TECHNICAL ASSIGNMENT 1

STRUCTURAL CONCEPTS / EXISTING CONDITIONS REPORT

Duquesne University Multipurpose/ Athletic Facility

Michael Szott
Structural Option
Advisor: M. Kevin Parfitt

October 5, 2006
Technical Report 1

Executive Summary

Duquesne University, located in the city of Pittsburgh, is in the process of expanding its campus. The land being developed is situated along Forbes Avenue, adjacent to the A.J. Palumbo Center, and "will be used for commercial and educational purposes, improving both the entrance to campus and the Forbes Avenue corridor." The first phase of the project, a multipurpose athletic facility, is currently under construction, and should be ready for use in January 2008. The building itself will be home to a variety of spaces including retail outlets, fitness and recreation facilities, athletic offices, and a ballroom/conference center.

The Multipurpose Facility rises 7 stories above grade, housing 125,000 square feet of floor space. The structure itself is comprised of composite steel, clad in red brick, rock face CMU, and glass. A steel pedestrian bridge spans from the 7th floor ballroom to an adjoining parking garage on Duquesne's campus.

The following report discusses the existing conditions of the building and the structural concepts used in its design. In addition to a description of the gravity and lateral systems within, spot check calculations have been done to verify the loading patterns associated with the building and to understand each systems function more accurately. These calculations were performed under the guidelines set forth in the 2003 International Building Code, referencing ASCE7-02. Typical plans and sketches of floor framing, lateral elements, and foundation systems are provided within to aid in one's understanding of each section.

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Structural System

The structural system of the Duquesne University Athletic Facility is designed to comfortably accommodate the buildings many functions. The entire framing system is designed using wide flange, composite steel sections. On the lower floors, a more dense column grid is used to support office, retail, and smaller athletic spaces. The upper stories are comprised of spacious gymnasiums and public gathering areas requiring an open plan. These levels contain framing that must span more than half the width of the structure. Lateral resistance is provided via concentrically braced frames located behind the exterior walls. The entire building is supported by auger cast piles and grade beams.

Foundation

The foundation consists of auger cast piles and grade beams. Each pile is a 24", 35 ton capacity pile, drilled to a depth between 22'-27'. The typical grade beam dimensions are 24"x36", with the largest beam being 72"x42". Each grade beam frames into a pile cap, whose depths ranging from 3'6" to 5'0". Each of these components are designed to have a minimum compressive strength, f'_c = 3000 psi, and contain deformed rebar in compliance with ASTM A615. (Figure 1.1)

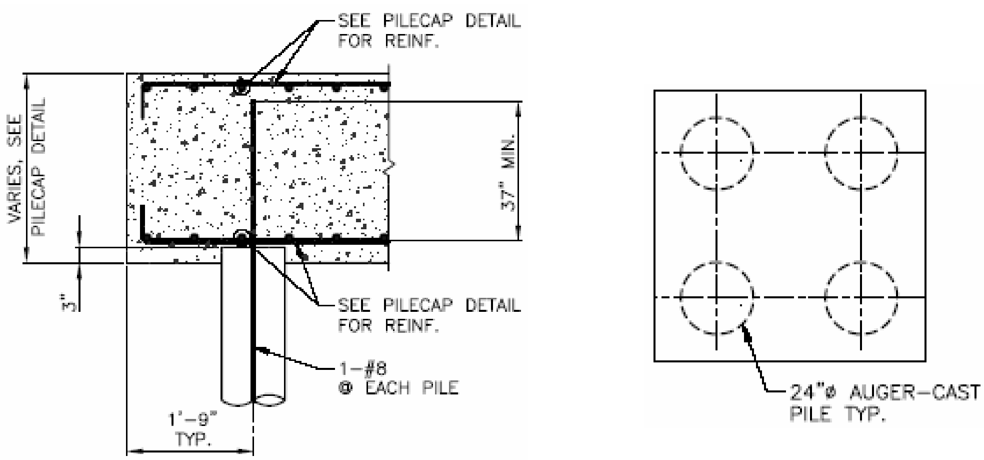


Figure 1.1 – Typical pile and pile cap detail

Columns

The columns associated with this facility are wide flange steel shapes ranging from W14x132's at the Watson Level (grade) to W8x24's at the Intermediate and High Roof Levels. The majority of the columns extend the entire seven story height of the building. Of that majority, the first splice level is typically seen at the third floor and every two floors thereafter. Because of the need for an open floor plan at the gymnasium and ballroom areas, these spaces were relegated to the upper floors of the facility. A more dense column grid is used on the lower floors, which contain spaces compatible with columns. All exterior columns are based on piers of strength, $f'_c = 5000$ psi.

Floor Framing

The floor framing for this structure is a composite slab and metal deck on composite wide flange beams and girders. The layout of the framing is dependent upon the loading and use of the floor above. The non-athletic spaces are generally framed in rectangular 20'x 25'-30' bays (Figure 1.2). For economy of cost and size, girders are placed in the short direction and thus the framing typically utilizes W18 beams and W16 girders. Of the remaining two athletic/gymnasium spaces, one is framed similarly to that of a typical floor, while the other is designed under different circumstances. The second gymnasium is located on the 5th floor, directly above the indoor running track of gymnasium one. Since a gym floor must be completely devoid of columns, the framing for the above floor consists of W36x210 beams, spanning 80'. These beams frame into smaller span girders, typically W27x84 members. (Figure 1.3)

