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Advisor: Professor Parfitt

Executive Summary

The Earth and Engineering Sciences building is a 4 story educational and laboratory facility. An additional basement level is located below grade and provides the foundation for the East Wing of the building. The structure encompasses a total of 106,000 square feet of usable space. Construction on this project was type 1B.

The structure consists of several types of materials and uses a composite design scheme. Steel is the primary design material, but it is also integrated with various reinforced concrete elements. The structural steel and reinforced steel are either A36 or A572 grade, depending on the location of use.

The exterior walls are reinforced concrete, while some CMU does exist. Precast concrete panels on granite are used in conjunction with a brick veneer to complete the envelope of the structure. These envelope elements do not provide significant strength benefits however as they are anchored to the main structural system.

The codes used in analysis are as follows:
The seismic and wind loads will be calculated from the ASCE7-02. Live and Dead loads will be taken from the schematics and available ASCE7-02 information. The BOCA 1993 code was used by the structural engineer.

A spot check will be performed later in this report to illustrate the structural integrity of the existing elements. The 3rd floor will be checked under full gravity load.

Structural System:

Foundation: Area - 16,535 Sq. Ft., Floor Height-16' (Below Grade)

1. Slabs – There are two slabs used in the basement. The slab on grade is a 5" concrete slab on top of 6" of crushed stone, reinforced with 6 x 6, W2.1 x W2.1 welded wire fabric. The other slab is used as a landing in the stairwell. This slab is an 8" normal weight concrete slab reinforced with #4's at 12" O.C. each way on top and bottom.
2. Spread Footings – There are eight styles of spread footings used. Each is reinforced with steel bars spanning each direction. The number and size of bars varies from as few as 3 bars to 9 bars, with sizes from #5 to #9. In footing F8.0A top steel is added.
3. Column Piers – Eleven different styles of piers are present in the foundation. Size of piers varies as well as the amount of rebar used. The size of bar is a #6, #7, or #8 with the number of bars varying. Piers range from 18" x 18" to 2'-2" x 2' in size.
4. Columns – The columns are all made of an A36 grade steel and span from the piers to the first floor. Column steel sizes are as follows:
   - W10 x 33
   - W10 x 39
   - W10 x 45
   - W10 x 68
5. Foundation Walls – The foundation walls as well as most exterior walls are a reinforced concrete (with the exception being CMU walls used in the auditorium wing). The reinforcing used is #5 bars at 8" spacing each way.

1st Floor: Area – 25,922 Sq. Ft., Floor Height – 17'- 4"

1. Slabs – Slab on grade is used on the west wing of the building due to the first floor being the foundation for this section of the building. Two additional floor slabs are used on this floor. The first is a 3", 20 GA galvanized composite metal deck with 3 ¼ " light weight concrete topping reinforced with 6 x 6, W2.1 x W2.1 welded wire fabric. The total thickness of this slab is 6 ¼ ". The second slab is a 1 ½" 20 GA galvanized composite metal deck with 3 ¼ " light weight concrete topping reinforced with 6 x 6, W2.1 x W2.1 welded wire fabric. The total thickness of this slab is 4 ¾".
2. Spread Footings – These are the same as the foundation listed above.
3. Column Piers – These are the same as listed above.
4. Grade Beams and Concrete Beams – These elements are used to support and tie in the concrete screen and veneer to the main structural elements and will be taken to be non critical structural elements.
5. Columns – The columns are all made of an A36 grade steel and span from the piers to the second floor or continue from the basement to the second floor. Column steel sizes are as follows:
   - W10 x 33
   - W10 x 39
   - W10 x 45
   - W10 x 49
   - W10 x 54
   - W10 x 60

6. Steel Beams – Steel beams used in this building are predominantly A36 grade steel, however in some cases an A572 Grade 50 steel was used. The beams tie into the slabs above them by varying numbers of ¾" Φ x 5 ¼ "shear studs. Beam spans range from 27'-4" to 32'-6" while the beams are spaced 10' on center. Beam sizes vary throughout the structure and each floor. The first floor sizes are as follows:
   - W8 x 10
   - W12 x 14, W12 x 16, W12 x 19
   - W14 x 22, W14 x 30
   - W16 x 26, W16 x 31
   - W18 x 35, W18 x 40
   - W21 x 16, W21 x 50
7. Exterior Walls - Exterior walls are a reinforced concrete (with the exception being CMU walls used in the auditorium wing). The reinforcing used is #5 bars at 8" spacing each way.

