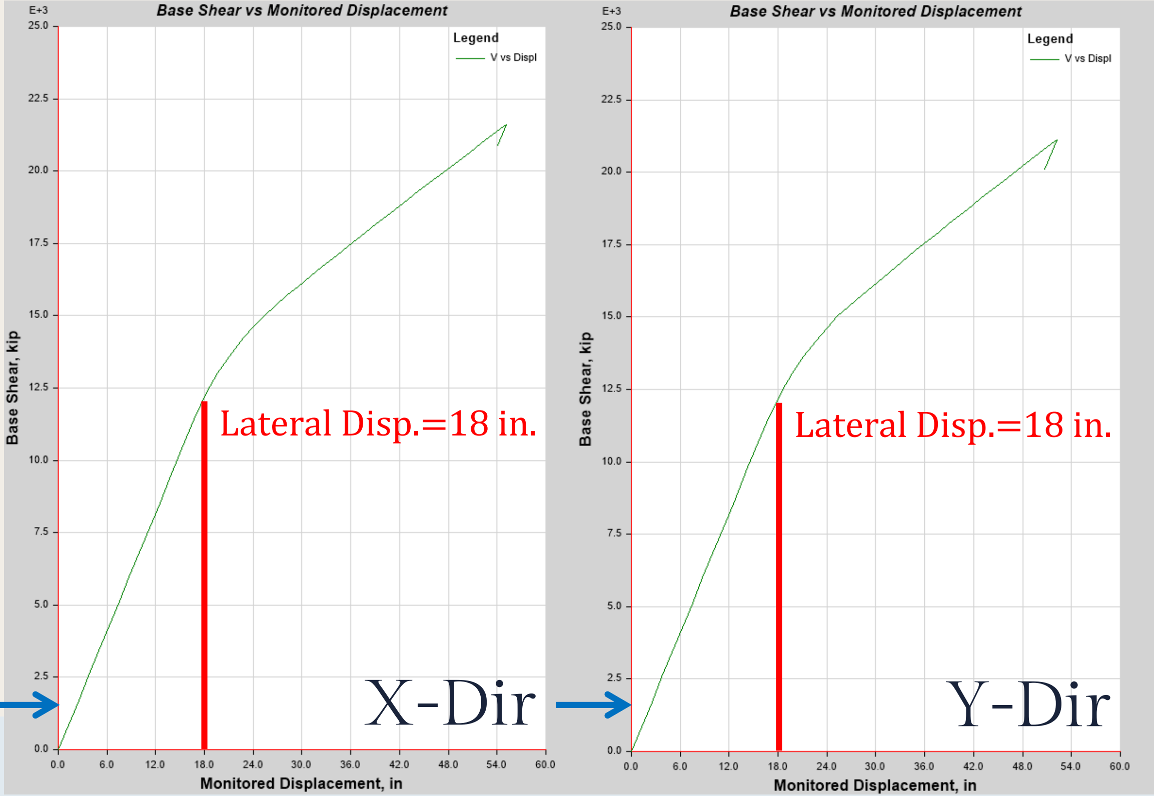
Set the plastic hinges at the relative positions of the 0.05 and 0.95 members of the beam and column.

