Appendices

Appendix A: Structural System Overview

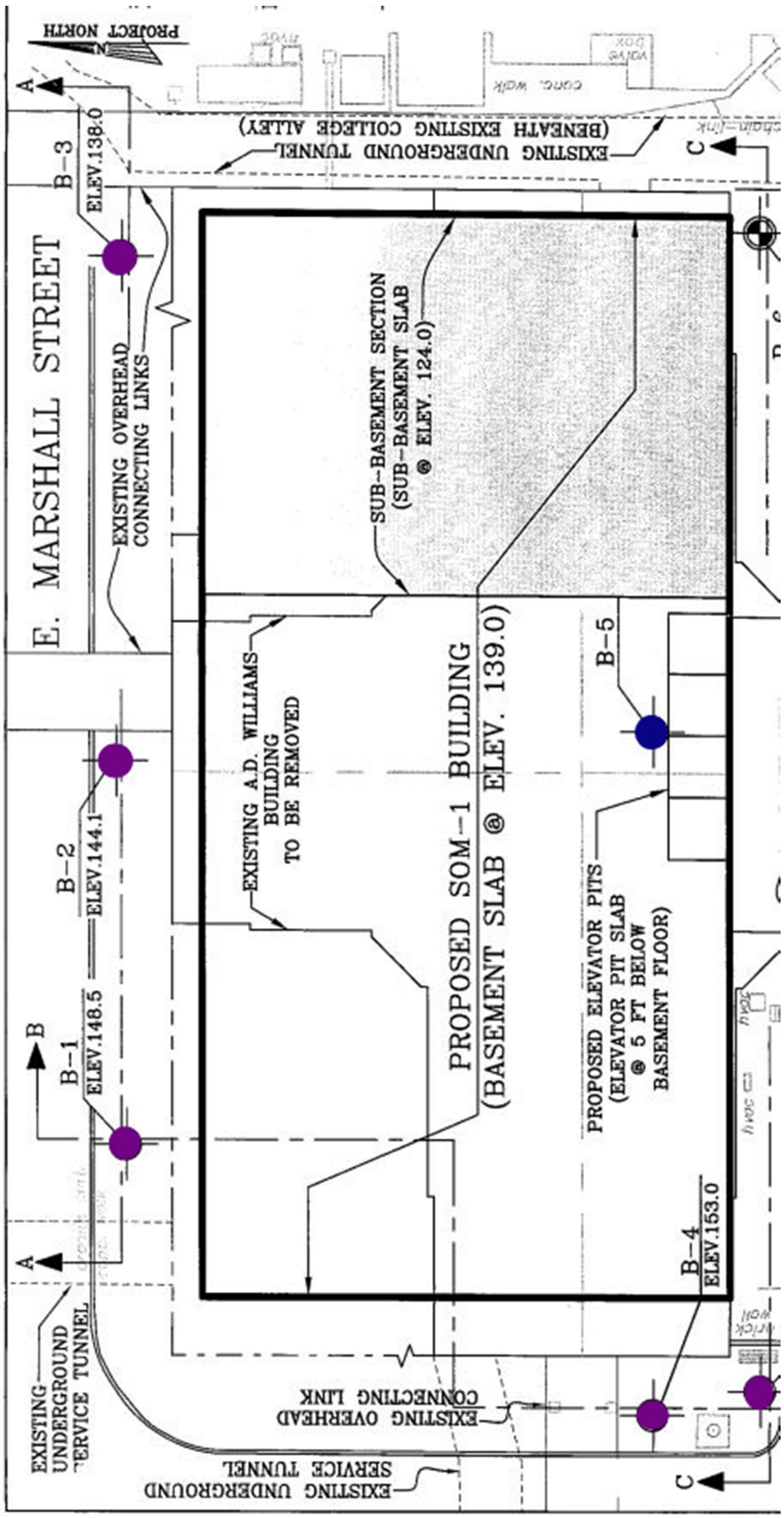
Appendix B: Gravity System Redesign

Appendix C: Lateral System Redesign

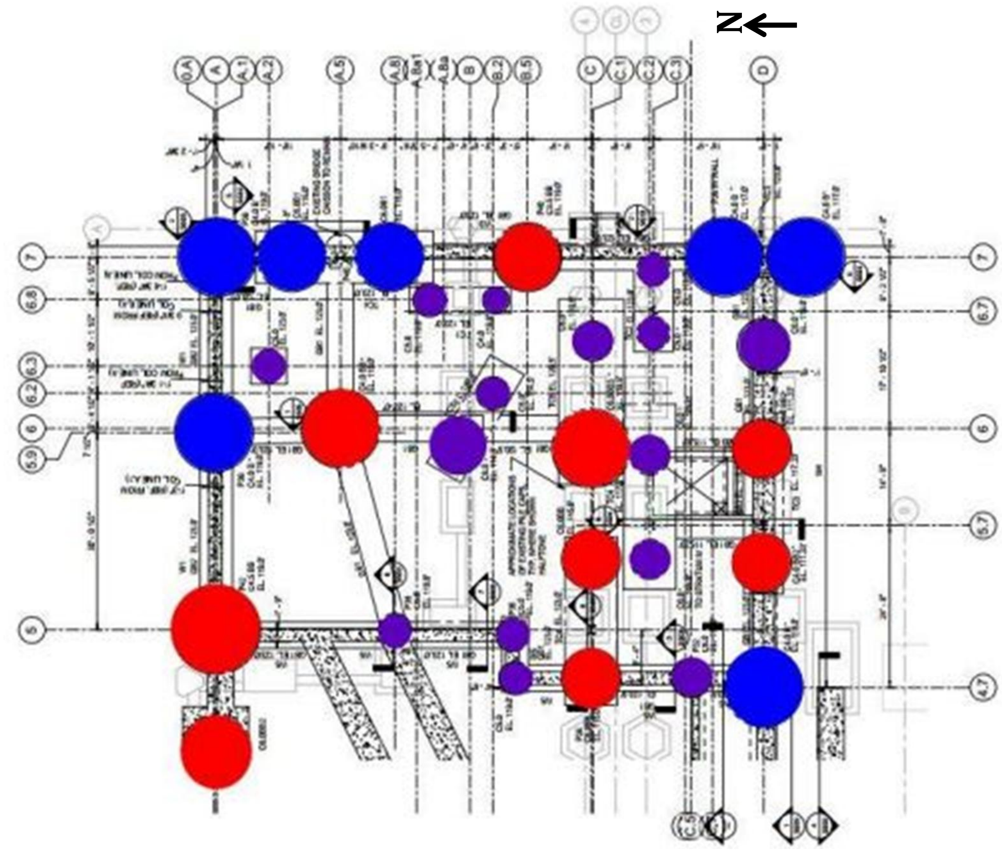
Appendix D: Cost & Schedule Analysis (Breadth 1)

Appendix E: Architectural Considerations (Breadth 2)