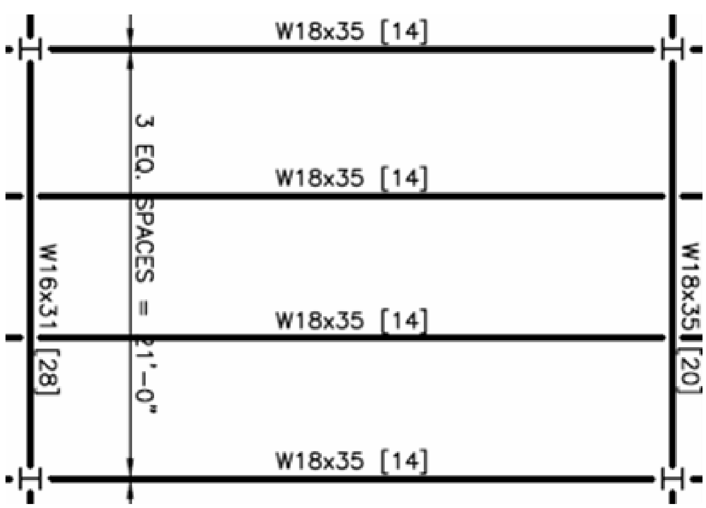


Figure 1.2 – Typical interior bay

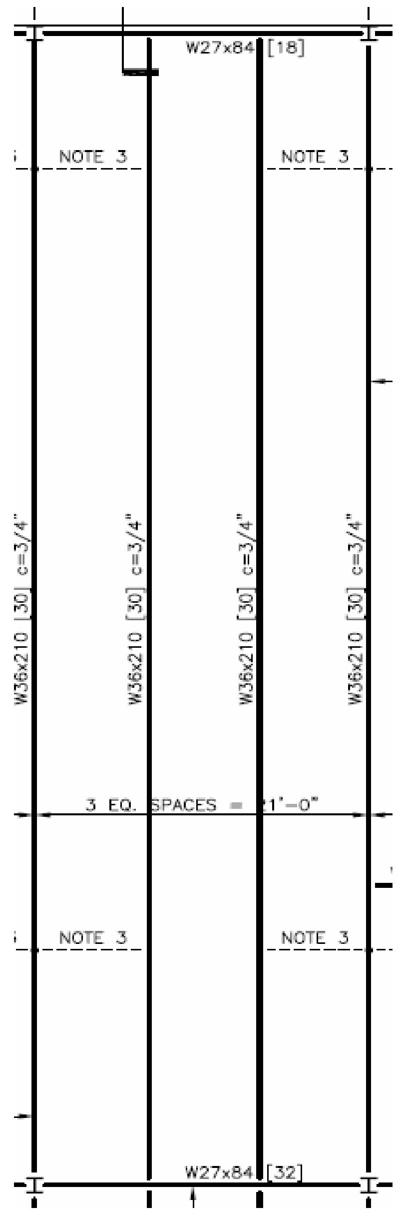


Figure 1.3 – 5th floor gymnasium

Lateral Elements

Lateral resistance is provided by a system of concentrically braced frames located on all four faces of the structure. On the South face of the building, frames are constructed around both elevator shafts and a stair tower. The same is true on the North and West faces of the building where bracing is positioned at stair towers. The typical columns used in each of bracing elements are W14's ranging from W14x53 to W14x132. Each floor to floor section makes use of a series of cross braced HSS members ranging in size from HSS6x4's to HSS8x4's, 1/4" to 5/8" thick. The bracing members designed to see 30 – 275 kips in tension. (Figure 1.4)

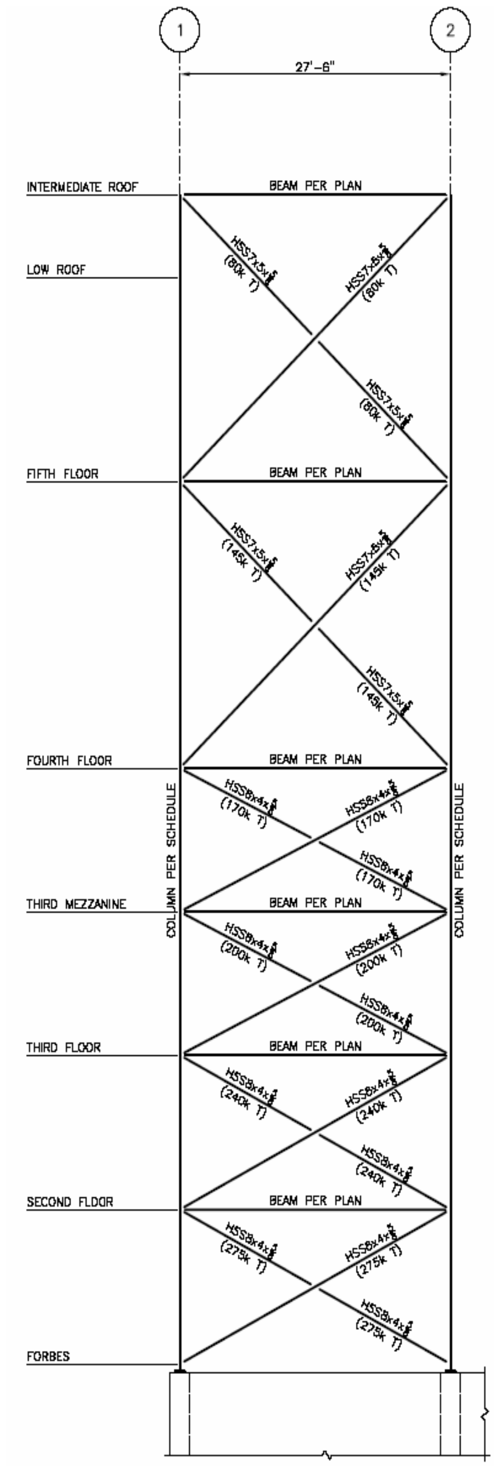


Figure 1.4 – Braced framing elevation

Codes and Code Requirements

Building Code:	International Building Code, IBC 2003 Referencing ASCE 7-02
Structural Concrete:	Code Requirements for Structural Concrete, ACI 318 Specifications for Structural Concrete, ACI 301
Structural Steel:	Specifications for Structural Steel Buildings AISC, 9th Edition ASD

Loading

Live Loads (ASCE 7-02, Table 4.1)

Lobbies and Public Spaces…………...........100 PSF
Corridors (above first floor)………………...80 PSF
Mechanical…………………………………75 PSF (assumed)
Athletic Floors………………………………100 PSF
Stairs and Exits…………………………….. 40 PSF
Offices………………………………………50 PSF

Dead Loads

Partition Allowance……………………….. 20 PSF
Reinforced Concrete Slab………………….. 150 PCF
Curtain Wall System………………………..15 PSF
MEP……………………………………….... 5 PSF
Metal Decking……………………………... 2-3 PSF (deck catalog)
Joist/Beam Weight…………………………Specific to each member

Snow Loading (ASCE Section 7, Figure 7.1)

Ground Snow……………………………….30 PSF
Flat Roof Snow…………………………….. 21 PSF
All other factors = 1.0

Wind Loading (ASCE 7-02)

Basic Wind Speed…………………………..90 MPH
Exposure Category…………………………III
Enclosure Classification……………………Enclosed
Building Category…………………………..B
Importance Factor………………………….. 1.15
Internal Pressure Coefficient………………..0.18

