

APPENDIX A PRELIMINARY DESIGN CALCULATIONS

Specimen sizes were determined in the preliminary stages of this research based on the hand calculations summarized in the following pages.

Relations were derived such that a range of column dimensions over each of the values of slenderness (i.e. 100, 150, 200) produced a wide range of values of axial demand versus plastic axial capacity so that possible trends could be observed more easily. Expressions for the limit behavior of a specimen were developed. Weight on the specimen and the displacements at formation of plastic collapse mechanism are presented in terms of the dimensions, the yield stress, and the spectral acceleration needed for plastic collapse. The ratio of axial demand to the axial force at yield is written in terms of the plastic spectral acceleration and the slenderness ratio of the columns. These calculations appear on the following three pages.

Following those calculations are tables of the final selected nominal sizes and various other parameters as described below:

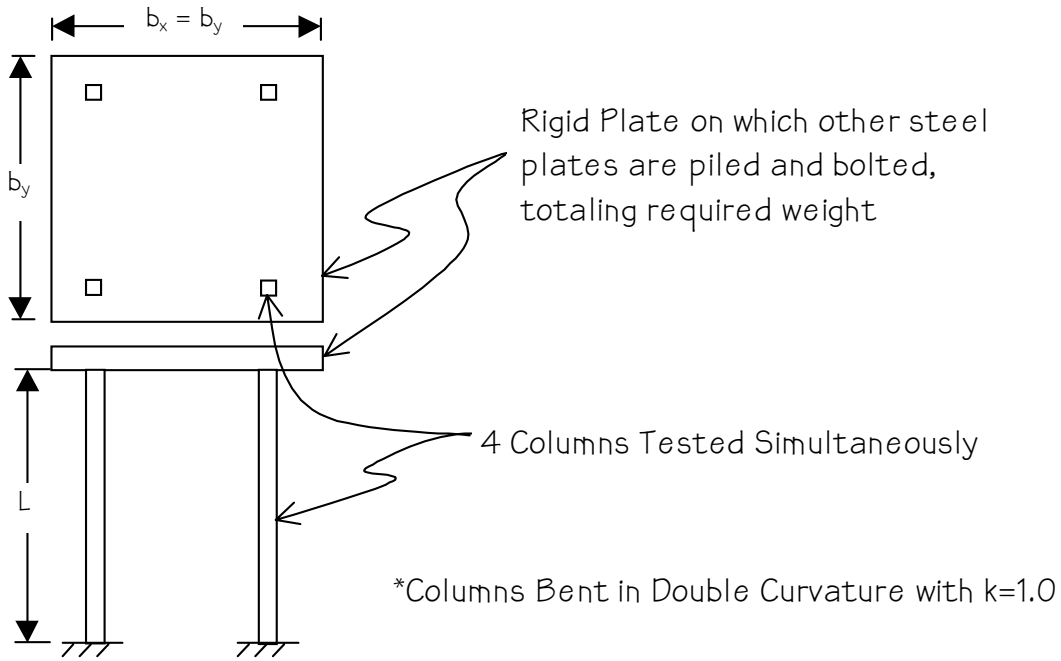
- Table A-1 lists nominal dimensions of each specimen, followed by calculated mechanical properties: moment of inertia, I , plastic modulus, Z , plastic axial capacity, P_y , plastic moment capacity, M_p , lateral shear force at first yield, V_y , and the lateral shear force at full plastic moment formation, V_p . The spectral acceleration, S_a , required to develop V_p in the specimen, and obtained using the procedures described in pages A-3 to A-6, is also listed.
- Table A-2 lists the nominal specimens dimensions, resulting stiffness, and applied mass. All these quantities are needed to calculate the fundamental frequencies and periods listed. Also listed is the “design” base shear for elastic response, V_e , to find the level of table excitation needed to produce a target ductility ratio of $\mu \cong 4$, and defined as equal to $R \cdot V_p$ where R is taken as 4 in this case. The base shear coefficient (or spectral acceleration) is calculated for this value of the base shear and compared with the preliminary value listed in table A-1. Note that the definition of V_e is for convenience in obtaining useful predictions of table accelerations required to achieve target ductilities and ensure that the table excitation capabilities are not exceeded. While this was done assuming a bilinear model yielding at M_p