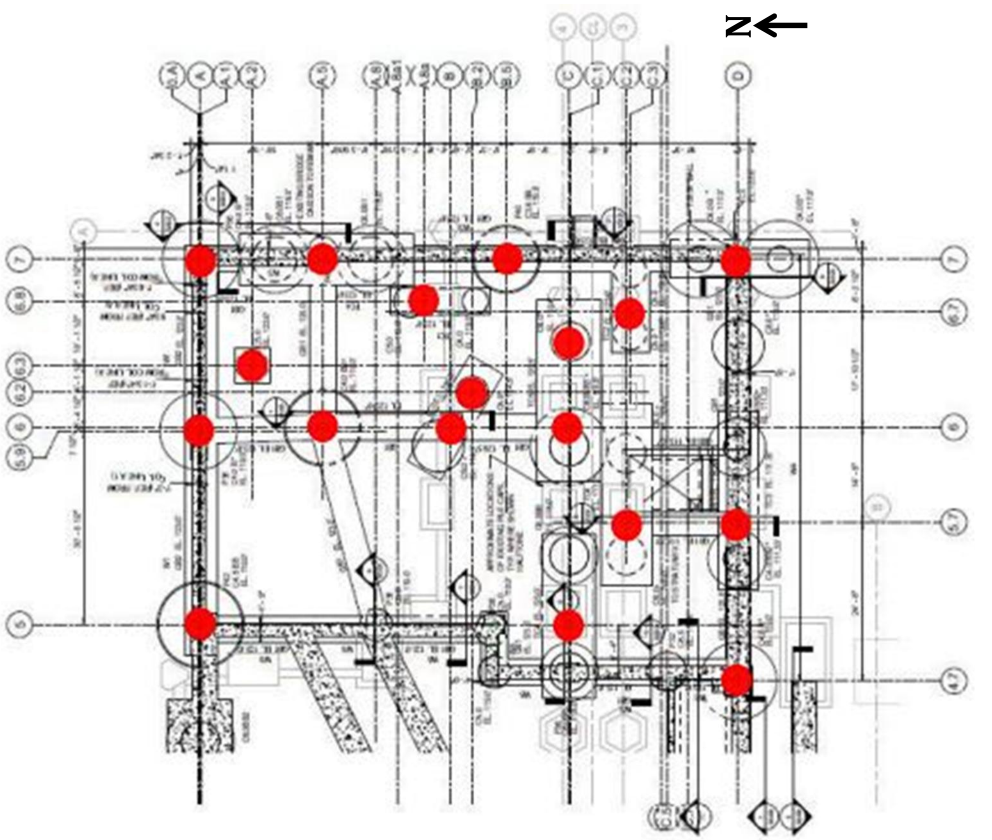
Appendix A: Structural System Overview



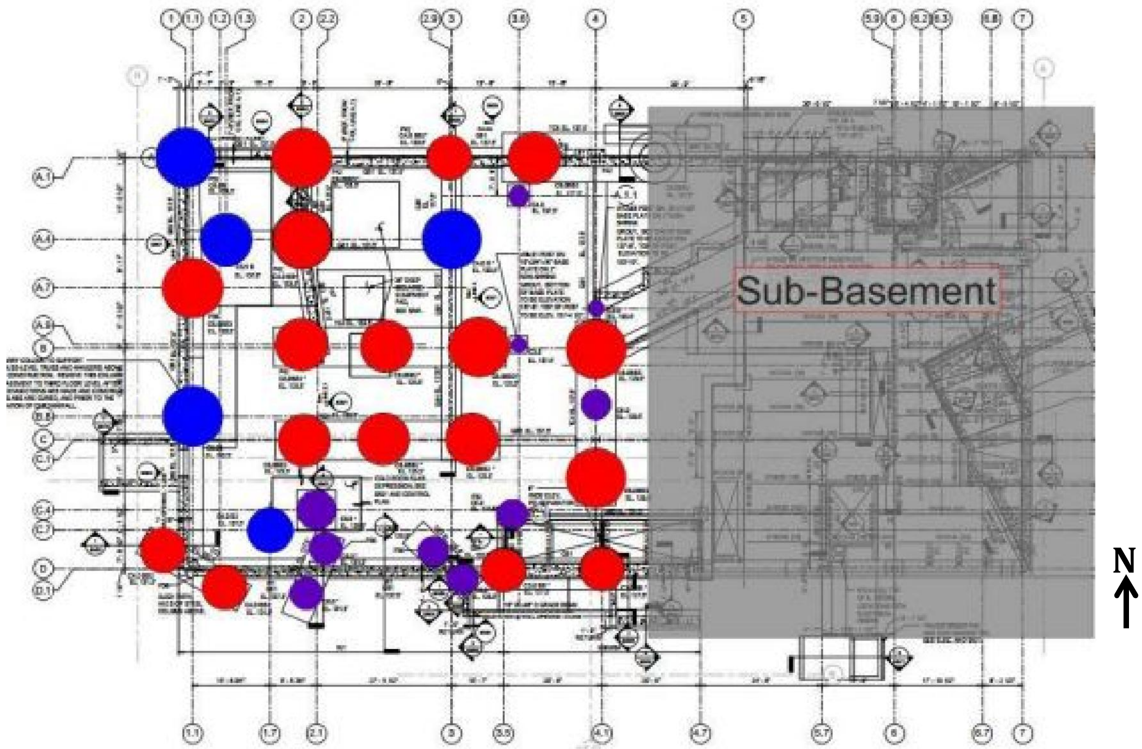
Test Boring Sites established in the field by civil engineer Geotech, Inc.
(Boring sites completed prior to demolition of the A.D. Williams Building shown in purple;
Boring site completed after demolition of the A.D. Williams Building shown in blue)



Drilled Pier Scheme for the Sub-Basement Level
(Straight Shaft = Purple; Single-Belled = Blue; Double-Belled = Red)