1. V=1825.573 kips
   X & Y lateral disp.=2.799 in.

2. X & Y lateral disp.=18 in.
   Strength decrease
   → Roof drifts of 1.15% rad

$$\frac{18\text{in.}}{62.4\text{in.}} \times 4\% = 1.15\%$$

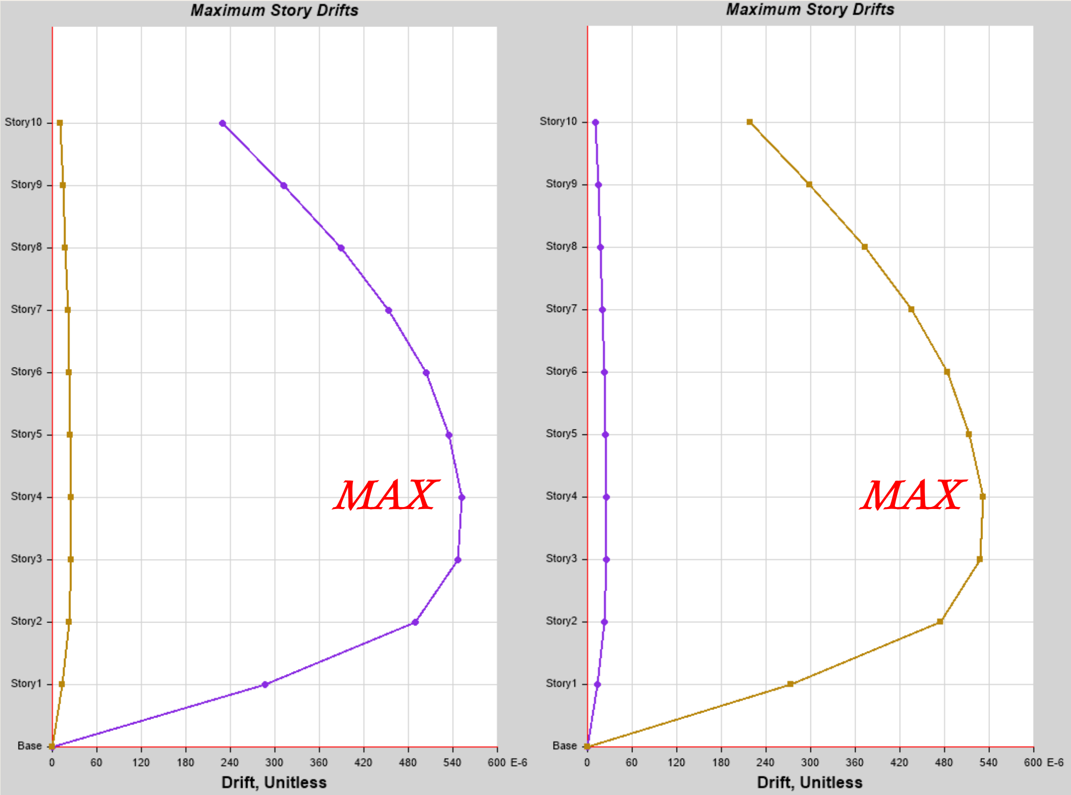
V=1825.573 kips



“ Story Drifts (Roof drifts of 2% rad)

The maximum inter-story drifts both occur on the fourth floor.