(i.e. V_p), for the more sophisticated analyses expected to follow this study, one must recognize that rectangular sections have a shape factor of 1.5, and that consequently,

$$V_p = 1.5 \cdot V_y$$

- Table A-3 lists the results of dynamic analyses conducted to find the peak displacement response of each specimen. Both a linear-elastic model and an elastic-perfectly-plastic bilinear model were considered in these analyses, completed using the program NONLIN. The elastic-perfectly-plastic bilinear model with the P- Δ effect included was used to calculate the minimum PGA that could theoretically be applied to the model so the model would progressively collapse under a single application of the ground motion history. This critical PGA was used to calculate the peak displacement response with an elastic response spectrum and also in the construction of an inelastic spectrum to compare with the NONLIN inelastic analyses. “N/A” is listed in the displacement column of the inelastic spectra results when no result could be read from the capacity-demand spectra plot. The minimum displacement response of all of these techniques is extracted for each specimen. A sample inelastic capacity-demand spectrum plot is shown for Specimen 2 in Figure A.1.
- Table A-4 lists the results of dynamic analyses to find the peak acceleration response of each specimen. Results are taken from the same analyses used in finding the displacement responses in Table A-3. Results are compared with the design spectral acceleration values for full plastic behavior.
- Tables A-5 and A-6 list the results of strength and stability analyses using first and second order methods, respectively. Parabolic limit equations for section strength are used, as well as bilinear equations as per AISC (1994) using first order strength, and magnified using the AISC moment magnification factor, and the inelastic P- Δ amplification factor presented in Chapter 2 (Bernal 1987). Four pages of sample calculations precede these tables, displaying the formulae used for the strength and stability check and results for Specimen 1, R=4.

Preliminary Calculations to find Specimen sizes



Assumptions: $F_y := 50 \cdot \text{ksi}$ $k := 1.0$ (Double Curvature)

$R := 4.0$ (Response Modification Factor)

Seismic Base Shear is given by: $V = C_s \cdot W$

$$V = \frac{V_e}{R} = \left(\frac{S_a}{R} \right) \cdot W \quad (1)$$

where: S_a : Design Spectral Response Acceleration

W : Weight on structure (Full Slab=4W)

Base Shear or Lateral Force on single column:

$$H = V = \frac{S_a \cdot W}{4} \quad (2)$$

Plastic Moment at Base due to this Force:

$$M_p = \frac{h^3}{4} \cdot F_y = \frac{H \cdot L}{2} = \frac{S_a \cdot W \cdot L}{4 \cdot 2} \quad (3)$$

Plastic Axial Capacity of Section:

$$P_y = h^2 \cdot F_y \quad P = W \quad (4a, b)$$

$$\frac{P}{P_y} = \frac{W}{h^2 \cdot F_y} = \frac{\left[\frac{2 \cdot (h^3 \cdot F_y)}{S_a \cdot L} \right]}{h^2 \cdot F_y} = \frac{2 \cdot h}{S_a \cdot L} \quad (5)$$

For a given slenderness: $\frac{k \cdot L}{r} = \text{Given} = \frac{L}{h} \cdot \sqrt{12}$

where: $r = \frac{h}{\sqrt{12}}$ for square sections, and $k=1.0$ as stated previously

Solving for h/L : $\frac{h}{L} = \frac{\sqrt{12}}{\left(\frac{k \cdot L}{r} \right)} \quad (6)$

Rewriting (5) in terms of Slenderness using (6):

$$\frac{P}{P_y} = \frac{4 \cdot \sqrt{3}}{S_a \cdot \left(\frac{k \cdot L}{r} \right)} \quad (7)$$

Deformation due to reduced elastic Base Shear: V_e/R :

$$\Delta_R = \frac{H}{K_s} = \frac{0.25 \cdot S_a \cdot W}{\frac{12 \cdot E \cdot I}{L^3}} = \frac{0.25 \cdot S_a \cdot W \cdot L^3}{E \cdot h^4} \quad (8)$$

$$\Delta_R = \frac{S_a \cdot W}{4 \cdot E \cdot h} \cdot \left(\frac{L}{h} \right)^3 = \frac{S_a \cdot W}{4 \cdot E \cdot h} \cdot \left(\frac{k \cdot L}{r} \right)^3 \cdot \frac{1}{(\sqrt{12})^3}$$

Substitute expression for W in (3) into (8):

$$\Delta_R = \frac{S_a}{4 \cdot E \cdot h} \cdot \left(\frac{2 \cdot h^3 \cdot F_y}{S_a \cdot L} \right) \cdot \left(\frac{L}{h} \right)^3 = \frac{F_y \cdot L^2}{2 \cdot E \cdot h} \quad (9)$$

Preliminary Charts for square section of $h = 3/8"$ and $h = 1/8"$:

