# Technical Report #1

## Administration Building

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Structural

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Pennsylvania

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# EXECUTIVE SUMMARY

The purpose of this report is to describe the physical existing conditions of the structure used for the Administration Building in Pennsylvania. It will provide an overview of all the structural components and the loads used in the design of the building. The loads were modeled using the most up-to date code, which is ASCCE 7-05.

The Administration Building consists of a composite metal deck supported by wide-flange beams, girders, and columns. The columns transfer the load to spread footings throughout the building. The basement level utilizes slab on the grade as the floor. At the roof level, this consists of wide-flange beams in-combination with open-web steel joists. The last framing aspect is the concentric braced frames used to resist lateral loads.

A wind analysis was performed for all sides of the building using the Main Wind-Force Resisting System. Along the long direction we obtained wind pressures in the mid twenties as the max pressure towards the top of the building. Being that the Administration Building is located in Pennsylvania, the wind was the controlling factor in the lateral system design.

Just like the wind analysis, a seismic analysis was performed for the building. Using ASCE 7-05 to determine the loading along the building, I was able to obtain the base shear and overturning moment. Like I mentioned above, the seismic was not the controlling factor for the lateral system.

Last but not least, spot checks of a composite beam, column and braced frame were performed. The composite beam was found to be sized properly, so I assumed I used the right loads for a typical floor. The typical column was adequate with some strength to spare. The braced frame was also found to be adequate to resist the wind load with a lot of extra strength left over. Overall, everything I checked was adequate based on my assumptions and analyses.

# STRUCTURAL SYSTEM OVERVIEW:

FOUNDATION:

The foundation system will consist of reinforced concrete spread footings that are sized utilizing bearing capacities ranging from 4,000 psf at soil bearing footings and 15,000 psf at rock-bearing footings. Total building settlements will be less than 1" with differential settlements not exceeding ½" or 1/300, based on a 20' bay. Typical perimeter frost walls are supported on continuous reinforced concrete strip footings. Foundation walls at basement or below grade levels are reinforced concrete basement walls designed for soil lateral loads and appropriate surcharge loads and supported by continuous reinforced concrete strip footings. These walls are drained on the soil side to minimize lateral surcharge loads on the walls and buildings. The slab on grade varies between a 5", 6" and 8" thickness, typically with 6x6-W4.0xW4.0 W.W.F.

FLOOR SYSTEM:

The structural floor system is 3¼" concrete slab on a 3", 20 gauge composite metal deck with ¾" steel studs, supported by wide-flange beams and wide-flange columns. The typical sizes of the beams range from W18x40 to W30x116. The girders range from W21x50 to W27x146. The columns range from W10x43 to W14x211. The concrete is normal weight (147 pcf), cast-in-place concrete and will have a 28 day strength of 4,000 psi. The concrete slab is reinforced with 6x6-W2.9xW2.9 W.W.F. to minimize plastic shrinkage cracking. The thickness of the concrete is established based on the required 2 hour fire rating for the floor construction without spray fireproofing applied to the underside of the metal deck. Structural steel shall comply with ASTM A572, Grade 50. Steel stud shear connectors shall conform to ASTM A108.

To maintain the 5'-0" building module within the typical bay sizes of 20'-0" and 40'-0", the typical beams supporting the composite slab are spaced at 10'-0" on center. These beams supporting the composite slab for the typical bays span to girders oriented across the width of the building. The wide flange steel girders in the long direction or the building support the wide flange steel beams that span the 3 bay width of the building consisting of (1) 20'-0" and (2) 40'-0" bays. Spanning the beams across the width of the building works best in combination with a braced frame lateral load resisting system.

ROOF SYSTEM:

The structural roof system consists of a 1½", 20 gauge, Type B, galvanized metal roof deck with spray fireproofing. Below mechanical equipment a concrete slab on composite metal deck is used instead of the standard roof deck and the concrete slab is reinforced with 6x6-W2.9xW2.9 W.W.F. to minimize shrinkage cracking. The framing members supporting the metal deck are either open-web joists or wide flange steel beams at 4'-0" and 5'-0" centers. The beams supporting the composite slab are wide flange steel beams at 10'-0" centers that span the width of the building.

LATERAL SYSTEM:

The typical composite steel-framed building utilizes a braced frame lateral load resisting system. The braced frames have been coordinated, located and configured to integrate with the architectural layout and mechanical distribution. These frames consist of wide flange columns, wide flange beams at each story and one HSS (hollow structural section) diagonal braces between each story. Typically the HSS braces will be HSS8x6x1/2.

EXTERIOR WALL SYSTEM:

Pre-fabricated brick truss panel assemblies comprised of structural tube and stud infill, steel relieving lintels, and shop-applied exterior brick face. There was a nine-month lead-time for brick materials. This system is independent of the floor and roof framing thus enabling smaller spandrel beam sizes.

