ATC 154 Project – Steel SMF Conceptual Design: Very High Seismic

The following is a report summarizing the conceptual design of steel special moment frames for the *Very High Seismic* designated archetype for the ATC 154 Project, prepared by the AISC Steel Solutions Center (SSC). This is one of three total conceptual designs for steel special moment frame designs in an archetype steel structure subjected to three different levels of seismicity ranging from high to 'ultra' high. The designed moment frames will form the basis of advanced analytical modeling to be carried out at the University of Washington to investigate if there is a higher probability of collapse for code-designed seismic force systems when going from high seismicity to very high seismicity.

Archetype Design Criteria

The conceptual steel moment frame design prepared by the SSC for the *Very High* archetype is based on archetype layouts and design criteria provided by John Hooper of MKA and Jim Harris of J.R. Harris & Company – who developed the preliminary archetype layouts and seismic design parameters.

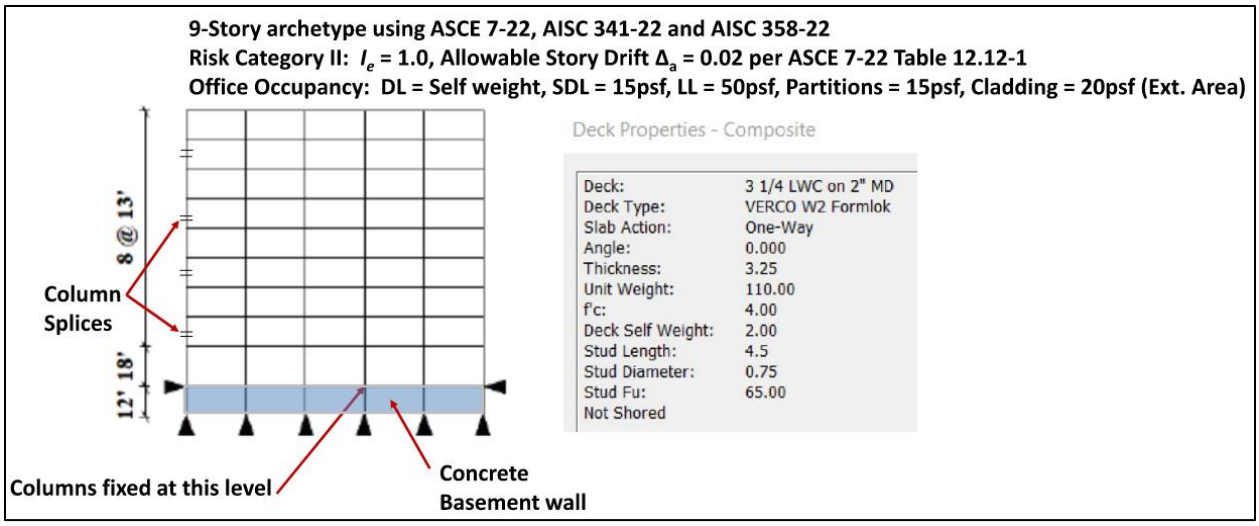


Figure 1: Elevation with Defined Loading and Base Boundary Conditions

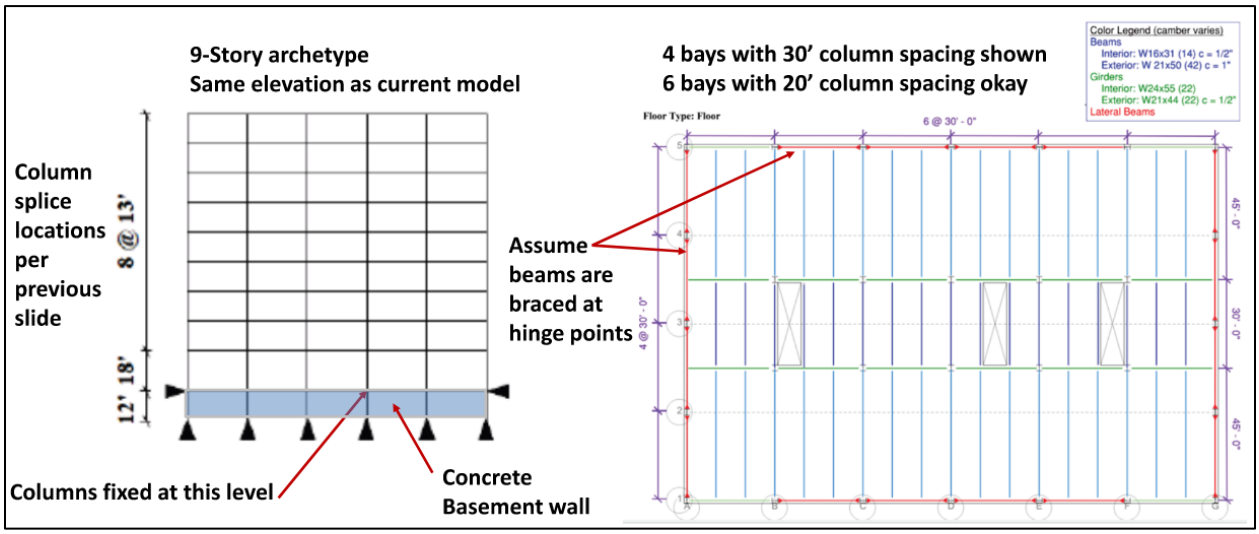


Figure 2: Elevation and Typical Floor Plan with Sized Gravity Framing (Sized by MKA)

The following criteria was also given:

- Member sizes (need to meet AISC 358 prequalification criteria)
  - Columns: W14
  - Beams: up to W36
- Connections (need to meet AISC 358 prequalification criteria)
  - Either WUF-W or RBS (the ATC-154 team recommended RBS connections as WUF-W connections are not pre-qualified to the likely seismic demands from the very high and ultra-high design cases). Therefore, the SSC chose to use RBS.
- Follow AISC 341 for final sizing and detailing of beam-column joint

Seismic Design Criteria

The seismic design criteria given for each archetype is shown in the table below. The blue shading denotes the archetype design included in this report.

Table 1: Seismic Design Parameters for Steel Frame Archetypes

Recommendations for Archetype Designs

	S_{MS}	S_{DS}	S_{M1}	S_{D1}	S_1
High D	1.5	1.0	0.9	0.6	0.47
Very High Seismic	2.25	1.5	1.8	1.2	0.72
Ultra High Seismic	3.0	2.0	2.7	1.8	1.07

Note: blue shading denotes archetype design included in this report

Where,

S_{MS} = The spectral response acceleration parameter at short periods adjusted for site class effects as determined in accordance with Section 11.4.3 of ASCE 7-22 for the risk-targeted maximum considered earthquake (MCE_R), 5% damped

S_{DS} = Design earthquake spectral response acceleration parameters at short periods as determined in accordance with Section 11.4.4 of ASCE 7-22

S_{M1} = MCE_R, 5% damped, spectral response acceleration parameter at a period of 1 second adjusted for site class effects as determined in accordance with Section 11.4.3 of ASCE 7-22

S_{D1} = Design, 5% damped, spectral response acceleration parameter at a period of 1 s as defined in Section 11.4.4 of ASCE 7-22

S_1 = MCE_R, 5% damped, spectral response acceleration parameter at a period of 1 s for Site Class BC site conditions as determined in accordance with Section 11.4.3 of ASCE 7-22

Conceptual Steel Special Moment Frame Design: Very High Seismic Archetype

The SSC utilized Bentley Systems RAM Structural System and RAM Frame to perform the lateral analysis and design the steel moment frames. The study structural model is based on the structural layout provided to us in the archetype design drawings. Gravity framing included in the model was as shown in the gravity design provided by MKA, which was the same as the *High D* archetype (gravity design information was provided in the *High D* archetype report). A typical floor framing plan and frame elevations are shown in Appendix 1.