S_a (g)	W (kip)	m (kg)	P/P_y	Δ_R (in)	Δ_R/L (%)
kL/r = 200			L = 21.65	h = 3/8	
1.00	0.244	110	0.009	1.0776	4.98%
0.50	0.487	221	0.017	1.0776	4.98%
0.25	0.974	442	0.035	1.0776	4.98%
kL/r = 150			L = 16.24	h = 3/8	
1.00	0.325	147	0.012	0.6061	3.73%
0.50	0.650	295	0.023	0.6061	3.73%
0.25	1.299	589	0.046	0.6061	3.73%
kL/r = 100			L = 10.83	h = 3/8	
1.00	0.487	221	0.017	0.2694	2.49%
0.50	0.974	442	0.035	0.2694	2.49%
0.25	1.949	884	0.069	0.2694	2.49%

S_a (g)	W (kip)	m (kg)	P/P_y	Δ_R (in)	Δ_R/L (%)
kL/r = 200			L = 7.22	h = 1/8	
1.00	0.027	12.3	0.009	0.3592	4.98%
0.50	0.054	24.5	0.017	0.3592	4.98%
0.25	0.108	49.1	0.035	0.3592	4.98%
kL/r = 150			L = 5.41	h = 1/8	
1.00	0.036	16.4	0.012	0.2020	3.73%
0.50	0.072	32.7	0.023	0.2020	3.73%
0.25	0.144	65.5	0.046	0.2020	3.73%
0.13	0.144	65.5	0.092	0.2020	3.73%
kL/r = 100			L = 3.61	h = 1/8	
1.00	0.054	24.5	0.017	0.0898	2.49%
0.50	0.108	49.1	0.035	0.0898	2.49%
0.25	0.217	98.2	0.069	0.0898	2.49%
0.13	0.433	196.4	0.139	0.0898	2.49%

TABLE A-1 Nominal Specimen Properties

Specimen	L (in)	b (in)	h (in)	A (in ²)	Z (in ³)	I (in ⁴)	r (in)	Actual kL/r	W / Col. (kip)	S _{DS} (g)	P _y (kip)	M _p (kip-in)	V _p (kip)	V _y (kip)
1	5.41	0.1875	0.1875	0.0352	0.0016	0.00010	0.054	100.0	0.0771	0.790	1.758	0.082	0.030	0.020
2	5.41	0.1875	0.1875	0.0352	0.0016	0.00010	0.054	100.0	0.1542	0.395	1.758	0.082	0.030	0.020
3	3.61	0.1250	0.1250	0.0156	0.0005	0.00002	0.036	100.0	0.1542	0.175	0.781	0.024	0.014	0.009
4	5.41	0.1875	0.1875	0.0352	0.0016	0.00010	0.054	100.0	0.2056	0.296	1.758	0.082	0.030	0.020
5	3.61	0.1250	0.1250	0.0156	0.0005	0.00002	0.036	100.0	0.2056	0.316	1.875	0.059	0.032	0.022
6	16.24	0.3750	0.3750	0.1406	0.0132	0.00165	0.108	150.0	0.2056	0.790	7.031	0.659	0.081	0.054
7	13.51	0.3125	0.3125	0.0977	0.0076	0.00079	0.090	149.8	0.2056	0.549	4.883	0.381	0.056	0.038
8	10.81	0.2500	0.2500	0.0625	0.0039	0.00033	0.072	149.8	0.2056	0.351	3.125	0.195	0.036	0.024
9	8.12	0.1875	0.1875	0.0352	0.0016	0.00010	0.054	150.0	0.2056	0.197	1.758	0.082	0.020	0.014
10	5.41	0.1250	0.1250	0.0156	0.0005	0.00002	0.036	149.9	0.1028	0.421	1.875	0.024	0.009	0.006
11	21.65	0.3750	0.3750	0.1406	0.0132	0.00165	0.108	200.0	0.1542	0.790	7.031	0.659	0.061	0.041
12	18.02	0.3125	0.3125	0.0977	0.0076	0.00079	0.090	199.8	0.1542	0.549	4.883	0.381	0.042	0.028
13	14.43	0.2500	0.2500	0.0625	0.0039	0.00033	0.072	199.9	0.1542	0.351	3.125	0.195	0.027	0.018
14	10.83	0.1875	0.1875	0.0352	0.0016	0.00010	0.054	200.1	0.1542	0.197	1.758	0.082	0.015	0.010
15	7.22	0.1250	0.1250	0.0156	0.0005	0.00002	0.036	200.1	0.0771	0.175	0.781	0.024	0.007	0.005

