School Without Walls

Washington, D.C.

Tech Report #1

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Structural Option

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EXECUTIVE SUMMARY

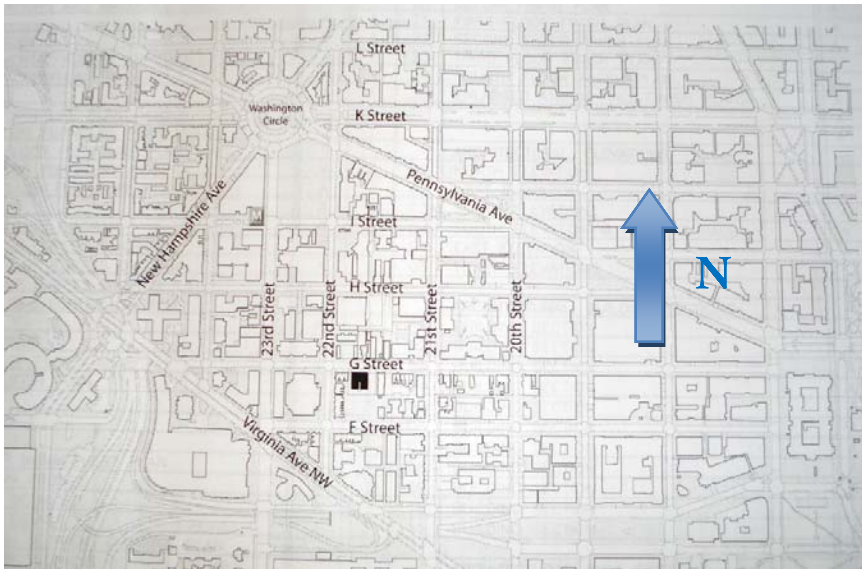
The purpose of this first technical report for the School Without Walls project in Washington D.C. is to analyze and provide an overview and explanation of the structural systems including the foundation, floor framing plans and lateral systems. A list of materials, material properties, and building codes used for analysis are also provided in this report. It is very important to recognize, that for the evaluation of the structural system, the most current building code, IBC 2006, was utilized whereas the structure was designed using IBC 2000.

A detailed lateral load analysis for seismic and wind loads was conducted according to ASCE 7-05. An expansion joint separates the existing 127 year old school from the new addition that was constructed. An expansion joint also divides the new addition, therefore creating essentially 3 buildings and 3 lateral systems. The division of the lateral systems can be viewed on page 10 of this report. The 4-story portion of the addition, referenced as Area 2 in the lateral load section of this report, is the lateral system in which was chosen for analysis. Wind was analyzed using Method 2 of chapter 6 and seismic was analyzed using chapters 11 and 12. It was found that wind blowing in the East-West direction is the controlling factor of the design of the lateral system.

A Beam spot check was conducted on a typical bay, located on the south side of the 2-story addition. The results and calculations were very similar to the beam used in design with only a slight variation in the number of shear studs. Discrepancies however occurred in the analysis of a column on the north end of the 4 story addition. This difference may be due to differing design loads or due to the fact that the column supports a braced frame which was not included into the analysis. Lateral loads were not taken into effect for the analysis.

Appendices located at the end of this technical report contain calculations, charts, figures and tables which verify all findings.

INTRODUCTION



Vicinity Map (Figure 1)

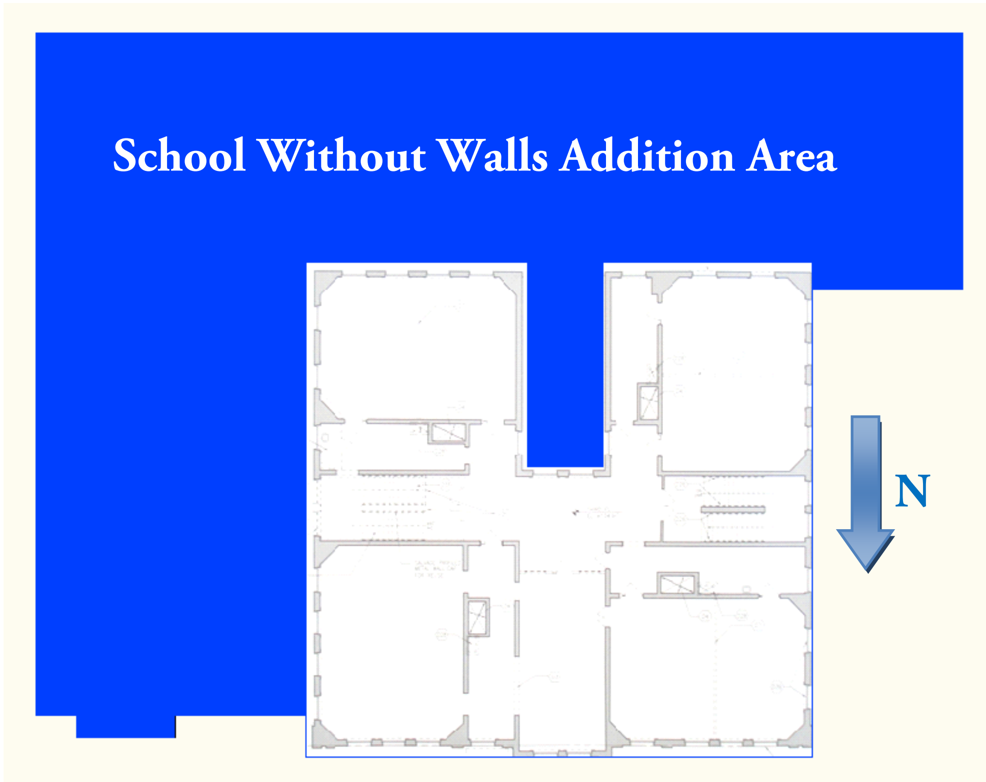
The Grant School has stood in the heart of the George Washington University campus since 1882 and has housed the School Without Walls since 1977. The "School Without Walls" name comes from the manner in which the students are taught. The academic curriculum is set up to encourage students to use the city as an active classroom, thus not restraining learning to the walls of the school.

The original 32,300 square foot, three story school was in dire need to modernize and expand due to the increasing number of students and outdated equipment. The 68,000 square foot addition and modernization, located in blue in figure 4, blends the 19th century School with a modern design by combining brick patterns with glass and metal windows and curtain walls. The existing three story school is made up of four large classrooms per floor, one at each corner of the square building. The new addition of the school provides an additional two large classrooms on each floor, an open atrium space, a large student commons, roof terrace area and a library. The basement was also reengineered and redesigned to serve as scientific laboratories for the school.

The School Without Walls project is expected to receive LEED Gold Certification.

Pre-modernization and Addition (Figure 2)


Post-modernization and Addition (Figure 3)



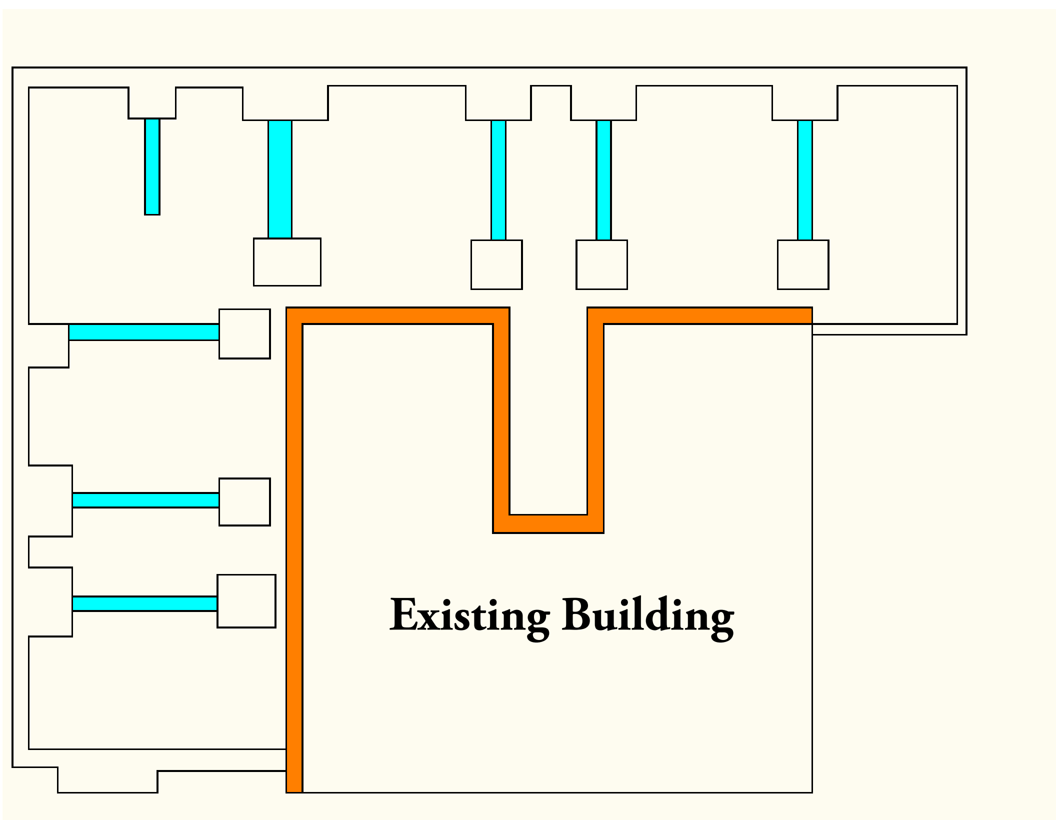
School Without Walls Addition (Figure 4)

North Elevation, Post-modernization and Addition (Figure 5)

STRUCTURAL SYSTEM

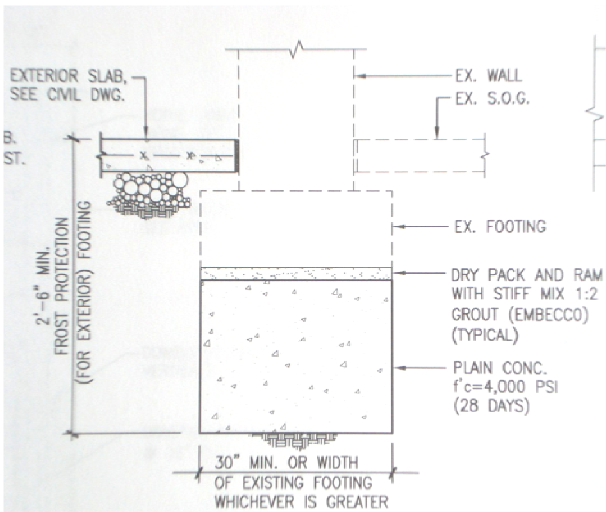
Foundation

The geotechnical engineering study was performed by Thomas L. Brown Associates, P.C. on January 28, 2007. After performing a series of in-situ tests, and after considering the lab test results, anticipated loads, and settlement analyses, a shallow foundation consisting of reinforced cast-in-place spread footings and grade beams was deemed appropriate. Based on the testing and analysis, the footings should be designed for an allowable bearing capacity of 3.0 ksf. Typical footings of the addition are 2' 6" wide by 2'0" tall and rest on compacted earth 3'0" below the top of the slab-on-grade. Typical grade beams, located in cyan on figure 6, along the east side of the building are 30"x30" and are 30"x24" along the south side of the building.