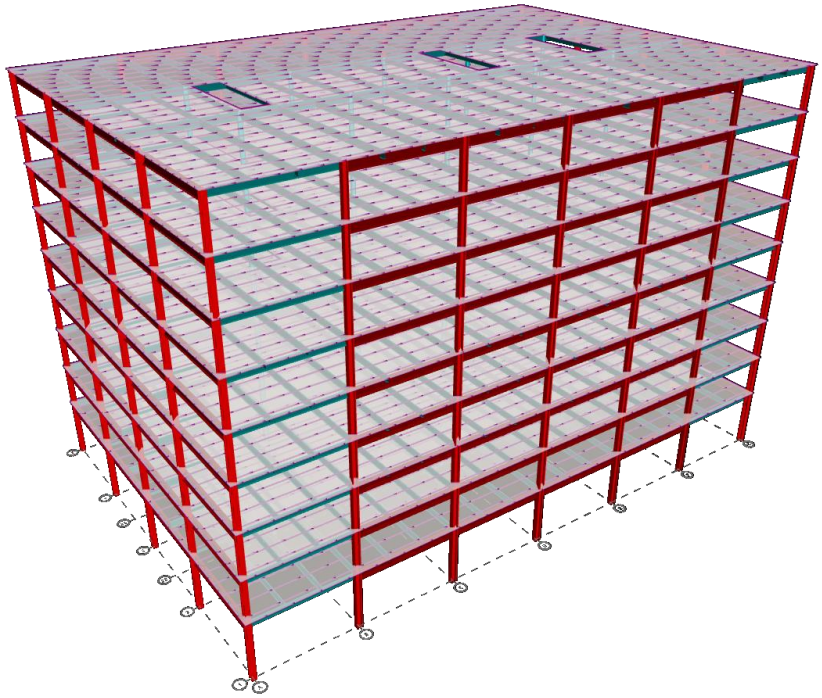


Figure 3: 3D rendering of archetype structure

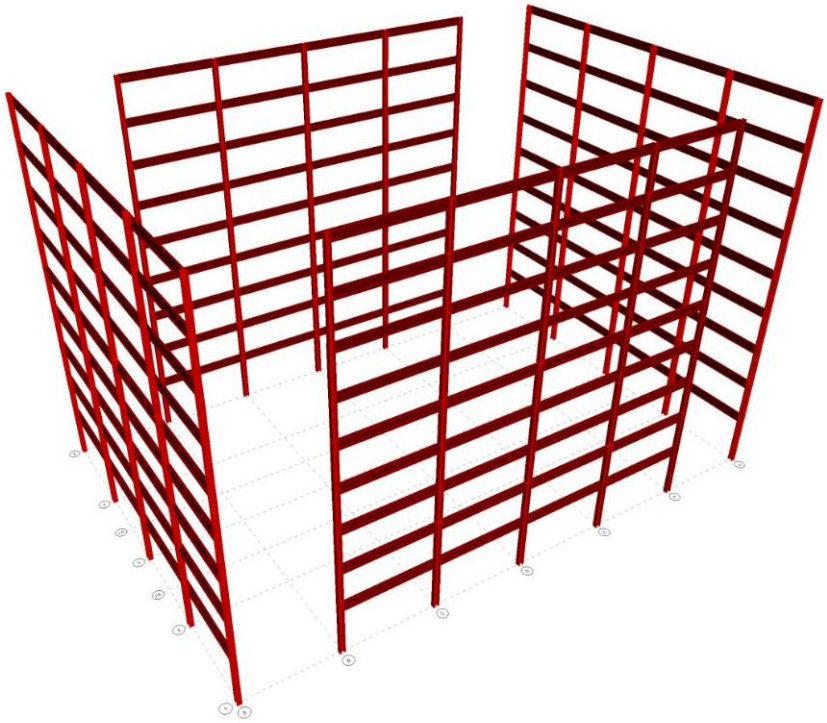


Figure 4: 3D rendering of archetype lateral frames only

Modeling Assumptions and Notes

The archetype was designed with loading and criteria per ASCE 7-22 *Minimum Design Loads and Associated Criteria for Buildings and Other Structures* (ASCE 7). Modal Response Spectrum Analysis was used per Section 12.9.1 of ASCE 7, with parameters for each mode combined using the complete quadratic combination (CQC) method. As agreed to at a coordination meeting in December of 2022, design checks were made based on LRFD requirements using AISC 360-16 *Specification for Structural Steel Buildings* (AISC 360), AISC 341-16 *Seismic Provisions for Structural Steel Buildings* (AISC 341), and AISC 358 *Prequalified Connections for Special and Intermediate Steel Moment Frames for Seismic Applications* (AISC 358). This was done due to the current capabilities of the analysis software used by AISC staff and minimizing the time needed to complete this analysis. AISC staff did not investigate the impacts that the use of the 2022 AISC Standards would have on the overall design with the exception that sections used in the design satisfy the seismic width-to-thickness requirements for highly ductile shapes per AISC 341-22. However, it is believed that the design would be generally consistent with AISC 360-22, AISC 341-22, and AISC 358-22.

The following is a list of assumptions and notes regarding the archetype lateral structural model:

1. A separate model for drift and strength were utilized. Both models were identical with a few key differences. This allowed the SSC to take advantage of provisions in Section 12.8.6 of ASCE 7 for the determination of displacements and drifts. For strength checks, the Direct Analysis Method was used per AISC 360 using reduced stiffnesses with $\tau_b = 1.0$. Unreduced stiffnesses were used in the determination of building periods and story drifts. See Appendix 2 for the analysis criteria used in RAM Frame for drift and strength.
2. Beams were assumed to be continuously braced. Based on discussions with MKA, it is our understanding that discrete beam bracing would be provided to satisfy the lateral bracing requirements of AISC 341 and AISC 358. For simplicity, this bracing was not included in the model.
3. Columns were assumed fixed at the base (i.e. at the top of the concrete basement wall). The concrete basement wall was not included in the model.
4. Reduced Beam Section (RBS) moment connections were utilized for all beam-column connections. The reduced section properties were used in the analysis.
5. Rigid end zone effects were not included, which is typical in the design of steel moment frames.
6. P-delta effects were included in the design of the frames for both drift and strength. The SSC used procedures recommended by Bentley that can be found on their help page here.
7. Rigid diaphragms were used at each level.
8. Materials:
    a. Beams and columns: $F_y = 50$ ksi
    b. Web plates and stiffener plates: $F_y = 50$ ksi
9. By inspection the structure is classified as regular and does not have any horizontal or vertical irregularities. (Note – the structure was checked for a torsional irregularity and the structure was found to not have a torsional irregularity). Therefore, accidental torsion was not included in the strength model per Section 12.8.4.2 of ASCE 7. Accidental torsion was included in the drift model to check for a torsional irregularity. Since the structure does meet any of the conditions listed in Section 12.5.4, the Independent Directional Procedure method per Section 12.5.1.1 of ASCE 7 was used.

Base Shear Calculation

The following is a summary of the base shear calculations for drift and strength. More detailed information can be found in Appendix 3. Base shear results are shown below for the Equivalent Lateral Force (ELF) method and Modal Response Spectrum Analysis (RSA). RSA base shear results were within 1% of ELF base shears for strength (after scaling). Unless otherwise noted, values pertain to both X and Y directions.

R =	8
Ω_o =	3
C_d =	5.5
Seismic Weight, W =	18,113 kips
Period, T =	2.104 sec (E-W or X-dir. period per RAM)
Period, T =	2.104 sec (N-S or Y-dir. period per RAM)
Ta =	1.307 sec
Cu =	1.4 sec
T-used (drift) =	2.104 sec
Cs (drift) =	0.0713
Base shear, V (drift, ELF) =	1291.2 kips (shown for reference only)
Base shear, V (drift, RSA) =	1176.7 kips (E-W or X-dir. per RAM)
Base shear, V (drift, RSA) =	1169.9 kips (N-S or Y-dir. per RAM)
T-used (strength) = Cu*Ta =	1.830 sec
Cs (strength) =	0.082
Base shear, V (strength) =	1484.9 kips

The combined response for the modal base shear using RSA, V_t in the strength model was found to be less than 100% of the calculated base shear using the ELF procedure, V for both orthogonal directions. Therefore, the RSA base shear for strength was multiplied by V/V_t in accordance with Section 12.9.1.4 of ASCE 7. Displacements did not require scaling.

Story Drift Ratio Check

Resulting displacements and story drifts for the structure at the center of mass are shown in Appendix 4. Story drifts are all within the allowable story drift ratio, Δ_a = of 0.02. For practicality, the story drift ratio was converted to a maximum allowable elastic drift ratio of 0.0036 (maximum allowable elastic drift ratio = allowable drift ratio * Ie / Cd = 0.02*1.0/5.5 = 0.0036). This ratio was then directly compared to the drift ratios reported by RAM Frame.

Stability Coefficient Check

The resulting stability coefficients for each level are shown in Appendix 5. The stability coefficients are all less than the maximum stability coefficient, θ_{max} = 0.182 per Section 12.8.7 of ASCE 7. The β value used in the calculation of θ_{max} was determined at the controlling floor (Level 3) according to the procedure recommended in NIST GCR 16-917-41 *NEHRP Seismic Design Technical Brief No. 2: Seismic Design of Steel Special Moment Frames, 2nd ed.* A β value of 0.39 was calculated, which is greater than

the minimum value per Section 12.8.7 of ASCE 7 which states that β shall not be less than $1.25/\Omega_o$ = 0.42. Conservatively, a β value of 0.5 was used in the calculation of θ_{max} to check stability.

Design Capacity Ratios (DCRs)

The resulting demand-capacity ratios (DCRs) for each frame member are shown in Appendix 6. Design checks were made based on LRFD requirements using AISC 360, AISC 341, and AISC 358. The Direct Analysis Method was used per AISC 360 using reduced stiffnesses with τb = 1.0. A P-delta analysis was used and B1 factors were applied. Strong column-weak beam requirements per AISC 341 were met for all frame members.

Reduced Beam Section (RBS) Properties

Reduced Beam Section (RBS) moment connections were utilized for all beam-column connections. The reduced section properties were used in the analysis. Reduced beam stiffness due to the RBS connection was therefore included in the analysis by direct modeling of the reduced section. The beam flange cut dimensions used in the analysis are shown in the figure below.

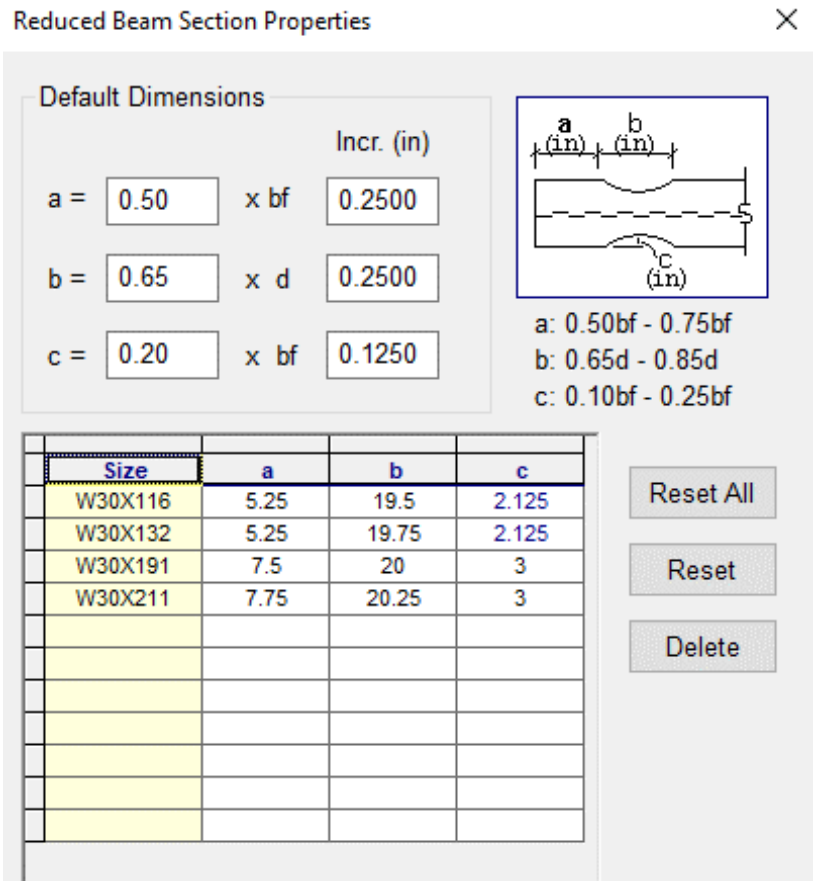
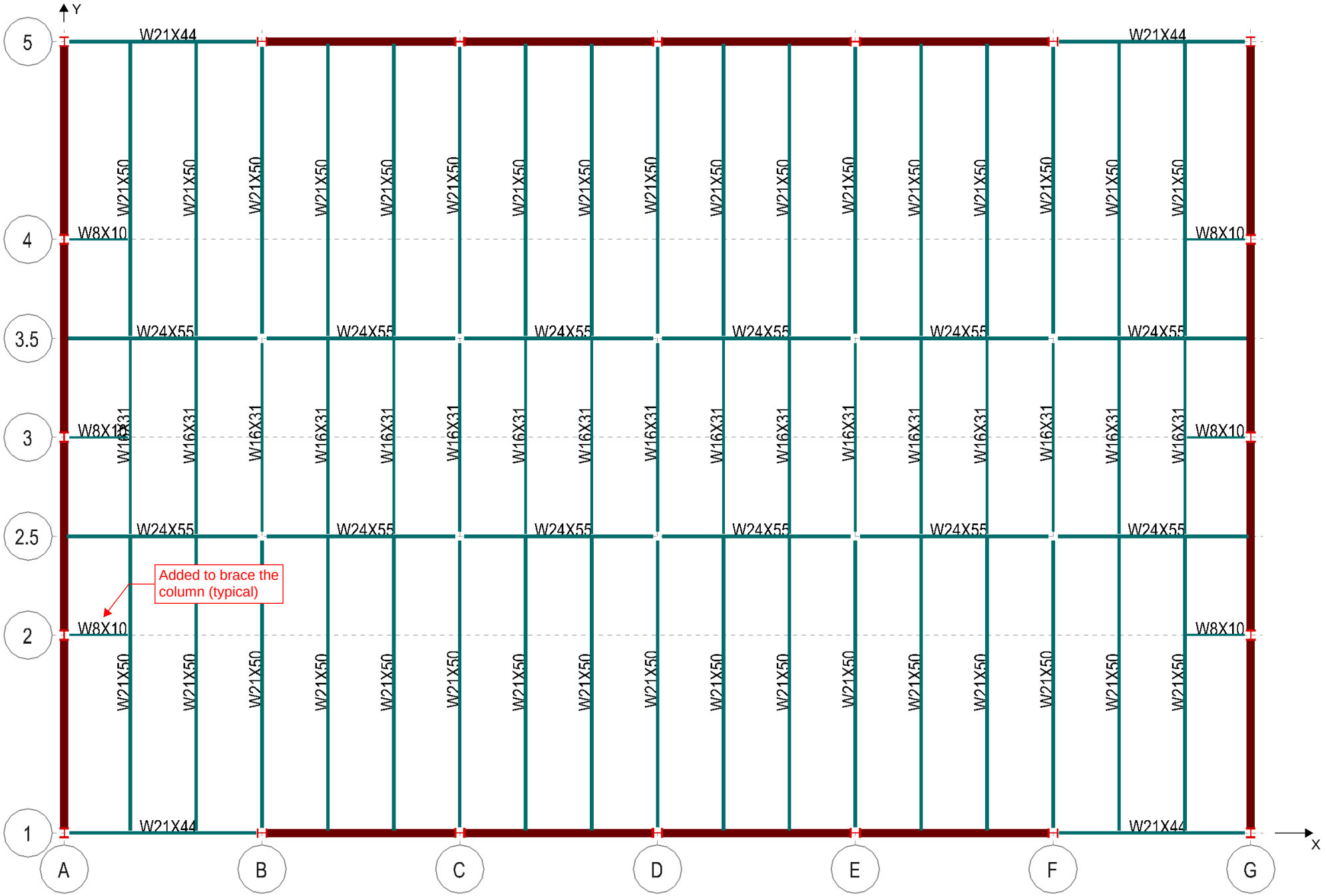