RESULTS						
z(ft)	k_z(T6-3)	q_z	$P_{sidewall}$(psf)	$P_{leeward}$(psf)	$P_{windward}$(psf)	P_{total}(psf)
0-15	0.57	11.554	-6.874	-8.959	7.856	16.816
20	0.62	12.567	-7.477	-8.959	8.546	17.505
25	0.66	13.378	-7.960	-8.959	9.097	18.056
30	0.70	14.189	-8.442	-8.959	9.648	18.607
40	0.76	15.405	-9.166	-8.959	10.475	19.434
50	0.81	16.418	-9.769	-8.959	11.164	20.124
60	0.85	17.229	-10.251	-8.959	11.716	20.675
70	0.89	18.040	-10.734	-8.959	12.267	21.226
80	0.93	18.851	-11.216	-8.959	12.818	21.777
90	0.96	19.459	-11.578	-8.959	13.232	22.191
100	0.99	20.067	-11.940	-8.959	13.645	22.604
120	1.04	21.080	-12.543	-8.959	14.335	23.294

Base Shear (N/S): **443.5 kips**
Overturning Moment: **28130 ft-kips**

Base Shear (E/W): **225.6 kips**
Overturning Moment: **14450 ft-kips**

Seismic Loads (ASCE7-02)

Seismic Design Category………………….. A
Seismic Use Group………………………… II
Importance Factor (I_E)…………………….. 1.25
S_S……………………………………………0.128
S_1……………………………………………0.057
S_{DS}…………………………………………..0.102
S_{D1}…………………………………………..0.065
Site Class……………………………………C
Response Coefficient
N-S…………………………0.0231
E-W…………………………0.0231
Response Modification Factor
N-S…………………………5
E-W…………………………5

Period (T) = 0.7
V = 356
K = 1.1

Level	Weight	Story Height h	h^k	Wx*hx^k	Cvx	Fx
2	2655	14	18.23	48396	0.04	13.0
3	2655	28	39.07	103738	0.08	27.8
Mezzanine	1800	41	59.44	106988	0.08	28.7
4	2655	54	80.47	213647	0.16	57.2
5	2655	80	123.99	329203	0.25	88.2
Low Roof	1460	104	165.48	241596	0.18	64.7
Inter. Roof	1460	114	183.06	267269	0.20	71.6
High Roof	92	120	193.69	17819	0.01	4.8
Sum	**15432**			**1328656**	**1**	**356.0**

Base Shear: **356 kips**
Overturning Moment: **27750 ft-kips**

Conclusions

Through my initial investigation of this structure, I have begun to understand my building more thoroughly. The system information, coupled with the spot checks and loading analysis have led me to believe that my assumptions in Technical Report 1 are accurate. Gravity loads from ASCE7-02 have yielded approximately the same structural elements used in the design documents. After a closer look at wind and seismic forces, I have concluded that the wind loads will control the design of lateral elements.

In addition to the contents of this report, I acknowledge that this analysis was not done with all encompassing factors in mind. For ease of calculation, I have made some general assumptions to simplify the analysis. The effects of parapet walls, irregularities in the geometry of the building, and the aspect of lateral soil pressure on the sub grade level were not included. Also, loading conditions and materials inside the building were approximated to a reasonable level in order to easily and accurately obtain the total weight of the structure.

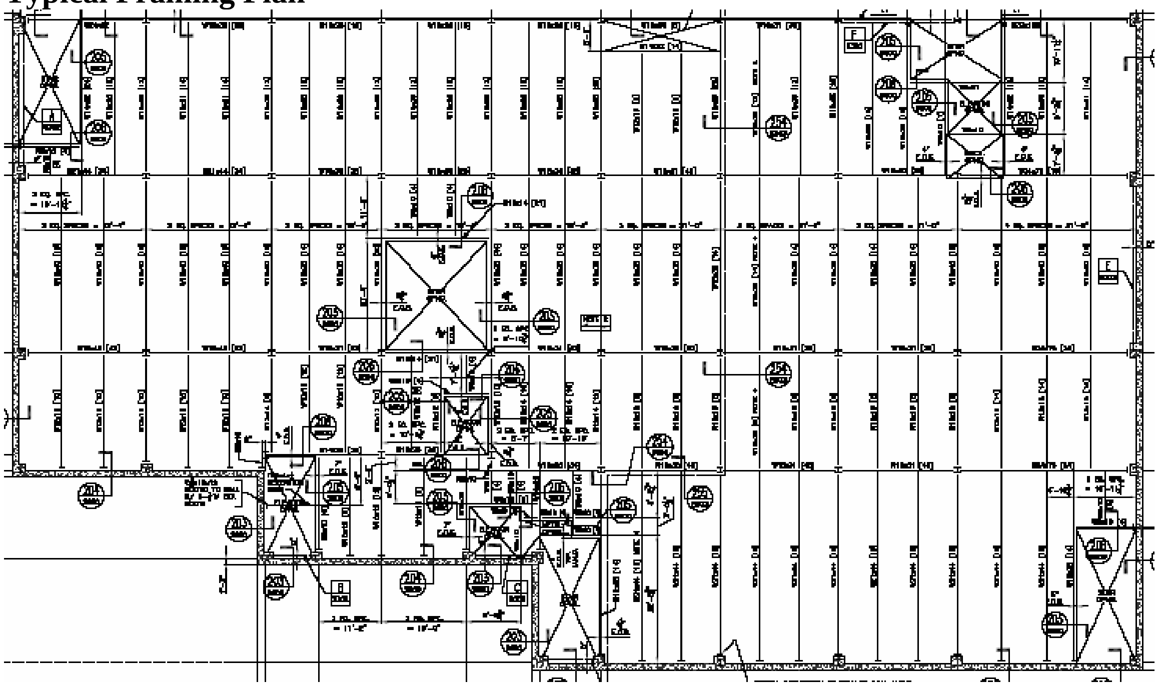
Structural Spot Checks

- Each load calculated by the designers was calculated using ASD methods
- Each load calculated as a check by the author of this report was obtained using LRFD methods (AISC Steel Manual: LRFD/ASD Edition)
- Approximations were made where necessary for ease of calculation