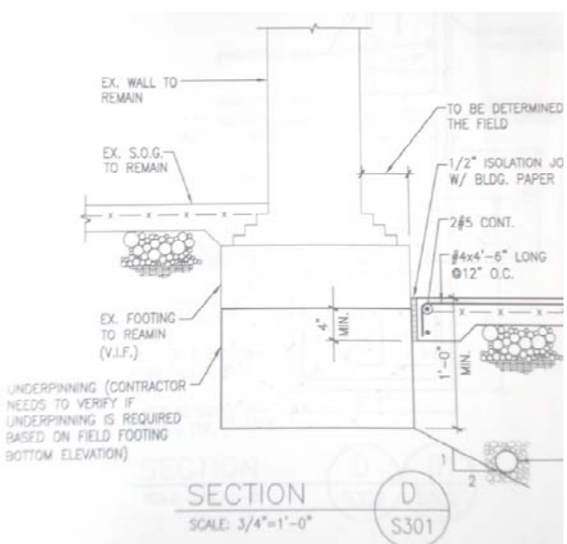
Foundation System (Figure 6)

Due to the increased load and the disruption of earth, underpinning the existing footings of the school became necessary. The area requiring underpinning is shown in orange on figure 5. The underpinning sequence will be performed in sections no larger than 4 feet wide, approximately spaced 12-15 feet apart.



Underpinning Detail (Figure 7)

Footing to be Underpinned (Figure 8)

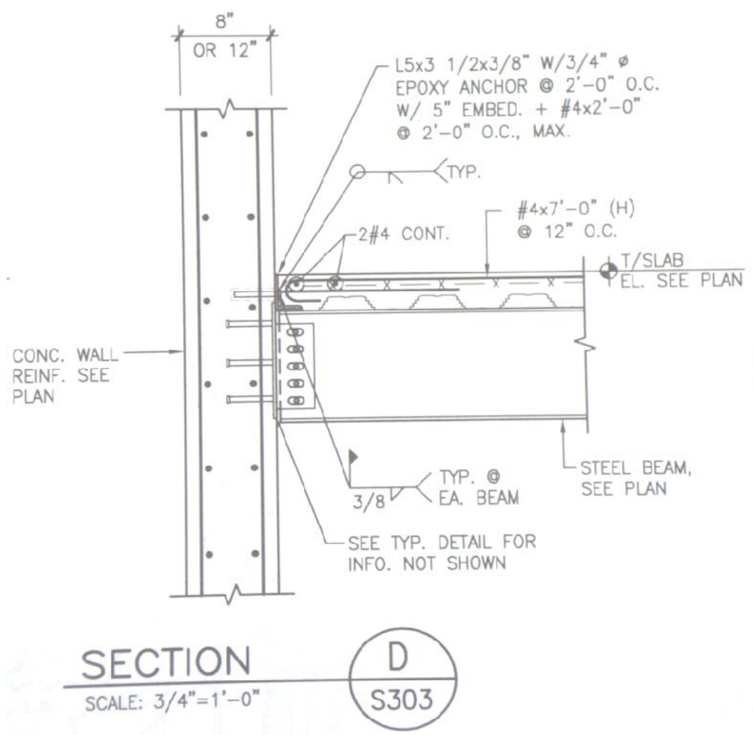


Exterior Wall of Existing Building (Figure 9)

The-slab-on grade in the original building will be removed and replaced by a 5" NWC slab-on-grade over gravel, at an elevation of +64.14'. The slab then ramps down into the new addition of the building to an elevation of +62.64'. This change in slab elevation can be viewed in figure 9. The slab-on-grade of the new addition will be 5" NWC over a 10 mil vapor retarder and 8" of free draining granular base.

Floor System

The floor system of School Without Walls is a composite system. The floor slab of the new addition is 3 ¼" LWC topping over a 2" 20 GA composite steel floor decking, bringing the total floor slab to 5 ¼" thick. Along the top flange of the beam, ¾"x4" long headed shear studs will be used for composite action. Bearing plates, shown in figure 10, are used on the first floor exterior wall of the new addition to carry the load of the beams and joists. Above the first floor, girders span between columns to carry this load.

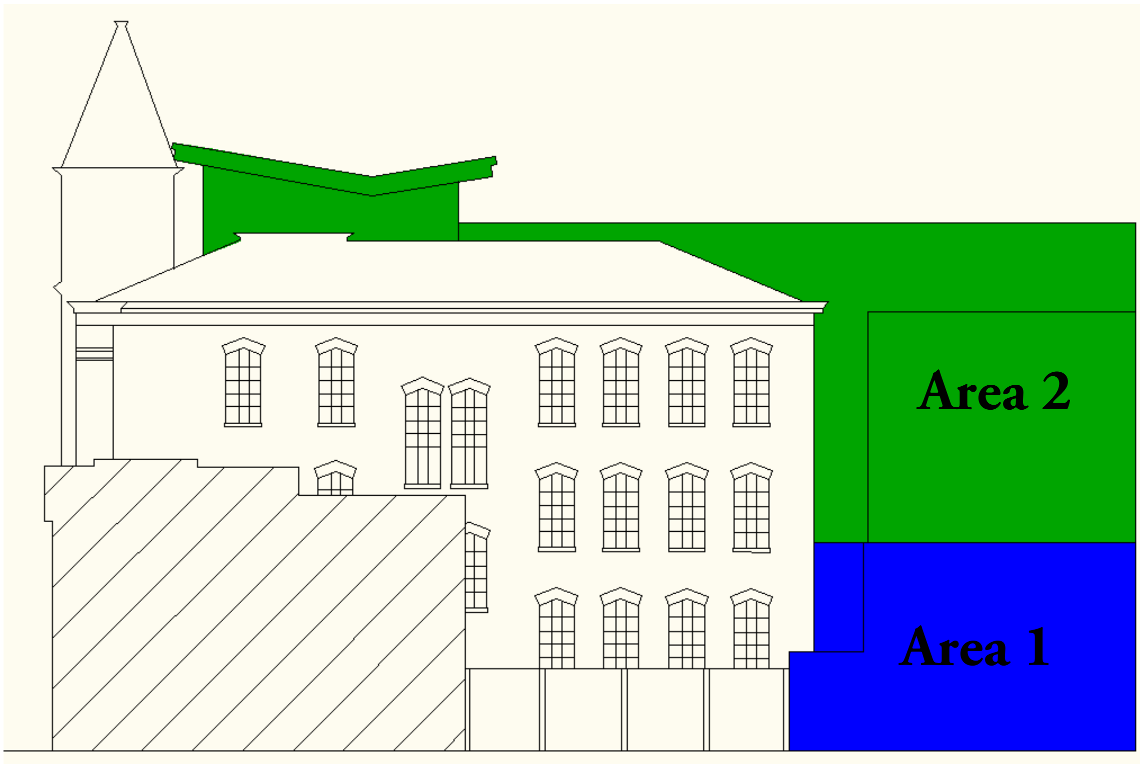


Bearing Plate Example (Figure 10)

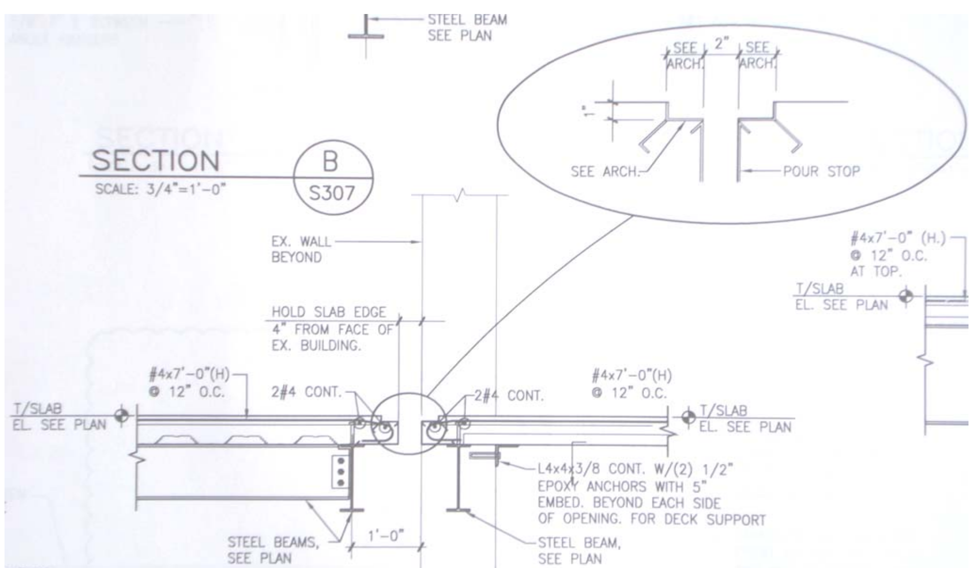
Lateral System

The lateral system of School Without Walls works as three different systems due to expansion joints. A 4" expansion joint separates the original school from the addition. A detail of this expansion joint can be observed in figure 13. An expansion joint is used to separate the addition of the school into two lateral systems. The structure supporting the outside terrace, Area 1 acts alone, as well as the structure supporting the library, Area 2. For the discussion of the lateral system, these sectors will be referred to as Area 1, Area 2, and Existing Building, as seen in figure 11 and figure 12.