2nd – 4th Floors: Area – 19,410 Sq. Ft. (2nd, 3rd), 19,784 Sq. Ft. (4th), Floor Height – 14'-8"

1. Slabs – The floor slabs are the same as the two slabs listed for the first floor with the addition of a 6" normal weight concrete slab with #4's at 12" o.c. used in each direction as reinforcement.
2. Columns – At the second floor the columns extending from the first floor are spliced with different columns. From the splice the new section of columns will extend to the roof. Sizes after the splice are W10 x 33, W10 x 39, or W10 x 45. All columns are A36 grade steel.

3. Beams – The beam specifics are the same on each floor with the following sizes used:
    - W8 x 13
    - W12 x 16
    - W14 x 22, W14 x 30
    - W16 x 26, W16 x 31
    - W18 x 35, W18 x 40
    - W21 x 50
    - W24 x 84 (A572 Grade 50)
4. Exterior Walls - Exterior walls are a reinforced concrete. The reinforcing used is #5 bars at 8" spacing each way

Roof:

1. The roof system is composed of several joist sizes in conjunction with steel beams.
2. One style of deck is used for the entire roof. It is a 1 ½", 20 GA. Galvanized metal roof deck, type "B".

Plan:

A plan of the west wing 3rd floor is located in Appendix D. The spot check was done in this location and can be seen on these plans.

Frame:

A section of the west wing framing is located in Appendix E.

Lateral System:

The lateral resisting system is composed primarily of a moment resisting frame located at the southern exterior wall. It is made up of several steel columns that are connected to steel beams by moment connections. The columns extend from the roof down to the first floor where they are anchored to solid concrete walls and footings. The other support comes from several concrete walls throughout the structure. These walls are not specifically labeled as shear walls, but it is apparent that they provide an increase in lateral stability. These walls are solid concrete walls, reinforced with rebar. Steel columns also extend from the basement to the roof frame at these walls. The concrete walls are located around the three stair wells and two elevator shafts. An inspection of the moment frame will be done in the spot check section.

Loads:

1. **Dead**
   - **1st – 4th Floor:** Metal Deck/Steel and Topping – 46 psf
     Spray-on Fireproofing – 4 psf
     Mech/Elec – 10 psf
     Sprinklers – 5 psf

	Ceiling	– 5 psf
		70 psf

▪ **Roof:**	Metal Deck	– 2 psf
	Roofing	– 2 psf
	Insulation	– 2 psf
	Spray-on Fireproofing	– 4 psf
	Mech/Elec	– 10 psf
	Sprinklers	– 5 psf
	Ceiling	– 5 psf
		30 psf

2. Live (See Appendix C for diagrams)

- 150 psf for Mechanical Areas
- 125 psf for Laboratory Areas
- 100 psf for Stairs and exits
- 80 psf for Corridors above first floor in schools
- 60 psf for Assembly areas and theatres with fixed seating

3. Snow (ASCE7-02)

- $S = .7C_eC_tC_sp_gI$
    i. $C_e = .9$ from Table 7-2
    ii. $C_t = 1$ from Table 7-3
    iii. $C_s = 1$ for flat roof from Fig. 7-2

iv. P_g = 30 psf from Fig. 7-1

v. I_s= 1 for Cat. II from Table 7- 4

- S = 18.9 psf, however the snow load cannot be less than the criteria S = 20I_s which is equal to 20 psf, so
  S = 20 psf

4. Wind (ASCE7-02)

(See Appendix A for spreadsheet used to determine wind pressure factors)