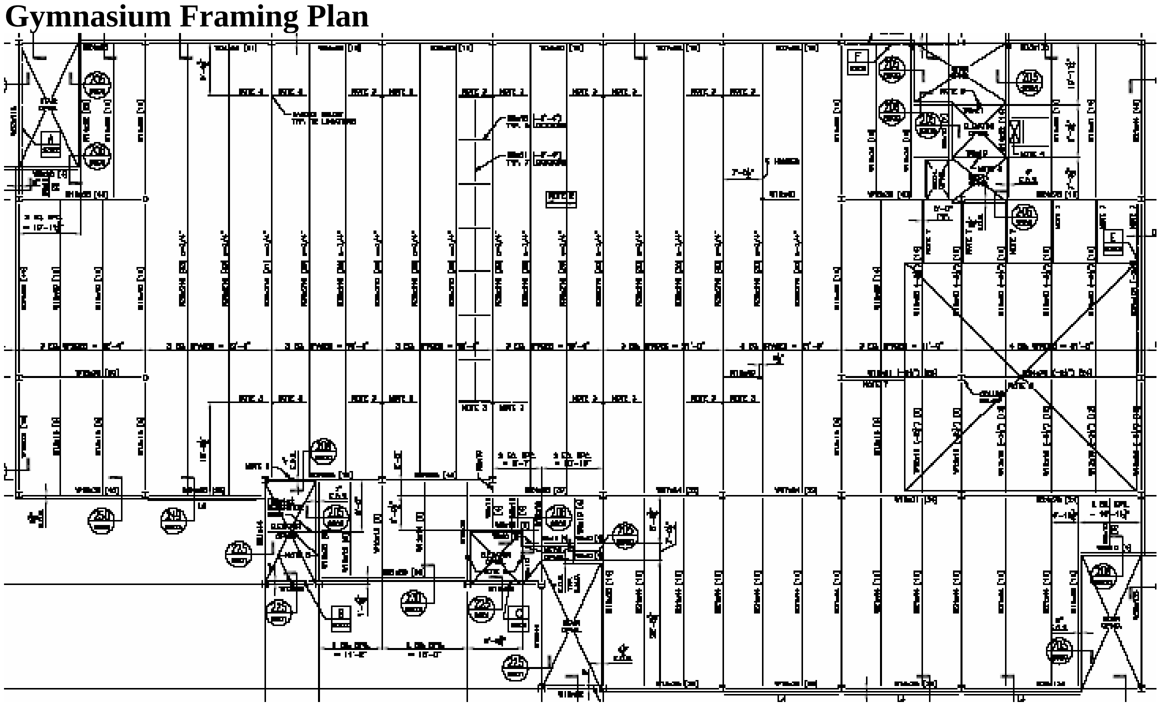
Appendices

A1: Floor Plans

Typical Framing Plan



Gymnasium Framing Plan



A2: Wind Load Analysis

North/South Direction

Building Name	Duquesne University Athletic Facility			
Building Location	Pittsburgh, PA			
Location Data	**Variable**	**Reference**	**Chart/Fig.**	**Value**
Occupancy Type	-	1.5.1	T1-1	III
Importance Factor	I	6.5.5	T6-1	1.15
Surface Roughness	-	6.5.6.2	-	-
Exposure Factor	-	6.5.6.3	-	B
Enclosure Classification**	-	-		Open
				Partially
			X	Enclosed
Internal Pressure Coefficient	GC_{pi}	-	-	0.18
Topographic	K_{zt}	6.5.7.2	F6-4*	1.00
*$K_{zt}=(1+k_1k_2k_3)^2$				
**Place an "X" in the box indicating Enclosure Classification				

Building Dimensions (ft)	Variable	Reference	Source	Value
Height Above Base	h_n	9.5.5.3	Spec	114
Height Above Ground	z	6.300	Spec	114
Horiz. Length II to Wind Dir.	L	6.300	Spec	116
Horiz. Length Perp. to Wind	B	6.300	Spec	200
Horizontal Dimension Ratio	L/B	F6-6	Spec	0.58
Mean Roof Height	h	6.200	*	114
*Average of roof eave height and height of highest point of roof				

Wind Velocity (mph)	Variable	Reference	Chart/Fig.	Value
Basic Wind Speed	V	6.5.4	F6.1	90
Wind Directionality	k_d	6.5.4.4	T6-4	0.85
3-sec Gust Power Law	α	6.300	T6-2	7.0
Mean Wind Speed Factor: α hat	a	6.5.8.2	T6-2	0.25
Wind Coefficient: b hat	b	6.5.8.2	T6-2	0.45
Min Height	z_{min}	6.5.8.2	T6-2	30
Equivalent Height: z hat	z	6.5.8.2	T6-2	68.4
Mean Hourly Wind Speed	V_z	6.5.8.2	Eq 6-14	71.27
Height atm Boundary	z_g	6.300	T6-2	1200
Velocity Pressure Exp.*	k_z	6.5.6.6	T6-3**	1.04
Velocity Pressure Exp.*	k_h	6.5.6.6	T6-3**	1.04
*Calculated for $(15'<z<z_g)$, or use Table 6-3				
**k_z and k_h: Use "Kz" Sheet to find value coordinating to largest "z"				

Integral Length Scale	Variable	Reference	Chart/Fig.	Value
Integral Length Scale Factor	l	6.5.8.1	T6-2	320
Integral Length Scale Exp	ε	6.5.8.1	T6-2	0.33
Integral Length Scale, Turb.	L_z	6.5.8.1	Eq 6-7	407.01
Turbulence Intensity Factor	c	6.300	T6-2	0.30
Intensity of Turbulence	I_z	6.5.8.1	Eq 6-5	0.27

Fundamental Period	Variable	Reference	Chart/Fig.	Value
Period Coefficient	C_t	9.5.3.2	T9.5.5.3.2	0.02
Period Exponent	x	9.5.3.2	T9.5.5.3.2	0.75
Approx. Fund. Period	T_a	9.5.3.2	$T_a=C_t(h_n^x)$	0.70
Natural Frequency	n_1	6.5.8.2	$n_1=1/T_a$	1.43
Rigid or Flexible?	-	6.5.8.2	$n_1>1?$	Rigid

Resonance	Variable	Reference	Chart/Fig.	Value	η
R_1 Coefficient	R_h	6.5.8.2	Eq 6-13	0.090	10.545
R_1 Coefficient	R_b	6.5.8.2	Eq 6-13	0.053	18.499
R_1 Coefficient	R_l	6.5.8.2	Eq 6-13	0.027	35.921
Reduced Frequency	N_1	6.5.8.2	Eq 6-13	8.184	
Resonance Coefficient	R_n	6.5.8.2	Eq 6-13	0.037	
Damping Ratio	β	6.300	Section 9	0.050	
Resonant Response Factor	R	6.5.8.2	Eq 6-10	0.044	

Gust Effect Factor	Variable	Reference	Chart/Fig.	Value
Gust Coefficient	g_q	6.5.8.2	Eq 6-8	3.4
Gust Coefficient	g_v	6.5.8.2	Eq 6-8	3.4
Gust Coefficient	g_r	6.5.8.2	Eq 6-9	4.27
Background Response	Q	6.5.8.1	Eq 6-6	0.81
Gust Factor	G_f	6.5.8.2	Eq 6-8	0.85

Wind Pressure	Variable	Reference	Chart/Fig.	Value
Velocity Pressure	qz	6.5.10	Eq 6-15	21.080
Velocity Pressure @ h	qh	6.5.12.2	T6-3*	21.080
*$q_h=0.00256k_hk_{zt}k_d(V^2)I$				