Separate Lateral Systems to the Building (Figure 11)

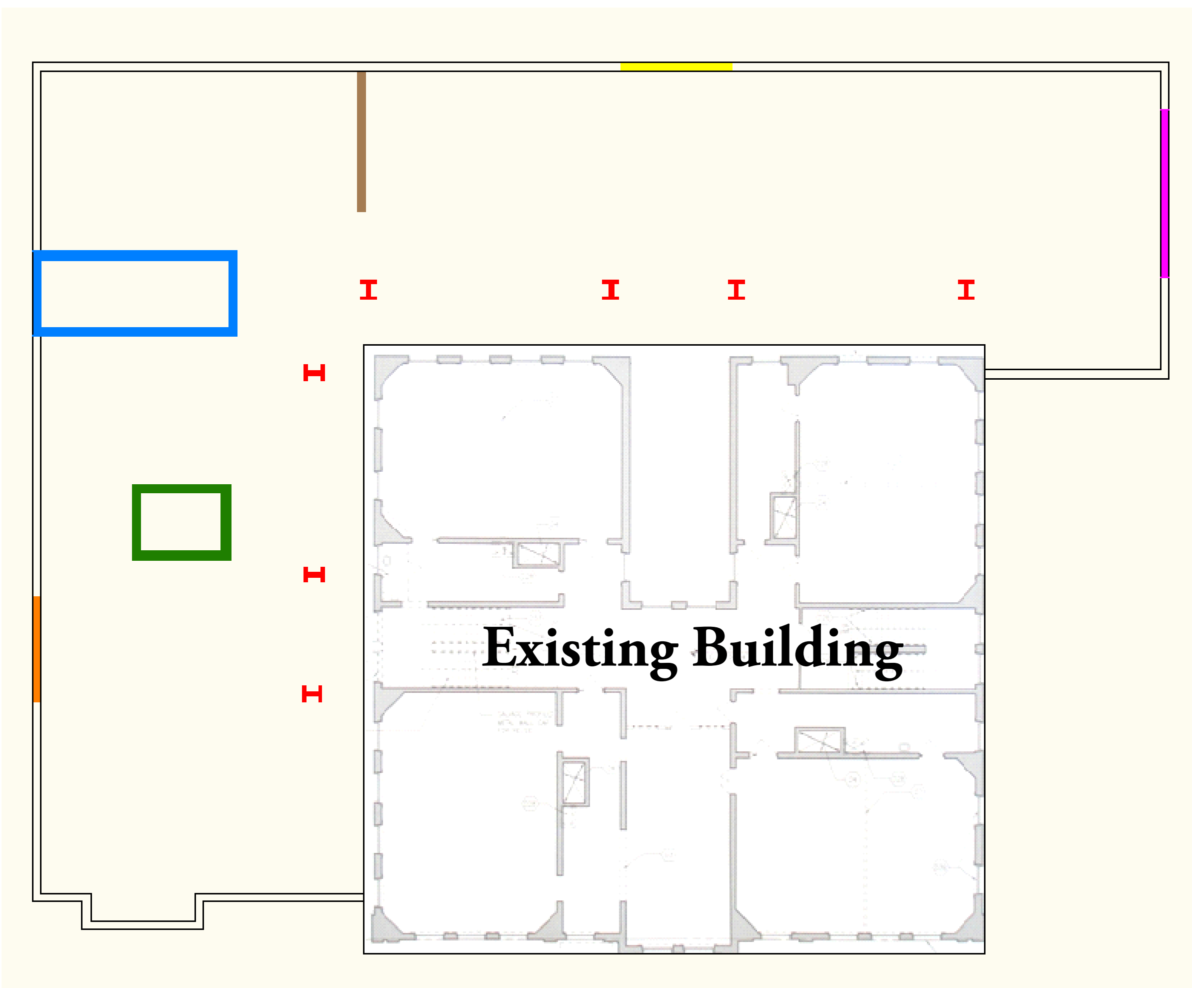


West Elevation Showing Area 1 and Area 2 (Figure 12)

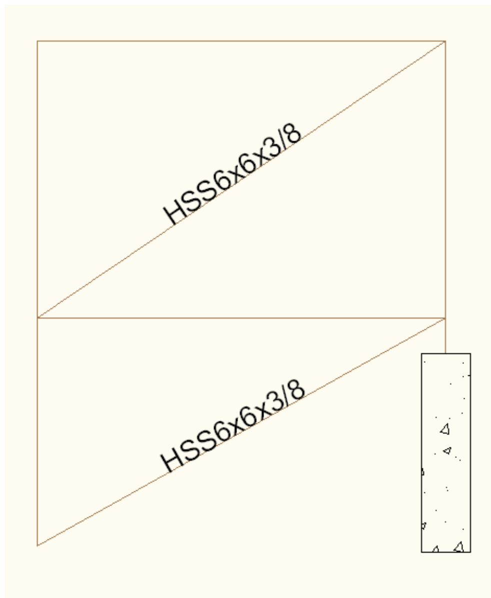


Expansion Joint on Building (Figure 13)

Columns surrounding the existing school, both in Area 1 and Area 2 sections have moment connections, located in red in figure 14, to resist lateral load. The Area 1 addition of the building utilizes a braced frame system to resist lateral load. The Area 2 addition utilizes a 12" concrete shear wall (located in blue in figure 14) at the stair core, and an 8" concrete shear wall (located in green in figure 14) at the elevator core. A braced frame is also used along the east exterior face of Area 2.

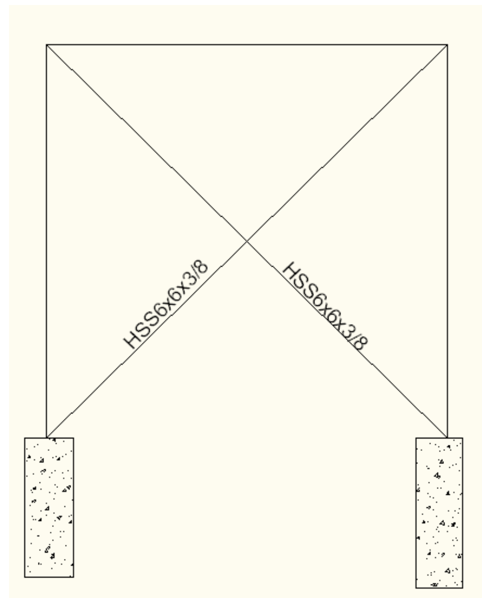


Lateral Systems (Figure 14)



Roof

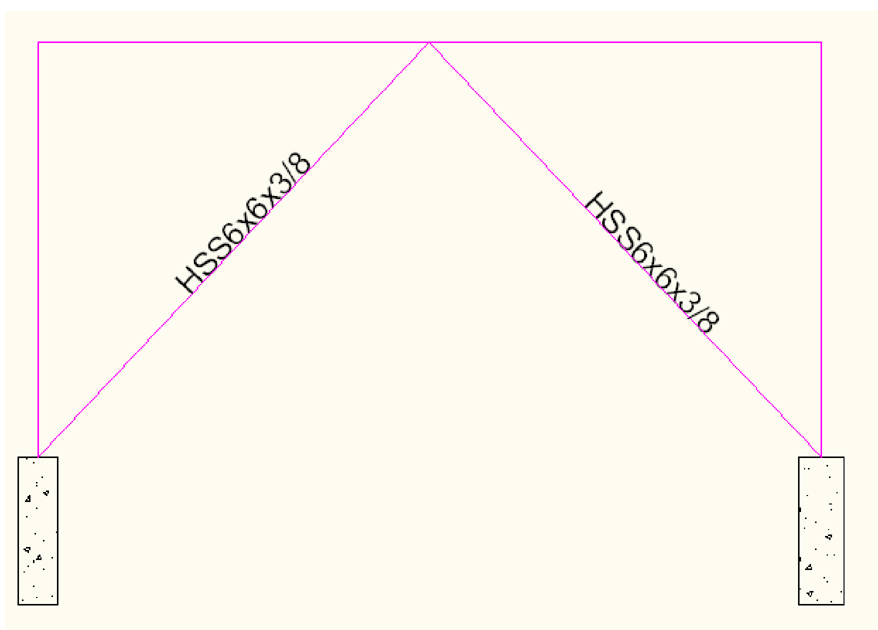
First Floor



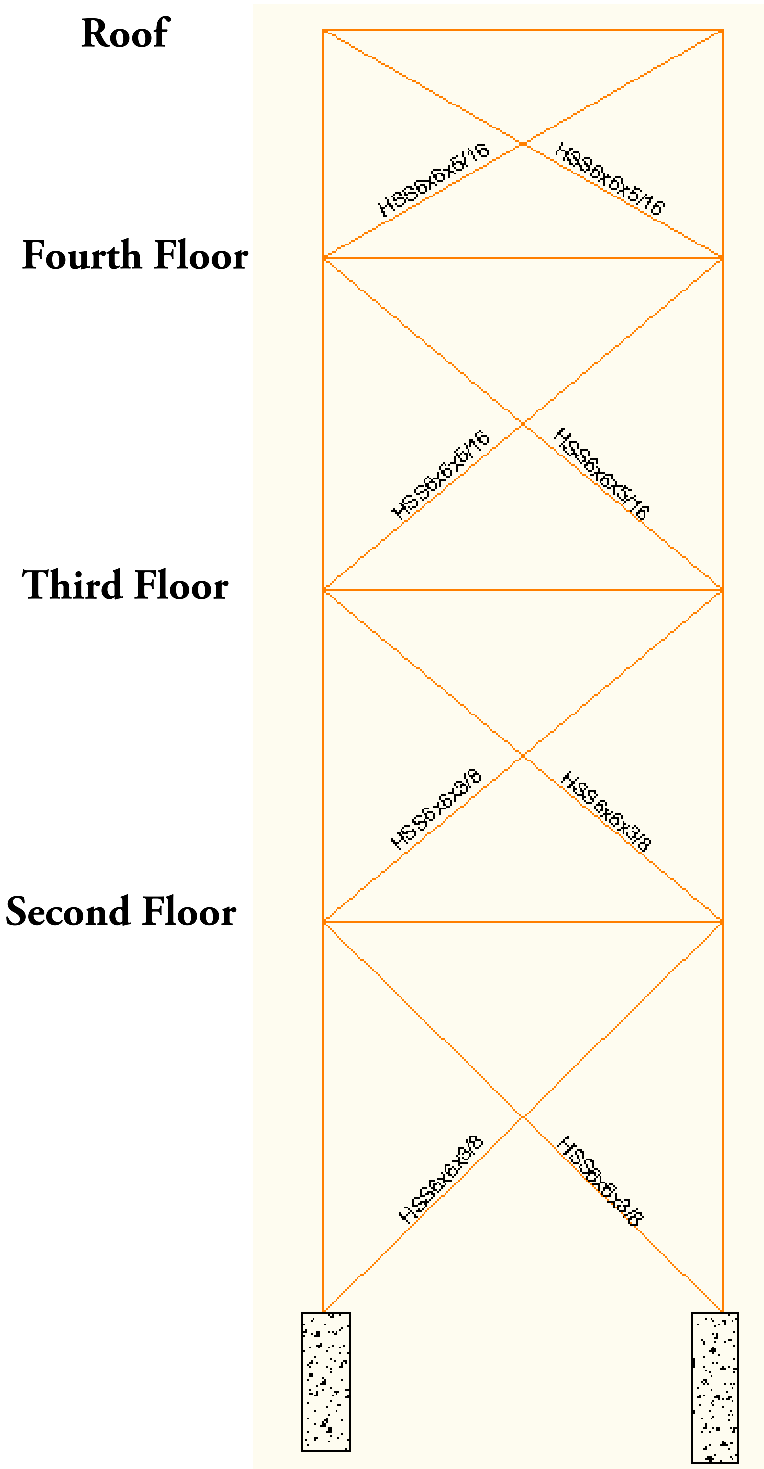
Lateral Bracing, Located in Brown (Figure 15)

Lateral Bracing, Located in Yellow (Figure 16)

Roof



Lateral Bracing, Located in Purple (Figure 17)



Lateral Bracing, Located in Orange (Figure 18)

CODE AND DESIGN REQUIREMENTS

Major Design Codes and Standards

- International Building Code 2000
- District of Columbia Construction Code/ Supplement 2003
- American Concrete Institute (ACI 318-99)
- ASCE- 7 *Current Edition*
- AISC- ASD *9th Edition*
- AISC- LRFD *3rd Edition* (Composite Beam Design Only)