Pressures:

N-S Direction

Leeward = q_hC_pG = - 8.38 psf

Windward = q_zC_pG = see table 1

E-W Direction

Leeward = q_hC_pG = - 3.51 psf

Windward = q_zC_pG = see table 1

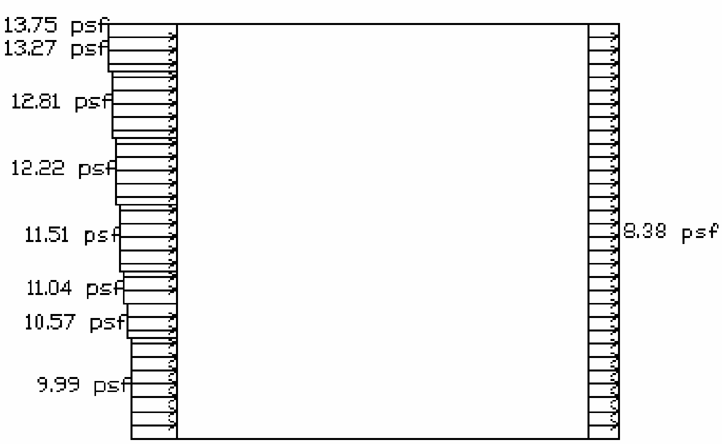
Table 1

Pressures		
Z (ft)	N-S (psf)	E-W (psf)
0-15	9.99	10.45
20	10.57	11.06
25	11.04	11.55
30	11.51	12.04
40	12.22	12.78
50	12.81	13.39
60	13.27	13.89
70	13.75	14.38

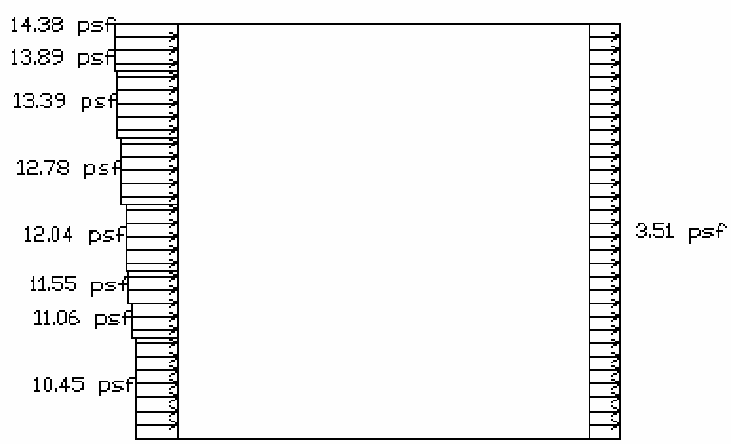
Table 2

	Forces (kips)					
Story	N-S windward	N-S leeward	N-S total	E-W windward	E-W leeward	E-W total
1	50.4	41.16	91.5	10.74	3.51	14.25
2	53.8	37.73	91.5	11.46	3.22	14.68
3	58.1	37.73	95.83	12.4	3.22	15.62
4	30.1	18.9	49	6.4	1.61	8.01

From Table 2 it can be seen that the North-South direction provides the greatest story forces. These forces yield a base shear of 327.83 kips and an overturning moment of 12,024 ft-k.