Ext. Pressure Coefficient	Variable	Reference	Chart/Fig.	Value
Windward Side	C_p	6.5.11.2	F6-6*	0.8
Leeward Side	C_p	6.5.11.2	F6-6*	-0.500
Sidewall	C_p	6.5.11.2	F6-6*	-0.7
*Formulas must be checked with any new code changes				
Leeward Pressure (psf)	P_1	6.5.12.2	$P_1=q_hG_fC_p$	-8.959
Final Pressure (psf)	$P=q_zG_fC_p-q_hG_fC_p$			

z(ft)	**k_z(T6-3)	q_z	$P_{sidewall}$(psf)	$P_{leeward}$(psf)	$P_{windward}$(psf)	P_{total}(psf)
0-15	0.57	11.554	-6.874	-8.959	7.856	16.816
20	0.62	12.567	-7.477	-8.959	8.546	17.505
25	0.66	13.378	-7.960	-8.959	9.097	18.056
30	0.70	14.189	-8.442	-8.959	9.648	18.607
40	0.76	15.405	-9.166	-8.959	10.475	19.434
50	0.81	16.418	-9.769	-8.959	11.164	20.124
60	0.85	17.229	-10.251	-8.959	11.716	20.675
70	0.89	18.040	-10.734	-8.959	12.267	21.226
80	0.93	18.851	-11.216	-8.959	12.818	21.777
90	0.96	19.459	-11.578	-8.959	13.232	22.191
100	0.99	20.067	-11.940	-8.959	13.645	22.604
120	1.04	21.080	-12.543	-8.959	14.335	23.294

East/West Direction

Building Dimensions (ft)	Variable	Reference	Source	Value
Height Above Base	h_n	9.5.5.3	Spec	114
Height Above Ground	z	6.300	Spec	114
Horiz. Length II to Wind Dir.	L	6.300	Spec	200
Horiz. Length Perp. to Wind	B	6.300	Spec	116
Horizontal Dimension Ratio	L/B	F6-6	Spec	1.72
Mean Roof Height	h	6.200	*	114
*Average of roof eave height and height of highest point of roof				

Wind Velocity (mph)	Variable	Reference	Chart/Fig.	Value
Basic Wind Speed	V	6.5.4	F6.1	90
Wind Directionality	k_d	6.5.4.4	T6-4	0.85
3-sec Gust Power Law	α	6.300	T6-2	7.0
Mean Wind Speed Factor: α hat	a	6.5.8.2	T6-2	0.25
Wind Coefficient: b hat	b	6.5.8.2	T6-2	0.45
Min Height	z_{min}	6.5.8.2	T6-2	30
Equivalent Height: z hat	z	6.5.8.2	T6-2	68.4
Mean Hourly Wind Speed	V_z	6.5.8.2	Eq 6-14	71.27
Height atm Boundary	z_g	6.300	T6-2	1200
Velocity Pressure Exp.*	k_z	6.5.6.6	T6-3**	1.04
Velocity Pressure Exp.*	k_h	6.5.6.6	T6-3**	1.04
*Calculated for (15'<z<z_g), or use Table 6-3				
**k_z and k_h: Use "Kz" Sheet to find value coordinating to largest "z"				

Integral Length Scale	Variable	Reference	Chart/Fig.	Value
Integral Length Scale Factor	l	6.5.8.1	T6-2	320
Integral Length Scale Exp	ε	6.5.8.1	T6-2	0.33
Integral Length Scale, Turb.	L_z	6.5.8.1	Eq 6-7	407.01
Turbulence Intensity Factor	c	6.300	T6-2	0.30
Intensity of Turbulence	I_z	6.5.8.1	Eq 6-5	0.27

Fundamental Period	Variable	Reference	Chart/Fig.	Value
Period Coefficient	C_t	9.5.3.2	T9.5.5.3.2	0.02
Period Exponent	x	9.5.3.2	T9.5.5.3.2	0.75
Approx. Fund. Period	T_a	9.5.3.2	$T_a=C_t(h_n^x)$	0.70
Natural Frequency	n_1	6.5.8.2	$n_1=1/T_a$	1.43
Rigid or Flexible?	-	6.5.8.2	$n_1>1$?	Rigid

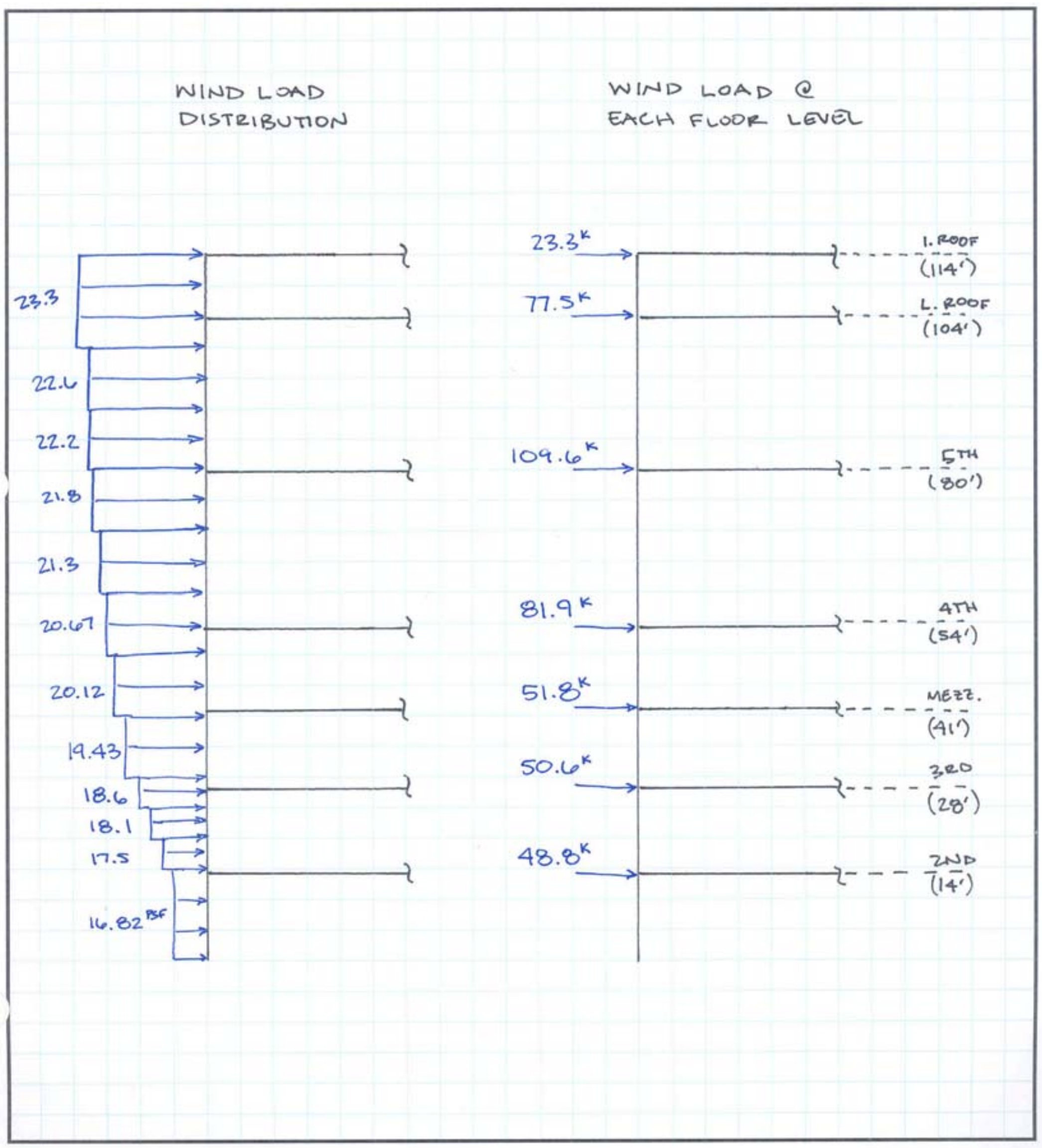
Resonance	Variable	Reference	Chart/Fig.	Value	η
R_1 Coefficient	R_h	6.5.8.2	Eq 6-13	0.090	10.545
R_1 Coefficient	R_b	6.5.8.2	Eq 6-13	0.089	10.730
R_1 Coefficient	R_l	6.5.8.2	Eq 6-13	0.016	61.933
Reduced Frequency	N_1	6.5.8.2	Eq 6-13	8.184	
Resonance Coefficient	R_n	6.5.8.2	Eq 6-13	0.037	
Damping Ratio	β	6.300	Section 9	0.050	
Resonant Response Factor	R	6.5.8.2	Eq 6-10	0.056	