Figure 5: Reduced beam section properties

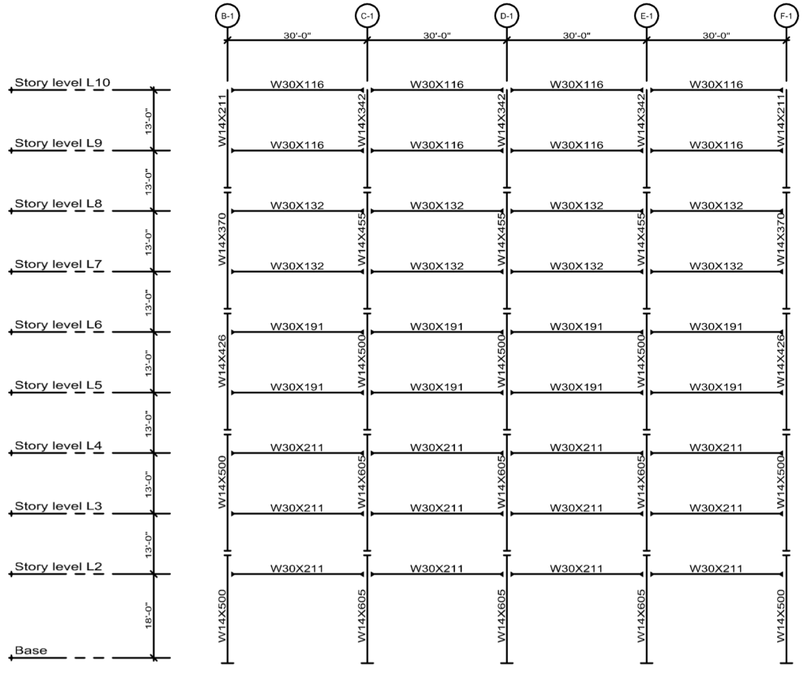
AISC Disclaimer

APPENDIX 1: TYPICAL FLOOR PLAN AND FRAME ELEVATIONS

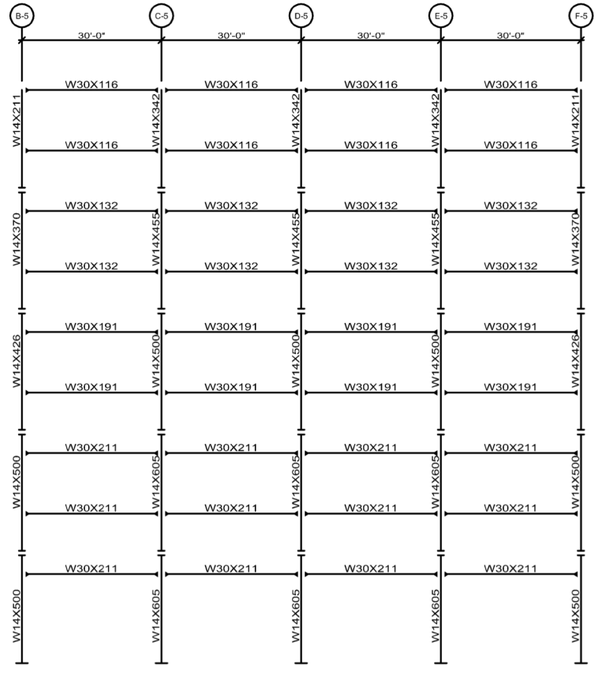


TYPICAL FLOOR PLAN

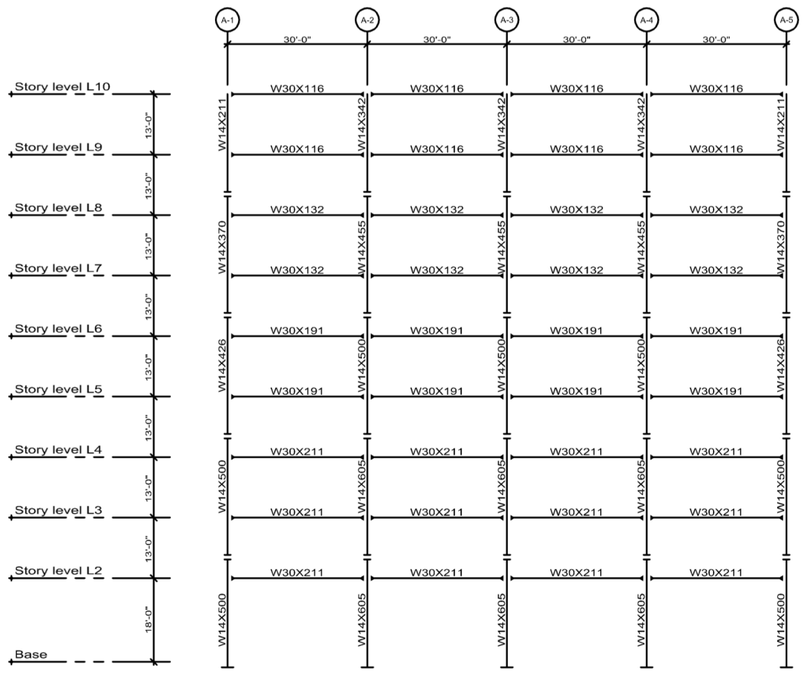
FRAME ELEVATIONS



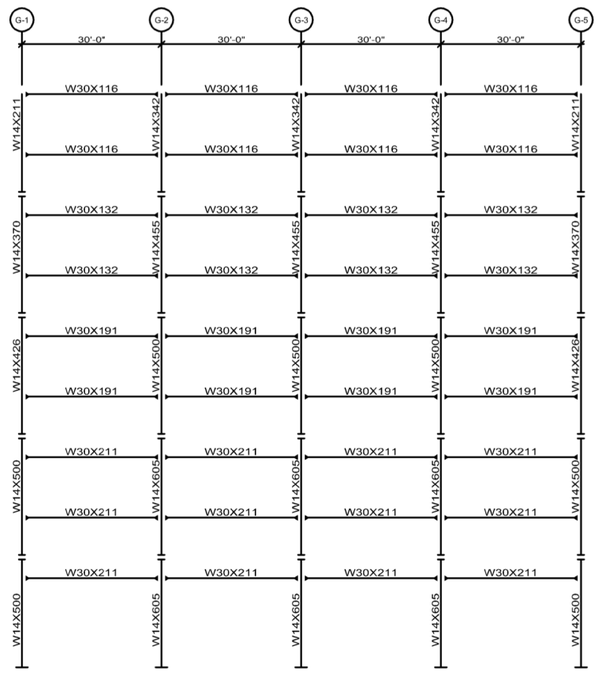
Frame along gridline 1



Frame along gridline 5

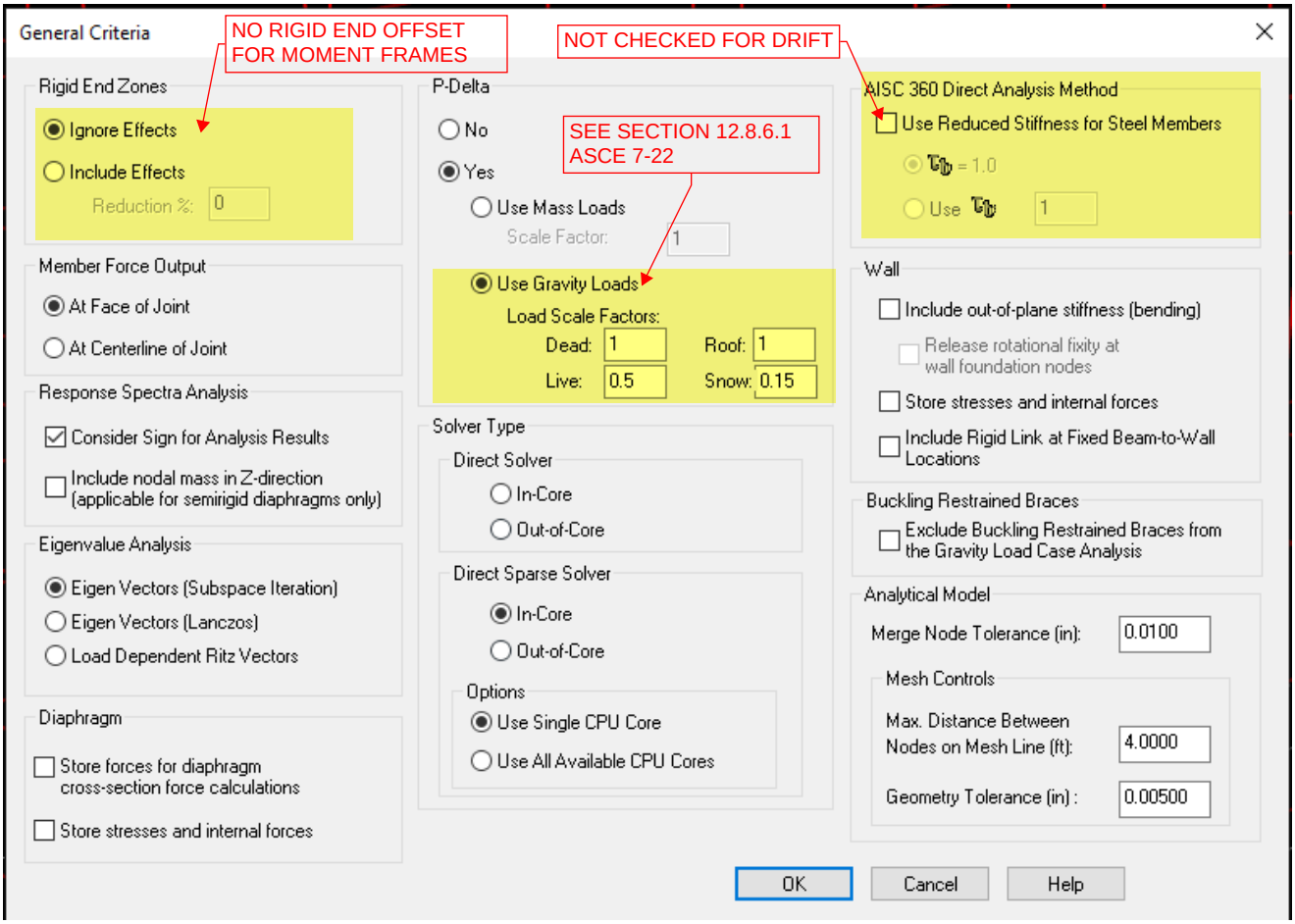


Frame along gridline A

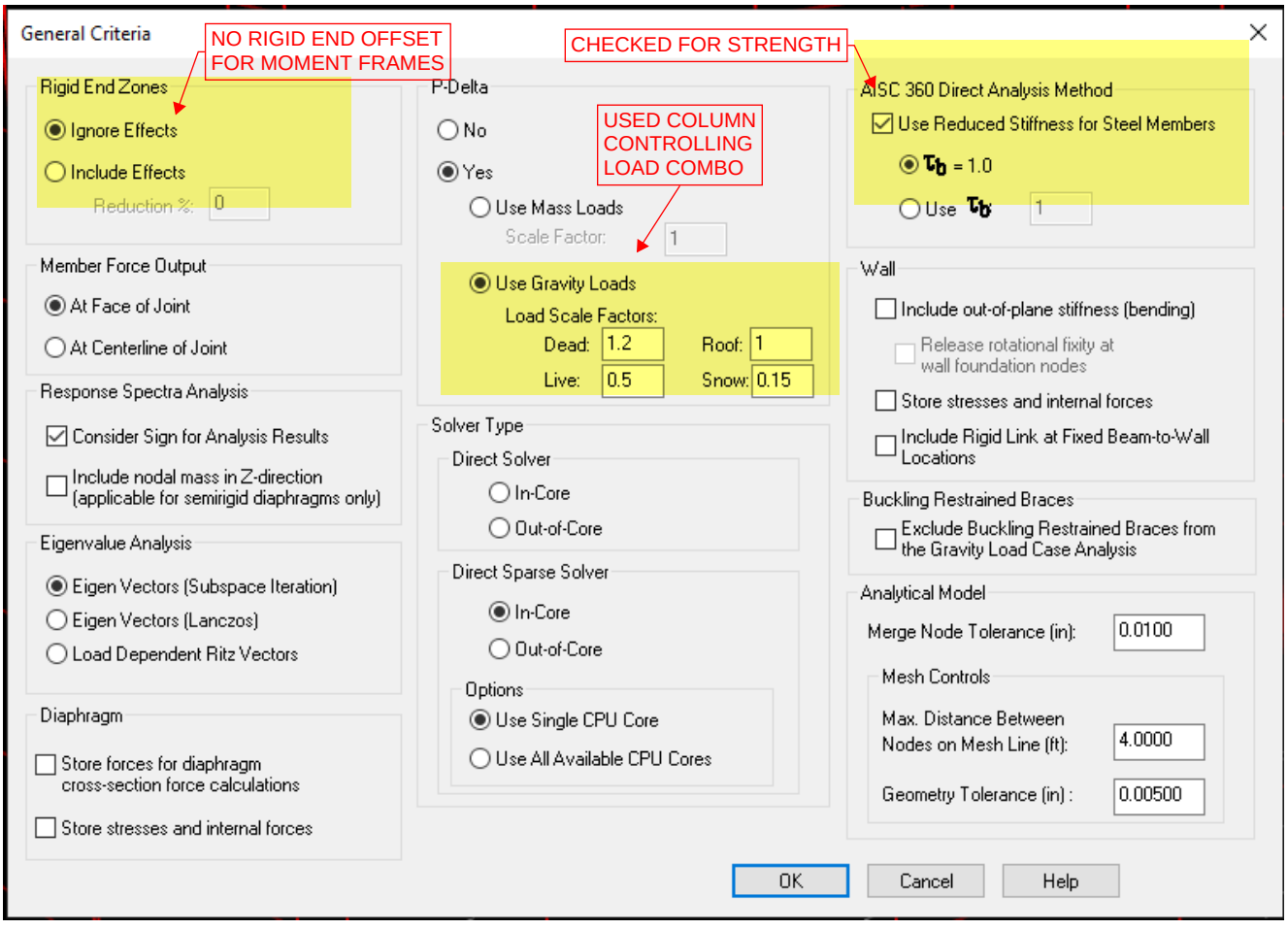


Frame along gridline G

ANALYSIS CRITERIA FOR DRIFT:



ANALYSIS CRITERIA FOR STRENGTH:



Loads and Applied Forces

RAM Frame 17.04.01.07
DataBase: ATC 154_SSC_SMF Study - Very High_Final - Drift 01/16/23 08:29:05

LOAD CASE: RSA_Drift

Note - results were checked and verified to be consistent with ASCE 7-22

Dynamic Response Spectra for ASCE 7-16
Damping Ratio: 0.050
Scale Factors (X-Dir): +Ecc Case: 0.1250 -Ecc Case: 0.1250
Scale Factors (Y-Dir): +Ecc Case: 0.1250 -Ecc Case: 0.1250
Design Spectral Acceleration Parameters : Use
SMS : 2.250 g SM1 = 1.800 g
SDS : 1.500 SD1: 1.200
To : 0.160 sec Ts : 0.800 sec TL : 6.000 sec
Modal Combination Technique: CQC
Ground Level: Base

Dir	Eccent
X	+ And -
Y	+ And -

DIRECTION

Type: Dyn_ASCE716_CQC_X_+E
Type: Dyn_ASCE716_CQC_X_-E
Type: Dyn_ASCE716_CQC_Y_+E
Type: Dyn_ASCE716_CQC_Y_-E

GENERATED RESPONSE SPECTRA CURVE

Period	Spectral Acceleration (S(T))
0.0000(To)	0.6000 g
0.1600(To)	1.5000 g
0.8000(Ts)	1.5000 g
0.8000 < T < 6.0000 (TL)	1.2000 g/T
T > 6.0000	7.2000 g/(T*T)

LOAD CASE: ELF_Drift

Note - results were checked and verified to be consistent with ASCE 7-22

Seismic ASCE 7-16 Equivalent Lateral Force
Importance Factor: 1.00 TL: 6.00 s
Site values are from a Ground Motion Hazard Analysis
Site Class D: Stiff Soil, Default
Ss: 0.001 g S1: 0.720 g
Use Specified: SDs: 1.500 g SD1: 1.200 g
Use Specified Seismic Design Category: D
Provisions for: Drift
Ground Level: Base