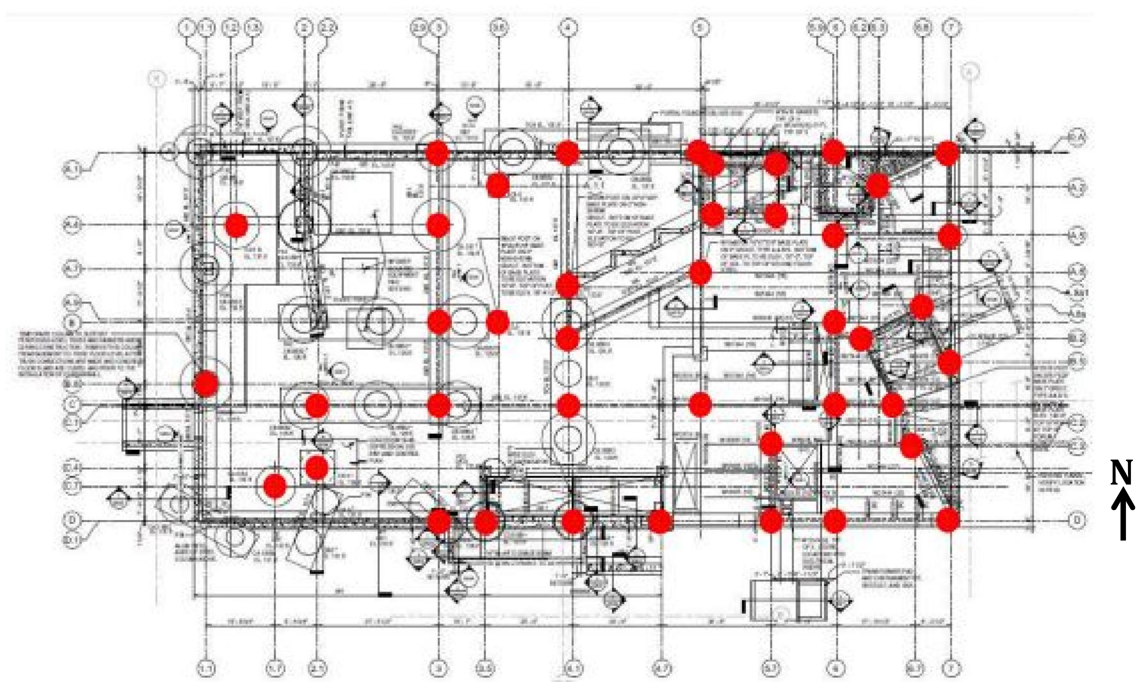


Column Layout (Highlighted in Red) for the Sub-Basement Level

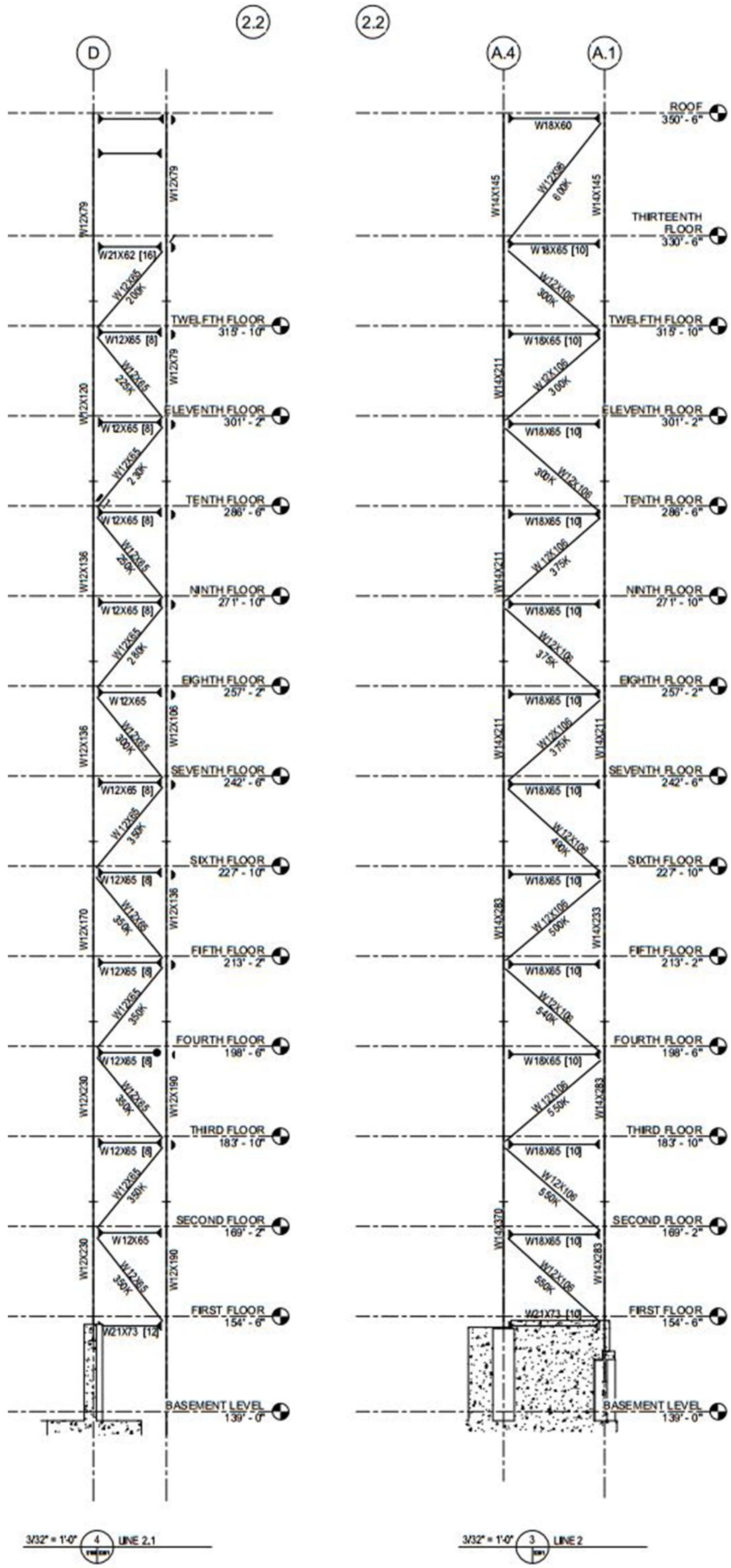


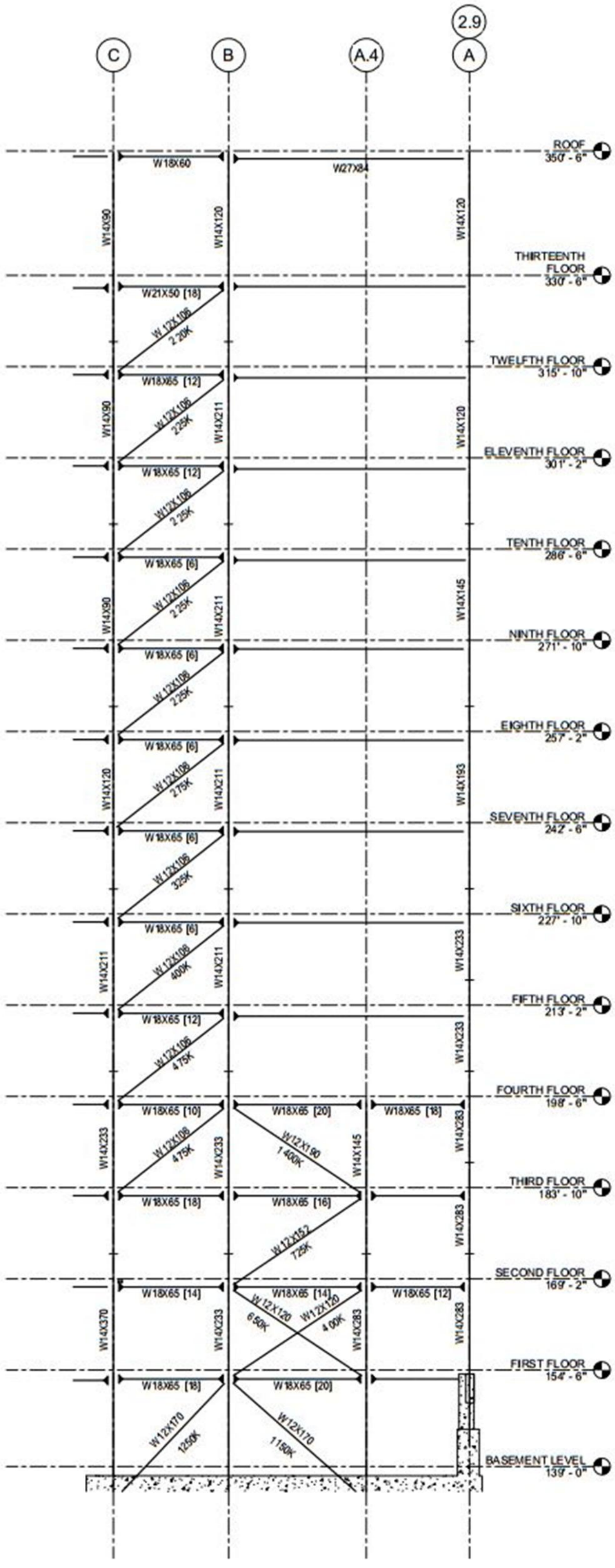
Drilled Pier Scheme for the Basement Level