North-South Direction



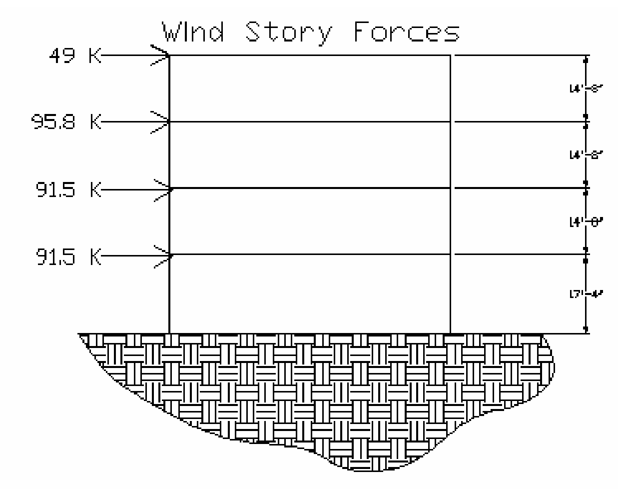
East-West Direction

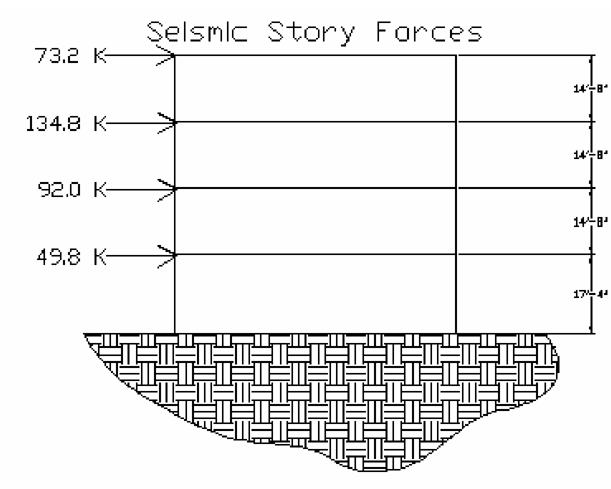
5. Seismic (See Appendix B for spreadsheet used to determine factors)

Table 3 will summarize the results of the seismic load analysis. The story shears, base shear, and overturning moment are all presented. The base shear is 349.7 kips and the overturning moment has a magnitude of 14,630 ft-kips.

Table 3

STORY	W_x	H_x	$W_xH_x^K$	C_{vx}	F_x (KIPS)	M_x (FT-KIPS)
4	618.16	62.00	38,326	0.20920	73.2	4,536
3	1,513.17	46.66	70,604	0.38538	134.8	6,288
2	1,505.63	32.00	48,180	0.26298	92.0	2,943
1	1,505.74	17.33	26,095	0.14243	49.8	863
Σ	5,142.70		183,205	1	349.7	14,630





Material Strengths:

- Steel
  - All steel A36 – Fy = 36 ksi
    Unless otherwise noted
- Concrete
  - All concrete f'c = 4 ksi
  - Minimum 28 day design compressive strength

Codes: ASCE7-02

IBC 2003

BOCA 1993

Spot Check:

Beam 1

$A_t = 10(32.5) = 325\ ft^2$
$A_I = 2(325) = 650\ ft^2$
$L = L_o\,(.25 + 15/\,(\surd\ A_I) = 104.8\ psf$
$1.2D + 1.6L = 1.2(70psf) + 1.6(104.8) = 251.68\ psf$
$251.68 * 10\ ft = 2.517\ klf$
$M_u = w_u l^2/8 = 2.517(32.5)^2/8 = 332.32\ ft\text{-}k$

Beam is in composite action with a 6 ¼ in concrete slab and metal deck

$B_{eff} = 97.5$ in – from ¼ span which was shorter than spacing
Try a W18 x 35
$A_s = 10.3\ in^2$
$Ts = Asfy = 10.3(36) = 370.8\ k$
$Cc = .85f'cB_{eff}a = 370.8\ k$ – $a=1.12\ in$
$Mn = 370.8(10.3/2) + 370.8(6\ ¼ - 1.12/2) = 4019.5\ in\text{-}k = 335\ ft – k$

ΦMn = .85(335) = 284.75 this fails

Upgrading to a W18 x 45 will pass; this is higher than the W18 x 35 that was specified on the plans. However in this spot check higher live loads were used than what was specified in the plan. It is concluded that the more conservative approach caused the outcome to be above the designer's outcome.