X Direction

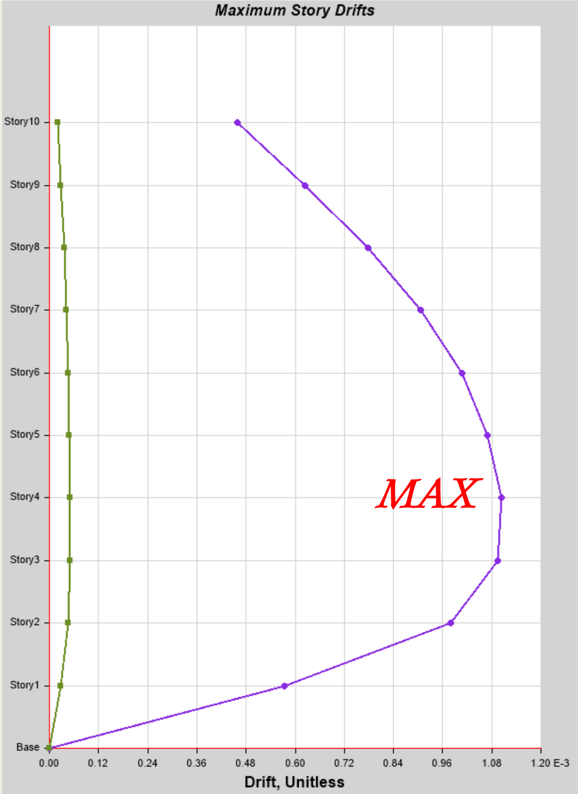


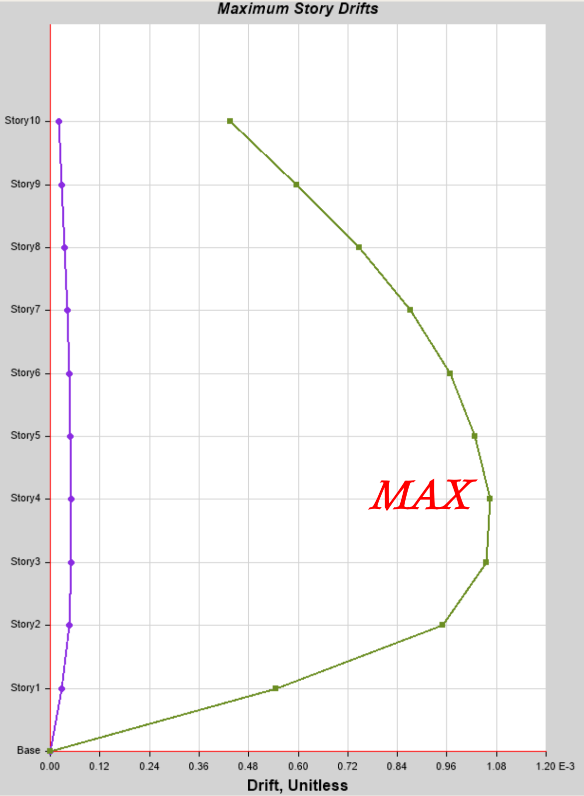
Y Direction

Story Drifts (Roof drifts of 4% rad)

The maximum inter-story drifts both occur on the fourth floor.

X Direction





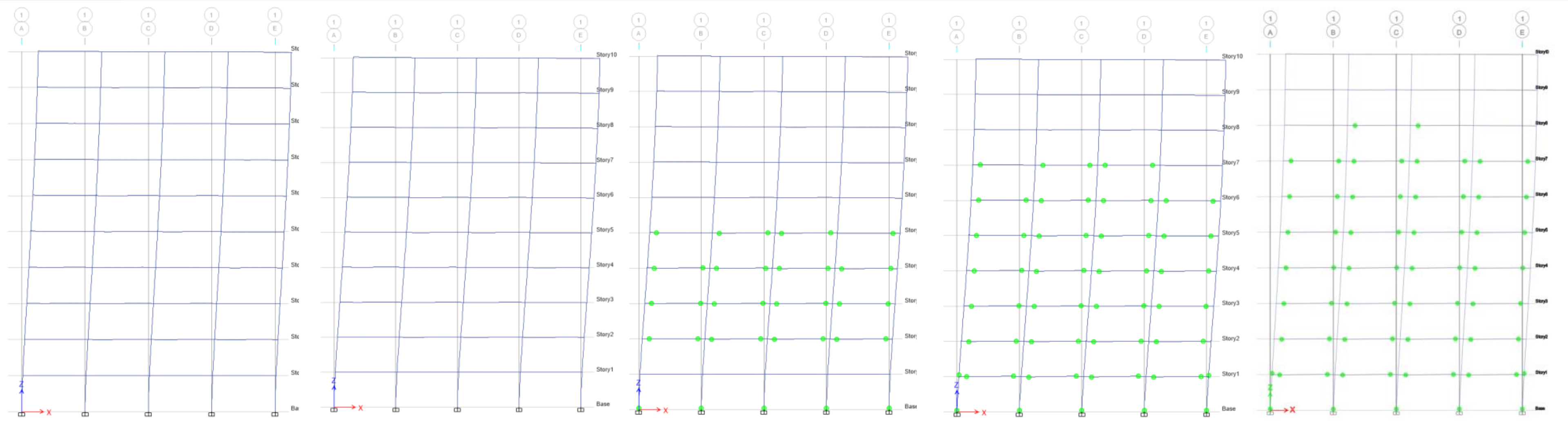
Y Direction

Plastic Hinge Distribution (X-Dir)