Dir	Eccent	R	Ta Equation	Building Period-T
X	+ And -	8.00	Std,Ct=0.028,x=0.80	Calculated
Y	+ And -	8.00	Std,Ct=0.028,x=0.80	Calculated

Dir	Ta	Cu	T	T-used	Cs Eq12.8-2	Cs(max) Eq12.8-3	Cs(min) Eq12.8-6	Cs-used	k
X	1.307	1.400	2.104	2.104	0.188	0.071	0.045	0.071	1.802

Dir	Ta	Cu	T	T-used	Cs Eq12.8-2	Cs(max) Eq12.8-3	Cs(min) Eq12.8-6	Cs-used	k
Y	1.307	1.400	2.104	2.104	0.188	0.071	0.045	0.071	1.802

Total Building Weight (kips) = 18112.52

APPLIED DIAPHRAGM FORCES

Applied forces are shown for ELF method for comparison.

Type: EQ_ASCE716_X_+E_Drft

Level	Diaph.#	Ht ft	Fx kips	Fy kips	X ft	Y ft
Story level L10	1	122.00	323.52	0.00	89.87	66.10
Story level L9	1	109.00	269.88	0.00	89.88	66.10
Story level L8	1	96.00	217.54	0.00	89.88	66.10
Story level L7	1	83.00	168.93	0.00	89.88	66.10
Story level L6	1	70.00	126.54	0.00	89.88	66.10
Story level L5	1	57.00	87.70	0.00	89.88	66.10
Story level L4	1	44.00	55.63	0.00	89.88	66.10
Story level L3	1	31.00	29.80	0.00	89.88	66.10
Story level L2	1	18.00	11.70	0.00	89.89	66.10

APPLIED STORY FORCES

Type: EQ_ASCE716_X_+E_Drft

Level	Ht ft	Fx kips	Fy kips
Story level L10	122.00	323.52	0.00
Story level L9	109.00	269.88	0.00

Story level L8	96.00	217.54	0.00
Story level L7	83.00	168.93	0.00
Story level L6	70.00	126.54	0.00
Story level L5	57.00	87.70	0.00
Story level L4	44.00	55.63	0.00
Story level L3	31.00	29.80	0.00
Story level L2	18.00	11.70	0.00
		1291.23	0.00

APPLIED DIAPHRAGM FORCES

Type: EQ_ASCE716_X_-E_Drft

Level	Diaph.#	Ht ft	Fx kips	Fy kips	X ft	Y ft
Story level L10	1	122.00	323.52	0.00	89.87	53.90
Story level L9	1	109.00	269.88	0.00	89.88	53.90
Story level L8	1	96.00	217.54	0.00	89.88	53.90
Story level L7	1	83.00	168.93	0.00	89.88	53.90
Story level L6	1	70.00	126.54	0.00	89.88	53.90
Story level L5	1	57.00	87.70	0.00	89.88	53.90
Story level L4	1	44.00	55.63	0.00	89.88	53.90
Story level L3	1	31.00	29.80	0.00	89.88	53.90
Story level L2	1	18.00	11.70	0.00	89.89	53.90