## CODES:

- -2000 International Building Code
- -American Institute of Steel Construction (AISC) standards
    - -Architecturally Exposed Structural Steel-Section 10
- -Specifications for Structural Steel Buildings – Load and Resistance Factor Design
- -AWS Structural Welding Code
- -Detailing, Fabrication and Erection – Specifications and Codes
- -Steel Joist Institute (SJI)
    - -Specification Section 05200
- -American Concrete Institute (ACI) standards
- -American Society for Testing and Materials (ASTM) standards
- -Independent Testing and Inspection Agency

ADOPTED CODES:

- -American Society of Civil Engineers 7-05 (ASCE 7-05)

# LOADS

FLOOR LIVE LOAD:

| ROOM | MIN DESIGN LOAD (PSF) ASCE7-05 | DESIGN LOAD |
|---|---|---|
| Fitness Center | 100 | 100 |
| Lobbies | 100 | 100 |
| Stairs and Exits | 100 | 100 |
| Offices | 50 | 100 |
| Dining Room | 100 | 100 |
| Mechanical Rooms | N/A | 150 |
| Corridors | 100-FIRST FLOOR 80-ALL OTHER FLOORS | 100 |
| Roof | 20 | 30 |

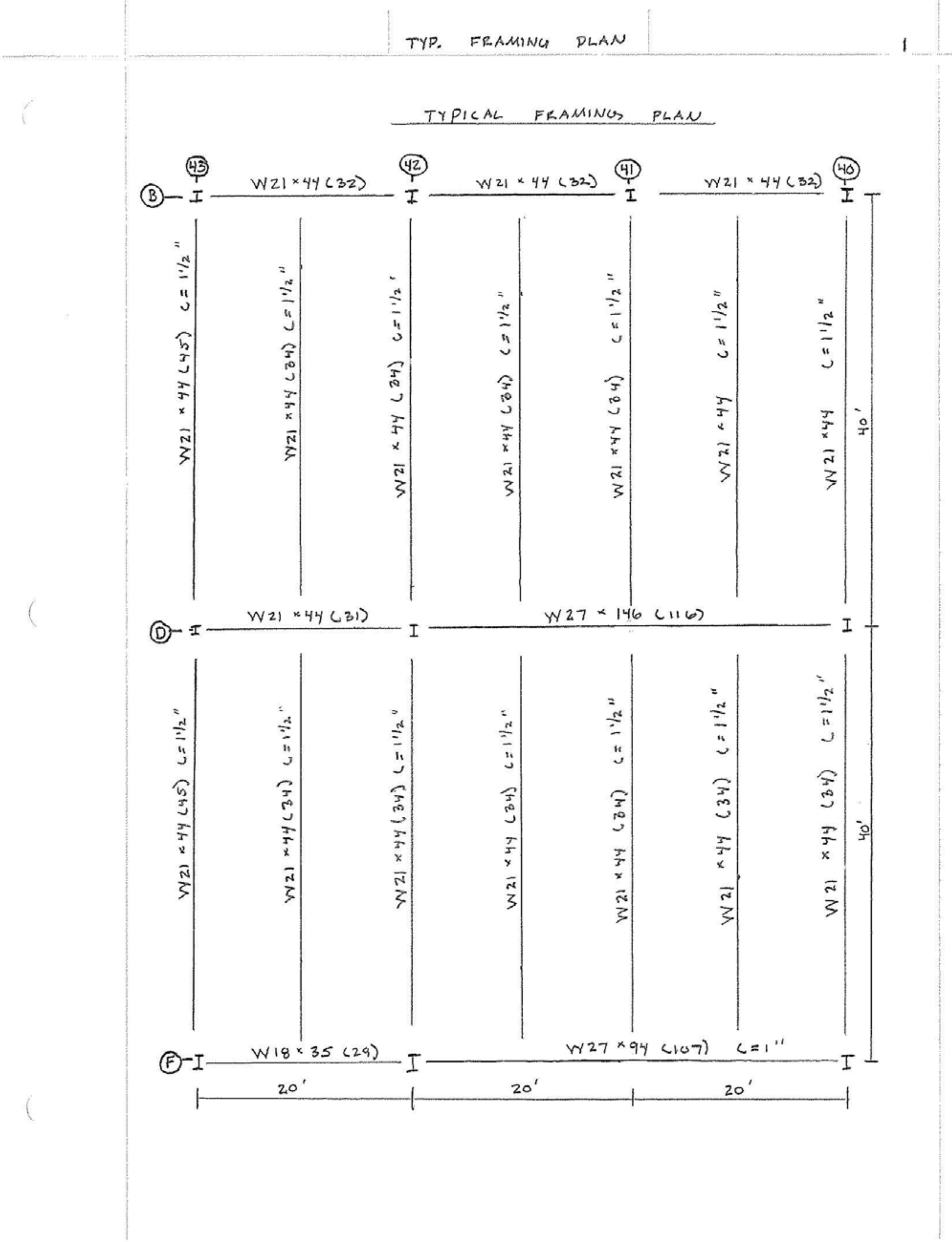
FLOOR DEAD LOAD:

| ITEM | DESIGN VALUE |
|---|---|
| CONCRETE SLAB | 42 PSF |
| SUPERIMPOSED DEAD LOAD | 30 PSF |
| STEEL STRUCTURE + DECK | 15 PSF |
| EXTERIOR BRICK TRUSS PANEL | 40 PSF |

ROOF SNOW LOAD:

| ITEM | DESIGN VALUE | CODE BASIS |
|---|---|---|
| ROOF LIVE LOAD | 30 PSF | ASCE7-05 |
| GROUND SNOW LOAD (Pg) | 30 PSF | ASCE7-05 |
| FLAT ROOF SNOW LOAD (Pf) | 24 PSF | ASCE7-05 |
| SNOW EXPOSURE FACTOR (Ce) | 0.9 | ASCE7-05 |
| SNOW IMPORTANCE FACTOR (I) | 1.2 | ASCE7-05 |