(Straight Shaft = Purple; Single-Belled = Blue; Double-Belled = Red)

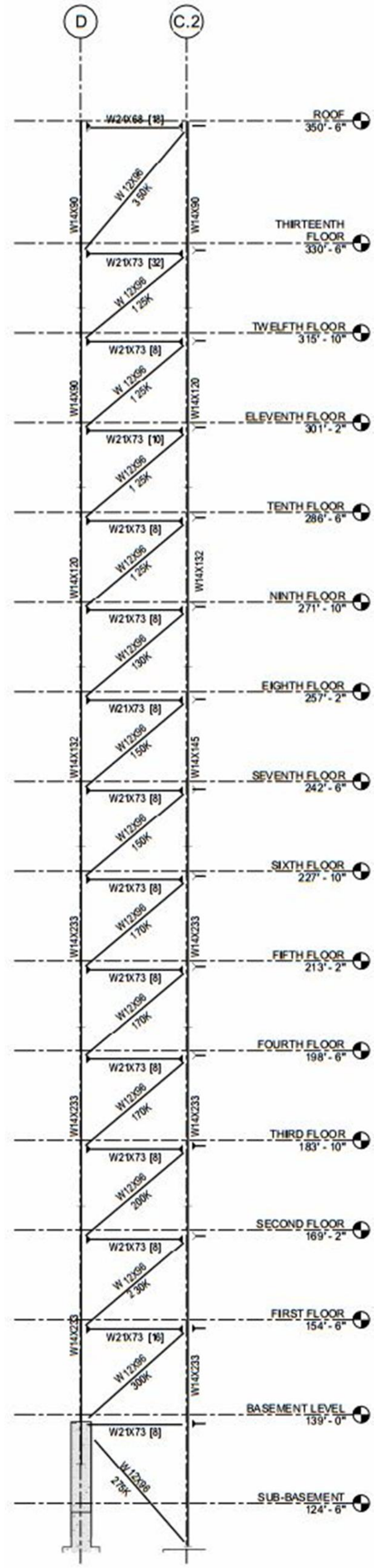


Column Layout (Highlighted in Red) for the Basement Level

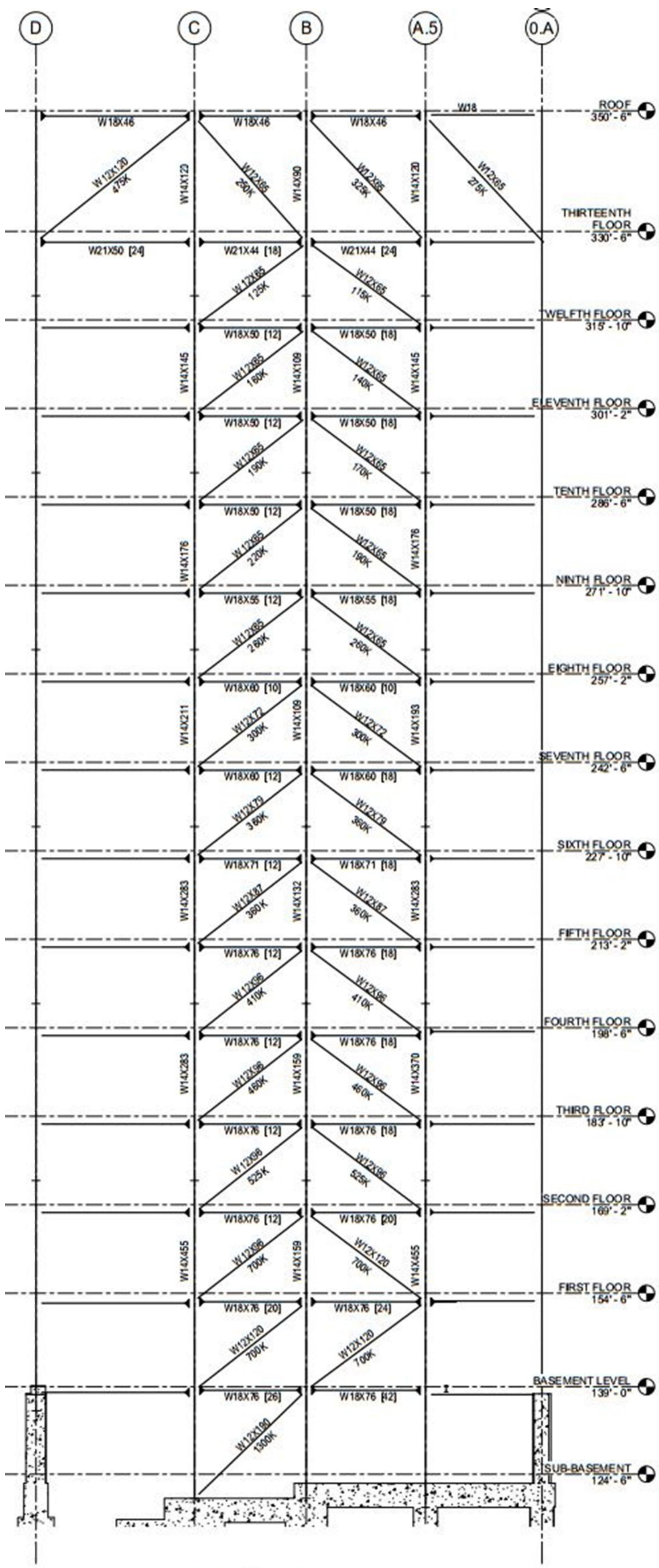

D
2.2
2.2
A.4
A.1
ROOF
350' - 6"
THIRTEENTH FLOOR
330' - 6"
TWELFTH FLOOR
315' - 10"
ELEVENTH FLOOR
301' - 2"
TENTH FLOOR
286' - 6"
NINTH FLOOR
271' - 10"
EIGHTH FLOOR
257' - 2"
SEVENTH FLOOR
242' - 6"
SIXTH FLOOR
227' - 10"
FIFTH FLOOR
213' - 2"
FOURTH FLOOR
198' - 6"
THIRD FLOOR
183' - 10"
SECOND FLOOR
169' - 2"
FIRST FLOOR
154' - 6"
BASEMENT LEVEL
139' - 0"
W12X79
W21X62 [16]
W12X65 [8]
W12X120
W12X136
W12X170
W12X230
W12X190
W21X73 [12]
W18X60
W14X145
W18X65 [10]
W12X106
W14X211
W14X283
W14X233
W14X370
W21X73 [10]
3/32" = 1'-0" 4 LINE 2.1
3/32" = 1'-0" 3 LINE 2