Thesis Codes

- International Building Code 2006
- AISC Steel Construction Manual *13th edition*
- American Concrete Institute (ACI 318-05)

MATERIALS

Structural Steel:

Wide Flanges……………………………………ASTM A-572 or A-992, Grade 50
Channels, Angles, Plates…………………………………………… ASTM A-36
Hollow Structural Sections (HSS)…………………………ASTM A-500, Grade B
Pipes……………………………………………ASTM A-53, Type E or S, Grade B

Metal Decking:

2" Composite Metal Deck………………………………………… ……..20 Gage

Bolts:

High Strength Steel Bolts…………………………ASTM A-325 or ASTM A-490
Anchor Bolts…………………………………………………ASTM F-1554, Grade 36

Concrete:

Over Composite Metal Deck……………………………………………f'c = 4,000 psi
Grout for CMU walls…………………………………………………… f'c = 3,000 psi
All Concrete Components U.O.N…………………………………...f'c = 4,000 psi

Reinforcing Steel:

Reinforcing Bars……………………………………………ASTM A-615, Grade 60
Welded Reinforcing…………………………………………ASTM A-706, Grade 60

Wood:

All Wood U.O.N……………………………………………… No. 2 Hem-Fir (North)

LOADS

Live Loads

Load Description	Load
Administrative Office	50 psf
Classrooms	40 psf
Corridors Above First Floor	80 psf
First Floor Corridors	100 psf
Student Commons	100 psf
Storage	125psf
Media Center	60 psf
Stack Room	150 psf
Roof Load	30 psf + add'l snow drift
Mechanical Room	150 psf
Roof Terrace	100 psf
Stairs	100 psf

Dead Loads

Load Description	Load
Metal Decking 20 Gage	3 psf
Normal Weight Concrete	150 pcf
Light Weight Concrete	110 pcf
Partitions	20 psf
Finishes	5 psf
M/E/P	10 psf

Snow Loads

Load Description	**Design Load and Factors**
Ground Snow Load	Pg= 25 psf
Snow Exposure Factor	Ce= 0.9
Snow Importance Factor	I= 1.1
Thermal Factor	Ct= 1.0
Flat Roof Snow Load	Pf= 17.3 psf

Lateral Loads

Wind Loads

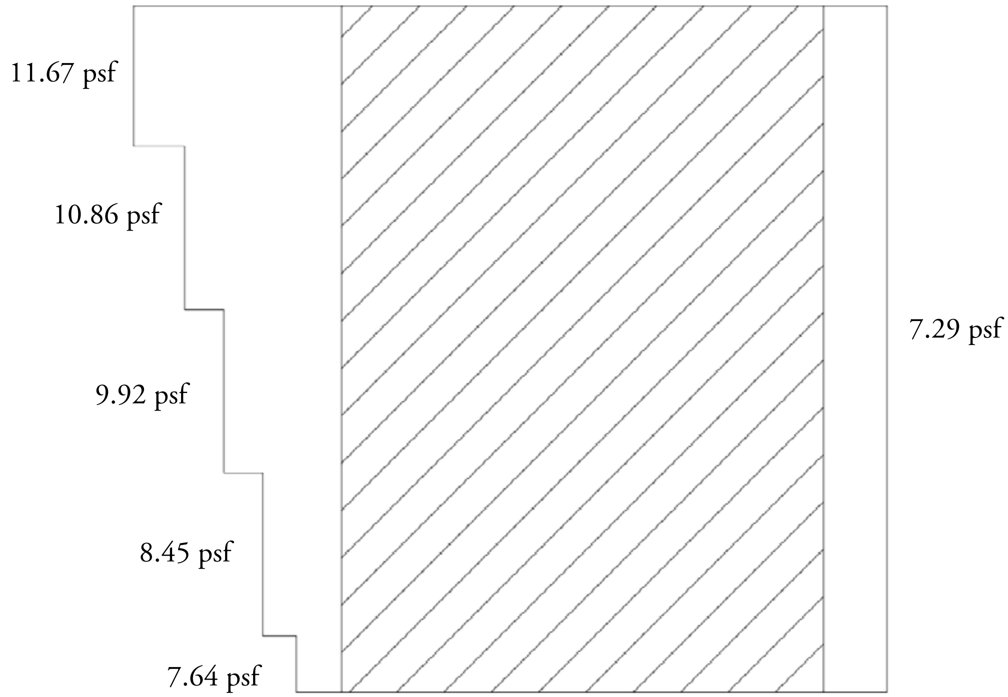
For the analysis of wind loads, Area1 and Area 2 were studied as different structures due to the expansion joint separating them.

Area 1 has a height h= 22.45', therefore, it is considered a low rise building. Method 1 listed in Chapter 6 of ASCE 7-05 was used to carry out my analysis of this section. The results and details of this analysis are located in Appendix C of this report.

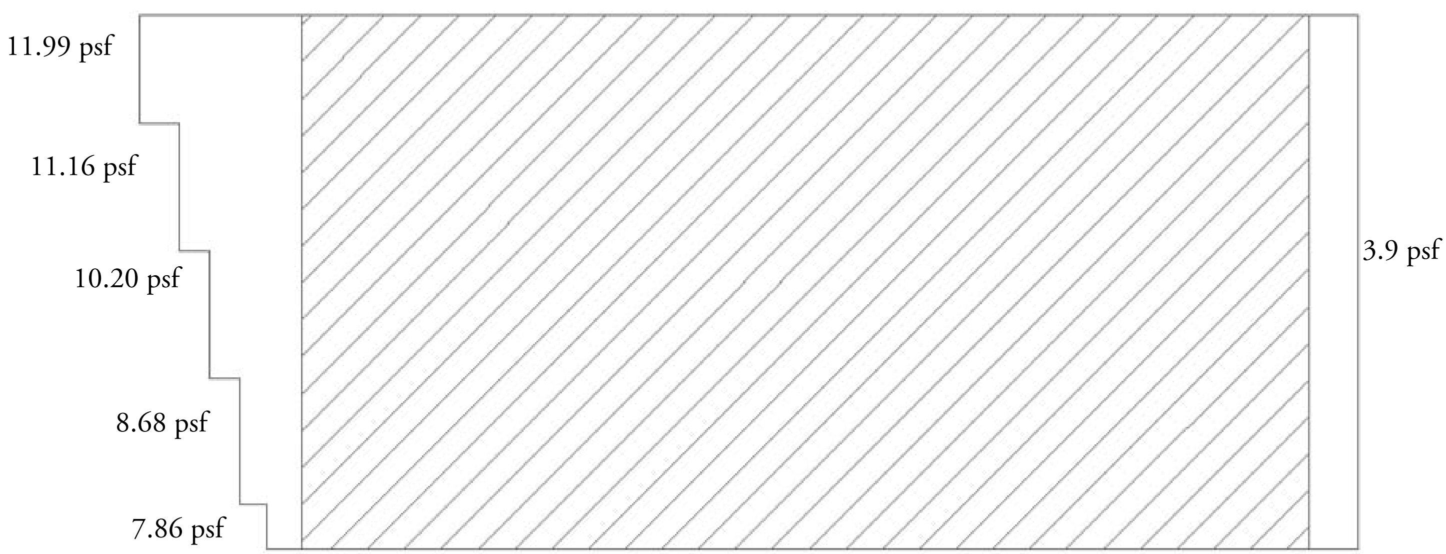
For my wind analysis for Area 2 Method 2 in ASCE 7-05 will be used due to the fact that its mean height is greater than 60'. For the analysis and calculations, the fourth floor is assumed to cover the entire footprint of Area 2. The extended portion of the library is also ignored due to its complex roof structure and its relatively small area. Details of these analyses can be found in Appendix C of this report. The results are located below in this section.

Classification	Category
V, Basic Wind Speed (Fig. 6-1)	90 mph
K_d (Table 6-4)	0.85
I (Table 6-1)	1.15
Occupancy Category (Table 1-1)	III
Exposure Category	B
K_{zt} (Topographic Factor)	1

	Level	Actual Height(ft)	Estimate Height (ft)	k_z	q_z	Wind Pressures (psf)		Internal Pressure (psf)
						N-S	E-W	
Windward	T.O. Roof	63.61	64	0.87	17.63	11.99	11.67	3.17
	4	50.95	51	0.81	16.42	11.16	10.86	3.17
	3	35.7	36	0.74	15.00	10.20	9.92	3.17
	2	20.45	21	0.63	12.77	8.68	8.45	3.17
	1	5.25	6	0.57	11.55	7.86	7.64	3.17
Leeward	All	All	All	0.87	17.63	-3.90	-7.29	3.17



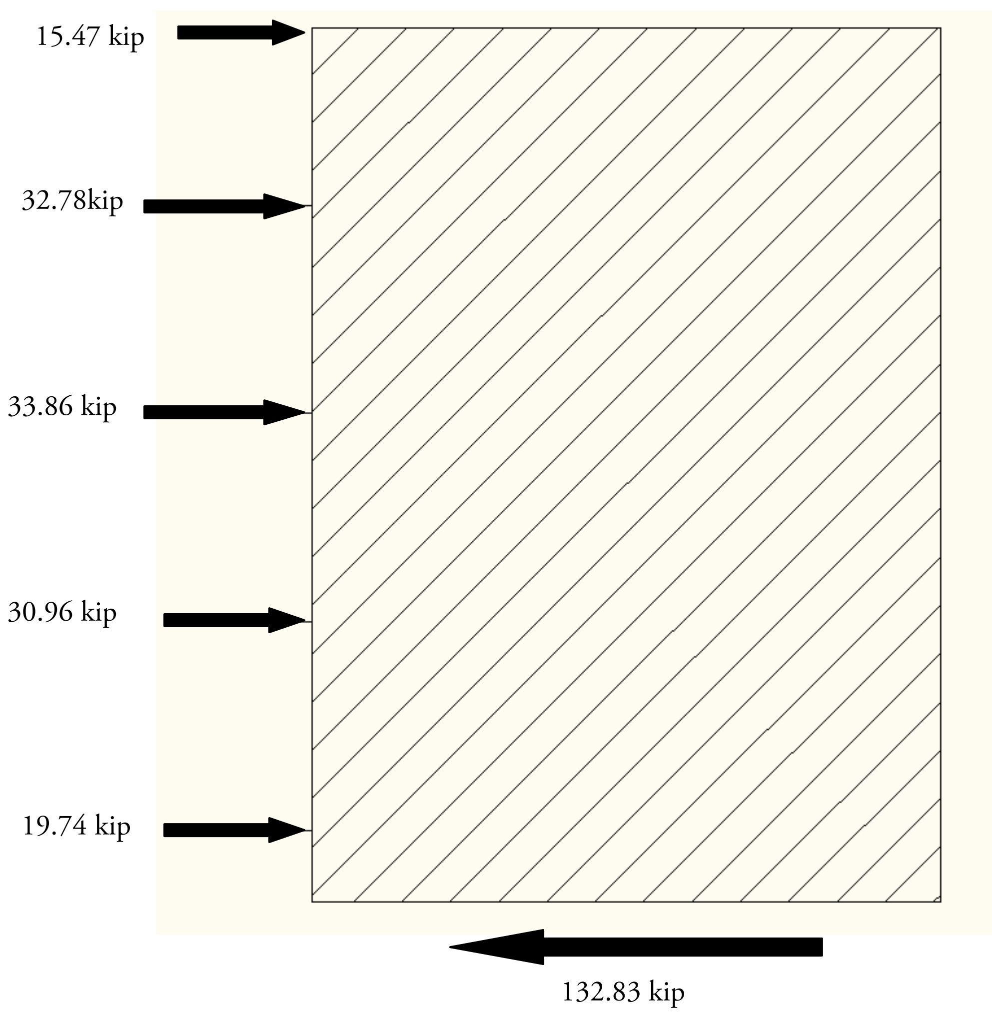
East-West Wind Pressure Diagram (Figure 19)