TABLE A-2 Computation of Required Spectral Acceleration

Specimen	Mass (kg)	Mass (slugs)	L (in)	b (in)	h (in)	k (lb/in)	ω_h (rad/s)	T_n (sec.)	$V_e=RV_p$ (kip)	Prev. S_a (g)	Req'd S_a (g)	Sa diff.
1	34.98	0.1996	5.41	0.1875	0.1875	226.37	33.68	0.187	0.122	0.790	1.580	-0.790
2	69.96	0.3992	5.41	0.1875	0.1875	226.37	23.81	0.264	0.122	0.395	0.790	-0.395
3	69.96	0.3992	3.61	0.1250	0.1250	150.49	19.42	0.324	0.054	0.175	0.351	-0.175
4	93.28	0.5322	5.41	0.1875	0.1875	226.37	20.62	0.305	0.122	0.296	0.592	-0.296
5	93.28	0.5322	3.61	0.1250	0.1250	150.49	16.82	0.374	0.130	0.132	0.631	-0.500
6	93.28	0.5322	16.24	0.3750	0.3750	133.90	15.86	0.396	0.325	0.790	1.579	-0.790
7	93.28	0.5322	13.51	0.3125	0.3125	112.16	14.52	0.433	0.226	0.549	1.098	-0.549
8	93.28	0.5322	10.81	0.2500	0.2500	89.68	12.98	0.484	0.145	0.351	0.703	-0.351
9	93.28	0.5322	8.12	0.1875	0.1875	66.95	11.22	0.560	0.081	0.197	0.395	-0.197
10	46.64	0.2661	5.41	0.1250	0.1250	44.71	12.96	0.485	0.036	0.176	0.351	-0.176
11	69.96	0.3992	21.65	0.3750	0.3750	56.51	11.90	0.528	0.244	0.790	1.579	-0.790
12	69.96	0.3992	18.02	0.3125	0.3125	47.26	10.88	0.577	0.169	0.549	1.098	-0.549
13	69.96	0.3992	14.43	0.2500	0.2500	37.70	9.72	0.647	0.108	0.351	0.702	-0.351
14	69.96	0.3992	10.83	0.1875	0.1875	28.22	8.41	0.747	0.061	0.197	0.395	-0.197
15	34.98	0.1996	7.22	0.1250	0.1250	18.81	9.71	0.647	0.027	0.175	0.351	-0.175

TABLE A-3 Computation of Maximum Displacement Response

Specimen	Δ_R	$\Delta_{max} =$	Δ_R/L	Peak Response in Nonlin				Elastic Spectra		Inelastic Spectra w/ P- Δ			OverallMin Displ. (in)	
	@Mp (in)	$R\Delta_R$ (in)		T (s)	Linear (in)	NL-EPP (in)	NL-PA (in)	PGA_{crit} (g)	Linear (in)	Scaled (in)	V_j/W	r		Displ. (in)
1	0.135	0.538	0.025	0.187	0.285	0.554	1.954	0.313	0.519	0.467	0.774	2.125	1.640	0.285
2	0.135	0.538	0.025	0.264	0.853	1.193	1.005	0.143	0.914	0.376	0.350	2.050	0.819	0.376
3	0.090	0.360	0.025	0.324	1.304	2.604	0.273	0.034	1.253	0.121	0.093	1.500	0.261	0.121
4	0.135	0.538	0.025	0.305	0.987	2.308	0.754	0.090	0.894	0.232	0.212	1.791	0.625	0.232
5	0.216	0.863	0.060	0.374	1.620	2.600	0.220	0.020	1.693	0.095	0.062	1.521	0.210	0.095
6	0.606	2.425	0.037	0.396	1.630	1.781	6.396	0.342	1.860	1.827	0.737	2.077	4.726	1.630
7	0.504	2.014	0.037	0.433	1.650	1.660	3.521	0.203	1.998	1.164	0.745	3.162	N/A	1.164
8	0.403	1.612	0.037	0.484	2.370	1.469	1.874	0.090	3.307	0.855	0.331	2.402	N/A	0.855
9	0.303	1.213	0.037	0.560	4.390	2.400	0.717	0.039	4.784	0.535	0.082	1.338	0.650	0.535
10	0.202	0.807	0.037	0.686	6.310	5.970	0.225	0.010	3.897	0.117	0.007	1.110	0.206	0.117
11	1.078	4.310	0.050	0.528	3.758	2.338	8.188	0.325	3.269	3.045	1.013	2.955	N/A	2.338
12	0.896	3.583	0.050	0.578	3.501	2.019	4.054	0.221	4.409	2.794	0.543	2.430	4.000	2.019
13	0.718	2.872	0.050	0.647	3.815	4.413	2.408	0.105	3.794	1.141	0.201	1.600	1.934	1.141
14	0.539	2.157	0.050	0.748	3.944	3.341	0.938	0.044	4.142	0.520	0.074	1.510	0.862	0.520
15	0.360	1.438	0.050	0.916	6.986	8.004	0.562	0.024	7.026	0.493	0.048	1.268	0.546	0.493