# TYPICAL FRAMING PLAN



# DESIGN IMPACTS

The Administration Building is a steel framed building with a concrete slab floor. Being a steel building, it only makes sense for the lateral system to be a concentric braced frame using Hallow Structural Section (HSS) as the braces. For the design, the use of Load and Resistance Factor Design (LRFD) was used. I believe these choices were made based on cost and the typical design that the structural engineer decided upon to use. Steel is a little more expensive than concrete but it can be put up a lot quicker and that is where the executive decision to use steel was made. The use of LRFD was chosen by the structural engineer as the code they will design by as a company.

The impact on using braced lateral frames is figuring out how much force each braced frame takes. If you used a shear wall, 100% of the lateral load would go to that one shear wall. Since the building is in Pennsylvania, wind is going to be bigger impact on the building compared to seismic. So wind is going to be very important in my design/analysis of the building. Finally, the last impact is the use of an older code that was implemented. My analysis of the building will be using ASCE 7-05 which is a much newer version than the code that used originally used.

# WIND LOADING

WIND 1

WIND

• DESIGN LOADS

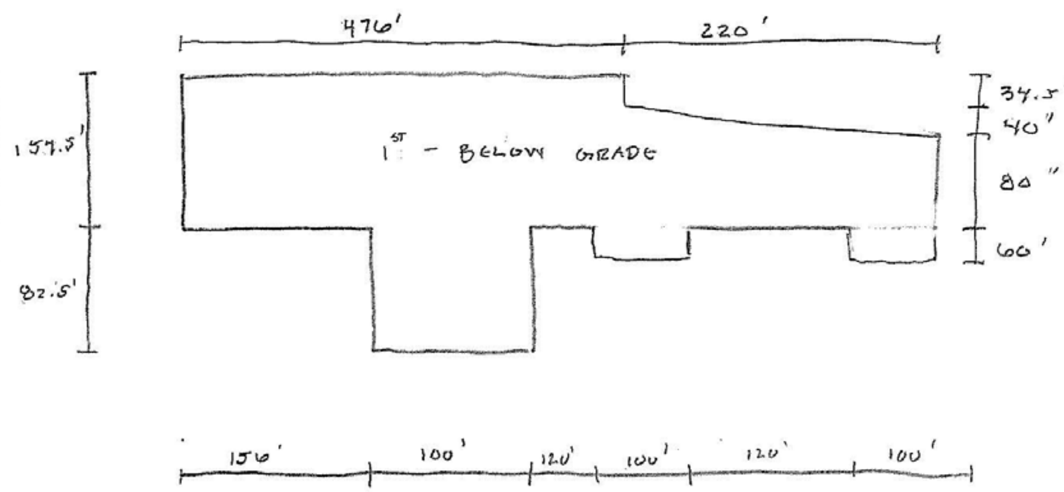
$V = 90$ MPH

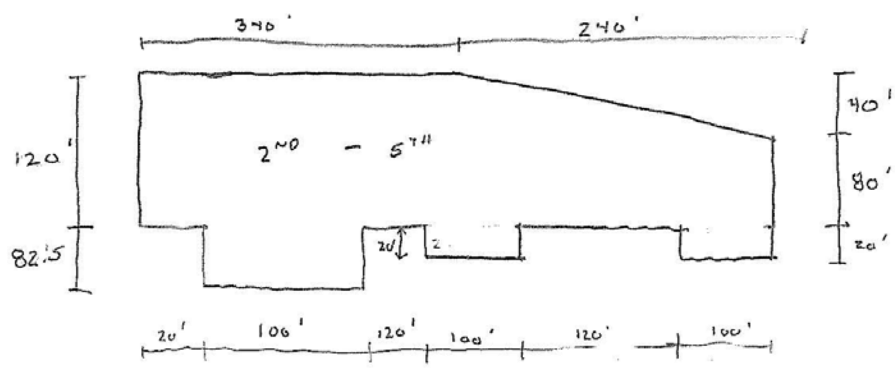
$I_W = 1.15$

WIND EXPOSURE C

MAIN WINDFORCE-RESISTING SYSTEM

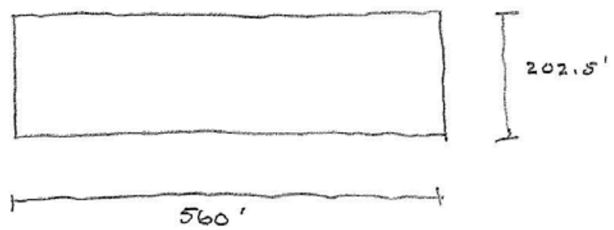
MEAN ROOF HEIGHT = 67' (COMPLETELY ABOVE GRADE)



WIND 2

1.