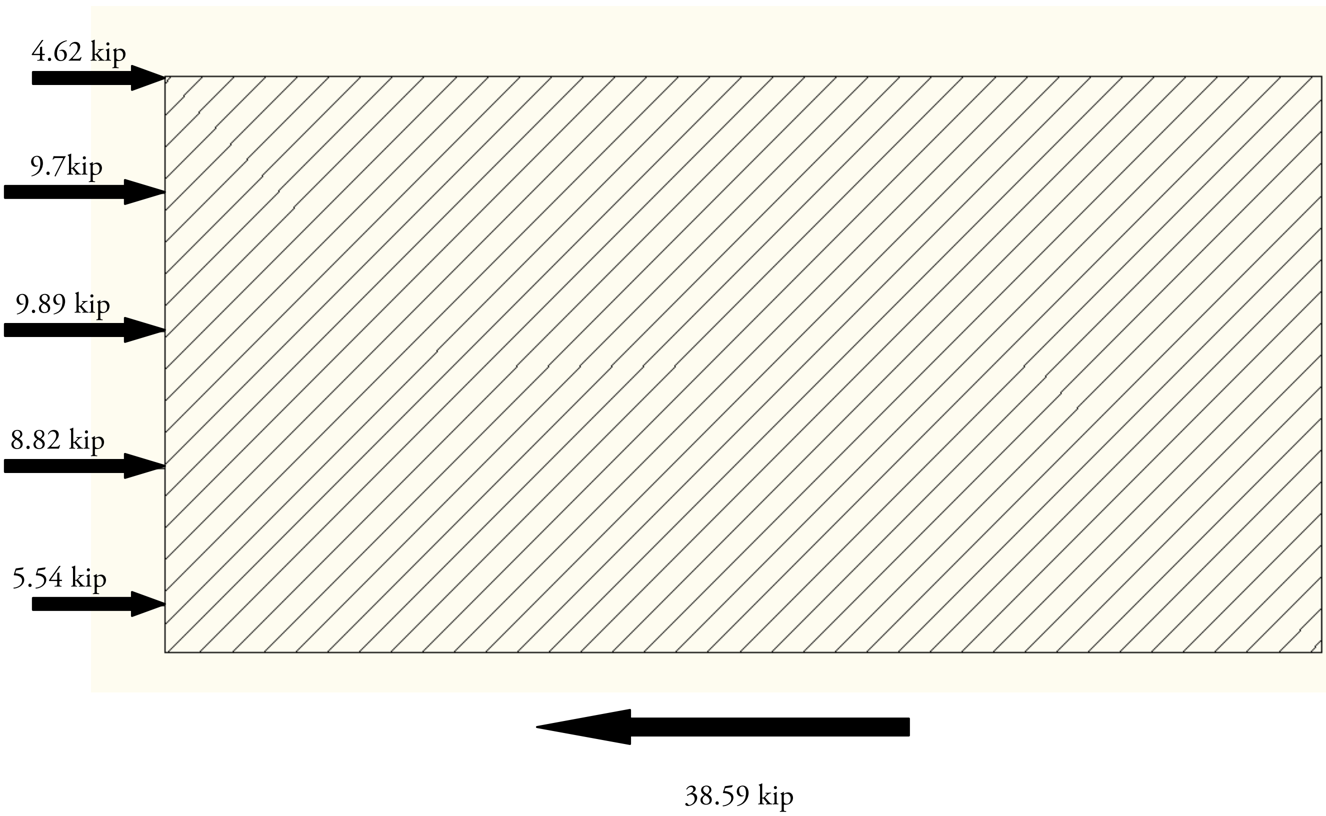
North-South Wind Pressure Diagram (Figure 20)

Wind Forces

				Load (kip)		Shear (kip)		Moment	
Level	Trib Height (ft)	Total Load N-S (psf)	Total Load E-W (psf)	N-S	E-W	N-S	E-W	N-S	E-W
T.O. Roof	6.33	15.89	18.96	4.62	15.47	0	0	294.35	984.66
4	14	15.07	18.15	9.70	32.78	4.62	15.47	494.31	1670.29
3	15.25	14.10	17.21	9.89	33.86	14.32	48.26	353.12	1208.92
2	15.25	12.58	15.74	8.82	30.96	24.22	82.12	180.52	633.16
1	10.25	11.76	14.93	5.54	19.74	33.04	113.08	29.10	103.66
						38.59	132.83	1351.42	4600.71



East-West Wind Force Diagram (Figure 21)



North-South Wind Force Diagram (Figure 22)

As seen from the force diagrams located above, the wind forces that blow in the East-West direction create the largest loads on the building due to the fact that they are applied to a much larger area than the North-South winds.

Seismic Loads

The seismic loads for this tech report were calculated using Chapters 11 and 12 of ASCE 7-05. This seismic analysis includes dead loads from beams, slabs, columns, walls and M/E/P equipment. These calculations can be viewed in Appendix B of this report. All assumptions and calculations for the seismic analysis can also be found in Appendix B.

The seismic forces for the School Without Walls project are less than the lateral loads created by wind due to the fact that the building is located in an area with low seismic activity.

Floor	w_x (kip)	h_x	k	$w_x h_x^k$	$\sum w_i h_i^k$	F_x (kip)	Story Shear V_x (kip)	Moment (k-ft)
Roof	159.70	63.61	1.33	39996.05	224059.6	7.29	--	463.84
4	504.21	50.95	1.33	93997.37	224059.6	17.13	7.29	873.14
3	501.05	35.7	1.33	58201.43	224059.6	10.61	24.42	378.81
2	494.94	20.45	1.33	27402.01	224059.6	4.99	35.04	102.16
1	491.80	5.25	1.33	4462.74	224059.6	0.81	40.03	4.27
Total	2151.72	63.61	1.33	224059.62	224059.6	40.85	40.85	1822.24

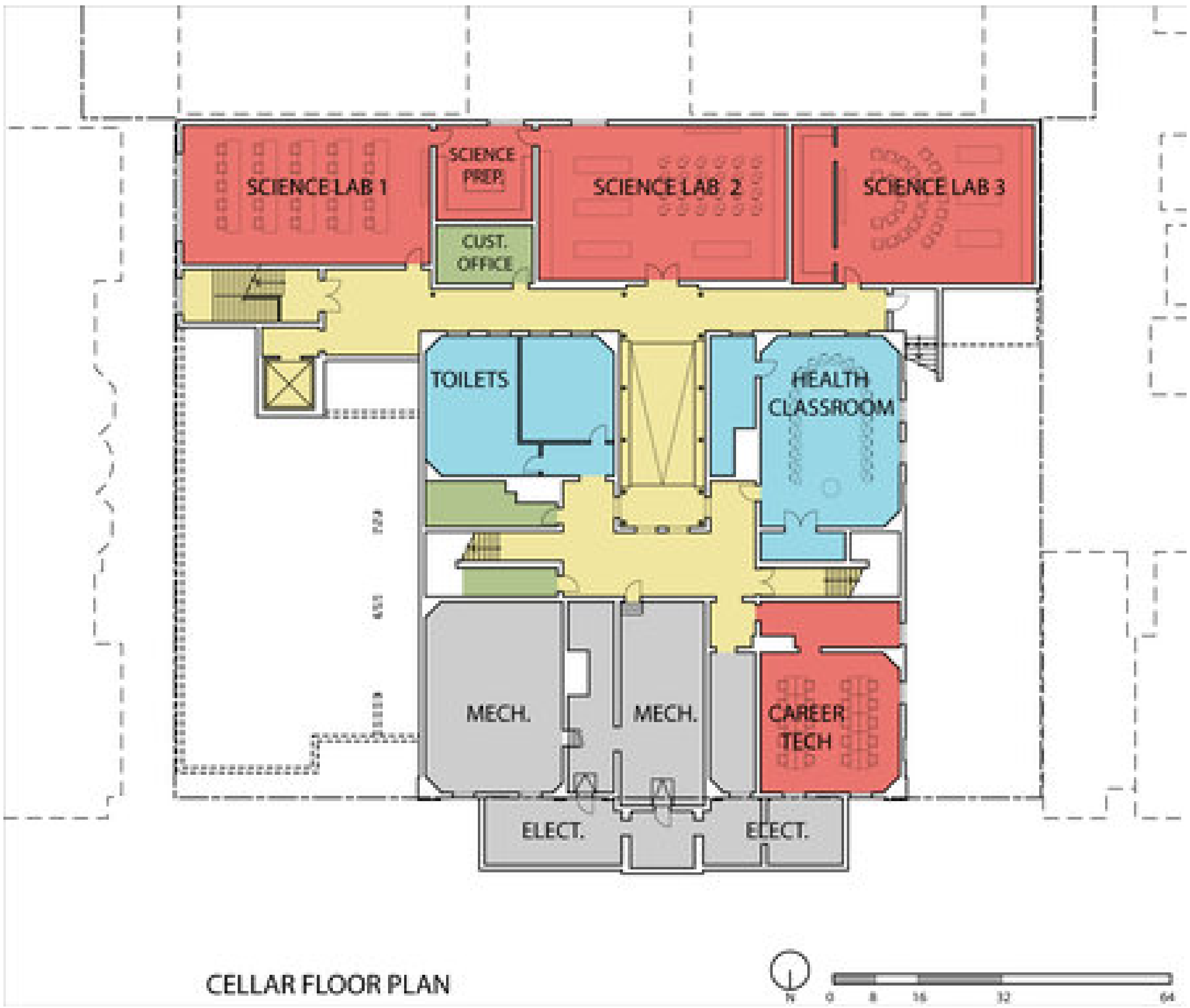
Conclusion

In the first technical report for the School Without Walls addition and modernization project, the existing structural system and conditions are investigated. This report contains a description of the foundation, floor system, and lateral system. Floor plans, details, elevations and other images are provided to introduce the structure.