No plastic hinge

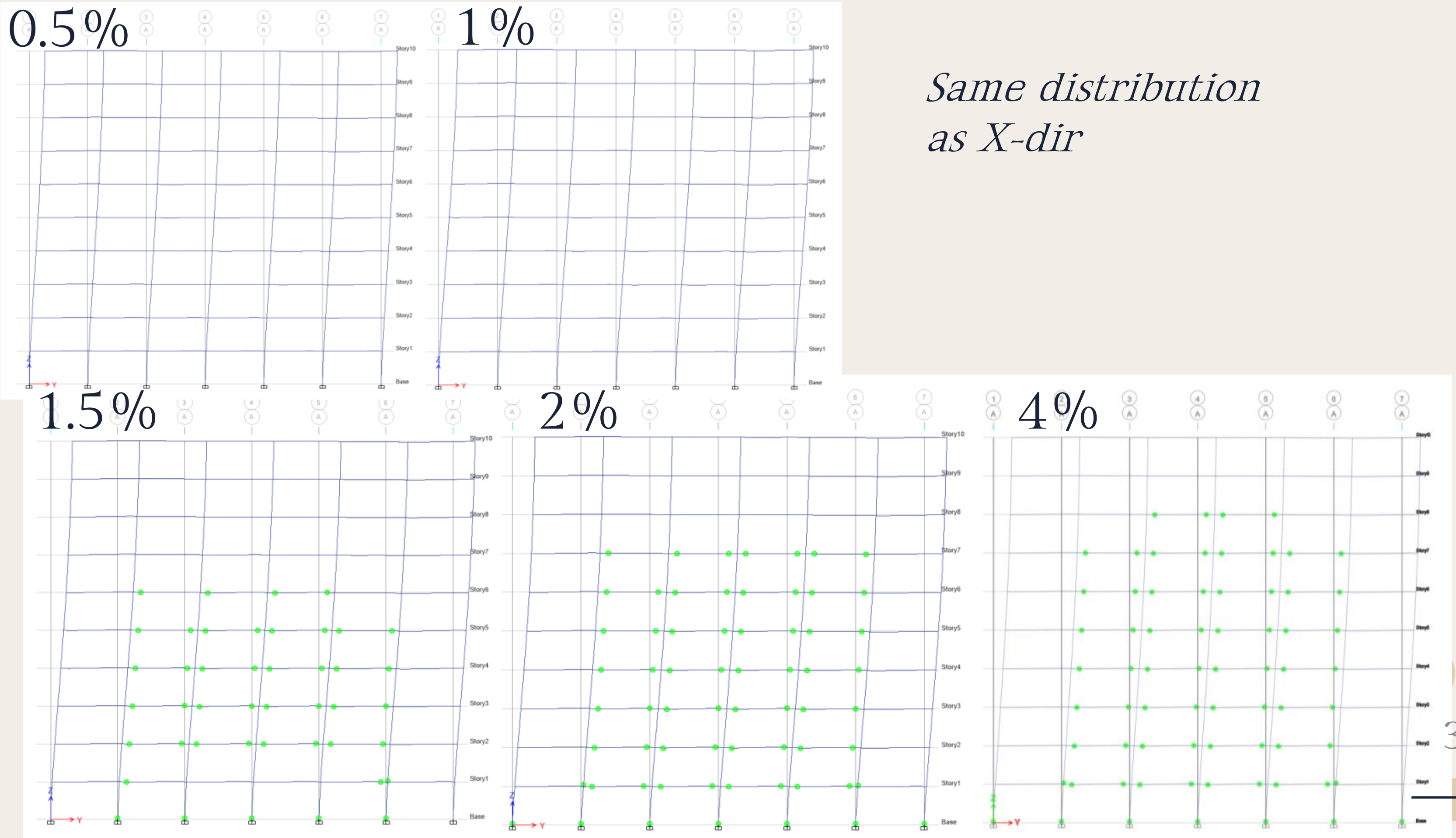
Plastic hinge occurs on 1st to 6th floors
→ Strength decrease before reaching 1.5%

10th floor
no plastic hinge



0.5% | 1% | 1.5% | 2% | 4%

Plastic Hinge Distribution (Y-Dir)