- $K_{zt} = 1.0 \rightarrow 6.5.7$
- GUST EFFECT FACTOR $G \rightarrow 6.5.8$

- RIGID = FUND. FREQ ≥ 1 Hz

$T_a = C_t h_n^x$

$= 0.028(67')^{0.8} = 0.81s \rightarrow 1/T_a = 1.24 \text{ Hz}$

→ RIGID

$G = 0.925\left(\frac{(1 + 1.7 g_Q I_{\bar{z}} Q)}{1 + 1.7 g_v I_{\bar{z}}}\right)$

$I_{\bar{z}} = c\left(\frac{33}{\bar{z}}\right)^{1/6} \rightarrow \bar{z} = 0.6h \geq z_{min}$

$= 0.6(67') = 40.2 \geq 15'$ ✓

$= 0.2\left(\frac{33}{40.2}\right)^{1/6}$

$= 0.194$

$g_Q = g_v = 3.4$

$Q = \sqrt{\frac{1}{1 + 0.63\left(\frac{B+h}{L_{\bar{z}}}\right)}} =$

$B = 202.5'$

$h = 67'$

$L_{\bar{z}} = L\left(\frac{\bar{z}}{33}\right)^{\bar{\epsilon}} = 500'\left(\frac{40.2'}{33}\right)^{1/5} = 520.13'$

$Q = \sqrt{\frac{1}{1 + 0.63\left(\frac{202.5' + 67'}{520.13'}\right)}} = 0.87$

Q = 0.75 (SHORT DIRECTION)

WIND 3

G = 0.93 (SHORT DIRECTION)

$$G = 0.925\left(\frac{(1 + 1.7(3.4)(0.194)(0.87))}{1 + 1.7(3.4)(0.194)}\right) = 0.86$$

- ENCLOSURE CLASSIFICATION → 6.5.9
  → ENCLOSED

- INTERNAL PRESSURE COEFFICIENT, $GC_{pi}$ → 6.5.11.1

  $GC_{pi}$ = +0.18
  −0.18

- EXT. PRESSURE COEFFICIENTS $C_p$ OR $GC_{pf}$ → 6.5.11.2/3

  − WALL PRESSURE, $C_p$

  WINDWARD WALL = 0.8 → $q_z$
  LEEWARD WALL = −0.3 → $q_h$
  SIDE WALL = −0.7 → $q_h$

  − ROOF PRESSURES, $C_p$

  0 − h/2 = −0.9/−0.18
  h/2 − h = −0.9/−0.18
  h − 2h = −0.5/−0.18
  > 2h = −0.3/−0.18