Both gravity loads and lateral loads were calculated and determined from ASCE 7-05. Seismic loads which were calculated in this report proved to be relatively small due to the small building footprint, and light weight of construction. My wind analysis also showed that winds coming from the North-South direction created relatively small loads due to the small area in which they act on. The wind coming from the East-West direction was determined to be my controlling lateral system.

Spot checks were conducted on a beam and a column of my building. The beam checked is part of the floor system supporting the student commons. My calculations of this composite element matched those of the engineer of record. The column in which I analyzed seemed to be conservative in nature. My results may have shown this due to the fact that lateral loads were not considered in my analysis.

Appendix A



Cellar Floor Plan (Figure 23)

Typical Floor Plan (Figure 24)

Appendix B

Beam Weight

First Floor Beams				
Number of beams	Shape	Weight (lb/ft)	Span (ft)	Total Weight (lb)
3	W10x12	12	5	180
1	W10x12	12	3	36
3	W10x12	12	6	216
9	W10x12	12	7	756
2	W10x12	12	8	192
3	W10x12	12	9	324
3	W10x12	12	12	432
4	W12x14	14	9	504
1	W12x19	19	5.5	104.5
1	W12x19	19	12.5	237.5
1	W12x19	19	18.5	351.5
1	W12x19	19	23.5	446.5
1	W14x22	22	12.5	275
1	W14x22	22	17	374
1	W14x22	22	23	506
1	W16x26	26	17	442
5	W16x26	26	26	3380
1	W18x35	35	9.5	332.5
2	W18x35	35	15	1050
1	W18x35	35	30	1050
2	W24x53	53	37	3922
2	W24x55	55	7	770
1	W24x55	55	18.5	1017.5
1	W24x55	55	15.5	852.5
1	W24x55	55	23.5	1292.5
2	W24x68	68	37	5032
2	W24x76	76	37	5624
1	W27x84	84	37	3108
				32808

Second Floor Beams

Number of beams	Shape	Weight (lb/ft)	Span (ft)	Total Weight (lb)
5	W10x12	12	5	300
1	W10x12	12	6	72
2	W10x12	12	7	168
2	W10x12	12	9	216
1	W10x12	12	11.5	138
1	W12x14	14	6	84
2	W12x14	14	12	336
1	W12x14	14	14	196
1	W12x16	16	12	192
1	W12x19	19	14	266
2	W14x22	22	7	308
4	W14x22	22	10	880
1	W14x22	22	17	374
2	W16x26	26	4	208
2	W16x26	26	6	312
1	W16x26	26	16	416
1	W16x26	26	17	442
5	W16x26	26	26	3380
1	W16x35	35	23.5	822.5
1	W18x35	35	18.5	647.5
2	W18x35	35	21.5	1505
5	W18x35	35	37	6475
1	W21x44	44	37	1628
1	W21x50	50	18.5	925
1	W21x50	50	26	1300
1	W24x55	55	30	1650
1	W24x62	62	37	2294
1	W24x68	68	37	2516
1	W24x76	76	30.5	2318
1	W27x84	84	29.5	2478
1	W27x84	84	37	3108
				35955

Third Floor Beams				
Number of beams	Shape	Weight (lb/ft)	Span (ft)	Total Weight (lb)
2	W10x12	12	7	168
4	W10x12	12	9	432
2	W10x12	12	9.5	228
1	W10x12	12	11	132
1	W10x22	22	12	264
1	W10x22	22	12.5	275
2	W12x14	14	12	336
1	W14x22	22	9.5	209
1	W14x22	22	17	374
1	W14x22	22	12.5	275
1	W14x22	22	18.5	407
2	W16x26	26	6	312
5	W16x26	26	26	3380
1	W16x26	26	16	416
1	W18x35	35	17	595
2	W18x35	35	21.5	1505
2	W18x35	35	34.5	2415
1	W18x40	40	18.5	740
1	W18x40	40	37	1480
1	W21x44	44	23.5	1034
1	W21x44	44	30.5	1342
1	W21x50	50	18.5	925
2	W24x55	55	7	770
1	W24x55	55	26	1430
3	W24x55	55	37	6105
1	W24x62	62	30	1860
1	W24x62	62	35	2170
1	W24x76	76	30.5	2318
1	W27x84	84	7	588
1	W27x84	84	29.5	2478
1	W27x84	84	37	3108
1	C15x33.9	33.9	21.5	728.85
1	C15x33.9	33.9	28.5	966.15
1	HSS12x8x1/2	62.33	7	436.31
1	HSS12x8x1/2	62.33	24	1495.92
1	HSS12x8x1/2	62.33	30	1869.9
				44348.13

Fourth Floor Beams				
Number of beams	Shape	Weight (lb/ft)	Span (ft)	Total Weight (lb)
3	W10x12	12	7	252
2	W10x12	12	9	216
2	W10x12	12	10	240
1	W10x12	12	12.5	150
2	W12x14	14	14	392
1	W12x14	14	19.5	273
3	W12x19	19	8	456
1	W12x19	19	12	228
1	W12x19	19	12.5	237.5
1	W12x19	19	13	247
2	W12x22	22	9	396
1	W14x22	22	12.5	275
1	W14x22	22	17	374
1	W16x26	26	24	624
4	W16x31	31	26	3224
2	W18x35	35	37	2590
1	W18x40	40	21.5	860
1	W18x40	40	26	1040
1	W21x44	44	17	748
1	W21x44	44	21.5	946
1	W21x44	44	27	1188
1	W21x50	50	30.5	1525
1	W24x55	55	18.5	1017.5
1	W24x62	62	37	2294
1	W24x68	68	30.5	2074
2	W24x68	68	37	5032
1	W24x76	76	37	2812
1	W27x84	84	23.5	1974
1	W27x84	84	30.5	2562
1	W30x99	99	18.5	1831.5
1	W30x99	99	29.5	2920.5
1	W30x99	99	37	3663
1	W30x116	116	37	4292
2	HSS12x6x3/8	42.72	5	427.2
1	HSS12x6x3/8	42.72	16	683.52
				49186.72

Roof Beams				
Number of beams	Shape	Weight (lb/ft)	Span (ft)	Total Weight (lb)
7	W10x12	12	5	420
8	W10x12	12	6	576
2	W10x12	12	7.5	180
1	W10x12	12	9	108
2	W10x12	12	12	288
6	W10x12	12	13	936
10	W12x14	14	5	700
6	W12x14	14	13	1092
4	W12x14	14	14	784
4	W12x14	14	24	1344
1	W12x19	19	8.5	161.5
1	W12x19	19	13	247
1	W12x19	19	15	285
1	W12x26	26	12	312
2	W12x26	26	24	1248
1	W12x58	58	24	1392
2	W12x65	65	38	4940
1	W14x22	22	10	220
1	W16x31	31	24	744
1	W16x36	36	25	900
1	W18x35	35	37	1295
1	W18x40	40	24.5	980
1	W18x40	40	30.5	1220
3	W18x40	40	37	4440
1	W18x46	46	18.5	851
1	W21x44	44	30.5	1342
1	HSS6x6x3/8	27.41	24	657.84
2	HSS8x8x3/8	37.61	24	1805.28
				29468.62

Total Weight of Beams (lb)	191766.47

Slab Weight

Floor	Area	Weight Concrete (lb/ft^3)	Thickness of Slab (ft)	Decking Weight (lb/ft^2)	Total Weight (lb)
1	5445	110	0.270833333	3	178550.625
2	5445	110	0.270833333	3	178550.625
3	5445	110	0.270833333	3	178550.625
4	5445	110	0.270833333	3	178550.625
	21780				**714202.5**

	Area	Weight (lb/ft^2)	Total Weight
Roof	3256	40	**130240**

Columns

Column	Size	Weight (lb/ft)
A-1	W12x65	65
A-1.5	HSS6x6x3/8	27.41
A.3-1.5	HSS8x8x3/8	37.61
A.3-2.5	HSS8x8x3/8	37.61
A-2	W12x96	96
A-2	W12x65	65
A-3	W12x96	96
A-3	W12x65	65
A-4	W12x65	65
A-4	W12x40	40
A-7	W12x40	40
A.5-7	W12x40	40
B-1	W12x40	40
B-1.1	W12x53	53
B-1.5	HSS8x8x3/8	37.61
B-2	W12x65	65
B-2	W12x40	40
B-2.5	HSS8x8x3/8	37.61
B-3	W12x65	65
B-3	W12x40	40
B-4	W12x53	53
B-4	W12x40	40
B-5.2	HSS8x8x3/8	37.61
B-7	HSS8x8x3/8	37.61
C.1-5	W12x45	45
C.1-7	W12x40	40

Floor Height (ft)	
First -Second	15.25
Second-Third	15.25
Third-Fourth	15.25
Fourth-Flat Roof	12.25
Fourth-Pitched Roof	19

Column Weights (lb)			
First Floor	Second Floor	Third Floor	Fourth Floor
991.25	991.25	991.25	N/A
N/A	N/A	N/A	335.7725
N/A	N/A	N/A	714.59
N/A	N/A	N/A	714.59
1464	1464	N/A	N/A
N/A	N/A	991.25	796.25
1464	1464	N/A	N/A
N/A	N/A	991.25	796.25
991.25	991.25	N/A	N/A
N/A	N/A	610	490
610	610	610	N/A
610	610	610	490
610	610	610	N/A
808.25	808.25	808.25	N/A
N/A	N/A	N/A	714.59
991.25	991.25	N/A	N/A
N/A	N/A	610	N/A
N/A	N/A	N/A	714.59
991.25	991.25	N/A	N/A
N/A	N/A	610	490
808.25	808.25	N/A	N/A
N/A	N/A	610	490
N/A	N/A	N/A	460.7225
N/A	N/A	N/A	460.7225
686.25	686.25	686.25	N/A
610	610	610	N/A
11635.75	**11635.75**	**9348.25**	**7668.0775**

Total Column Weight (lb)	40287.83

Wall Loads

Floor	Area	Weight (lb/ft^2)	Weight of Wall (lb)
1	2607.75	30	78232.5
2	2607.75	30	78232.5
3	2607.75	30	78232.5
4	2607.75	30	78232.5
			312930

Additional Loads

Floor	Area	Partitions (lb/ft^2)	Finishes (lb/ft^2)	M/E/P (lb/ft^2)	Total Weight (lb)
1	5445	20	5	10	190575
2	5445	20	5	10	190575
3	5445	20	5	10	190575
4	5445	20	5	10	190575
					762300

Total Building Weight of Area 2

Total Building Weight (kip)	2150

Seismic Calculation

SEISMIC CALCULATIONS (ASCE 7-05)

OCCUPANY CATEGORY III (TABLE 1-1)
IMPORTANCE FACTOR (I) 1.25 (TABLE 11.5-1)

USGS (http://earthquake.usgs.gov/research/hazmaps/design/)

SPECTRAL RESPONSE ACCEL. AT SHORT PERIOD (S_S): .154 g
SPECTRAL RESPONSE ACCEL. AT 1-SEC PERIOD (S_1): .05 g

SITE CLASS: C (VERY DENSE SOIL + SOFT ROCK)