Same distribution as X-dir

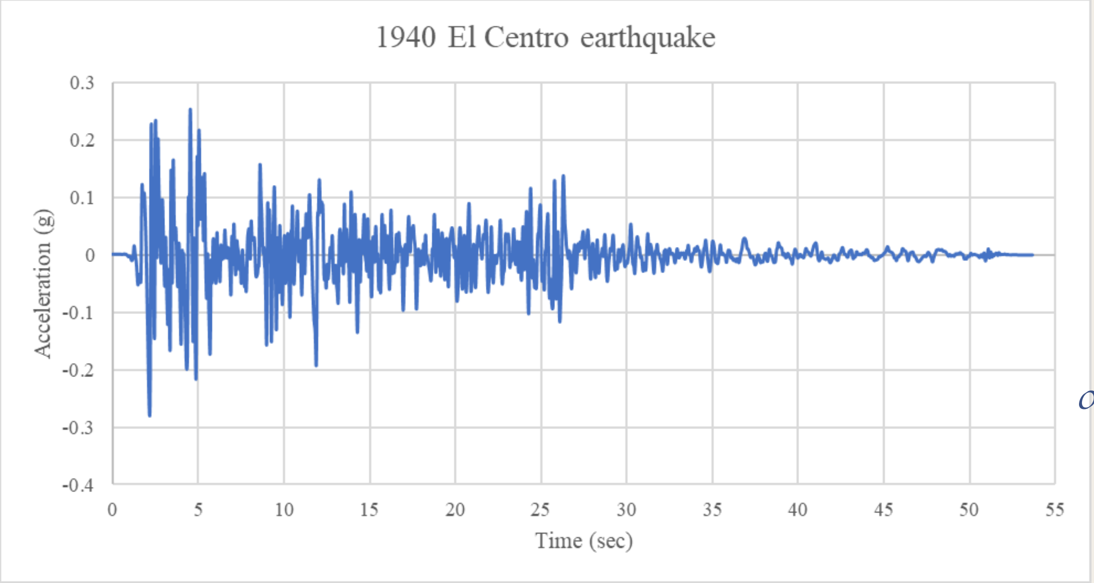
Nonlinear Time History Analysis

- *Maximum Inter-Story Drift*
- *Maximum Floor Acceleration*
- *Floor Shear Distribution*

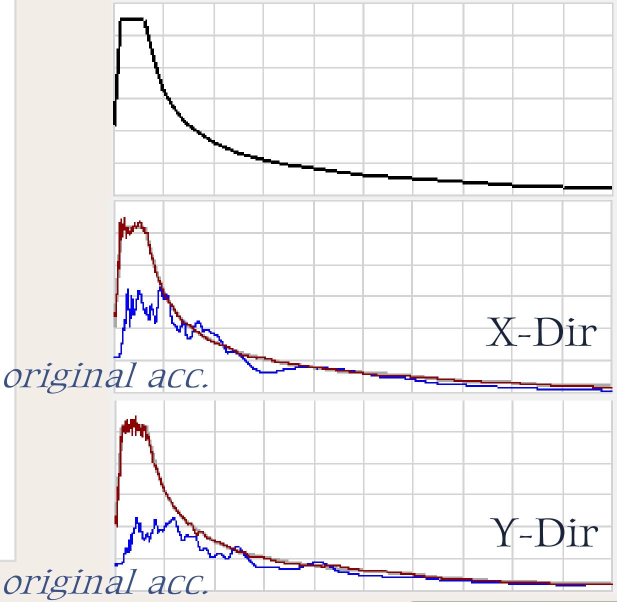
“

10

The design-based level of appropriate scaled ground motions.