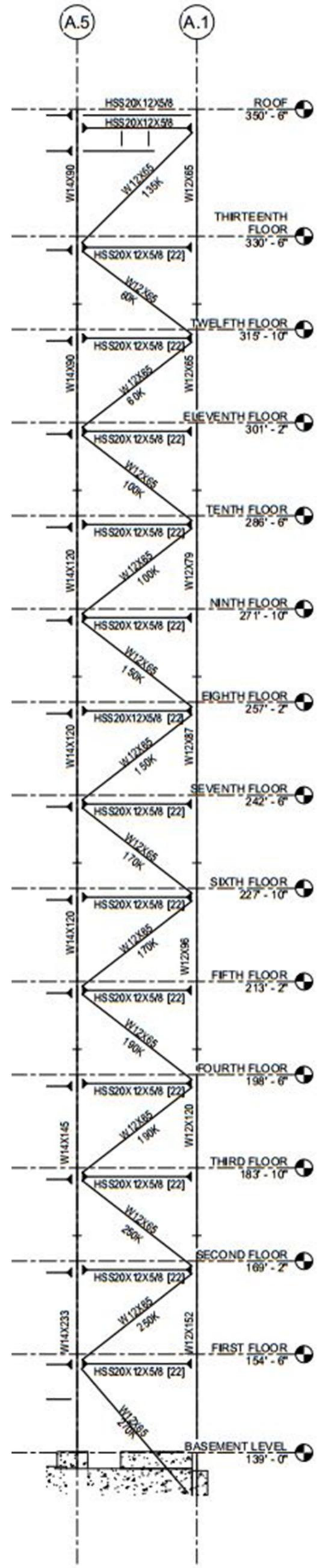
3/32" = 1'-0" 2 LINE 3



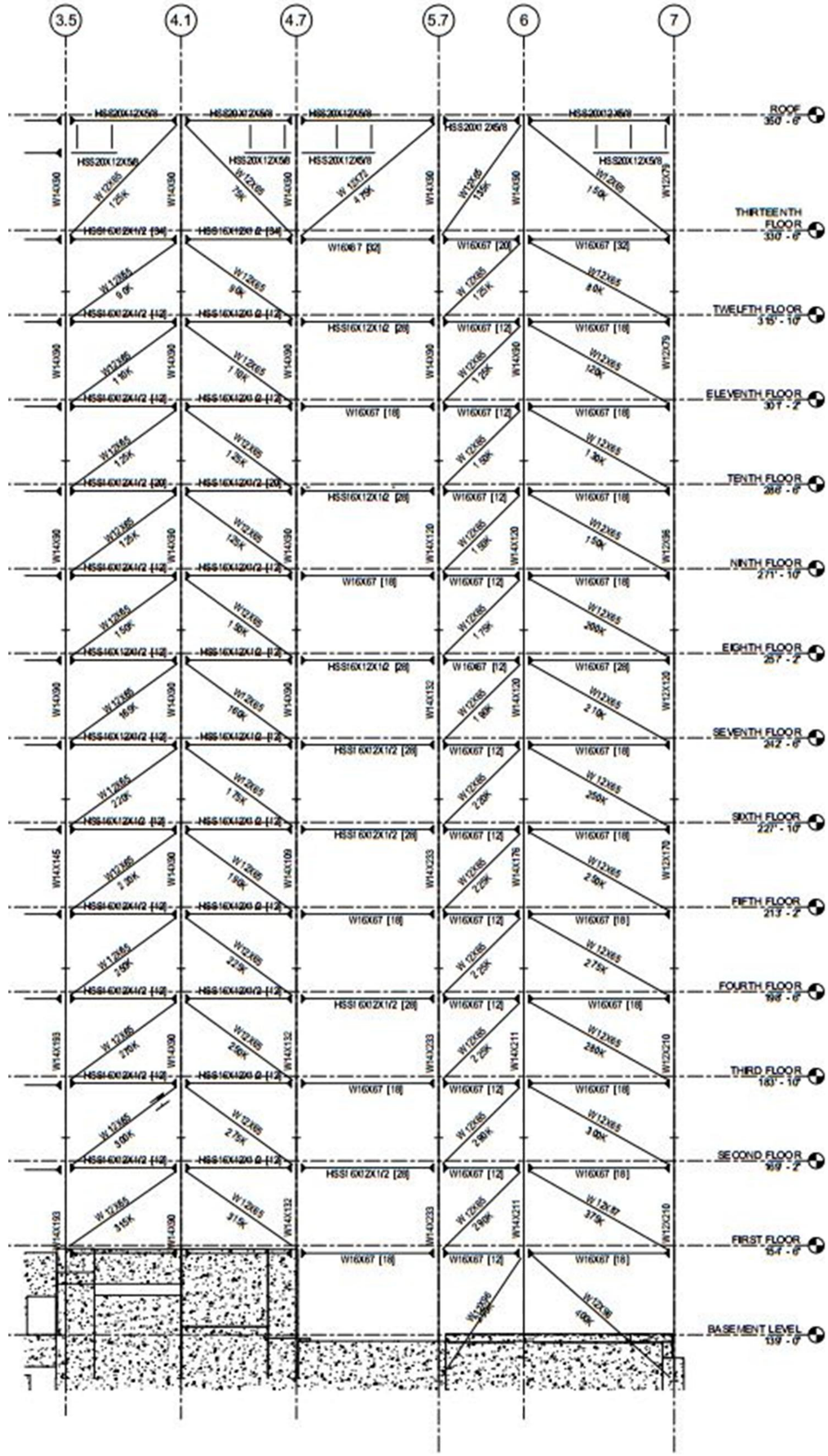
3/32" = 1'-0" 1 LINE 5.7



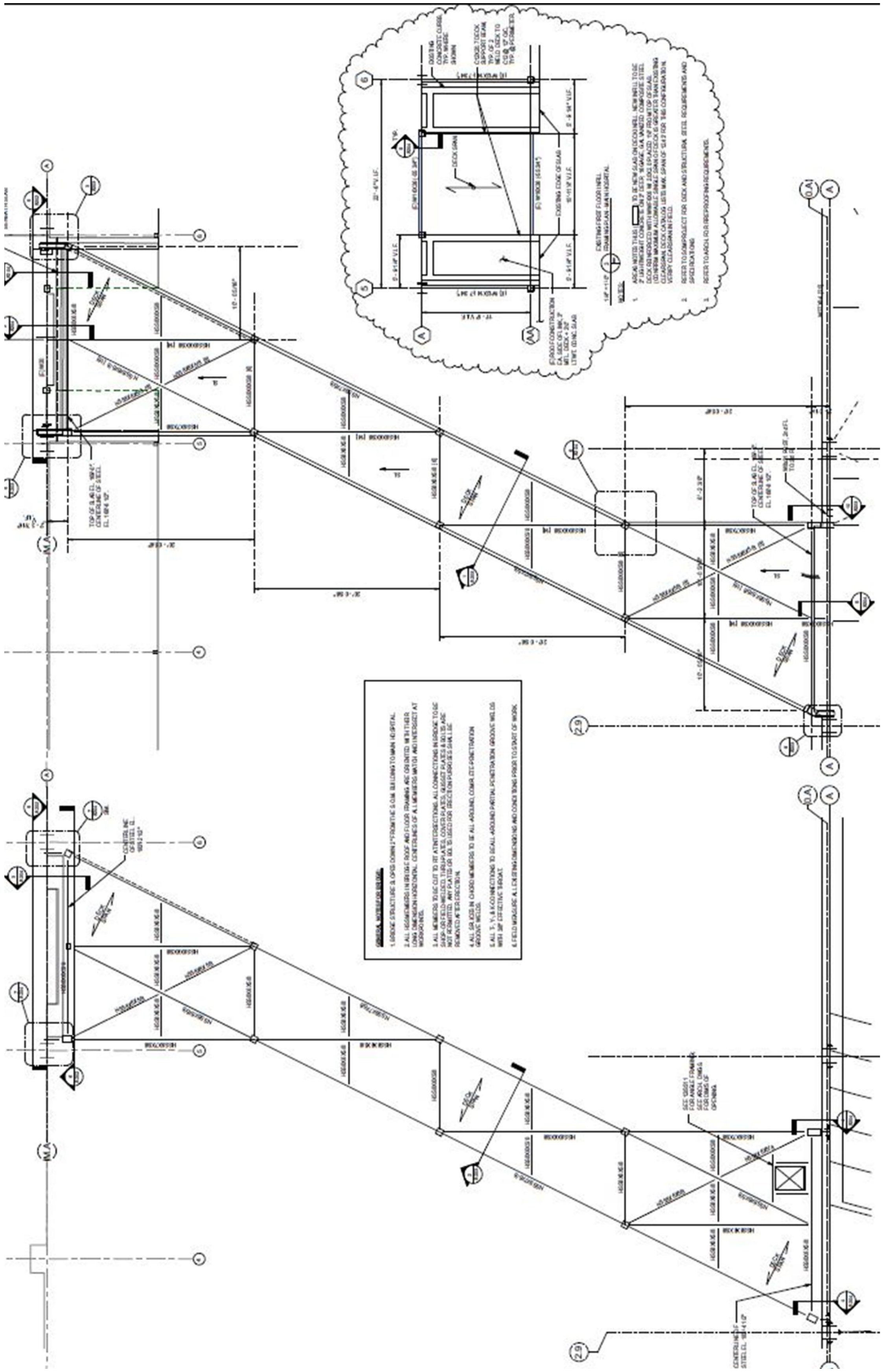
3/32" = 1'-0" 3 LINE 6