WIND 4

· VELOCITY PRESSURE $q_z$ OR $q_h$ → 6.5.10

$q_z = 0.00256 K_z K_{zt} K_d V^2 I$

$K_d = 0.85$ $I = 1.15$

$K_{zt} = 1.0$

$K_z$ = REFER TO CHART

$V = 90$

$q_z = 20.3 K_z$ -

$q_h = 20.3(1.17) = 23.75$

· DESIGN WIND LOAD $p$ → 6.5.12/13/14/15

$p = qGC_p - q_i(GC_{pi})$ → PSF

$q = q_z$ FOR WINDWARD WALLS

$q = q_h$ FOR LEEWARD WALLS

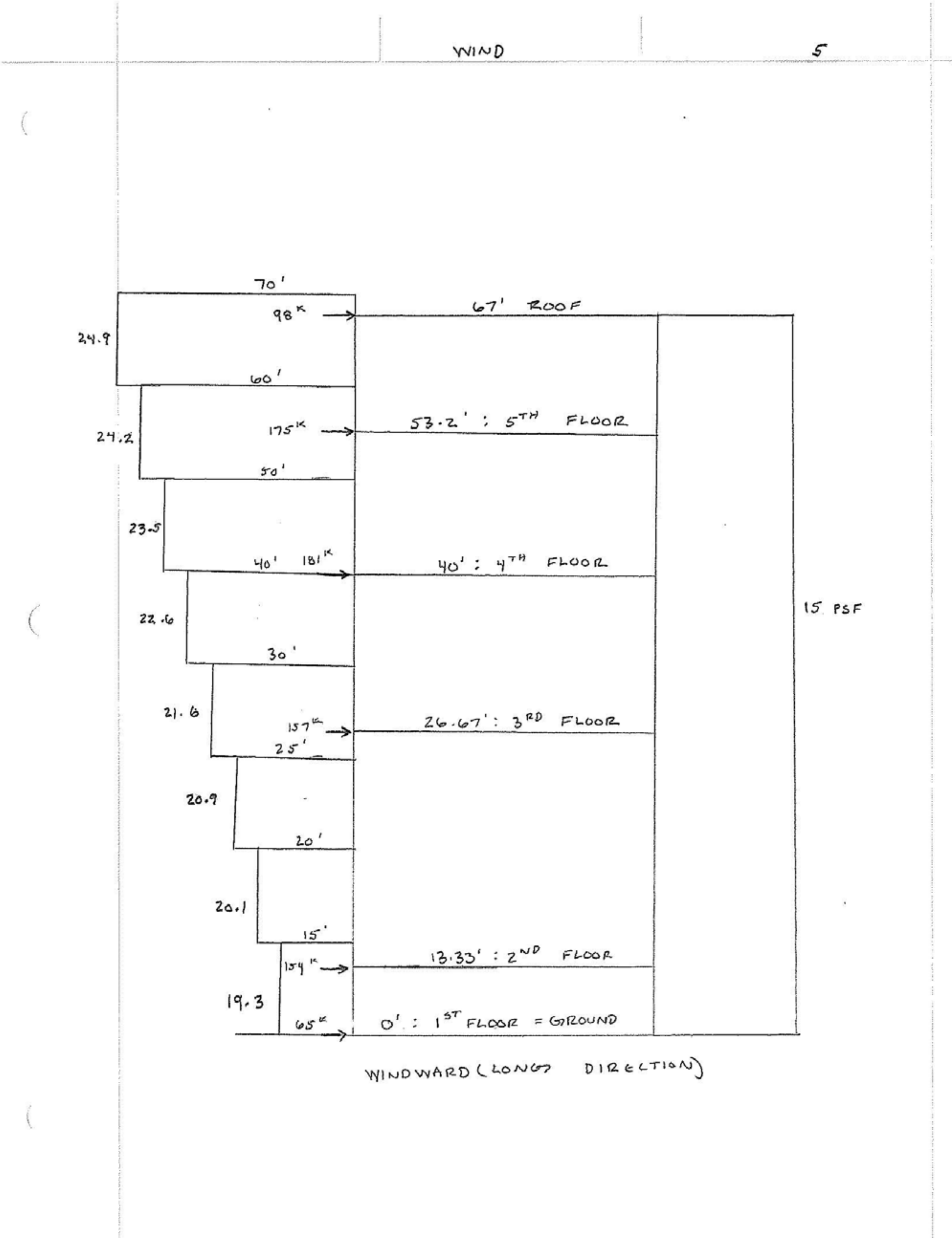
$q_i = q_h$ FOR (-) INT. PRESSURE

$q_i = q_z$ FOR (+) INT. PRESSURE

$G = 0.86$

$C_p = 0.8$

$GC_{pi} = +0.18 / -0.18$


WIND
5
70'
98K
67' ROOF
24.9
60'
24.2
175K
53.2' : 5TH FLOOR
50'
23.5
40' 181K
40' : 4TH FLOOR
22.6
15 PSF
30'
21.6
157K
26.67' : 3RD FLOOR
25'
20.9
20'
20.1
15'
154K
13.33' : 2ND FLOOR
19.3
65K
0' : 1ST FLOOR = GROUND
WINDWARD (LONG DIRECTION)

WIND PRESSURES

WINDWARD WALL PRESSURE – M.W.F.R.S.

| HEIGHT(FT) | Kz | qz | P(SHORT DIRECTION,PSF) | P(LONG DIRECTION,PSF) |
|---|---|---|---|---|
| 0-15 | 0.85 | 17.255 | 18.1 | 19.3 |
| 15-20 | 0.9 | 18.27 | 18.9 | 20.1 |
| 20-25 | 0.94 | 19.082 | 19.6 | 20.9 |
| 25-30 | 0.98 | 19.894 | 20.3 | 21.6 |
| 30-40 | 1.04 | 21.112 | 21.2 | 22.6 |
| 40-50 | 1.09 | 22.127 | 22.1 | 23.5 |
| 50-60 | 1.13 | 22.939 | 22.7 | 24.2 |
| 60-70 | 1.17 | 23.751 | 23.4 | 24.9 |

LEEWARD WALL PRESSURE – M.W.F.R.S.

| DIRECTION | PRESSURE (PSF) |
|---|---|
| LONG | -9.4 |
| SHORT | -15 |

SIDEWALL PRESSURE – M.W.F.R.S.

| DIRECTION | PRESSURE (PSF) |
|---|---|
| LONG | -19.3 |
| SHORT | -18.1 |

# SEISMIC LOADING

| ITEM | DESIGN VALUE |
|---|---|
| SITE CLASS | C |
| SPECTRAL RESPONSE ACCELERATION AT SHORT PERIODS (Ss) | 0.328 |
| SPECTRAL RESPONSE ACCELERATION AT PERIOD OF 1s (S1) | 0.008 |
| SHORT PERIOD SITE COEFFICIENT (Fa) | 1.2 |
| LONG PERIOD SITE COEFFICIENT (Fv) | 1.7 |
| DAMPED SPECTRAL RESPONSE ACCELERATION AT SHORT PERIODS (Sds) | 0.26 |
| DAMPED SPECTRAL RESPONSE ACCELERATION AT PERIOD OF 1s (Sd1) | 0.0091 |
| SEISMIC RESISTING SYSTEM | CONCETRICALLY BRACED FRAMES |
| RESPONSE MODIFICATION COEFFICIENT, (R) | 5 |
| OVERSTRENGTH FACTOR | 2 |
| DEFLECTION AMPLICATION FACTOR | 4.5 |
| IMPORTANCE FACTOR | 1.25 |
| OCCUPANCY CATEGORY | 3 |
| SEISMIC DESIGN CATEGORY | B |
| BASE SHEAR | 566 (K) |

BASE SHEAR:

| FLOOR | DEAD LOAD (PSF) | WALL DEAD LOAD (PSF) | FLOOR AREA (SF) | WALL AREA | W(k) | Cs | V=CsW |
|---|---|---|---|---|---|---|---|
| 1 | 100 | 40 | 50000 | 0 | 5000 | 0 | 50 |
| 2 | 100 | 40 | 113680 | 10507 | 11788.28 | 0 | 117.883 |
| 3 | 100 | 40 | 113680 | 21014 | 12208.56 | 0 | 122.086 |
| 4 | 100 | 40 | 113680 | 21014 | 12208.56 | 0 | 122.086 |
| 5 | 100 | 40 | 113680 | 21014 | 12208.56 | 0 | 122.086 |
| ROOF | 24 | 40 | 113680 | 10507 | 3148.6 | 0 | 31.486 |
| **TOTAL** | | | | | **56562.56** | | **565.626** |