APPLIED STORY FORCES

Type: EQ_ASCE716_X_-E_Drft

Level	Ht ft	Fx kips	Fy kips
Story level L10	122.00	323.52	0.00
Story level L9	109.00	269.88	0.00
Story level L8	96.00	217.54	0.00
Story level L7	83.00	168.93	0.00
Story level L6	70.00	126.54	0.00
Story level L5	57.00	87.70	0.00
Story level L4	44.00	55.63	0.00
Story level L3	31.00	29.80	0.00
Story level L2	18.00	11.70	0.00
		1291.23	0.00

APPLIED DIAPHRAGM FORCES

Type: EQ_ASCE716_Y_+E_Drft

Level	Diaph.#	Ht	Fx	Fy	X	Y

		ft	kips	kips	ft	ft
Story level L10	1	122.00	0.00	323.52	98.97	60.00
Story level L9	1	109.00	0.00	269.88	98.98	60.00
Story level L8	1	96.00	0.00	217.54	98.98	60.00
Story level L7	1	83.00	0.00	168.93	98.98	60.00
Story level L6	1	70.00	0.00	126.54	98.98	60.00
Story level L5	1	57.00	0.00	87.70	98.98	60.00
Story level L4	1	44.00	0.00	55.63	98.98	60.00
Story level L3	1	31.00	0.00	29.80	98.98	60.00
Story level L2	1	18.00	0.00	11.70	98.99	60.00

APPLIED STORY FORCES

Type: EQ_ASCE716_Y_+E_Drft

Level	Ht	Fx	Fy
	ft	kips	kips
Story level L10	122.00	0.00	323.52
Story level L9	109.00	0.00	269.88
Story level L8	96.00	0.00	217.54
Story level L7	83.00	0.00	168.93
Story level L6	70.00	0.00	126.54
Story level L5	57.00	0.00	87.70
Story level L4	44.00	0.00	55.63
Story level L3	31.00	0.00	29.80
Story level L2	18.00	0.00	11.70
		0.00	1291.23

APPLIED DIAPHRAGM FORCES

Type: EQ_ASCE716_Y_-E_Drft

Level	Diaph.#	Ht	Fx	Fy	X	Y
		ft	kips	kips	ft	ft
Story level L10	1	122.00	0.00	323.52	80.77	60.00
Story level L9	1	109.00	0.00	269.88	80.78	60.00
Story level L8	1	96.00	0.00	217.54	80.78	60.00
Story level L7	1	83.00	0.00	168.93	80.78	60.00
Story level L6	1	70.00	0.00	126.54	80.78	60.00
Story level L5	1	57.00	0.00	87.70	80.78	60.00
Story level L4	1	44.00	0.00	55.63	80.78	60.00
Story level L3	1	31.00	0.00	29.80	80.78	60.00
Story level L2	1	18.00	0.00	11.70	80.79	60.00

APPLIED STORY FORCES

Type: EQ_ASCE716_Y_-E_Drft

Level	Ht	Fx	Fy

Loads and Applied Forces

	ft	kips	kips
Story level L10	122.00	0.00	323.52
Story level L9	109.00	0.00	269.88
Story level L8	96.00	0.00	217.54
Story level L7	83.00	0.00	168.93
Story level L6	70.00	0.00	126.54
Story level L5	57.00	0.00	87.70
Story level L4	44.00	0.00	55.63
Story level L3	31.00	0.00	29.80
Story level L2	18.00	0.00	11.70
		0.00	1291.23

BASE SHEAR (Dynamic Load Cases)

LdC	Shear-X	Shear-Y
Dyn1	**-1176.68**	**0.91**
Dyn2	**-1176.67**	**-0.91**
Dyn3	**0.00**	**-1169.94**
Dyn4	**-0.00**	**-1169.24**

RSA BASE SHEAR - DRIFT

Loads and Applied Forces

RAM Frame 17.04.01.07
DataBase: ATC 154_SSC_SMF Study - Very High_Final - Strength 01/16/23 08:49:53

LOAD CASE: ELF_Strength

Note - results were checked and verified to be consistent with ASCE 7-22

Seismic ASCE 7-16 Equivalent Lateral Force
Importance Factor: 1.00 TL: 6.00 s
Site values are from a Ground Motion Hazard Analysis
Site Class D: Stiff Soil, Default
Ss: 0.001 g S1: 0.720 g
Use Specified: SDs: 1.500 g SD1: 1.200 g
Use Specified Seismic Design Category: D
Provisions for: Force
Ground Level: Base

Dir	Eccent	R	Ta Equation	Building Period-T
X	None	8.00	Std,Ct=0.028,x=0.80	User Defined
Y	None	8.00	Std,Ct=0.028,x=0.80	User Defined

Dir	Ta	Cu	T	T-used	Cs Eq12.8-2	Cs(max) Eq12.8-3	Cs(min) Eq12.8-5	Cs-used	k
X	1.307	1.400	2.104	1.830	0.188	0.082	0.066	0.082	1.665

Dir	Ta	Cu	T	T-used	Cs Eq12.8-2	Cs(max) Eq12.8-3	Cs(min) Eq12.8-5	Cs-used	k
Y	1.307	1.400	2.104	1.830	0.188	0.082	0.066	0.082	1.665

Total Building Weight (kips) = 18112.52

APPLIED DIAPHRAGM FORCES

Type: EQ_ASCE716_X_NoE_F

Level	Diaph.#	Ht ft	Fx kips	Fy kips	X ft	Y ft
Story level L10	1	122.00	355.96	0.00	89.87	60.00
Story level L9	1	109.00	301.56	0.00	89.88	60.00
Story level L8	1	96.00	247.35	0.00	89.88	60.00
Story level L7	1	83.00	195.96	0.00	89.88	60.00
Story level L6	1	70.00	150.25	0.00	89.88	60.00
Story level L5	1	57.00	107.12	0.00	89.88	60.00
Story level L4	1	44.00	70.40	0.00	89.88	60.00
Story level L3	1	31.00	39.57	0.00	89.88	60.00
Story level L2	1	18.00	16.73	0.00	89.89	60.00

APPLIED STORY FORCES

Type: EQ_ASCE716_X_NoE_F

Level	Ht ft	Fx kips	Fy kips
Story level L10	122.00	355.96	0.00
Story level L9	109.00	301.56	0.00

Story level L8	96.00	247.35	0.00
Story level L7	83.00	195.96	0.00
Story level L6	70.00	150.25	0.00
Story level L5	57.00	107.12	0.00
Story level L4	44.00	70.40	0.00
Story level L3	31.00	39.57	0.00
Story level L2	18.00	16.73	0.00
		1484.90	0.00

APPLIED DIAPHRAGM FORCES

Type: EQ_ASCE716_Y_NoE_F

Level	Diaph.#	Ht	Fx	Fy	X	Y
		ft	kips	kips	ft	ft
Story level L10	1	122.00	0.00	355.96	89.87	60.00
Story level L9	1	109.00	0.00	301.56	89.88	60.00
Story level L8	1	96.00	0.00	247.35	89.88	60.00
Story level L7	1	83.00	0.00	195.96	89.88	60.00
Story level L6	1	70.00	0.00	150.25	89.88	60.00
Story level L5	1	57.00	0.00	107.12	89.88	60.00
Story level L4	1	44.00	0.00	70.40	89.88	60.00
Story level L3	1	31.00	0.00	39.57	89.88	60.00
Story level L2	1	18.00	0.00	16.73	89.89	60.00

APPLIED STORY FORCES

Type: EQ_ASCE716_Y_NoE_F

Level	Ht	Fx	Fy
	ft	kips	kips
Story level L10	122.00	0.00	355.96
Story level L9	109.00	0.00	301.56
Story level L8	96.00	0.00	247.35
Story level L7	83.00	0.00	195.96
Story level L6	70.00	0.00	150.25
Story level L5	57.00	0.00	107.12
Story level L4	44.00	0.00	70.40
Story level L3	31.00	0.00	39.57
Story level L2	18.00	0.00	16.73
		0.00	1484.90

BASE SHEAR (Dynamic Load Cases)

LdC	Shear-X	Shear-Y
Dyn5	**-1483.86**	**-0.00**
Dyn6	**0.00**	**-1483.85**

RSA BASE SHEAR - STRENGTH

Periods and Modes

RAM Frame 17.04.01.07
DataBase: ATC 154_SSC_SMF Study - Very High_Final - Drift 01/16/23 08:29:05

CRITERIA:

Rigid End Zones: Ignore Effects
P-Delta: Yes Scale Factor (DL): 1.00 Scale Factor (LL): 0.50
Scale Factor (Roof): 1.00 Scale Factor (Snow): 0.15
Ground Level: Base
Mesh Criteria :
Max. Distance Between Nodes on Mesh Line (ft) : 4.00
Merge Node Tolerance (in) : 0.0100
Geometry Tolerance (in) : 0.0050
Walls Out-of-plane Stiffness Not Included in Analysis.
Sign considered for Dynamic Load Case Results.
Rigid Links Not Included at Fixed Beam-to-Wall Locations
Eigenvalue Analysis : Eigen Vectors (Subspace Iteration)

Load Case: Eigen Eigen Solution

FREQUENCIES AND PERIODS:

Mode	Period (T) sec	Cyclic Frequency (f) Hz	Circular Frequency (ω) rad/sec	Eigenvalue (rad/sec)**2
1	2.1041	0.4753	2.9862	8.9171
2	2.1041	0.4753	2.9862	8.9172
3	1.3128	0.7617	4.7861	22.9070
4	0.7568	1.3214	8.3026	68.9335
5	0.7568	1.3214	8.3026	68.9337
6	0.4792	2.0868	13.1118	171.9188
7	0.4222	2.3684	14.8814	221.4560
8	0.4222	2.3685	14.8814	221.4565
9	0.2801	3.5700	22.4308	503.1415
10	0.2801	3.5700	22.4308	503.1426

MODAL PARTICIPATION FACTORS:

Mode	X-Dir	Y-Dir	Rotation
1	-0.0767	73.8819	-0.5031
2	73.8819	0.0767	-0.0000
3	-0.0001	0.0893	420.1150
4	-0.0247	28.0484	-0.2064
5	28.0485	0.0247	0.0000
6	-0.0000	0.0338	158.6126
7	-0.0199	16.2629	-0.1067
8	16.2629	0.0199	0.0001
9	0.0122	-10.9020	0.1005
10	-10.9020	-0.0122	0.0000

Periods and Modes

MODAL DIRECTION FACTORS:

Mode	X-Dir	Y-Dir	Rotation
1	0.00	100.00	0.00
2	100.00	0.00	0.00
3	0.00	0.00	100.00
4	0.00	100.00	0.00
5	100.00	0.00	0.00
6	0.00	0.00	100.00
7	0.00	100.00	0.00
8	100.00	0.00	0.00
9	0.00	100.00	0.00
10	100.00	0.00	0.00