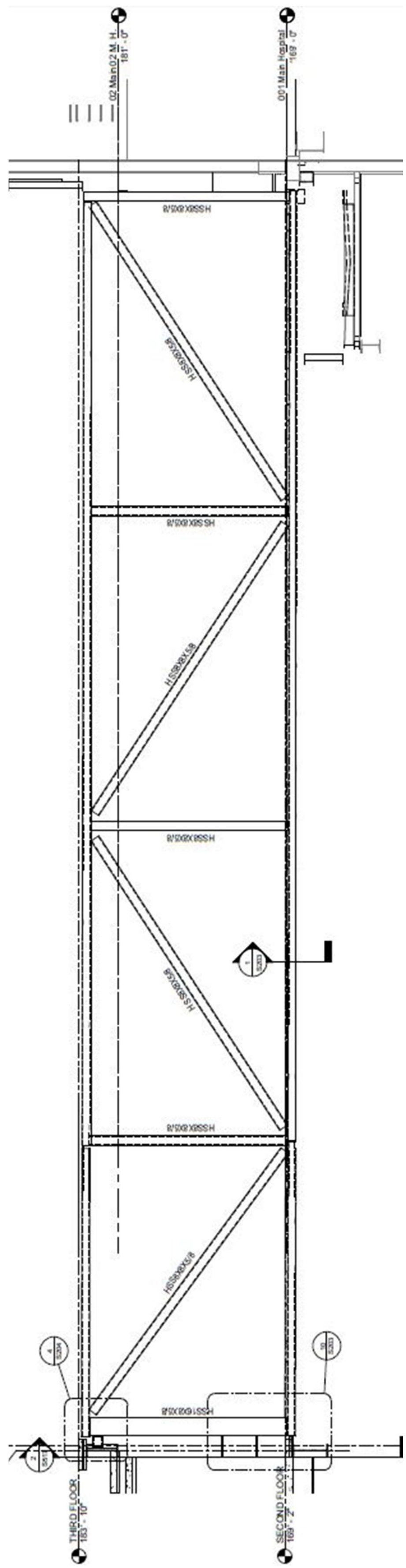
3/32" = 1'-0" 2 BRACING ELEVATION LINE 7



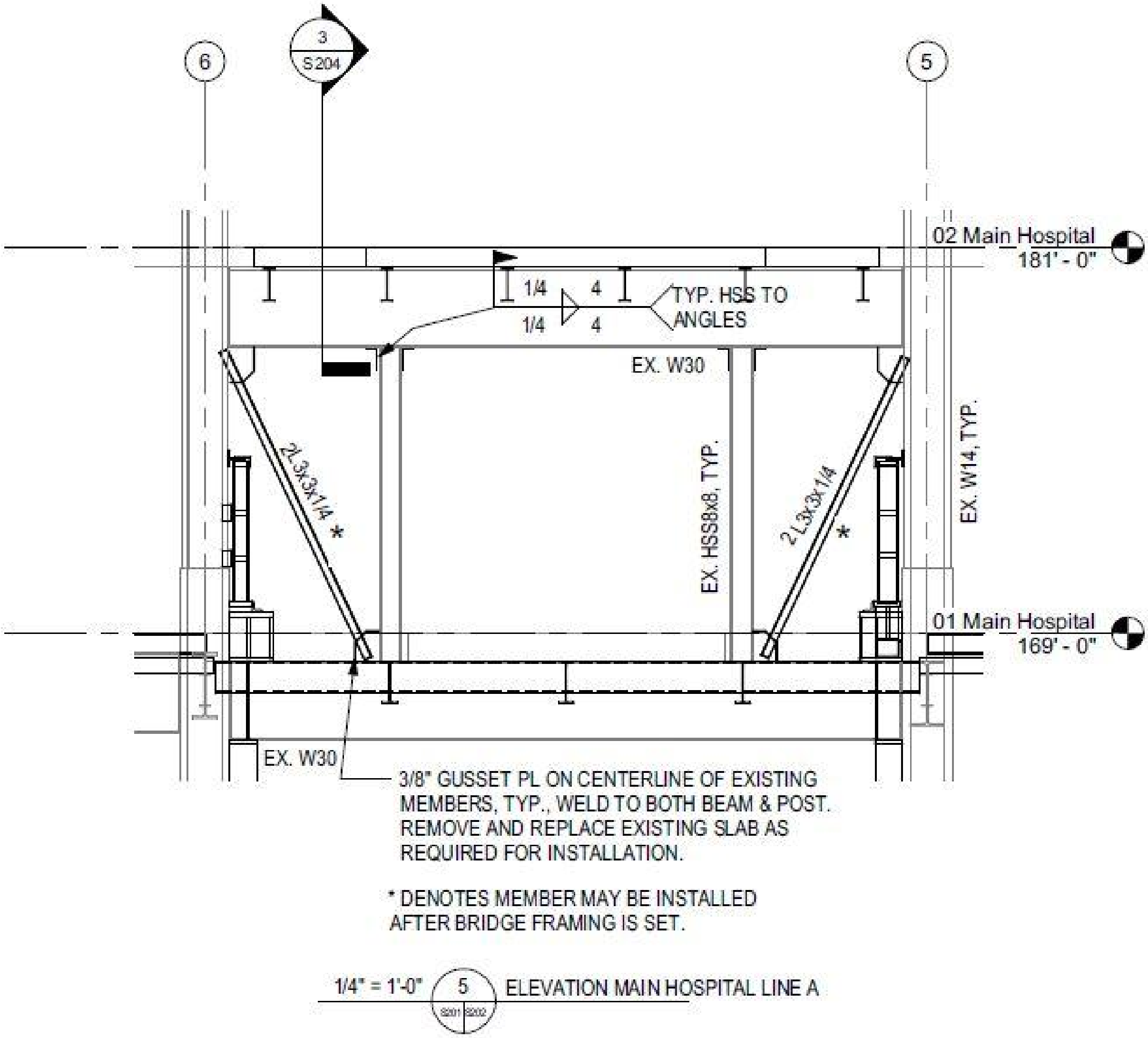
3/32" = 1'-0" BRACING ELEVATION LINE D



Bridge Plan (S201)