SEISMIC LOAD DISTRIBUTION:

| FLOOR | W(k) | hx(FT) | Hx^k(Wx) | Cvx | Fx=CvxV | Mx=hx*Fx (K-FT) |
|---|---|---|---|---|---|---|
| 1 | 5000 | 20 | 2000000 | 0.01142 | 6.463919 | 129.2783873 |
| 2 | 11788 | 33.33 | 13095158.4 | 0.074776 | 42.32302 | 1410.626385 |
| 3 | 12209 | 46.67 | 26592287.4 | 0.151847 | 85.9452 | 4011.062517 |
| 4 | 12209 | 60 | 43952400 | 0.250976 | 142.0524 | 8523.143088 |
| 5 | 12209 | 73.33 | 65651320.2 | 0.374881 | 212.1824 | 15559.33686 |
| ROOF | 3149 | 87 | 23834781 | 0.136101 | 77.03305 | 6701.87546 |
| **TOTAL** | **56563** | | **175125947** | **1** | **566** | **36335.3227** |

SEISMIC

- SITE CLASS C → 67' TALL ABOVE GRADE
- $S_s = 0.328g$
  $S_1 = 0.008g$
- $F_a = 1.2$
  $F_v = 1.7$
- $S_{MS} = F_a \cdot S_s = 1.2(0.328) = 0.3936$
  $S_{M1} = F_v \cdot S_1 = 1.7(0.008) = 0.0136$
- $S_{DS} = (2/3) S_{MS} = 0.26$
  $S_{D1} = (2/3) S_{M1} = 0.0091$
- COMPOSITE STEEL + CONCRETE CONCENTRICALLY BRACED FRAMES

  $R = 5$

  $\Omega_o = 2$

  $C_d = 4.5$
- $I = 1.25$ → OCCUPANCY CAT. III
- SEISMIC DESIGN CATEGORY B

SEISMIC 2

- DESIGN BASE SHEAR

$V = C_s \cdot W$

- $T_a = C_t h_n^x$

$= 0.028(67')^{0.8} = 0.81s$

- $C_u T_a = 1.7(0.81) = 1.38$

- $T_L = 6s$

- $C_s =$
  - $S_{DS} / (R/I) = 0.26/(5/1.25) = 0.065$
  - $S_{D1} / [T(R/I)] = 0.0091/(0.81(5/1.25)) = 0.0028$
  - $\frac{S_{D1} \cdot T_L}{T^2 (R/I)} = \frac{0.0091(6)}{(0.81)^2 (5/1.25)} = 0.021$

$C_s = 0.0028 < 0.01 \rightarrow \underline{0.01}$

- W:
  - FLAT SNOW ROOF LOAD = 24 PSF
  - TYP. FLOOR:
    - 42 PSF CONC. SLAB
    - 30 PSF SDL
    - 15 PSF STEEL STRUCTURE + METAL DECK
    - 13 PSF PARTION LOAD

    100 PSF

- WALLS
  - BRICK TRUSS PANEL = 40 PSF

- AREAS;
  - TYPICAL FLOOR: 560' × 203' = 113,680 FT²
  - TYPICAL WALL: 560'(13.3')2 + 203(13.3')2 = 21,014 FT²
  - BASEMENT: 50,000 FT²