Girder 1

Assume Beams transfer loads to girder.
Beam 1 would transfer a point load of 41 kips.
Beam 2:

$A_t = 10(32.5) = 325\ ft^2$
$A_I = 2(325) = 650\ ft^2$
$L = L_o(.25 + 15/(\sqrt{A_I}) = 67$ psf
1.2D + 1.6L = 1.2(70psf) + 1.6(67) = 191.2 psf
191.2 * 10 ft = 1.912 klf
$M_u = w_u l^2/8 = 1.912(30)^2/8 = 215.1$ ft-k
A point load of 28.8 k is distributed to the girder.

Total point load at midspan = 70 k
$M_u = 350$ ft-k

Zreq = 350(12)/.9(36) = 130 in^3
Try W18 x 65
Bf/2tf = 5.06 < 10.8 - compact
b/tw = 35.7 < 107 - Mn = Mp

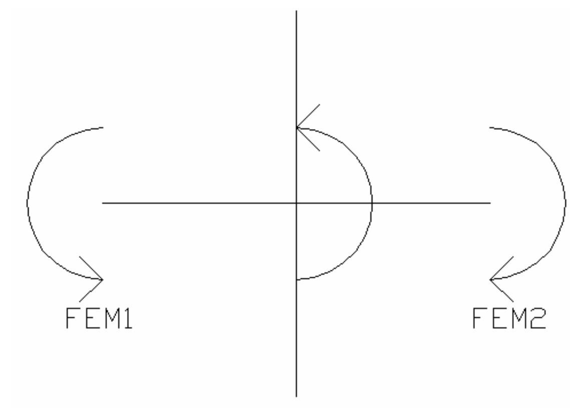
For W18 x 65:
ΦMp = ΦfyZ/12 = .9(36)133/12 = 359.1 ft-k -------O.K.

The girder is larger than specified by the engineer. This may be due to the difference in loading criterion used. The method used here was more conservative and assumed a larger live load case.

Column 1

$A_t = 15(31'3") = 469\ ft^2$
$A_I = 4(469) = 1876\ ft^2$
$L = L_o(.25 + 15/(\sqrt{A_I}) = 47.7$ psf
1.2D + 1.6L = 1.2(70psf) + 1.6(47.7) = 160.32 psf
1.2D = 84 psf

Roof: R_{LL} = 60psf (469) = 28 k
R_{DL} = 30psf (469) = 14 k
Level 2: A_I = 4(469) = 1876 ft^2
LL = 22.4 k DL = 32.8 k
Level 3: A_I = 3752 k
LL = 37.1 k DL = 65.7 k
w_u = .084(15) = 1.26 k/ft
w_u = .16(15) = 2.4 k/ft



Fem1 = 1.26 $(32.5)^2$/8 = 110.91 ft-k
Fem2 = 2.4$(30)^2$/8 = 180 ft –k
$M_{@}$joint = 69 ft-k
Assume ½ goes above and below joint

M_d = 69/2 = 34.5ft –k
P_d = 1.2(14 + 32.8 + 65.7) + 1.6(22.4 + 37.1) + .5(28) = 244.2 k
P_{eq} = 244.2 + 24/d(34.5) = 327 k -------assumed d = 10”

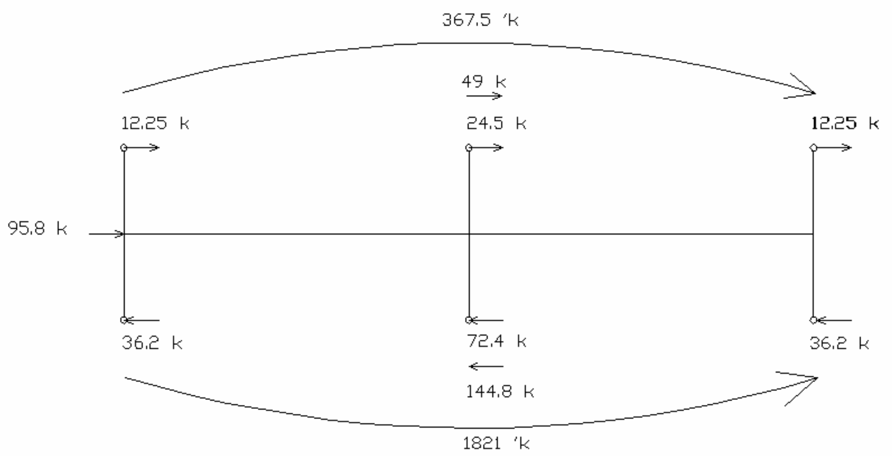
Try W10 x 45 @ KL=15’ ----- P = 405.65 k
Try W10 x 39 @ KL=15’ ----- P = 350.75 k ------ use this
Try W10 x 33 @ KL=15’ ----- P = 296.16 k -------No Good