SITE COEFFICIENTS:

F_a (TABLE 11.4-1) : 1.2
F_v (TABLE 11.4-2) : 1.7

$S_{MS} = F_a S_S = 1.2(.154) = .185$ (EQN 11.4-1)
$S_{M1} = F_v S_1 = 1.7(.05) = .085$ (EQN 11.4-2)
$S_{DS} = 2S_{MS}/3 = 2(.185)/3 = .123$ (EQN 11.4-3)
$S_{D1} = 2S_{M1}/3 = 2(.085)/3 = .057$ (EQN 11.4-4)

DESIGN CATEGORY

$S_{DS} = .123$ $S_{DS} < .167$ ∴ CATEGORY A
$S_{D1} = .057$ $S_{D1} < .067$ ∴ CATEGORY A

$T_S = S_{D1}/S_{DS} = .463$

$T_a = C_t h_n^x$ (EQN 12.8-7) $C_t = .03$ (TABLE 12.8-2)
$x = .75$

$T_a = .03(63.6)^{.75} = .676$

$T = C_u T_a$ (SEC 12.8.2)

$C_u = 1.7$ (TABLE 12.8-1)

$T = 1.7(.676) = 1.15$

$T_L = 8$ (FIG 22-15)

$C_S = \dfrac{S_{D1}}{T\left(\frac{R}{I}\right)}$

$R = 3.25$ (TABLE 12.2-1)

ASSUME ORDINARY CONCENTRICALLY BRACED FRAME / ORDINARY REINFORCED CONCRETE SHEAR WALL

$C_S = \dfrac{.057}{(1.15)\left(\frac{3.25}{1.25}\right)}$

$\Omega = 2$ $\quad C_d = 3.25$

$C_S = .019 \therefore$ OK

$V = C_S W$

$W = 2021.487^k$

$V = .019(2021.5) = 38.4^k$

$k = .75 + .5T = .75 + .5(1.15) = 1.325$

Appendix C

Area 1

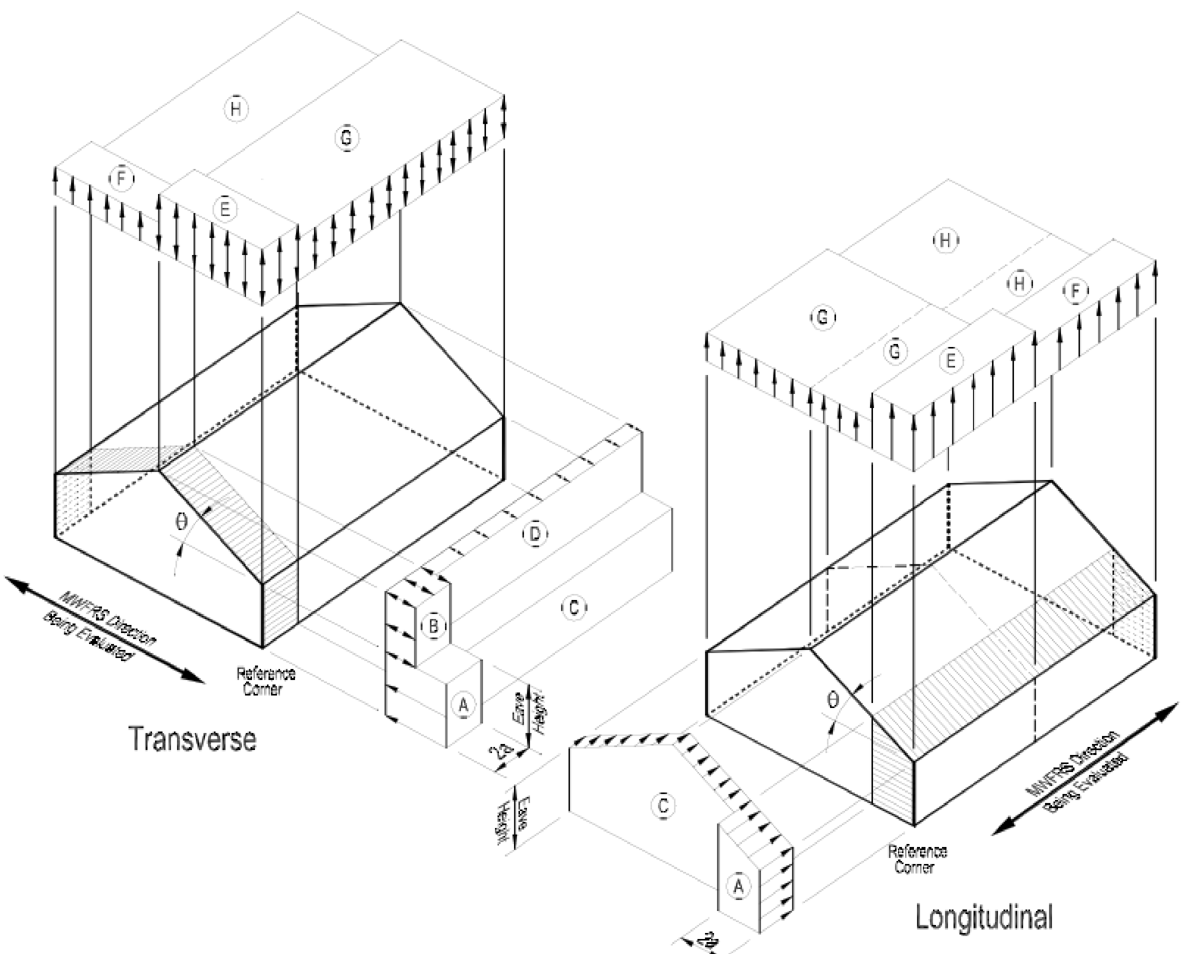
Values for my wind analysis were determined from Method 1 of ASCE 7-05. Horizontal and vertical pressures can be located in the table below. These pressures were adjusted using the equation $p_s = \lambda K_{zt} I p_{s30}$. The adjusted values can easily be applied to figure located on page 38.

Main Wind Force Resisting System – Method 1		h ≤ 60 ft.
Figure 6-2 (cont'd)	Design Wind Pressures	Walls & Roofs
Enclosed Buildings		

Simplified Design Wind Pressure, p_{s30} (psf) *(Exposure B at h = 30 ft., K_{zt} = 1.0, with I = 1.0)*

Basic Wind Speed (mph)	Roof Angle (degrees)	Load Case	Zones: Horizontal Pressures A	B	C	D	Vertical Pressures E	F	G	H	Overhangs E_{OH}	G_{OH}
85	0 to 5°	1	11.5	-5.9	7.6	-3.5	-13.8	-7.8	-9.6	-6.1	-19.3	-15.1
	10°	1	12.9	-5.4	8.6	-3.1	-13.8	-8.4	-9.6	-6.5	-19.3	-15.1
	15°	1	14.4	-4.8	9.6	-2.7	-13.8	-9.0	-9.6	-6.9	-19.3	-15.1
	20°	1	15.9	-4.2	10.6	-2.3	-13.8	-9.6	-9.6	-7.3	-19.3	-15.1
	25°	1	14.4	2.3	10.4	2.4	-6.4	-8.7	-4.6	-7.0	-11.9	-10.1
		2	-------	-------	-------	-------	-2.4	-4.7	-0.7	-3.0	-------	-------
	30 to 45	1	12.9	8.8	10.2	7.0	1.0	-7.8	0.3	-6.7	-4.5	-5.2
		2	12.9	8.8	10.2	7.0	5.0	-3.9	4.3	-2.8	-4.5	-5.2
90	0 to 5°	1	12.8	-6.7	8.5	-4.0	-15.4	-8.8	-10.7	-6.8	-21.6	-16.9
	10°	1	14.5	-6.0	9.6	-3.5	-15.4	-9.4	-10.7	-7.2	-21.6	-16.9
	15°	1	16.1	-5.4	10.7	-3.0	-15.4	-10.1	-10.7	-7.7	-21.6	-16.9
	20°	1	17.8	-4.7	11.9	-2.6	-15.4	-10.7	-10.7	-8.1	-21.6	-16.9
	25°	1	16.1	2.6	11.7	2.7	-7.2	-9.8	-5.2	-7.8	-13.3	-11.4
		2	-------	-------	-------	-------	-2.7	-5.3	-0.7	-3.4	-------	-------
	30 to 45	1	14.4	9.9	11.5	7.9	1.1	-8.8	0.4	-7.5	-5.1	-5.8
		2	14.4	9.9	11.5	7.9	5.6	-4.3	4.8	-3.1	-5.1	-5.8

Horizontal Pressures (psf)				Vertical Pressures (psf)			
A	B	C	D	E	F	G	H
12.8	-6.7	8.5	-4.0	-15.4	-8.8	-10.7	-6.8
Adjusted Pressures (psf)				Adjusted Pressures (psf)			
14.7	-7.7	9.8	-4.6	17.71	-10.1	-12.3	-7.8



Area 2

WIND DESIGN

ASCE 7-05 METHOD 2

BASIC WIND SPEED $V = 90$ mph (FIGURE 6-1)

IMPORTANCE FACTOR $I = 1.15$ (TABLE 6-1)

OCCUPANCY CATEGORY III (TABLE 1-1)

EXPOSURE CATEGORY B (SECT 6.5.6.3)

VELOCITY EXPOSURE COEFFICIENT K_z
(TABLE 6-3)

FLOOR	ACTUAL HT. (ft)	EST. HT (ft)	K_z
1	5.25	6	.57
2	20.45	21	.63
3	35.7	36	.74
4	50.95	51	.81
ROOF	63.61	64	.87

INTERPOLATION

$$y = y_a + (x - x_a)\frac{(y_b - y_a)}{(x_b - x_a)}$$

FOR FLOOR 2 ($h = 21$)

$$K_{21} = .62 + (21 - 20)\frac{(.66 - .62)}{(25 - 20)} = .63$$

FOR FLOOR 3

$$K_{36} = .7 + (36 - 30)\frac{(.76 - .7)}{(40 - 30)} =$$

FOR FLOOR 4

$$K_{51} \approx .81$$

FOR ROOF

$$K_h = .85 + (64 - 60)\frac{(.89 - .85)}{(70 - 60)} = .87$$

TOPOGRAPHIC FACTOR $K_{zt} = 1.0$

WIND DIRECTIONALITY FACTOR $K_d = .85$

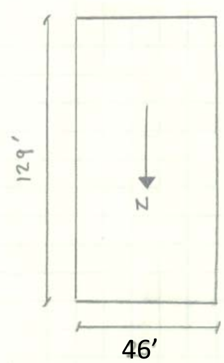
DETERMINE VELOCITY PRESSURE (q_z)