FIGURE A-1 Spectral Capacity of Specimen # 2
Spectral Demand from NONLIN (with P- Δ)

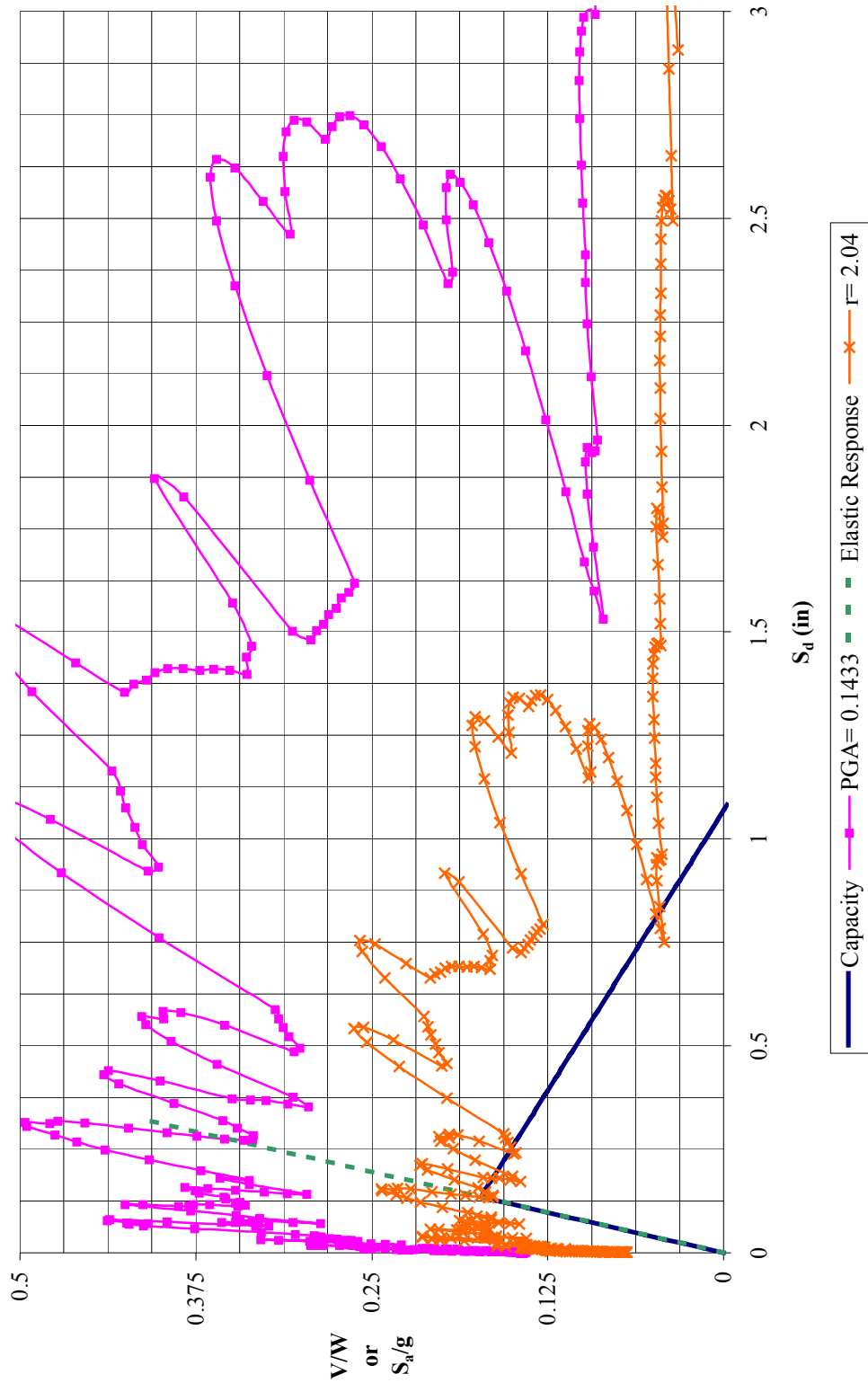


TABLE A-4 Computation of Maximum Acceleration Response

Specimen	Peak Response in Nonlin						Elastic Spectra		Overall Min. Resp. Accel. (g)	Required Resp. Accel. (g)
	T (s)	PGA (g)	Linear (g)	NL-EPP (g)	NL-PA (g)	Linear (in)	Scaled (in)			
1	0.187	0.313	0.908	0.473	0.484	1.762	1.732	0.473	1.580	
2	0.264	0.143	0.590	0.436	0.296	1.330	0.598	0.436	0.790	
3	0.324	0.034	0.133	0.342	0.095	1.213	0.128	0.342	0.351	
4	0.305	0.090	0.297	0.376	0.915	0.982	0.278	0.376	0.592	
5	0.374	0.020	0.068	0.325	0.043	1.231	0.076	0.325	0.631	
6	0.396	0.342	1.090	0.565	0.522	1.219	1.308	0.565	1.579	
7	0.433	0.203	0.581	0.478	0.325	1.079	0.687	0.478	1.098	
8	0.484	0.090	0.322	0.396	0.225	1.437	0.406	0.396	0.703	
9	0.560	0.039	0.177	0.351	0.095	1.559	0.190	0.351	0.395	
10	0.485	0.010	0.046	0.341	0.012	0.849	0.028	0.341	0.351	
11	0.528	0.325	1.344	0.577	0.593	1.189	1.211	0.577	1.579	
12	0.577	0.221	0.909	0.478	0.415	1.340	0.927	0.478	1.098	
13	0.647	0.105	0.346	0.402	0.236	0.918	0.302	0.402	0.702	
14	0.747	0.044	0.098	0.379	0.070	0.753	0.103	0.379	0.395	
15	0.647	0.024	0.076	0.359	0.060	0.858	0.066	0.359	0.351	

Strength & Stability Calculations

(Check of Table values using Specimen #1 & R=4)

Specimen #1 Properties(single column): $E = 199948 \cdot \text{MPa}$

$$h = 4.8 \cdot \text{mm} \quad L := 137.2 \cdot \text{mm} \quad \text{mass} := 34.98 \cdot \text{kg} \quad W := \text{mass} \cdot g \quad W = 343 \cdot \text{N}$$

Cross-Sectional Area:

$$A_g := h^2 \quad A_g = 0.035 \cdot \text{in}^2$$

Moment of Inertia:

$$I := \frac{h^4}{12} \quad I = 42.9 \cdot \text{mm}^4$$

Plastic Section Modulus:

$$Z := \frac{h^3}{4} \quad Z = 1.648 \cdot 10^{-3} \cdot \text{in}^3$$

Radius of Gyration:

$$r := \sqrt{\frac{h^2}{12}} \quad r = 1.4 \cdot \text{mm}$$

Assumptions: $F_y := 50 \text{ ksi}$ $k := 1.0$ $R := 4$ use $\phi := 1.0$ for experiment

Critical compressive stress

from Table 3-50 in AISC LRFD Manual: $\phi F_{cr} := 20.46 \text{ ksi}$ for $\frac{k \cdot L}{r} = 100$

$$\phi_c := 0.85$$

Axial Capacity of Specimen #1: $P_n := \left(\frac{\phi F_{cr}}{\phi_c} \right) \cdot A_g \quad P_n = 3764 \cdot \text{N}$

Plastic Moment:

$$M_p := Z \cdot F_y \quad M_p = 9309 \cdot \text{N} \cdot \text{mm}$$

Plastic Axial Capacity:

$$P_y := A_g \cdot F_y \quad P_y = 7819 \cdot \text{N}$$

$$P_u := W$$

Limit Analysis on Section:

Ultimate moment that can be applied on column based on limit analysis of cross section strength interaction (Bruneau et al. 1998):

$$M_{pr} := \left[1 - \left(\frac{P_u}{P_y} \right)^2 \right] \cdot M_p \quad M_{pr} = 9292 \cdot \text{N} \cdot \text{mm} \quad \frac{M_{pr}}{M_p} = 99.81\%$$

Corresponding Base Shear: $V_{Lim} := \frac{2 \cdot M_{pr}}{L} \quad V_{Lim} = 135.2 \cdot \text{N}$

Corresponding Spectral Acceleration: $S_{a, Lim} := \frac{V_{Lim} \cdot R}{W} \cdot g \quad S_{a, Lim} = 1.577 \cdot g$

1st Order Analysis (AISC 1994):

$$\left| \begin{array}{l} \left(\frac{P_u}{\phi \cdot P_n} + \frac{8}{9} \cdot \frac{M_u}{\phi \cdot M_n} \leq 1.0 \right) \text{ if } \frac{P_u}{\phi \cdot P_n} \geq 0.2 \\ \left(\frac{P_u}{2 \cdot \phi \cdot P_n} + \frac{M_u}{\phi \cdot M_n} \leq 1.0 \right) \text{ if } \frac{P_u}{\phi \cdot P_n} < 0.2 \end{array} \right. \quad (\text{AISC H1-1a})$$

$$\frac{P_u}{\phi \cdot P_n} = 0.091 < 0.2$$

Ultimate moment that can be applied on column based on 1st order strength interaction:

$$M_{u,1} := \left(1 - \frac{P_u}{2 \cdot \phi \cdot P_n} \right) \cdot M_p \quad M_{u,1} = 8885 \cdot \text{N} \cdot \text{mm} \quad \frac{M_{u,1}}{M_p} = 95.44\%$$