SEISMIC 3

- $V = C_s \cdot W$

  $V = 566^k$ → REFER TO TABLE

- VERTICAL DISTRIBUTION OF FORCES

  - $F_x = C_{vx} V$

    $$C_{vx} = \frac{w_x h_x^k}{\Sigma w_i h_i^k}$$

    $k = 2$

    $h_x = 87'$

    $W_i = 56,563^k$

- OVERTURNING MOMENT $= 36,336^{k\text{-}ft}$

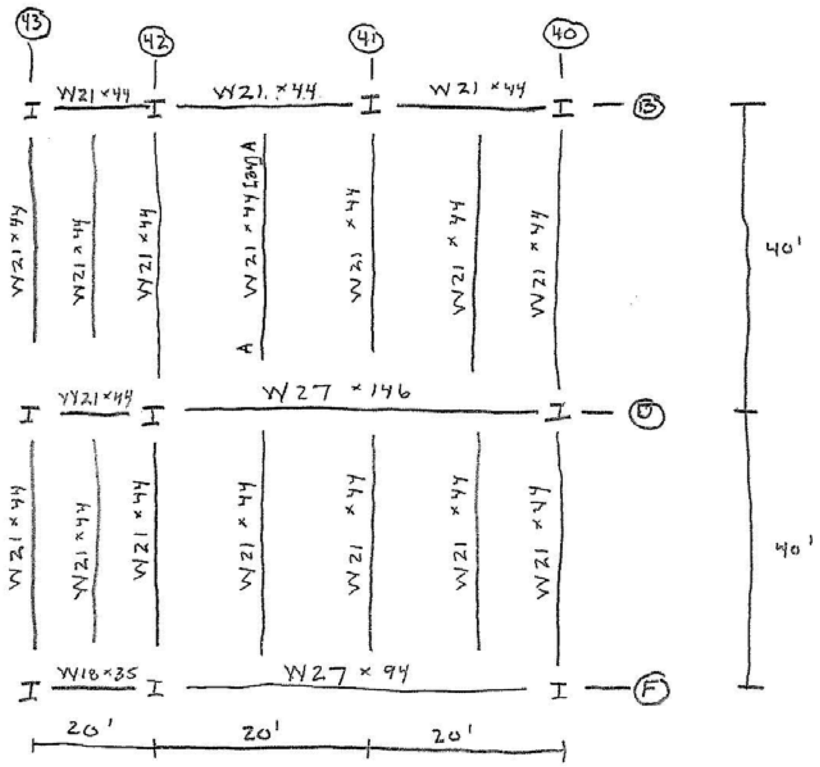
# SPOT CHECK-COMPOSITE BEAM

SPOT CHECK

1

SPOT CHECK

• DINING → FLOOR 2 (LEVEL 210')




COL D-42 = W14×211 , H = 20'

LL = 100 PSF REDUCIBLE

DL = 42 PSF SLAB

+30 SDL

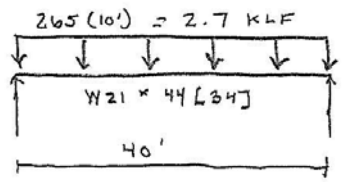
+15 STEEL + DECK

87 PSF

$W_u = 1.2(87\,PSF) + 1.6(100) = 265\,PSF$ (LRFD)

SPOT CHECK 2

BM A




$V_{max} = \frac{PL}{2} = \frac{2.7 KLF (40')}{2} = 54^{K}$

$M_{max} = \frac{wL^2}{8} = \frac{2.7 KLF (40')^2}{8} = 540^{K-FT}$

3¼" SLAB NWC
3" METAL DECK
$f'_c$ = 4000 PSI
Fy = 50,000 PSI

TRY TFL w/ $Y2 = 5''$ ($\phi M_n = 746^{k-ft}$, $\Sigma Q_n = 649^{k}$)

$b_{eff} = \frac{40'(12)}{4} = 120'' \longrightarrow b_{eff} = 120''$

$10'(12) = 120''$

$T_s = A_s F_y = 13 in^2 (50 KSI) = 650^{K}$
$C_c = 0.85(f'_c) b_{eff}(a) = 649^{K}$

$a = \frac{\Sigma Q_n}{0.85(f'_c) b_{eff}} = \frac{649^{K}}{0.85(4 KSI)(120'')} = 1.59''$

$Y_2 = 6.25 - \frac{1.59}{2} = 5.455'' > 5''$ ✓

$M_n = T_s\left(\frac{d}{2}\right) + C_c\left(t - a/2\right)$
$= 649\left(\frac{20.7}{2}\right) + 649(5.455) = 854.78^{k-ft}$

$\phi M_n = 0.9(854.78) = 769^{k-ft}$

$Y_2 = 5.5'' \longrightarrow \phi M_n = 771 > 769^{k-ft}$ @ TFL ✓

# SPOT CHECK-COLUMN

SPOT CHECK 3

- COL D-42 = W14 × 24    H = 20'

LL = 100 PSF

DL = 87 PSF

SUPPORTS 4 FLOORS

$A_T = \frac{60'(80')\,4}{2} = 4{,}800 \text{ FT}^2$

$K_{LL} = 4 \rightarrow$ TABLE 4-2

$L = L_o\left(0.25 + \frac{15}{\sqrt{K_{LL} A_T}}\right) > 0.4 L_o$

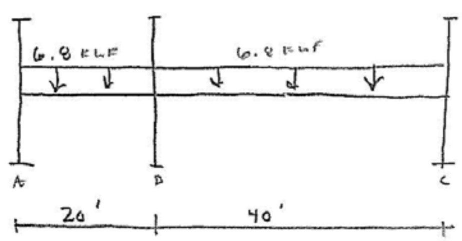
$= 0.25 + \frac{15}{\sqrt{4(4800)}} = 0.35 L_o < 0.4 L_o$ N.G.

$L = 0.4(100 \text{ PSF}) = 40 \text{ PSF}$

$1.4D = 1.4(87) = 122 \text{ PSF}$

$1.2D + 1.6L = 1.2(87) + 1.6(40) = 169 \text{ PSF}$ *

$P_U = 169 \text{ PSF}(4800 \text{ FT}^2) = 812^{K}$




$W_U = 169 \text{ PSF}(40') = 6.8 \text{ KLF}$

$FEM_{AB} = \frac{WL^2}{12} = \frac{6.8 \text{ KLF}(20')^2}{12} = 227^{K\text{-}FT}$