Gust Effect Factor	Variable	Reference	Chart/Fig.	Value
Gust Coefficient	g_q	6.5.8.2	Eq 6-8	3.4
Gust Coefficient	g_v	6.5.8.2	Eq 6-8	3.4
Gust Coefficient	g_r	6.5.8.2	Eq 6-9	4.27
Background Response	Q	6.5.8.1	Eq 6-6	0.83
Gust Factor	G_f	6.5.8.2	Eq 6-8	0.85

Wind Pressure	Variable	Reference	Chart/Fig.	Value
Velocity Pressure	qz	6.5.10	Eq 6-15	21.080
Velocity Pressure @ h	qh	6.5.12.2	T6-3*	21.080
*$q_h=0.00256k_hk_{zt}k_d(V^2)I$				

Ext. Pressure Coefficient	Variable	Reference	Chart/Fig.	Value
Windward Side	C_p	6.5.11.2	F6-6*	0.8
Leeward Side	C_p	6.5.11.2	F6-6*	-0.355
Sidewall	C_p	6.5.11.2	F6-6*	-0.7
*Formulas must be checked with any new code changes				
Leeward Pressure (psf)	P_1	6.5.12.2	$P_1=q_hG_fC_p$	-6.364
Final Pressure (psf)	$P=q_zG_fC_p-q_hG_fC_p$			

z(ft)	**k_z(T6-3)	q_z	$P_{sidewall}$(psf)	$P_{leeward}$(psf)	$P_{windward}$(psf)	P_{total}(psf)
0-15	0.57	11.554	-6.874	-6.364	7.856	14.220
20	0.62	12.567	-7.477	-6.364	8.546	14.910
25	0.66	13.378	-7.960	-6.364	9.097	15.461
30	0.70	14.189	-8.442	-6.364	9.648	16.012
40	0.76	15.405	-9.166	-6.364	10.475	16.839
50	0.81	16.418	-9.769	-6.364	11.164	17.528
60	0.85	17.229	-10.251	-6.364	11.716	18.080
70	0.89	18.040	-10.734	-6.364	12.267	18.631
80	0.93	18.851	-11.216	-6.364	12.818	19.182
90	0.96	19.459	-11.578	-6.364	13.232	19.596
100	0.99	20.067	-11.940	-6.364	13.645	20.009
120	1.04	21.080	-12.543	-6.364	14.335	20.699



A3: Seismic Load Analysis

Seismic Loading
ASCE7-02
Calculation of Building Weight

Floor	Area		DL		Weight	
2	20000.000	SF	0.115	KSF	2300.000	kips
3	20000.000	SF	0.115	KSF	2300.000	kips
3/Mezzanine	12500.000	SF	0.115	KSF	1437.500	kips
4	20000.000	SF	0.115	KSF	2300.000	kips
5	20000.000	SF	0.115	KSF	2300.000	kips
Low Roof	9600.000	SF	0.115	KSF	1104.000	kips
Intermediate Roof	9600.000	SF	0.115	KSF	1104.000	kips
High Roof	800.000	SF	0.115	KSF	92.000	kips
		SF		KSF	0.000	kips
		SF		KSF	0.000	kips
		SF		KSF	0.000	kips
				Total:	12937.500	kips

Precast Panels

Wall	Perimeter		Height		DL		Weight	
2	632.000	LF	14.00	Ft	0.04	KSF	353.92	kips
3	632.000	LF	14.00	Ft	0.04	KSF	353.92	kips
3/Mezzanine	632.000	LF	14.00	Ft	0.04	KSF	353.92	kips
4	632.000	LF	14.00	Ft	0.04	KSF	353.92	kips
5	632.000	LF	14.00	Ft	0.04	KSF	353.92	kips
Low Roof	632.000	LF	14.00	Ft	0.04	KSF	353.92	kips
Intermediate Roof	632.000	LF	14.00	Ft	0.04	KSF	353.92	kips
						Total:	2477.44	kips