Corresponding Base Shear: $V_1 := \frac{2 \cdot M_{u,1}}{L} \quad V_1 = 129.321 \cdot \text{N}$

Corresponding Spectral Acceleration: $S_{a,1} := \frac{V_1 \cdot R}{W} \cdot g \quad S_{a,1} = 1.508 \cdot g$

2nd Order Analysis (AISC 1994): $M_u = B_1 \cdot M_{nt} + B_2 \cdot M_{lt}$ (AISC C1-1)

$$M_{nt} := 0 \quad B_2 = \frac{1}{1 - \frac{\sum P_u \cdot \Delta_{oh}}{\sum V \cdot L}} \quad (C1-4)$$

B_2 can be rewritten as:

$$B_2 = \frac{1}{1 - \frac{P_u}{K \cdot L}}$$

where $K := \frac{12 \cdot E \cdot I}{L^3}$ is the lateral column stiffness

$$K = 39.6 \cdot \frac{N}{mm}$$

Noting that the stability factor is given by: $\theta := \frac{P_u}{K \cdot L} \quad \theta = 0.063$

B_2 can be again rewritten as:

$$B_2 := \frac{1}{1 - \theta}$$

$$B_2 = 1.067$$

Ultimate moment on column based on 2nd order analysis and strength interaction:

$$M_{u,2} := \left(1 - \frac{P_u}{2 \cdot \phi \cdot P_n}\right) \cdot \frac{M_p}{B_2} \quad M_{u,2} = 8326 \cdot N \cdot mm \quad \frac{M_{u,2}}{M_p} = 89.43\%$$

Given:

$$2 \cdot M = P_u \cdot R \cdot \Delta_e + V \cdot L \quad \text{or} \quad \frac{2 \cdot M}{V} = \frac{P_u \cdot \Delta_{oh}}{V} + L = \frac{P_u}{K} + L = L \cdot (\theta + 1)$$

Corresponding Base Shear: $V_2 := \frac{2 \cdot M_{u,2}}{L \cdot (\theta + 1)} \quad V_2 = 113.999 \cdot N$

Corresponding Spectral Acceleration: $S_{a,2} := \frac{V_2 \cdot R}{W} \cdot g \quad S_{a,2} = 1.329 \cdot g$

2nd Order Analysis, using inelastic amplification factor:

Inelastic P-Δ Amplification Factor (Bernal 1987):

$$\alpha = \frac{1 + \beta \cdot \theta}{1 - \theta} \quad \text{where:} \quad \beta = 1.87 \cdot (\mu - 1)$$

taking a target ductility of 4: $\beta := 1.87 \cdot (4 - 1) \quad \beta = 5.61$

$$\alpha := \frac{1 + \beta \cdot \theta}{1 - \theta} \quad \alpha = 1.444$$

Ultimate moment on column based on 2nd order analysis and strength interaction:

$$M_{u,2\alpha} := \left(1 - \frac{P_u}{2 \cdot \phi \cdot P_n} \right) \cdot \frac{M_p}{\alpha} \quad M_{u,2\alpha} = 6152 \cdot \text{N} \cdot \text{mm} \quad \frac{M_{u,2\alpha}}{M_p} = 66.09\%$$

Given:

Corresponding Base Shear: $V_{2\alpha} := \frac{2 \cdot M_{u,2\alpha}}{L \cdot (\theta + 1)} \quad V_{2\alpha} = 84.239 \cdot \text{N}$

Corresponding Spectral Acceleration: $S_{a,2\alpha} := \frac{V_{2\alpha} \cdot R}{W} \cdot g \quad S_{a,2\alpha} = 0.982 \cdot g$