MODAL EFFECTIVE MASS FACTORS:

Mode	X-Dir		Y-Dir		Rotation	
	%Mass	%SumM	%Mass	%SumM	%Mass	%SumM
1	0.00	0.00	80.87	80.87	0.00	0.00
2	80.87	80.87	0.00	80.87	0.00	0.00
3	0.00	80.87	0.00	80.87	81.41	81.41
4	0.00	80.87	11.66	92.52	0.00	81.41
5	11.66	92.52	0.00	92.52	0.00	81.41
6	0.00	92.52	0.00	92.52	11.60	93.02
7	0.00	92.52	3.92	96.44	0.00	93.02
8	3.92	96.44	0.00	96.44	0.00	93.02
9	0.00	96.44	1.76	98.20	0.00	93.02
10	1.76	98.20	0.00	98.20	0.00	93.02

Drift

RAM Structural System 17.04.01.07
DataBase: ATC 154_SSC_SMF Study - Very High_Final - Drift 01/16/23 08:29:05
Building Code: IBC Steel Code: IBC

CRITERIA:

Rigid End Zones: Ignore Effects
Member Force Output: At Face of Joint
P-Delta: Yes Scale Factor (DL): 1.00 Scale Factor (LL): 0.50
Scale Factor (Roof): 1.00 Scale Factor (Snow): 0.15
Ground Level: Base

LOAD CASE DEFINITIONS:

Dyn1	RSA_Drift	Dyn_ASCE716_CQC_X_+E
Dyn2	RSA_Drift	Dyn_ASCE716_CQC_X_-E
Dyn3	RSA_Drift	Dyn_ASCE716_CQC_Y_+E
Dyn4	RSA_Drift	Dyn_ASCE716_CQC_Y_-E

RESULTS:

All drift ratios less than 0.0036

Location (ft): (89.870, 60.000)

Story	LdC	Displacement X in	Displacement Y in	Story Drift X in	Story Drift Y in	Drift Ratio X	Drift Ratio Y
Story level L10	Dyn1	4.1944	-0.0032	0.3191	-0.0002	0.0020	0.0000
	Dyn2	4.1944	0.0032	0.3191	0.0002	0.0020	0.0000
	Dyn3	-0.0000	4.1674	-0.0000	0.3173	0.0000	0.0020
	Dyn4	0.0000	4.1660	0.0000	0.3172	0.0000	0.0020
Story level L9	Dyn1	3.9422	-0.0030	0.4706	-0.0004	0.0030	0.0000
	Dyn2	3.9422	0.0030	0.4706	0.0004	0.0030	0.0000
	Dyn3	-0.0000	3.9168	-0.0000	0.4679	0.0000	0.0030
	Dyn4	0.0000	3.9155	0.0000	0.4678	0.0000	0.0030
Story level L8	Dyn1	3.5569	-0.0027	0.5124	-0.0004	0.0033	0.0000
	Dyn2	3.5569	0.0027	0.5124	0.0004	0.0033	0.0000
	Dyn3	-0.0000	3.5340	-0.0000	0.5093	0.0000	0.0033
	Dyn4	0.0000	3.5328	0.0000	0.5092	0.0000	0.0033
Story level L7	Dyn1	3.1180	-0.0024	0.5248	-0.0004	0.0034	0.0000
	Dyn2	3.1180	0.0024	0.5248	0.0004	0.0034	0.0000
	Dyn3	-0.0000	3.0980	-0.0000	0.5216	0.0000	0.0033
	Dyn4	0.0000	3.0970	0.0000	0.5214	0.0000	0.0033
Story level L6	Dyn1	2.6497	-0.0020	0.5070	-0.0004	0.0033	0.0000
	Dyn2	2.6497	0.0020	0.5070	0.0004	0.0033	0.0000
	Dyn3	-0.0000	2.6329	-0.0000	0.5038	0.0000	0.0032
	Dyn4	0.0000	2.6320	0.0000	0.5036	0.0000	0.0032

Drift

All drift ratios less than 0.0036
(typical all load cases)

Story	LdC	Displacement		Story Drift		Drift Ratio	
Story level L5	Dyn1	2.1750	-0.0017	0.5296	-0.0004	0.0034	0.0000
	Dyn2	2.1750	0.0017	0.5296	0.0004	0.0034	0.0000
	Dyn3	-0.0000	2.1613	-0.0000	0.5262	0.0000	0.0034
	Dyn4	0.0000	2.1607	0.0000	0.5260	0.0000	0.0034
Story level L4	Dyn1	1.6618	-0.0013	0.5250	-0.0004	0.0034	0.0000
	Dyn2	1.6618	0.0013	0.5250	0.0004	0.0034	0.0000
	Dyn3	-0.0000	1.6516	-0.0000	0.5216	0.0000	0.0033
	Dyn4	0.0000	1.6511	0.0000	0.5215	0.0000	0.0033
Story level L3	Dyn1	1.1424	0.0009	0.5506	-0.0004	0.0035	0.0000
	Dyn2	1.1424	-0.0009	0.5506	0.0004	0.0035	0.0000
	Dyn3	-0.0000	1.1355	-0.0000	0.5472	0.0000	0.0035
	Dyn4	0.0000	1.1352	0.0000	0.5471	0.0000	0.0035
Story level L2	Dyn1	0.5928	0.0005	0.5928	0.0005	0.0027	0.0000
	Dyn2	0.5928	-0.0005	0.5928	-0.0005	0.0027	0.0000
	Dyn3	-0.0000	0.5893	-0.0000	0.5893	0.0000	0.0027
	Dyn4	0.0000	0.5891	0.0000	0.5891	0.0000	0.0027

All less than 1.2 --> no torsional irregularity

TORSIONAL IRREGULARITY DATA:

X-Axis:

Story	LdC	Drift in	Coord ft	Drift in	Coord ft	Max/Min	Max/Ave
Story level L10	Dyn2	0.3352	(0.00 0.00)	0.3032	(0.00 120.00)	1.105	1.050
Story level L9	Dyn2	0.4952	(0.00 0.00)	0.4464	(0.00 120.00)	1.109	1.052
Story level L8	Dyn2	0.5383	(0.00 0.00)	0.4869	(0.00 120.00)	1.105	1.050
Story level L7	Dyn2	0.5509	(0.00 0.00)	0.4991	(0.00 120.00)	1.104	1.049
Story level L6	Dyn2	0.5318	(0.00 0.00)	0.4826	(0.00 120.00)	1.102	1.049
Story level L5	Dyn2	0.5557	(0.00 0.00)	0.5040	(0.00 120.00)	1.102	1.049
Story level L4	Dyn2	0.5506	(0.00 0.00)	0.4999	(0.00 120.00)	1.101	1.048
Story level L3	Dyn2	0.5778	(0.00 0.00)	0.5240	(0.00 120.00)	1.103	1.049
Story level L2	Dyn2	0.6245	(0.00 0.00)	0.5617	(0.00 120.00)	1.112	1.053

Y-Axis:

Story	LdC	Drift in	Coord ft	Drift in	Coord ft	Max/Min	Max/Ave
Story level L10	Dyn4	0.3535	(0.00 0.00)	0.2818	(180.00 0.00)	1.255	1.113
Story level L9	Dyn4	0.5232	(0.00 0.00)	0.4141	(180.00 0.00)	1.264	1.116
Story level L8	Dyn4	0.5676	(0.00 0.00)	0.4528	(180.00 0.00)	1.254	1.112
Story level L7	Dyn4	0.5804	(0.00 0.00)	0.4647	(180.00 0.00)	1.249	1.111
Story level L6	Dyn4	0.5596	(0.00 0.00)	0.4498	(180.00 0.00)	1.244	1.109
Story level L5	Dyn4	0.5848	(0.00 0.00)	0.4696	(180.00 0.00)	1.245	1.109
Story level L4	Dyn4	0.5792	(0.00 0.00)	0.4661	(180.00 0.00)	1.243	1.108
Story level L3	Dyn4	0.6083	(0.00 0.00)	0.4883	(180.00 0.00)	1.246	1.109
Story level L2	Dyn4	0.6607	(0.00 0.00)	0.5206	(180.00 0.00)	1.269	1.119

ASCE 7 Stability Coefficients

RAM Frame 17.04.01.07
DataBase: ATC 154_SSC_SMF Study - Very High_Final - Drift 01/16/23 08:29:05

CRITERIA:

Rigid End Zones: Ignore Effects
Member Force Output: At Face of Joint
P-Delta: Yes Scale Factor (DL): 1.00 Scale Factor (LL): 0.50
Scale Factor (Roof): 1.00 Scale Factor (Snow): 0.15
Ground Level: Base
Mesh Criteria :
Max. Distance Between Nodes on Mesh Line (ft) : 4.00
Merge Node Tolerance (in) : 0.0100
Geometry Tolerance (in) : 0.0050
Walls Out-of-plane Stiffness Not Included in Analysis.
Sign considered for Dynamic Load Case Results.
Rigid Links Not Included at Fixed Beam-to-Wall Locations
Eigenvalue Analysis : Eigen Vectors (Subspace Iteration)

STABILITY COEFFICIENTS:ASCE 7-10/16 Eq. (12.8-16)

Per Section 12.8.6.1, ASCE 7-22 - reducible live loads can be used (0.5L where L=0.4Lo --> 0.5*0.4=0.2)

β = 0.50
Cd : X-Dir = 5.50 Y-Dir = 5.50
Note that the reported drifts are unfactored elastic story drift values.
Calculated vertical load includes dead, live and roof loads. Live loads are reduced with live load reduction factors.
Calculated vertical load is the sum of the total vertical load at and above story.
Vertical Load Factors:
Dead Load : 1.00 Live Load : 0.20 Roof Load : 1.00 Snow Load : 0.20

LOAD CASE: ELF_Drift

All values for theta/(1+theta) less than theta-max. Theta/(1+theta) used for comparison since P-delta analysis was used.