Total Building Weight:	15414.940	Kips

Calculation of Base Shear

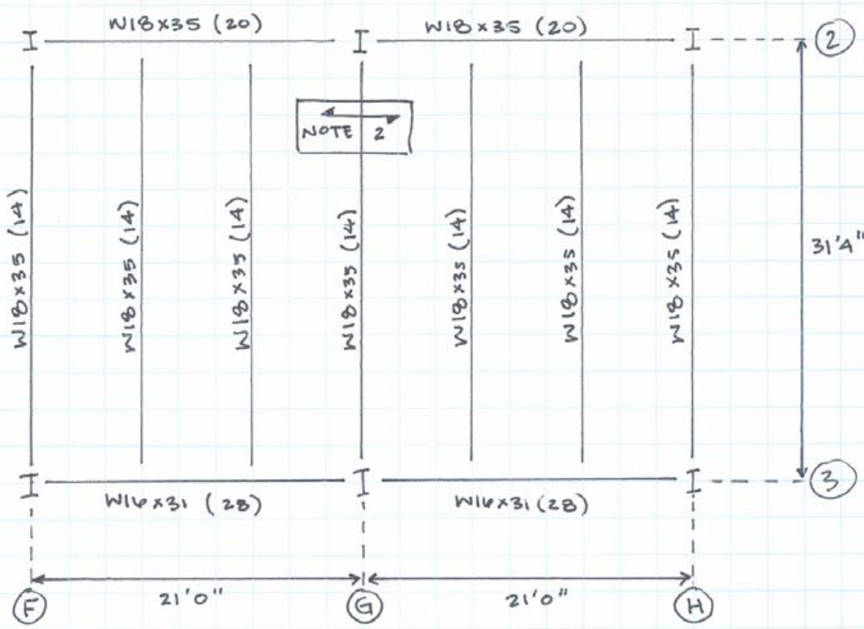
S_s	0.128	R	5	Ct	0.02	
S_1	0.057	Ω_0	5	x	0.75	
S_{ms}	0.154	C_d	5	h	114	ft
S_{m1}	0.097	I	1.25	Ta	0.70	
S_{ds}	0.102					
S_{d1}	0.065					

C_s	0.023

C_sW	356.78	kips

A4: Spot Check Calculations

TYPICAL INTERIOR BAY : 2ND FLOOR FRAMING



LOADING:

LIVE

ATHLETIC ⟶ 100 PSF

DEAD

PARTITION ⟶ 20 PSF

MEP ⟶ 5 PSF

MISC. ⟶ 5 PSF

METAL DECK ⟶ 3 PSF

SLAB ⟶ 70 PSF (DECK CATALOG)

NOTE 2: (PER DESIGNER)

4½" NWC

2" MTL. DECK

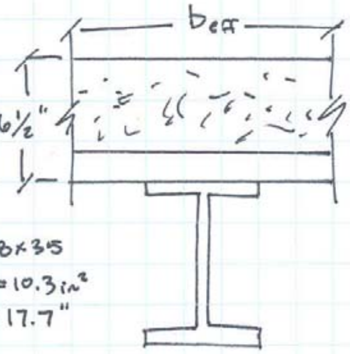
20 GAGE

REINF. W/ 6x6-W1.4xW1.4

SPOT CHECK BEAM

FACTORED LOAD : $1.2D + 1.6L$

$1.2(103) + 1.6(100) = 283 \text{ PSF } (7') = \underline{\underline{1985 \text{ PLF}}}$



W18x35
$A_s = 10.3 \text{ in}^2$
$d = 17.7"$

$W_u = 1.985 \text{ KLF} + 1.2\,(40 \text{ PLF})(7') = \underline{\underline{2.32 \text{ KLF}}}$ (SW)

$f'_c = 4 \text{ ksi}$

$f_y = 50 \text{ ksi}$

$b_{eff} = \begin{cases} \ell/4 = 7.85' \\ \text{SPACE} = 7' \therefore \text{USE} \checkmark \end{cases}$

$M_u = \frac{w\ell^2}{8} = \frac{2.32\,(31.33)^2}{8} = 284.6'^{K}$

$T = A_s f_y$ $\quad \Sigma Q_n = 515^K$

$= 10.3(50)$

$= \underline{\underline{515^K}}$

$\phi M_n = \left[515^K(5.6") + 515^K\left(\frac{17.7"}{2}\right)\right] 0.9$

$= 0.9(622'^K)$

$\boxed{\phi M_n = 560'^K > 285'^K \therefore \text{OK}}$

$C_c = 515^K = 0.85 f'_c b_{eff}\, a$

$515^K = 0.85(4)(84")a$

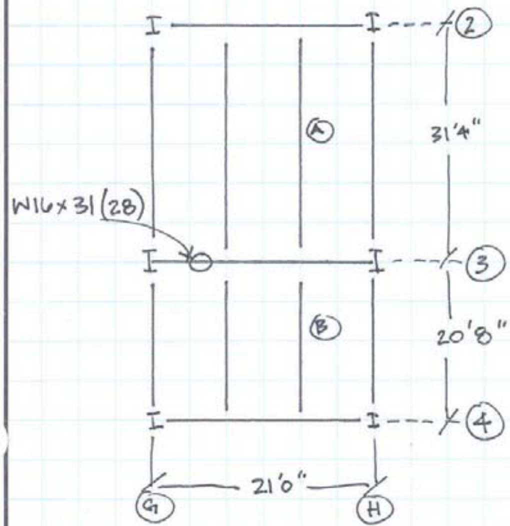
$a = 1.80"$

$Y2 = 6.5" - \frac{1.8"}{2} = 5.6" \therefore \text{OK}$

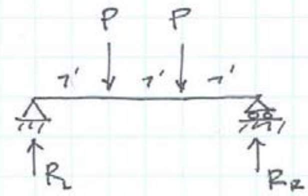
@ $Y2 = 5.5"$, TFL $\phi M_n = 554'^K$

ASSUMING THAT EXTRA LOADING IS PRESENT OR OTHER FLOOR AREAS REQUIRE THIS CONSTRUCTION (SYMMETRY), THE DESIGN IS JUSTIFIED.

SPOT CHECK TYPICAL GIRDER (2ND FLOOR)



*BEAMS SPACED EQUALLY



LOADS: $W_u = 1.985$ KLF

Ⓐ $\frac{1.985 \text{ klf} (31.33')}{2} = \underline{\underline{31.1^K}}$

Ⓑ $\frac{1.985 \text{ klf} (20.67')}{2} = \underline{\underline{20.5^K}}$

$M_{MAX} = Pa$
$= 51.6^K (7')$
$= \underline{\underline{361.2'^K}}$

$\underline{\underline{P_{TOTAL} = 51.6^K}}$

(LRFD, T3-10, T3-19) ∴ TRY W18×50

$\phi M_p = 379'^K > 361.2'^K$

$A_s = 14.7 \text{ in}^2$
$d = 18"$

∴ DESIGNER USES W16×31 (28)

COLUMN CHECK (COLUMN J-4)

- INTERIOR GRAVITY COLUMN
- EXTENDS FROM WATSON LEVEL (GRADE) TO LOW ROOF
- NO LATERAL LOADS CONTRIBUTE TO LOADING

SIZES:

WATSON, FORBES, 2ND FL., 3RD FL. } W12x96

4TH FL., 5TH FL. } W12x65

ROOF - W12x40

LOADING: ROOF

SNOW/ROOF LIVE : $0.7p_g = 0.7(30) = 21\text{ psf}\,(1.6) = 34\text{ psf}$

DEAD {
SLAB + DECK : $20\text{ psf}\,(1.2) = 24\text{ psf}$
BEAMS (: $30\text{ psf}\,(1.2) = 36\text{ psf}$
}

94 PSF TOTAL

$A_T = 26' \times 27' = 702\text{ sf}$

$$\frac{702\text{ sf}\,(94\text{ psf})}{1000\#} = 66^K$$

LRFD ; T4-1

W12x40

$KL = 26'$

$\phi P_n = 102^k > 66^k \quad \therefore \text{ok}$

5TH FLOOR (+66^K)

$L = L_o (0.25 + 15/\sqrt{A_I})$
$= L_o (0.25 + 15/\sqrt{4560})$
$= 0.473 L_o$

LIVE: 100 PSF (1.6)(0.473) = 76 PSF
SLAB: 70 PSF (1.2) = 84 PSF
BEAMS: 60 PSF (1.2) = 72 PSF
232 PSF TOTAL

$A_T = 1140$ SF

$$\frac{232\text{ PSF}(1140\text{ SF})}{1000\#} = 264^K + 66^K = 330^K$$

LRFD: T4-1

W12x65
KL = 26'
$\phi P_n = 393^K$ ∴ OK

4TH FLOOR (+330^K)

$L = L_o (0.25 + 15/\sqrt{2880})$
$= 0.529 L_o$

LIVE: 100 PSF (1.6)(0.529) = 85 PSF
SLAB: 80 PSF (1.2) = 96 PSF
BEAMS: 10 PSF (1.2) = 12 PSF
193 PSF TOTAL

$A_T = 710$ SF

$$\frac{710\text{ SF}(193\text{ PSF})}{1000\#} = 137^K + 330^K = 467^K$$

LRFD: T4-1

W12x65
KL = 13'
$\phi P_n = 706^K$ ∴ OK

(MEZZANINE)

3RD FLOOR $(+467^k)$

$L = L_o\left(0.25 + 15/\sqrt{2735}\right)$
$= 0.537 L_o$

LIVE: 100 PSF (1.6)(0.537) = 86 PSF
SLAB: 70 PSF (1.2) = 84 PSF
BEAMS: 10 PSF (1.2) = 12 PSF
182 PSF TOTAL

$A_T = 676$ SF

$$\frac{676\text{ SF}(182\text{ PSF})}{1000\#} = 123^k + 467^k = \underline{\underline{590^k}}$$

LRFD: T4-1

W12x96
KL = 13'
$\phi P_n = 1050^k$ ∴ OK

3RD FLOOR $(+590^k)$

$L = L_o\left(0.25 + 15/\sqrt{2808}\right)$
$= 0.533 L_o$

LIVE: 100 PSF (1.6)(0.533) = 86 PSF
SLAB: 70 PSF (1.2) = 84 PSF
BEAMS: 10 PSF (1.2) = 12 PSF
182 PSF

AS IN MEZZ (3) = $123^k + 590^k = \underline{\underline{713^k}}$

LRFD: T4-1

W12x96
KL = 14'
$\phi P_n = 1020^k$ ∴ OK

ASSUMING 2ND / 1ST FLOORS ARE THE SAME AS THE 3RD:

2ND $(+713^k)$

$123^k + 713^k = 836^k$

LRFD: T4-1

FORBES $(+836^k)$

$123^k + 836^k = 959^k$

W12x96

$KL = 14'$

$\phi P_n = 1020^k \quad \therefore$ OK

CHECK @ 2ND FLOOR LEVEL:

P_u @ 2ND $= 836^k$

M_u @ 2ND $= 285'^k = FEM \longrightarrow \frac{FEM}{2} = 142.5'^k$

$\alpha = 24/d = 24/12 = 2$

$P_{EFF} = P_u + \alpha M_u = 836^k + 2(142.5'^k) = 1121^k$

* FLOOR LOAD (BEAM) NOT REDUCED

FLOOR LIVE = 100 PSF

$L = L_o(0.25 + 15/\sqrt{A_I})$

$= L_o(0.25 + 15/\sqrt{660})$

$= 0.84 L_o$

$100\,psf(0.84) = 84\,psf$

$84\,psf(7') = 588\,plf$

$M_o = \frac{w\ell^2}{8} = 75'^k$

$P_{EFF} = P_u + \alpha M_u$

$= 836 + 2(75)$

$= 986^k$

LRFD: T4-1

W12x96

$KL = 14'$

$\phi P_n = 1020^k \quad \therefore$ OK

LATERAL SPOT CHECK

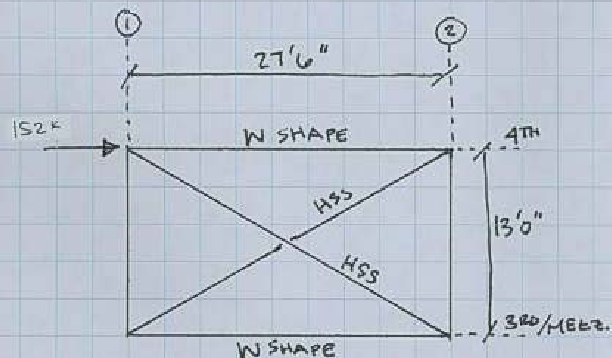
FRAMES BETWEEN A1-A2 ; 3RD MEZZ. - 4TH FLOOR
K2-K3 ; 3RD MEZZ - 4TH FLOOR

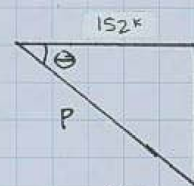
* A1A2 : $\Delta = 0.06090''$; $1/\Delta = 16.42$
* K2K3 : $\Delta = 0.06585''$; $1/\Delta = 15.186$
* UNDER A 100K LOAD

A1A2: $16.42/\Sigma = 0.5195$
K2K3: $15.186/\Sigma = 0.4805$

LOAD @ 4TH FLOOR LEVEL (WIND): Σ LOAD FROM ROOF = 292.1^K

ALONG COLUMN LINE A:





$\theta = \tan^{-1}(13'/27.5')$
$\theta = 25.3°$

$L = 27.5'/\cos 25.3° = 30.4'$

$\cos\theta = 152/P$
$P = 168^K$

** DESIGNED TO TAKE 170^K OF LOAD IN TENSION