TABLE A-5 First Order Strength and Stability Analysis

Spec.	W (N)	L (mm)	P _y (N)	P _n (N)	P _u /P _y	P _u /P _n	M _p (N-mm)	First Order Limit Equation-P _y				First Order AISC-P _n			
								M _{lim} (N-mm)	% of M _p	V (N)	S _a (g)	M _{u,1} (N-mm)	% of M _p	V (N)	S _a (g)
1	343.0	137.4	7825	3767	0.044	0.091	9,317	9,299	99.8	135.3	1.58	8,893	95.4	129.4	1.509
2	686.1	137.4	7825	3767	0.088	0.182	9,317	9,245	99.2	134.6	0.78	8,468	90.9	123.3	0.719
3	695.9	91.7	3478	1672	0.200	0.416	2,761	2,650	96.0	57.8	0.33	1,813	65.7	39.5	0.227
4	914.8	137.4	7825	3767	0.117	0.243	9,317	9,189	98.6	133.7	0.58	7,936	85.2	115.5	0.505
5	914.8	91.7	3478	1672	0.263	0.547	2,761	2,570	93.1	56.0	0.25	1,406	50.9	30.7	0.134
6	914.8	412.5	31300	6977	0.029	0.131	74,534	74,470	99.9	361.1	1.58	69,647	93.4	337.7	1.477
7	914.8	343.2	21736	4862	0.042	0.188	43,133	43,057	99.8	250.9	1.10	39,075	90.6	227.7	0.996
8	914.8	274.6	13911	3110	0.066	0.294	22,084	21,989	99.6	160.2	0.70	17,538	79.4	127.7	0.559
9	914.8	206.2	7825	1744	0.117	0.524	9,317	9,189	98.6	89.1	0.39	4,984	53.5	48.3	0.211
10	457.4	137.4	3478	776	0.132	0.589	2,761	2,713	98.3	39.5	0.35	1,275	46.2	18.6	0.162
11	686.1	549.9	31300	3926	0.022	0.175	74,534	74,498	100.0	270.9	1.58	68,021	91.3	247.4	1.442
12	686.1	457.7	21736	2733	0.032	0.251	43,133	43,090	99.9	188.3	1.10	36,342	84.3	158.8	0.926
13	686.1	366.5	13911	1746	0.049	0.393	22,084	22,030	99.8	120.2	0.70	15,079	68.3	82.3	0.480
14	686.1	275.1	7825	981	0.088	0.700	9,317	9,245	99.2	67.2	0.39	3,147	33.8	22.9	0.133
15	343.0	183.4	3478	436	0.099	0.787	2,761	2,734	99.0	29.8	0.35	661	23.9	7.2	0.084

TABLE A-6 Second Order Strength and Stability Analysis

Spec.	M_p (N-mm)	θ	Amplification Factors				α ($\mu=R=4$)				B_2 ($R=4$)			
			B_2 ($R=4$)	α ($\mu=4$)	α or B_2 ($\mu=R=1$)	$M_{ult.2}$ (N-mm)	% of M_p	V (N)	S_a (g)	$M_{ult.2}$ (N-mm)	% of M_p	V (N)	S_a (g)	
1	9,317	0.063	1.34	1.44	1.07	6,157	66.1	84.3	0.983	8,333	89.4	114.1	0.333	
2	9,317	0.126	2.02	1.95	1.14	4,337	46.6	56.1	0.327	7,402	79.4	95.7	0.139	
3	2,761	0.288	-6.59	3.67	1.40	494	17.9	8.4	0.048	1,291	46.8	21.9	0.031	
4	9,317	0.168	3.05	2.33	1.20	3,400	36.5	42.4	0.185	6,603	70.9	82.3	0.090	
5	2,761	0.281	-8.19	3.58	1.39	393	14.2	6.7	0.029	1,012	36.7	17.2	0.019	
6	74,534	0.095	1.61	1.69	1.10	41,200	55.3	182.5	0.798	63,060	84.6	279.3	0.305	
7	43,133	0.136	2.19	2.04	1.16	19,173	44.5	98.4	0.430	33,772	78.3	173.3	0.189	
8	22,084	0.212	6.60	2.78	1.27	6,309	28.6	37.9	0.166	13,817	62.6	83.0	0.091	
9	9,317	0.378	-1.95	5.02	1.61	992	10.7	7.0	0.031	3,099	33.3	21.8	0.024	
10	2,761	0.425	-1.43	5.89	1.74	217	7.8	2.2	0.019	733	26.6	7.5	0.016	
11	74,534	0.126	2.02	1.95	1.14	34,820	46.7	112.5	0.656	59,446	79.8	192.0	0.280	
12	43,133	0.181	3.63	2.46	1.22	14,762	34.2	54.6	0.318	29,760	69.0	110.1	0.160	
13	22,084	0.284	-7.46	3.62	1.40	4,171	18.9	17.7	0.103	10,804	48.9	45.9	0.067	
14	9,317	0.505	-0.98	7.74	2.02	407	4.4	2.0	0.011	1,559	16.7	7.5	0.011	
15	2,761	0.568	-0.79	9.68	2.31	68	2.5	0.5	0.006	286	10.3	2.0	0.006	