$FEM_{DC} = \frac{6.8(40)^2}{12} = 901^{K\text{-}FT}$

$\Delta FEM = 901 - 227 = 674^{K\text{-}FT}$

SPOT CHECK 4

W14 ×211

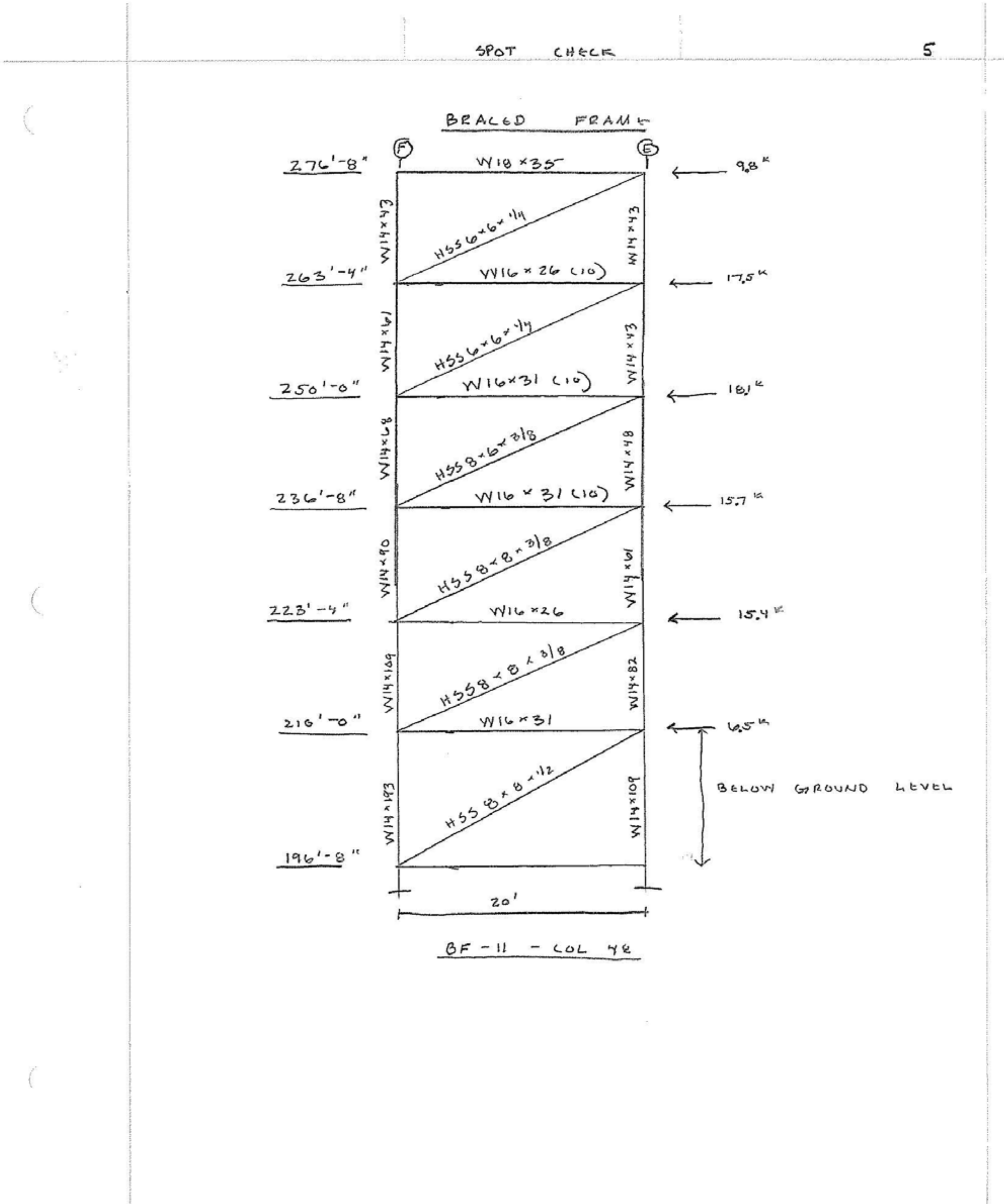
$\phi P_n = 2160^k$
$\phi M_p = 1460^{1k}$

$P_u = 812^k$
$M_u = 674^{k \cdot ft}$

$\frac{P_u}{P_n} = \frac{812}{2160} = 0.38 \rightarrow$ EQ H1-1A

$0.38 + \frac{8}{9}\left(\frac{674}{1460}\right) = 0.79 < 1$ ✓

# SPOT CHECK-BRACED FRAME

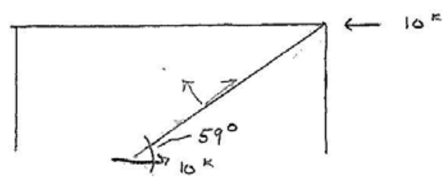


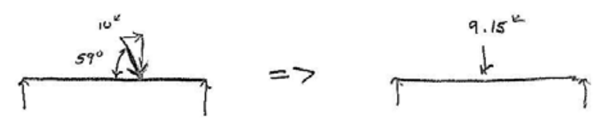
SPOT CHECK 6

- BRACED FRAMES IN SHORT DIRECTION

| | | |
|---|---|---|
| - BF-11 | E - F | → 10% |
| - BF-12 | D - F | → 20% |
| - BF-14 | D - F | → 20% |
| - BF-16 | D - G | → 30% |
| - BF-18 | C - D | → 20% |

↳ ASSUMPTION




$\cos(31)\ 10^k = 9.15^k$

OR

AXIAL COMPRESSION:

$\frac{10}{\cos 59} = 20^k << 78^k$ ✓