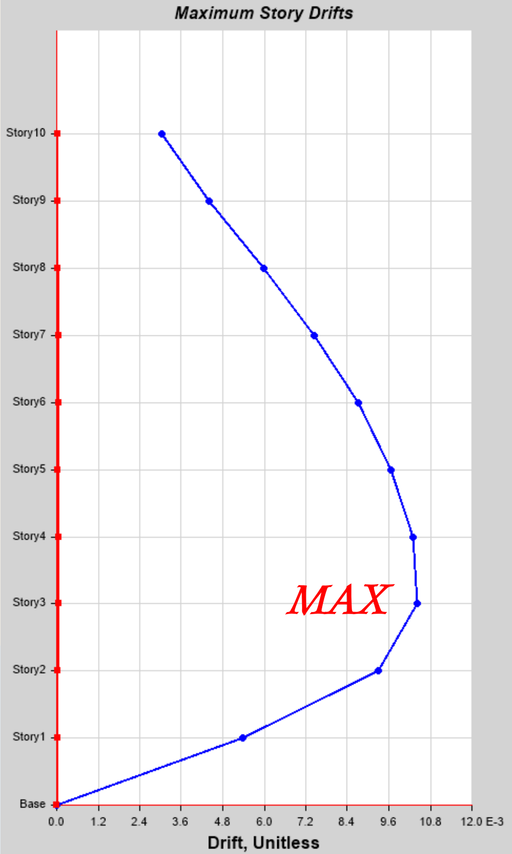


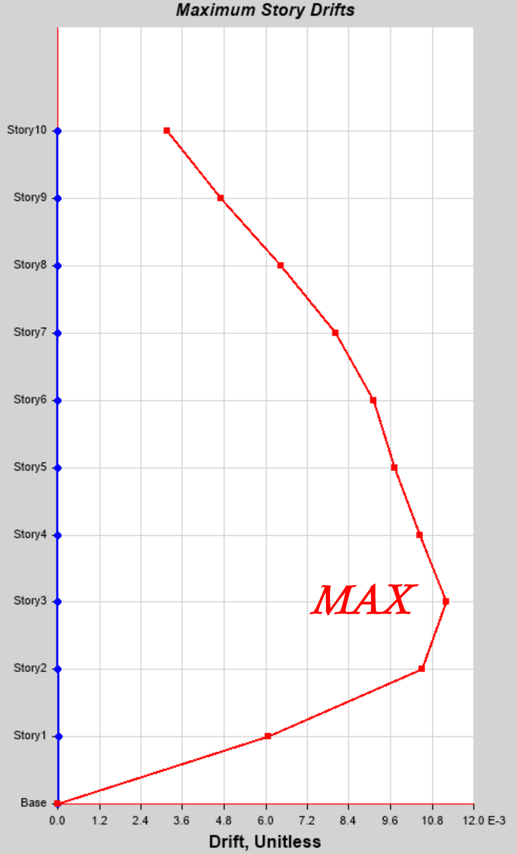
475 year return period spectrum



Maximum Inter-Story Drift

X Direction

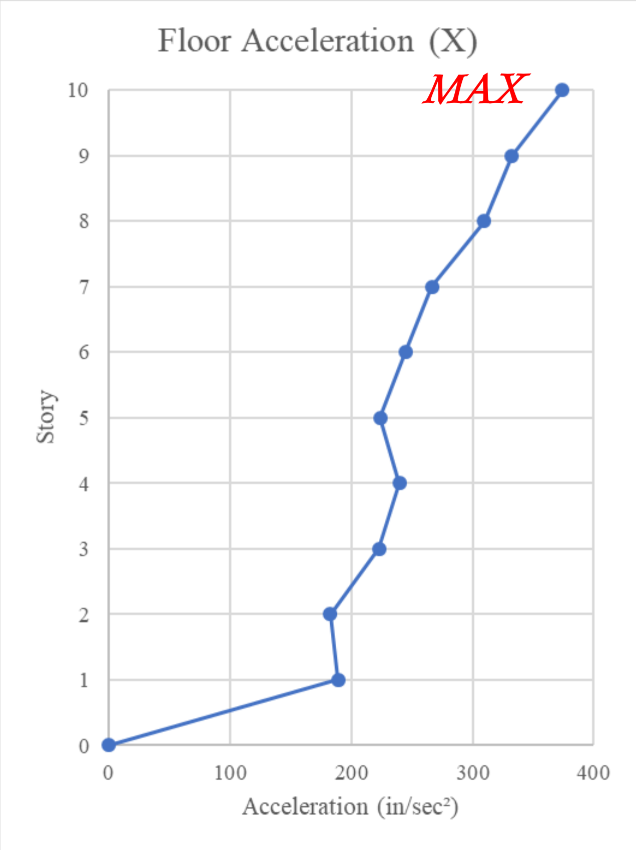


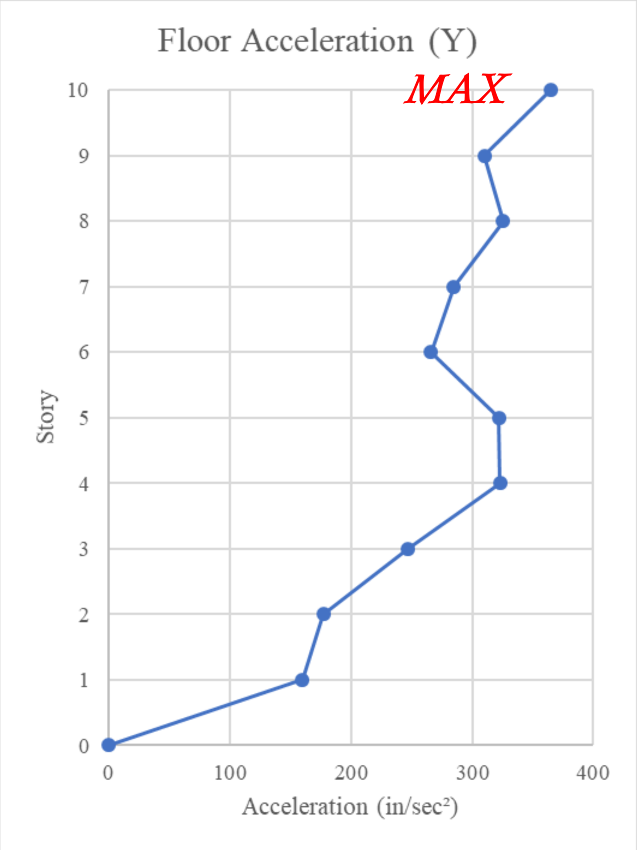


Y Direction

Maximum Floor Acceleration

X-Dir

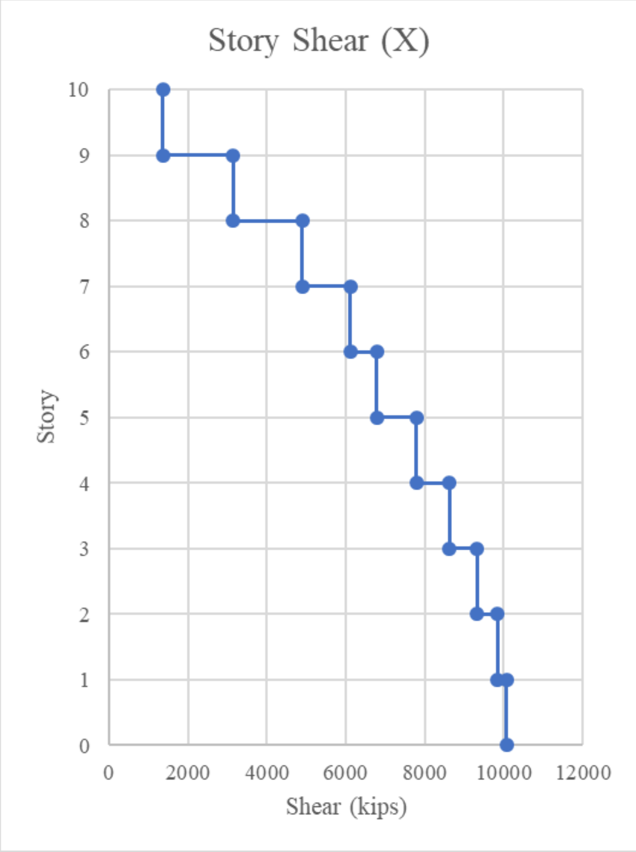


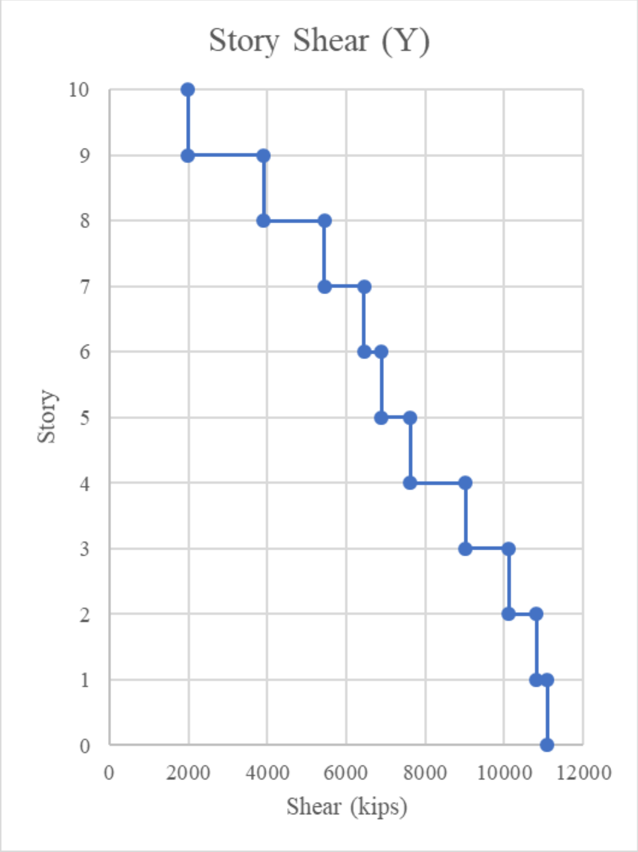


Y-Dir

Floor Shear Distribution

X-Dir





Y-Dir

“

11

Discussion & Suggestion

Discussion & Suggestion

1. *When the lateral displacement of the top floor reaches 2%, plastic hinges appear at the bottom of the columns on the second floor, which shows that the strength of the columns is insufficient. It is recommended that the cross-section be enlarged to improve its strength.*

2. *The stress ratio of the section is smaller than that of other parts, and most of them are shown in light blue on ETABS, which means that our section design this time is conservative and less economical.*

3. *To ensure that the inter-story drift doesn't exceed the limit of 0.00341, the columns and beams are designed with large sections. It is recommended to use a Special Concentrically Braced Frame (SCBF) for a more economical design.*

THANKS!