Bridge Elevation (S202)



Bridge Detailed Elevation at Connection to Main Hospital (S202)

Appendix B: Gravity System Redesign

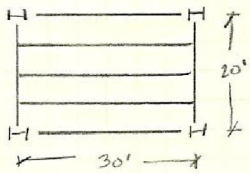
Marissa Delozier | AE Senior Thesis | Gravity System Redesign | 1/

Objective: Redesign current gravity system utilizing non-composite floor system with bar joists and steel girders

Assumptions: LL = 80 psf
DL = 10 psf (does not include slab/deck or self wt)
2 hr fire rating reqd. → 2 ½" NW concrete topping (still require fireproofing on bar joists & girders)

4 possible configurations to consider:
I. 30' x 20' w/ joists traveling in 30' dir.
II. 30' x 40' " " " " " "
III. 30' x 20' " " " " 20' "
IV. 30' x 40' " " " " 40' "

I. 30' x 20' Bay (w/ joists traveling in 30' direction)

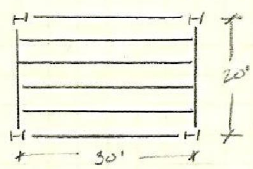


Total Load = 1.2(10) + 1.6(80) = 140 psf

Try 5', 2 spans
Possible Decking:
· 1.0C20 , 158 psf , 7'3" ✗
· 1.3C22 , 154 psf , 7'10" ✗
158 psf > 140 psf ∴ ok ✓
7'3" > 5' ∴ ok ✓
weight = 38 psf
New Total Load = 1.2(38) + 140 = 186 psf

W_{TL} = (186)(5) = 930 lb/ft + joist wt W_{LL} = (38 + 10 + 80)(5) = 640 lb/ft + joist wt

Possible Joists: K-series cannot be used, W_{LL} is too high!



Try 4', 1 span
Possible Decking:
· 1.0C24 , 147 psf , 4'4" ✓
· 1.3C26 , 145 psf , 4'3"
147 psf > 140 psf ∴ ok ✓
4'4" > 4' ∴ ok ✓
Weight = 37 psf
New Total Load = 1.2(37) + 140 = 184.4 psf

W_{TL} = (184.4)(4) = 738 lb/ft + joist wt W_{LL} = (37 + 10 + 80)(4) = 508 lb/ft + joist wt

Possible Joists: 20K10 , 799 , 12.2 , 336 ✗
22K10 , 825 , 12.6 , 385 ✓
24K9 , 816 , 12.0 , 419
26K8 , 816 , 12.1 , 457

Try 20K10 → 738 + (12.2)(1.2) = 753 < 799 ∴ ok ✓
w for ℓ/240 = 336(1.5) = 504 < 508 ∴ NOT ok

Marissa Delozier | AE Senior Thesis | Gravity System Redesign | 2/

I. (cont.)

Try 22K10 → 738 + (12.6)(1.2) = 753 < 825 ∴ ok ✓

w for L/240 = 385(1.5) = 578 > 508 ∴ ok ✓

∴ use 22K10 bar joists at 4'

LL = 80 psf

DL = 10 + 37 = 47 psf

$W_u = [1.2(47) + 1.6(80)](20) = 3.69$ klf

$M_u = W_u L^2/8 = (3.69)(20)^2/8 = 185$ ft·k

Possible Girders:	ϕM_n	I
W16x40	274	518
W18x35	249	510 ✓
W14x34	205	340

$\Delta = L/240 = (20)(12)/240 = 1''$ $\Delta_{LL} = L/360 = (20)(12)/360 = 0.67''$

$\Delta_{LL} = \frac{5wL^4}{384EI} \le 0.67'' \rightarrow \frac{5(80/1000)(30)(20)^4(1728)}{384(29000)I} \le 0.67''$

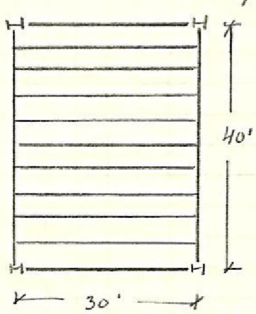
$\therefore I \ge 445 \text{ in}^4$

Try W18x35 → 249 > 185 ∴ ok ✓

510 > 445 ∴ ok ✓

∴ use W18x35 girders

II. 30' x 40' Bay (w/ joists traveling in 30' direction)



Total Load = 140 psf

Using 1.0C24 decking found in ex. I,

4', 1 span

22K10 bar joists at 4' will still apply

LL = 80 psf

DL = 47 psf

$W_u = [1.2(47) + 1.6(80)](40) = 7.38$ klf

$M_u = (7.38)(40)^2/8 = 1476$ ft·k

Possible Girders:	ϕM_n	I
W33x118	1560	5900
W30x124	1530	5360
W24x146	1570	4580

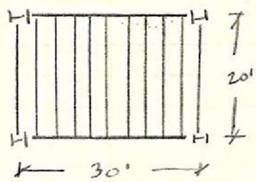
$\Delta = L/240 = (40)(12)/240 = 2''$ $\Delta_{LL} = L/360 = (40)(12)/360 = 1.33''$

$\Delta_{LL} = \frac{5wL^4}{384EI} \le 1.33'' \rightarrow \frac{5(80/1000)(30)(40)^4(1728)}{384(29000)I} \le 1.33''$ $\therefore I \ge 3584 \text{ in}^4$

∴ use W24x146 girders

Marissa Delozier | AE Senior Thesis | Gravity System Redesign | 3/

III. 30' x 20' Bay (w/ joists traveling in 20' direction)



Total Load = 140 psf

Try 3', 2 spans
Possible Decking:
- 0.6C24 , 151 psf , 3'11" ✓
- 1.0C26 , 187 psf , 4'4"

151 psf > 140 ∴ ok ✓
3'11" > 3' ∴ ok ✓
Weight = 35 psf
New Total Load = 1.2(35) + 140 = 182 psf

$W_{tot} = (182)(3) = 546$ lb/ft + joist wt $\quad W_{tL} = (35 + 10 + 80)(3) = 375$ lb/ft + joist wt

Possible Joists:				
12K5	613	7.1	230	X
14K4	642	6.7	287	✓
16K3	615	6.3	330	

Try 12K5 → 546 + 7.1(1.2) = 555 < 613 ∴ ok ✓
w for L/240 = 230(1.5) = 345 < 375 ∴ NOT OK
Try 14K4 → 546 + 6.7(1.2) = 554 < 642 ∴ ok ✓
w for L/240 = 287(1.5) = 431 > 375 ∴ ok ✓

∴ use 14K4 bar joists at 3'

LL = 80 psf
DL = 10 + 35 = 45 psf $\quad W_u = [1.2(45) + 1.6(80)](30) = 5.46$ klf
$M_u = (5.46)(30)^2 / 8 = 614$ ft·k

$\Delta = L/240 = (30)(12)/240 = 1.5"$ $\quad \Delta_{LL} = L/360 = (30)(12)/360 = 1"$