The column selected in this method was slightly smaller than the specified column from the engineer. This could be that the column in this case disregarded lateral effects and different loading cases.

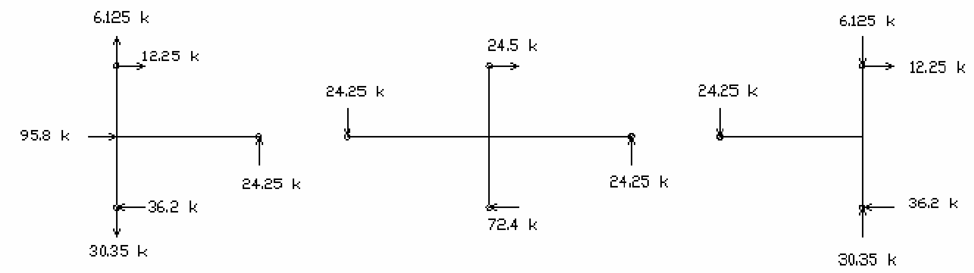
Lateral Analysis:

A portal frame analysis was used to determine the effects of story shear from wind loading on the steel frame. The portal frame is pictured below with a moment diagram. It was determined that a W18 x 65 beam would be needed to resist this bending moment.

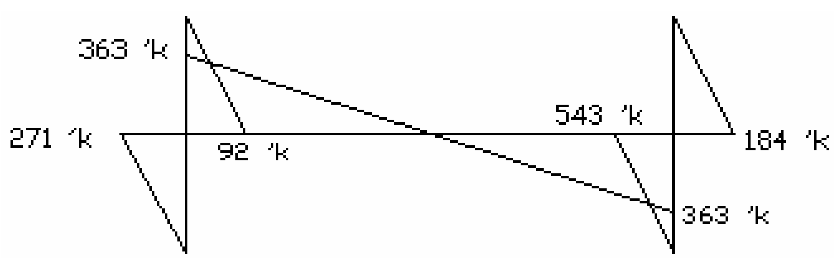
Portal Frame



Interior Effects



Moment Diagram



APPENDIX A

Velocity Pressure		
K_{zt}	1	From Fig. 6-4
K_d	0.85	From Table 6-4
V	90	From Fig 6-1
I	1	From Table 6-1

Gust Factor Calculator			
Frequency	2.26		Rigid
C_t	0.02		
h	62		
x	0.75		
G	0.85		
z_{min}	15		
c	0.2		
l	500		
ε	0.200		
gq	3.4		
gv	3.4		
z	37.2	z_h	37.2
h	62		
L_z	512.12		
I_z	0.20		
Base	307	Q	0.813126
G	0.833		

External Pressure Coefficients					
	Windward Wall				
	C_p	0.8	From Fig. 6-6		
	Leeward Wall				
N-S	length	62.6	C_p	-0.5	From Fig. 6-6
	base	307			
	ratio l/b	0.20			
E-W	length	307	Cp	-0.2	From Fig. 6-6
	base	62.6			
	ratio l/b	4.90			