Type : EQ_ASCE716_X_+E_Drft

Level	Diaph. #	Ht	Shear X	Shear Y	Drift X	Drift Y	Vertical Load
		ft	kips	kips	in	in	kips
Story level L10	1	122.00	328.53	0.00	0.39	0.00	1797.47
Story level L9	1	109.00	608.85	0.00	0.60	0.00	3557.22
Story level L8	1	96.00	837.51	0.00	0.69	0.00	5352.66
Story level L7	1	83.00	1017.27	0.00	0.72	0.00	7154.17
Story level L6	1	70.00	1151.98	0.00	0.70	0.00	8970.47
Story level L5	1	57.00	1249.95	0.00	0.71	0.00	10788.64
Story level L4	1	44.00	1311.72	0.00	0.67	0.00	12631.63
Story level L3	1	31.00	1350.43	0.00	0.67	0.00	14478.73
Story level L2	1	18.00	1351.45	0.00	0.70	0.00	16455.65

Level	Diaph. #	θx	θy	θx/(1+θx)	θy/(1+θy)	θxmax	θymax
Story level L10	1	0.014	0.000	0.014	0.000	0.182	0.182
Story level L9	1	0.023	0.000	0.022	0.000	0.182	0.182
Story level L8	1	0.028	0.000	0.027	0.000	0.182	0.182
Story level L7	1	0.033	0.000	0.032	0.000	0.182	0.182

Story level L6	1	0.035	0.000	0.034	0.000	0.182	0.182
Story level L5	1	0.039	0.000	0.038	0.000	0.182	0.182
Story level L4	1	0.042	0.000	0.040	0.000	0.182	0.182
Story level L3	1	0.046	0.000	0.044	0.000	0.182	0.182
Story level L2	1	0.039	0.000	0.038	0.000	0.182	0.182

Type : EQ_ASCE716_X_-E_Drft

Level	Diaph. #	Ht	Shear X	Shear Y	Drift X	Drift Y	Vertical Load
		ft	kips	kips	in	in	kips
Story level L10	1	122.00	328.53	-0.00	0.39	-0.00	1797.47
Story level L9	1	109.00	608.85	-0.00	0.60	-0.00	3557.22
Story level L8	1	96.00	837.51	-0.00	0.69	-0.00	5352.66
Story level L7	1	83.00	1017.27	-0.00	0.72	-0.00	7154.17
Story level L6	1	70.00	1151.98	-0.00	0.70	-0.00	8970.47
Story level L5	1	57.00	1249.95	-0.00	0.71	-0.00	10788.64
Story level L4	1	44.00	1311.72	-0.00	0.67	-0.00	12631.63
Story level L3	1	31.00	1350.43	-0.00	0.67	-0.00	14478.73
Story level L2	1	18.00	1351.45	-0.00	0.70	-0.00	16455.65

Level	Diaph. #	θx	θy	θx/(1+θx)	θy/(1+θy)	θxmax	θymax
Story level L10	1	0.014	0.000	0.014	0.000	0.182	0.182
Story level L9	1	0.023	0.000	0.022	0.000	0.182	0.182
Story level L8	1	0.028	0.000	0.027	0.000	0.182	0.182
Story level L7	1	0.033	0.000	0.032	0.000	0.182	0.182
Story level L6	1	0.035	0.000	0.034	0.000	0.182	0.182
Story level L5	1	0.039	0.000	0.038	0.000	0.182	0.182
Story level L4	1	0.042	0.000	0.040	0.000	0.182	0.182
Story level L3	1	0.046	0.000	0.044	0.000	0.182	0.182
Story level L2	1	0.039	0.000	0.038	0.000	0.182	0.182

Type : EQ_ASCE716_Y_+E_Drft

Level	Diaph. #	Ht	Shear X	Shear Y	Drift X	Drift Y	Vertical Load
		ft	kips	kips	in	in	kips
Story level L10	1	122.00	0.00	328.53	0.00	0.39	1797.47
Story level L9	1	109.00	-0.00	608.84	0.00	0.60	3557.22
Story level L8	1	96.00	0.00	837.51	0.00	0.69	5352.66
Story level L7	1	83.00	0.00	1017.27	0.00	0.72	7154.17
Story level L6	1	70.00	0.00	1151.98	0.00	0.70	8970.47
Story level L5	1	57.00	-0.00	1249.95	0.00	0.71	10788.64
Story level L4	1	44.00	0.00	1311.71	0.00	0.67	12631.63
Story level L3	1	31.00	0.00	1350.42	0.00	0.67	14478.73
Story level L2	1	18.00	0.00	1351.44	0.00	0.70	16455.65

Level	Diaph. #	θx	θy	θx/(1+θx)	θy/(1+θy)	θxmax	θymax
Story level L10	1	0.000	0.014	0.000	0.014	0.182	0.182
Story level L9	1	0.000	0.023	0.000	0.022	0.182	0.182

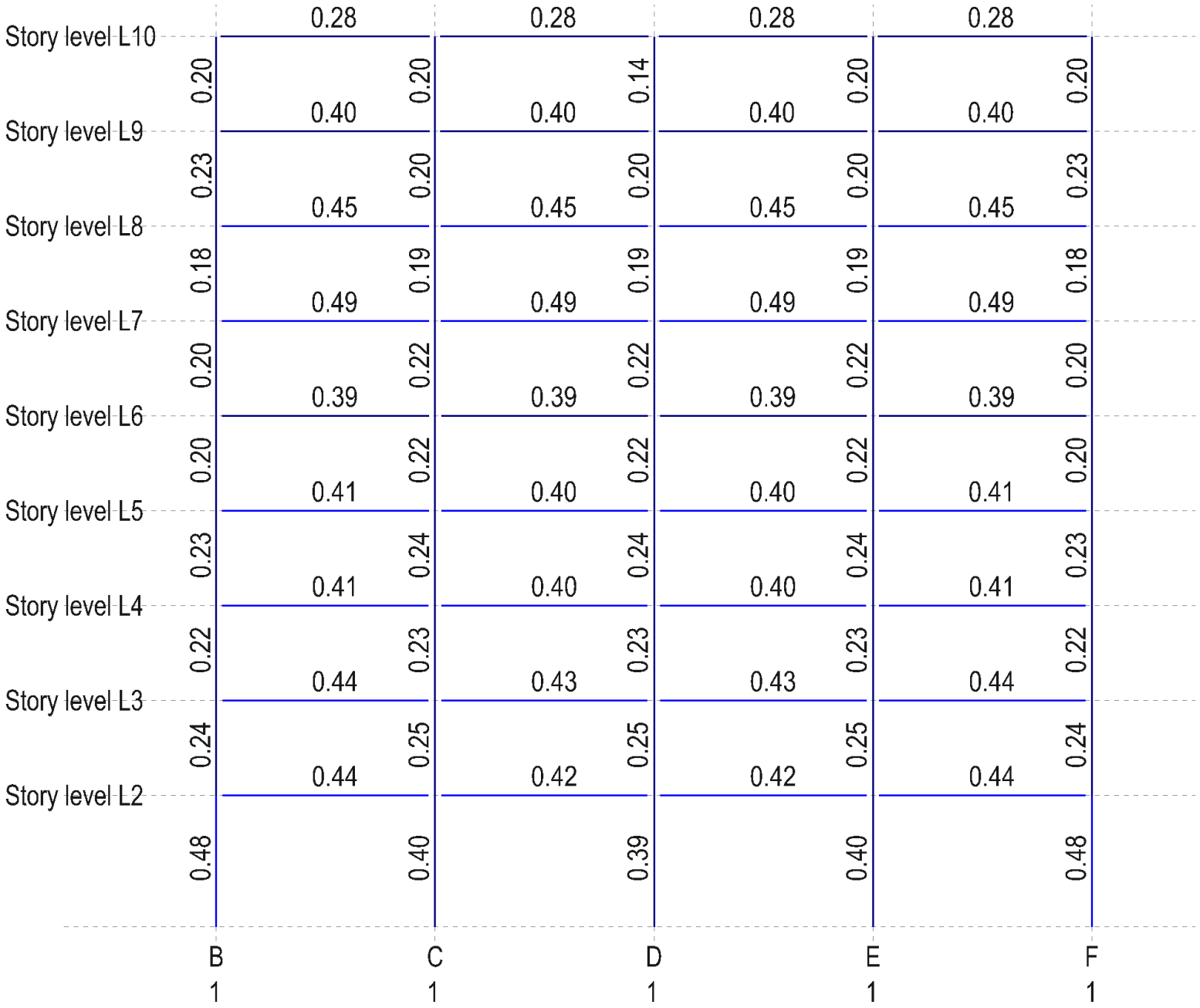
Story level L8	1	0.000	0.028	0.000	0.027	0.182	0.182
Story level L7	1	0.000	0.033	0.000	0.032	0.182	0.182
Story level L6	1	0.000	0.035	0.000	0.034	0.182	0.182
Story level L5	1	0.000	0.039	0.000	0.038	0.182	0.182
Story level L4	1	0.000	0.042	0.000	0.040	0.182	0.182
Story level L3	1	0.000	0.046	0.000	0.044	0.182	0.182
Story level L2	1	0.000	0.039	0.000	0.038	0.182	0.182

Type : EQ_ASCE716_Y_-E_Drft

Level	Diaph. #	Ht	Shear X	Shear Y	Drift X	Drift Y	Vertical Load
		ft	kips	kips	in	in	kips
Story level L10	1	122.00	-0.00	328.53	-0.00	0.39	1797.47
Story level L9	1	109.00	0.00	608.85	-0.00	0.60	3557.22
Story level L8	1	96.00	-0.00	837.51	-0.00	0.69	5352.66
Story level L7	1	83.00	-0.00	1017.27	-0.00	0.72	7154.17
Story level L6	1	70.00	-0.00	1151.99	-0.00	0.70	8970.47
Story level L5	1	57.00	0.00	1249.96	-0.00	0.71	10788.64
Story level L4	1	44.00	-0.00	1311.72	-0.00	0.67	12631.63
Story level L3	1	31.00	-0.00	1350.43	-0.00	0.67	14478.73
Story level L2	1	18.00	-0.00	1351.45	-0.00	0.70	16455.65