HEIGHT (ft)	K_z	q_z
6	.57	11.55
21	.63	12.77
36	.74	15
51	.81	16.42
64	.87	17.63

$q_z = .00256\, K_z K_{zt} K_d V^2 I$

ASSUME BUILDING IS RIGID $n_1 = 100/H \geq 1$

$g_Q = g_v = 3.4$



	N-S DIRECTION	E-W DIRECTION
B (ft)	46'	129'
L (ft)	129'	46'
h	64.3	64.3

$\bar{z} = .6h = 38.6\text{ ft} \geq z_{min}$

$z_{min} = 30\text{ ft}$

$I_{\bar{z}} = c\left(\frac{33}{\bar{z}}\right)^{1/6} = .292$

$c = .3$

$L_{\bar{z}} = \ell\left(\frac{\bar{z}}{33}\right)^{\bar{\epsilon}} = 337.16$

$$Q = \sqrt{\frac{1}{1 + .63\left(\frac{B+h}{L_z}\right)^{.63}}}$$

N-S DIRECTION

$$Q = \sqrt{\frac{1}{1 + .63\left(\frac{46+64.3}{337.16}\right)^{.63}}}$$

$Q = .873$

E-W DIRECTION

$$Q = \sqrt{\frac{1}{1 + .63\left(\frac{129+64.3}{337.16}\right)^{.63}}}$$

$Q = .832$

GUST EFFECT FACTORS (G)

$$G_{N-S} = .925\left(\frac{1 + 1.7(3.4)(.292)(.873)}{1 + 1.7(3.4)(.292)}\right) = .851$$

$$G_{E-W} = .925\left(\frac{1 + 1.7(3.4)(.292)(.832)}{1 + 1.7(3.4)(.292)}\right) = .827$$

ENCLOSURE CLASSIFICATION: ENCLOSED (SECT 6.2)

INTERNAL PRESSURE COEFFICIENT $GC_{pi} = \pm .18$ (Fig 6-5)

EXTERNAL PRESSURE COEFFICIENTS, Cp

WINDWARD WALL = .8
SIDE WALL = -.7

LEEWARD WALL

$C_{p_{N-S}} = L/B = 129/46 = 2.8 \rightarrow -.26$

$C_{p_{E-W}} = L/B = 46/129 = .36 \rightarrow -.5$

$$C_{p_{N-S}} = -.3 + (2.8-2)\frac{(-.2-(-.3))}{(4-2)} = -.26$$

DESIGN WIND PRESSURES, P

WINDWARD WALL

$p = q_z G C_p - q_h (G C_{pi})$

ROOF, LEEWARD

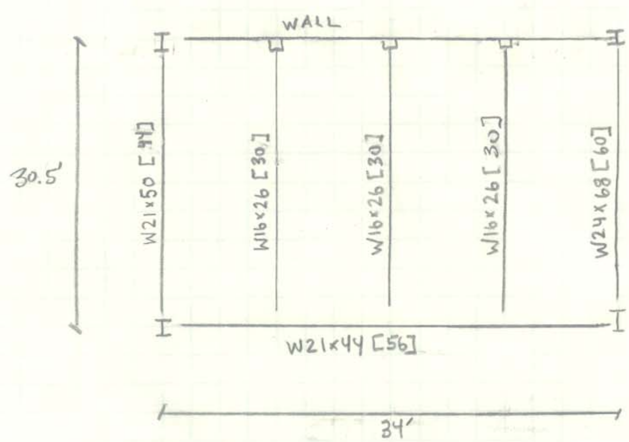
$P_h = q_h \, G C_p - q_h (G C_{pi})$

	Wind Direction	
	N-S	E-W
Stiffness	Rigid	Rigid
B (feet)	46	129
L (feet)	129	46
h (feet)	64.3	64.3
g_q	3.4	3.4
g_v	3.4	3.4
z(feet)	38.6	38.6
I_z	0.292	0.292
c	0.3	0.3
L_z	337.16	337.16
l (feet)	320	320
ϵ	1/3.0	1/3.0
Q	0.873	0.832
G	0.851	0.827

	N-S	E-W
Windward	0.8	0.8
Leeward	-0.26	-0.5
Sidewall	-0.7	-0.7

Appendix D

TYPICAL INTERIOR BAY



LOADS : COMMONS, ASSUME $100\ ^{lb}/_{ft^2}$

DEAD LOAD : SLAB - $110\ ^{lb}/_{ft^3}\ (.27ft) = 29.7\ ^{lb}/_{ft^2}$

DECK - $3\ ^{lb}/_{ft^2}$

FINISHES - $5\ ^{lb}/_{ft^2}$

MEP - $10\ ^{lb}/_{ft^2}$

BEAM SW - $15\ ^{lb}/_{ft^2}$

PARTITIONS - $20\ ^{lb}/_{ft^2}$

CHECK BEAM

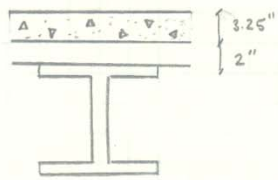
LRFD : $1.2(82.7) + 1.6(100) = 259.24\ ^{lb}/_{ft^2}$

TRIB WIDTH = 8.5'

$w_u = 2.2\ ^{k}/_{ft}$

$$M_u = \frac{2.2\,(26')^2}{8} = 256.2'^{k}$$

b_{eff} MIN
$\frac{30.5(12)}{4} = 91.5''$ ← CONTROLS
$8.5(12) = 102''$



ASSUME $a = 1$

$Y_2 = 5.25 - 1/2 = 4.75$

TRY $a = 4.5$

USING W16x26 $\Sigma Q_n = 145$ $\phi M_p = 166^{k\text{-}ft}$

$\phi M_n = 269^{k\text{-}ft}$

CHECK $a = \dfrac{\Sigma Q_n}{.85 f'_c b_{eff}} = \dfrac{145}{.85(4)(91.5} = .47 < 1.0 \therefore$ OK

DECK PERPENDICULAR (3/4" STUDS)
WEAK POSITION

$Q_N = 17.2^k$

$\#$ STUDS $= \dfrac{145}{17.2}(2) = 18$ SHEAR STUDS

CONSTRUCTION DEFLECTION $\Delta_{ALLOW} = \dfrac{l}{360}$

$\Delta_{CONST} = \dfrac{5 W_{CONST}\, l^4}{384(EI)}$

$W_{CONC} = 110^{lb}/_{ft^3}\,(8.5')(^{3.25}/_{12}) = .304$ klf

$W_{DECK} = 3^{lb}/_{ft^2}\,(8.5') = .025$ klf

$W_{BEAM} = 26^{lb}/_{ft} = .026$

$W_{CONST} = .356$

$I_{REQ} = \dfrac{5 W_{CONC}\, l^4}{384\, \Delta_{CONST}\, E} = \dfrac{5(.356)(30.5)^4(1728)}{384(1)(29000)} = 242\,in^4$

$I_{W16x26} = 301\,in^4 > 242\,in^4 \therefore$ OK

COLUMN SPOT CHECK A-2

ROOF $P_u = 42.24^k$

W12x65 ; h= 12'8"

$A_g = 19.1 in^4$

$I_x = 533 in^4$ $I_y = 174 in^4$

$r_x = 5.28"$ $r_y = 3.02"$

$\frac{KL}{r_x} = 28.8$ $\frac{KL}{r_y} = 50.3$ ← CONTROLS

$4.71\sqrt{\frac{E}{F_y}} = 113$

$50.3 < 113$ ∴ ELASTIC

$F_{cr} = 6.58^{F_y/F_e} F_y$

$F_e = \frac{\pi^2 E}{\left(\frac{KL}{r}\right)^2} = 113.12 ksi$

$F_{cr} = 41.55 ksi$

$\phi P_n = .9(41.55)(19.1) = 714^k$

$P_u = 55.44^k << 714^k$ ∴ OK

CHECK BOTTOM FLOOR

$P_u = 373$

W12×96 $\quad A_g = 28.2\,in^2$

$I_x = 833\,in^4 \quad r_x = 5.44\,in$

$I_y = 270\,in^4 \quad r_y = 3.09\,in$

$h = 15.25$

$\frac{KL}{r_y} = 59.22 < 113 \quad \therefore$ ELASTIC

$F_{cr} = .658^{F_y/F_e} F_y \qquad F_e = \frac{\pi^2(29000)}{(59.22)^2} = 81.6$

$F_{cr} = 38.7$

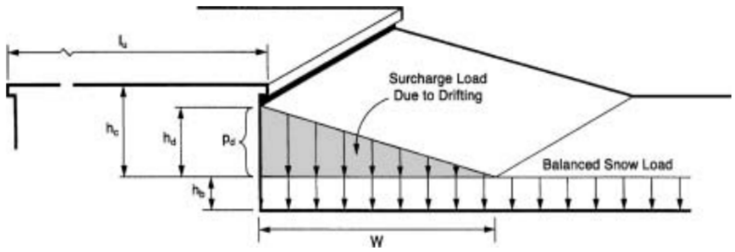
$\phi P_n = .9(38.7)(28.2) = 981.9^k$

$P_u = 386.32 \ll 981.9 \quad \therefore$ OK

COLUMN SIZES ARE EXTREMELY CONSERVATIVE
POSSIBLE LOAD DESIGN DIFFERENCES
EXTRA LOAD FROM BRACED FRAME

Floor	Tributary Area (ft^2)	Dead Load (psf)	Live Load (psf)	Live Load (k)	Dead Load (k)	Load Combination (k)	Total Load (k)
Roof	440	65	30	13.2	28.6	55.44	55.44
4	440	80	100	44	35.2	112.64	168.08
3	440	80	40	17.6	35.2	70.4	238.48
2	440	80	40	17.6	35.2	70.4	308.88
1	440	80	50	22	35.2	77.44	386.32

Appendix E



ASCE 7-05 Snow Drift Figure (Figure 25)

FLAT ROOF SNOW LOADS

$p_f = .7 C_e C_t I p_g$ (EQN 7-1)

$C_e = .9$
$p_g = 25$
$C_t = 1.0$
$I = 1.1$

$p_f = 17.3$ psf   STRUCTURE DESIGNED FOR 19psf

DIFFERENCE IN ROOF HEIGHT 30.5' (DRIFT ON ROOF TERRACE)

$\gamma = .13(17.3) + 14 = 16.25$ pcf $<$ 30pcf

$h_d = .43\sqrt[3]{l_u}\sqrt[4]{p_g + 10} - 1.5$

LEEWARD DRIFT

$l_{upper\ rf} = 46'$

$h_d = .43\sqrt[3]{46}\sqrt[4]{37.3} - 1.5 = 2.3'$

WINDWARD DRIFT

$l_{lower\ rf} = 90'$

$h_d = .75(.43)\sqrt[3]{90}\sqrt[4]{37.3} - 1.5 = 2.1'$

$h_b = p_f/\gamma = 1.06$

$h_c = 29.5'$

$w = \min \begin{cases} 8(h_c) = 236 \\ 4(h_d) = 4(2.3) = 9.2\text{ ft} \end{cases}$

$w = (h_{drift} + h_b)\gamma = 2.88(16.25) = 46.8$ psf @ HIGH END

$w = 17.3$ psf @ LOW END