Z (ft)	K_z (Table 6-3)	q_z
0-15	0.85	14.982
20	0.9	15.863
25	0.94	16.568
30	0.98	17.273
40	1.04	18.331
50	1.09	19.212
60	1.13	19.917
70	1.17	20.622
80	1.21	21.327
90	1.24	21.856
100	1.26	22.208
120	1.31	23.090
140	1.36	23.971
160	1.39	24.500

q_h	20.105

Interpolation at max. height

APPENDIX B

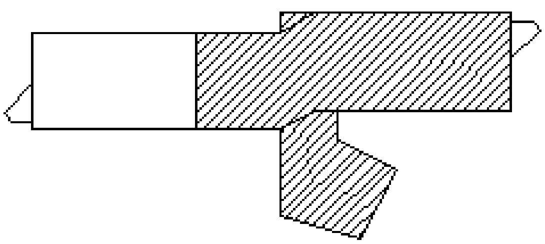
Building Properties	
B (ft)	62.5
L (ft)	307
h (ft)	62.00
# of Stories	4.00
ave. h/floor (ft)	15.50
Seismic Use group	I
Imp. (e)	1
Site Classification	C
S_s (%g)	0.17
S_1 (%g)	0.06
R	3
F_a	1.2
F_v	1.7
S_{DS}	0.204
S_{D1}	0.102
Distribution Factor	
k	1

Response	
T	0.44
C_s	0.07

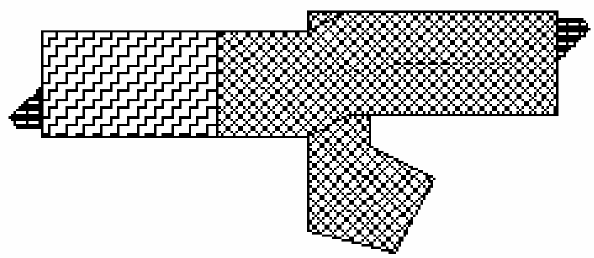
Loading (psf)	
Roof Dead	30
Snow	20
Floor Dead	70
Ex. Wall Dead	15
avg. w_{roof} (lbs)	738.3
avg. w_{floors} (lbs)	1,514.9
W_{total} (lbs)	5,142.7
V (lbs)	349.7