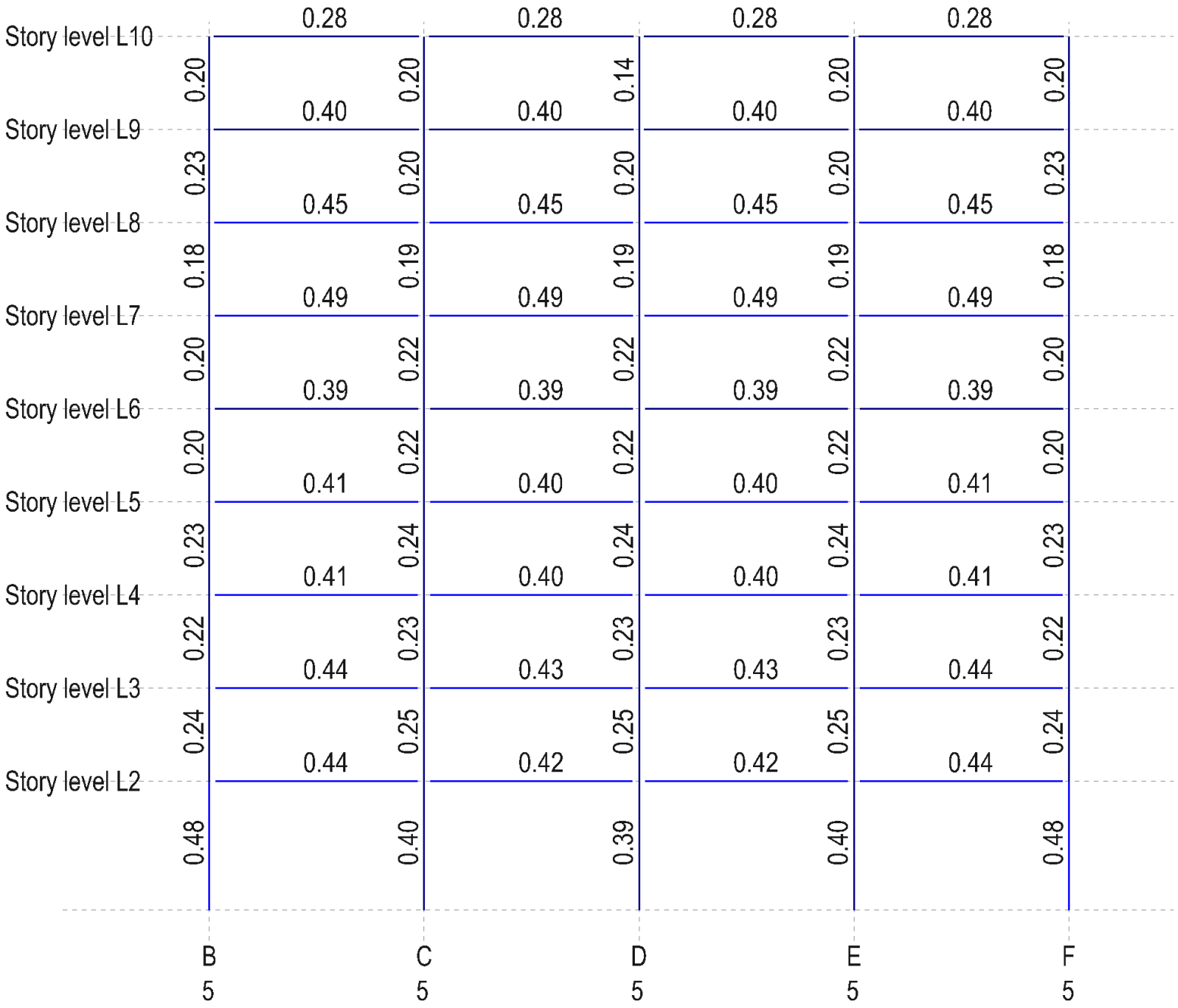
Level	Diaph. #	θx	θy	θx/(1+θx)	θy/(1+θy)	θxmax	θymax
Story level L10	1	0.000	0.014	0.000	0.014	0.182	0.182
Story level L9	1	0.000	0.023	0.000	0.022	0.182	0.182
Story level L8	1	0.000	0.028	0.000	0.027	0.182	0.182
Story level L7	1	0.000	0.033	0.000	0.032	0.182	0.182
Story level L6	1	0.000	0.035	0.000	0.034	0.182	0.182
Story level L5	1	0.000	0.039	0.000	0.038	0.182	0.182
Story level L4	1	0.000	0.042	0.000	0.040	0.182	0.182
Story level L3	1	0.000	0.046	0.000	0.044	0.182	0.182
Story level L2	1	0.000	0.039	0.000	0.038	0.182	0.182

APPENDIX 6: FRAME DEMAND CAPACITY RATIOS (DCRs)

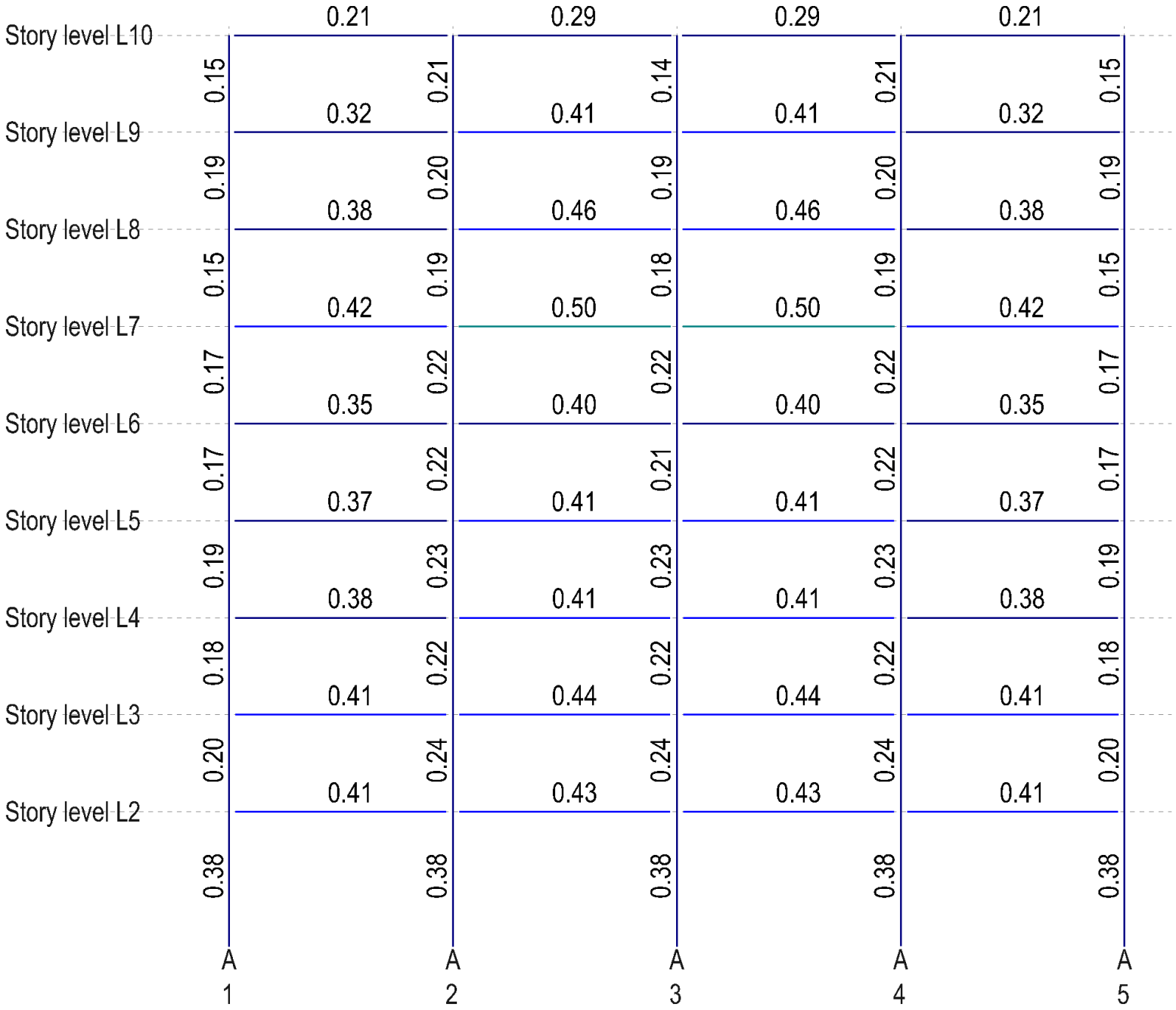


FRAME ALONG GRIDLINE 1

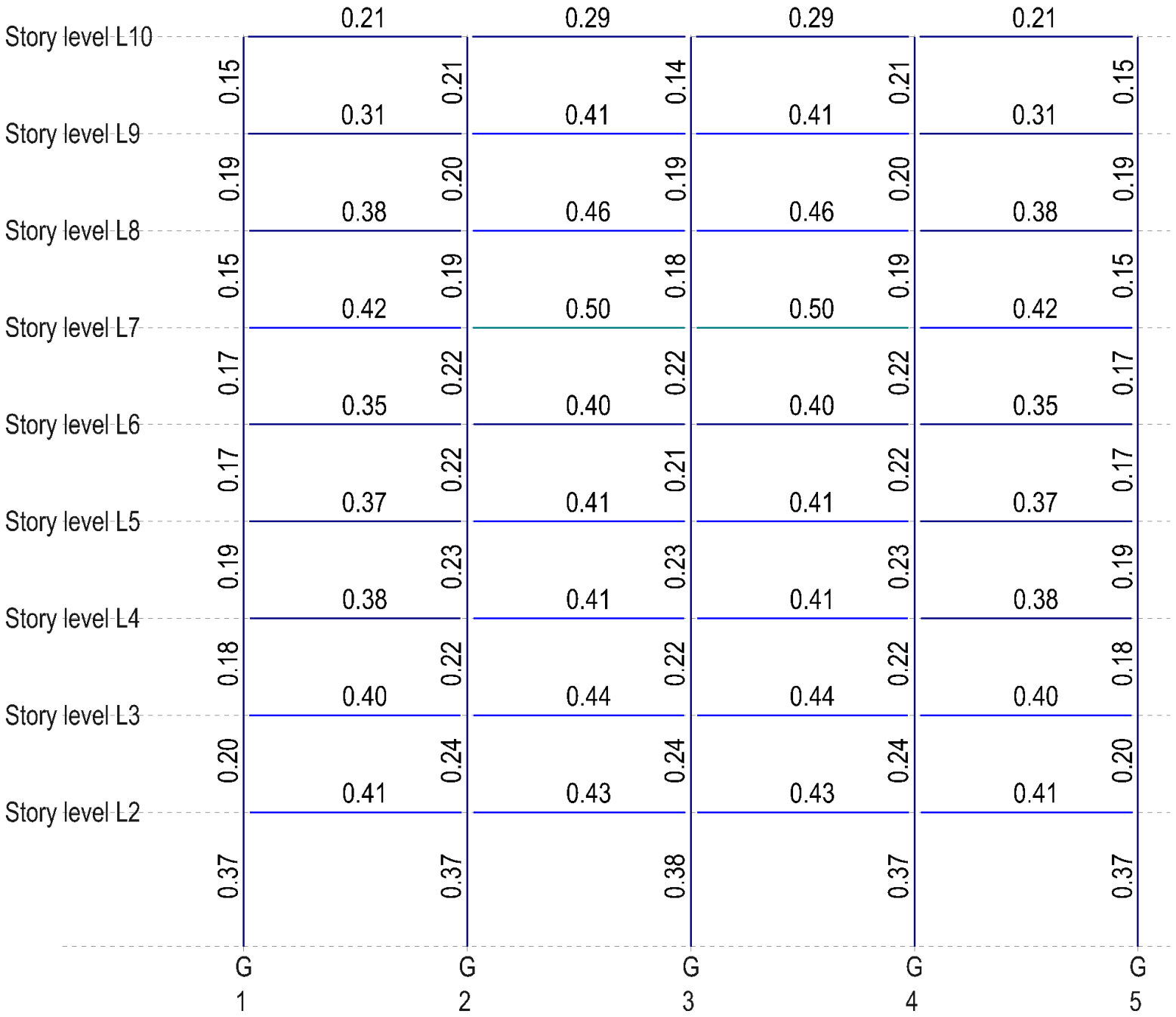
Note: No web doubler plates required (typical all frames)



FRAME ALONG GRIDLINE 5



FRAME ALONG GRIDLINE A



FRAME ALONG GRIDLINE G