APPENDIX C
Drawings not to scale
Live Loads

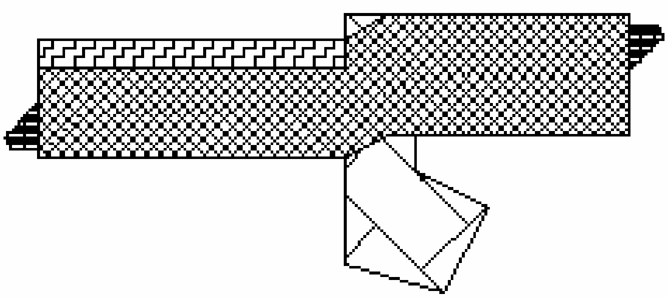
Basement



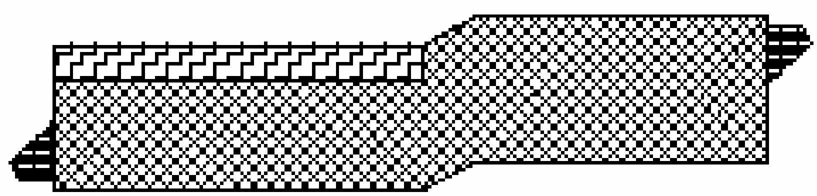
1st Floor

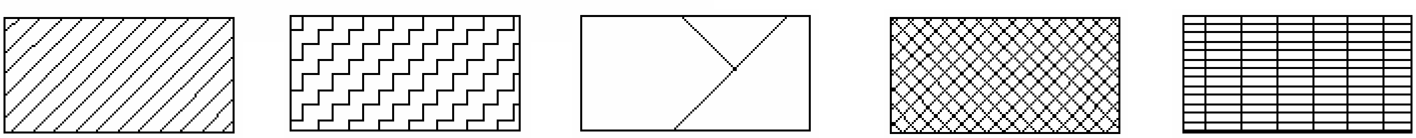


2nd Floor



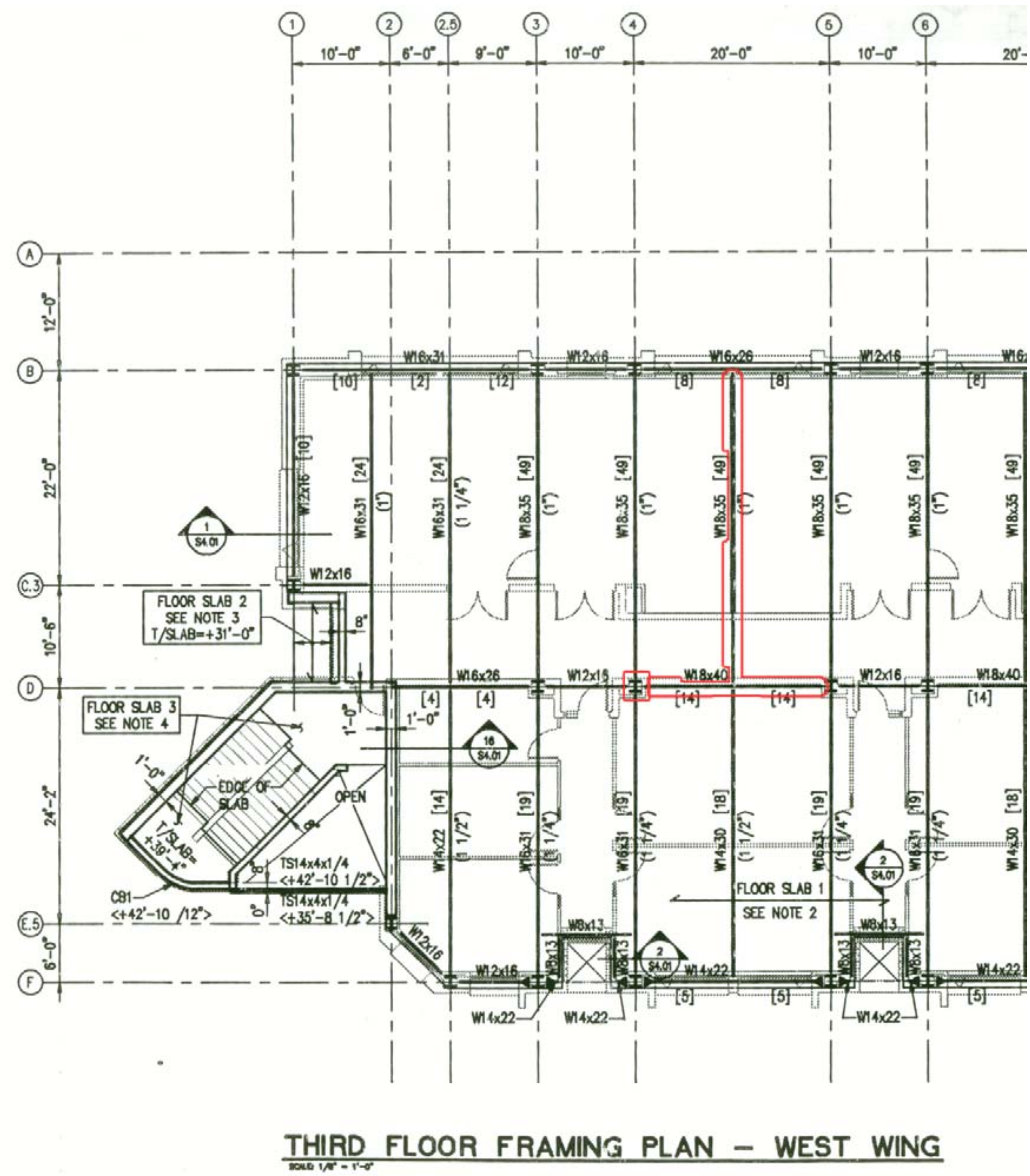
3rd – 4th Floor





150 psf   125 psf   60 psf   80 psf   100 psf

APPENDIX D
Plan of 3rd Floor West Wing (spot check elements highlighted)



APPENDIX E
Section Through the west wing