$\Delta_{LL} = \frac{5wL^4}{384EI} \le 1" \rightarrow \frac{5(80/1000)(20)(30)^4(1728)}{384(29000)I} \le 1"$ $\quad \therefore I \ge 1006$ in^4

Possible Girders:	ϕM_n	I	
W24x68	664	1830	✓
W21x73	645	1600	

Try W24x68 → 664 > 614 ∴ ok ✓
1830 > 1006 ∴ ok ✓

∴ use W24x68 girders

IV. 30' x 40' Bay (w/ joists traveling in 40' direction)

Total Load = 140 psf

Using 0.6C24 decking found in ex. III, 3', 2 spans

Marissa Delozier | AE Senior Thesis | Gravity System Redesign | 4/

IV. (cont.)

W_{TL} = 546 lb/ft + joist wt W_{LL} = 375 lb/ft + joist wt

Possible Joists :

24K12	657	16.0	247	X
24K10	589	13.8	243	X
26K12	657	16.6	269	✓
28K10	636	14.3	284	

Try 24K12 → 546 + 16(1.2) = 565 < 657 ∴ ok ✓
w for L/240 = 247 (1.5) = 371 < 375 ∴ Not ok
24K10 → Not ok
Try 26K12 → 546 + 16.6(1.2) = 566 < 657 ∴ ok ✓
w for L/240 = 269 (1.5) = 404 > 375 ∴ ok ✓

∴ use 26K12 bar joists at 3'

W_u = 5.46 klf M_u = 614 ft·k   Δ = 1.5" Δ_{LL} = 1"

$$\Delta_{LL} = \frac{5(80/1000)(40)(30)^4(1728)}{384(29000)\,I} \le 1'' \quad \therefore I \ge 2011 \text{ in}^4$$

Possible Girders :

	ϕM_n	I	
W24x76	750	2100	✓
W21x93	829	2070	
W18x119	983	2190	

Try W24x76 → 750 > 614
2100 > 2011

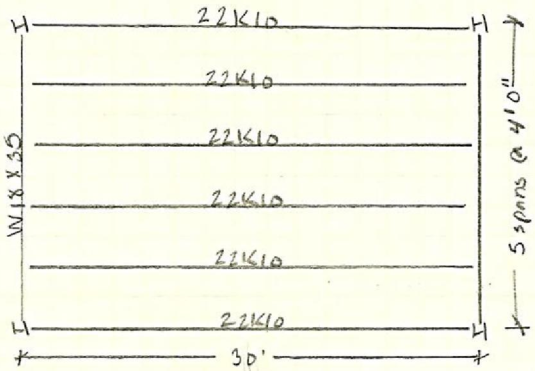
∴ use W24x76 girders

Marissa Delozier | AE Senior Thesis | Gravity System Redesign | 1

Vibration Control

Reference: AISC Design Guide 11 - Floor Vibrations Due to Human Activity

I)



Deck

$W_c = 145$ pcf $f'_c = 3000$ psi

thickness = $2\frac{1}{2}" + 1" = 3\frac{1}{2}"$

slab + deck wt = 37 psf

Offices | Classrooms = LL = 11 psf

Joists

22K10

Wt = 12.6 plf

D = 22"

$I_{chords} = 26.767(W)(L^3)(10^{-6}) = 26.767(385)(30-0.33)^3(10^{-6})$ ← found from load table

$I_{chords} = 269 \text{ in}^4$

$A_{chords} = I_{chords}/(D/2)^2 = 269/(22/2)^2 = 2.22 \text{ in}^2$

assume $y_c = 11"$

$E_c = w_c^{1.5}\sqrt{f'_c} = 145^{1.5}\sqrt{3.0} = 3025$ ksi

n = modular ratio = $E_s / 1.35 E_c = 29000/(1.35)(3025) = 7.1$

$\bar{Y} = \dfrac{2.22(1+11) - (48/7.1)(2.5)(2.5/2)}{2.22 + (48/7.1)(2.5)} = 0.30"$ below top of deck

$I_{comp} = 269 + 2.22(1 + 11 - 0.3)^2 + \dfrac{(48/7.1)(2.5)^3}{12} + (48/7.1)(2.5)(0.3 + \frac{2.5}{2})^2$

$= 622 \text{ in}^4$

since $6 \le L/d = (30\times12)/22 = 16.4 \le 24 \rightarrow C = 0.9(1 - e^{-0.282(16.4)})^{2.8}$

$C = 0.88$

$\gamma = \frac{1}{C} - 1 = \frac{1}{0.88} - 1 = 0.14$

$I_{joist} = \dfrac{1}{\frac{\gamma}{I_{chords}} + \frac{1}{I_{comp}}} = \dfrac{1}{\frac{0.14}{269} + \frac{1}{622}} = 470 \text{ in}^4$

$W_{joist} = (48/12)(11 + 37 + 5) + 12.6 = 225$ plf

$\Delta_{joist} = \dfrac{5 w_j L_j^4}{384 E_s I_j} = \dfrac{5(225)(30)^4(1728)}{384(29\times10^6)(470)} = 0.30"$

$f_{joist} = 0.18\sqrt{g/\Delta_j} = 0.18\sqrt{386/0.30} = 6.46$ Hz

$D_{slab} = 12 d_e^3 / 12n = 12(3)^3/(12)(7.1) = 3.8 \text{ in}^4/\text{ft}$

$D_{joist} = I_{joist}/S = 470/(4) = 118 \text{ in}^4/\text{ft}$

Marissa Delozier | AE Senior Thesis | Gravity System Redesign | 1

I) (cont) $B_j = C_j(D_s/D_j)^{1/4}L_j$ ($C_j = 2.0$ for most joists)
$= 2(3.8/118)^{1/4}(30) = 25.4' < \frac{2}{3}(3 \times 20') = 40'$ ∴ ok ✓
$W_j = (w_j/s)B_jL_j = (225/4)(25.4)(30) = 42.8^K$

Girders
W18x35
$A = 10.3\ in^2$
$I_x = 510\ in^4$
$d = 17.7\ in$

$w_{eff} = 0.4L_g = 0.4(20)(12) = 96'' < L_j = 30 \times 12 = 360''$
$d_c = 2.5 + 1.0/2 = 3.0''$

$\bar{Y} = \frac{10.3(0.5 + 3.5 + 17.7/2) - (96/7.1)(3)(3/2)}{10.3 + (96/7.1)(3)} = 1.41''$ below

$I_{girder} = 510 + 10.3(0.5 + 3.5 + (17.7/2) - 1.41)^2 + (96/7.1)(3)^3/12 + (96/7.1)(3)(1.41 + 1.5)^2$
$= 2232\ in^4$

$I_{g\,red.} = I_{nc} + (I_c - I_{nc})/4 = 510 + (2232 - 510)/4 = 941\ in^4$

$w_{girder} = L_g(w_j/s) + \text{girder wt} = 20(225/4) + 35 = 1160\ plf$

$\Delta_{girder} = \frac{5(1160)(20)^4(1728)}{384(29 \times 10^6)(941)} = 0.15\ in$

$f_{girder} = 0.18\sqrt{386/0.15} = 9.13\ Hz$

$D_{joist} = 118\ in^4/ft$ $D_{girder} = I_g/L_j = 941/30 = 31.4\ in^4/ft$

$B_g = C_g(D_j/D_g)^{1/4}L_g$ ($C_g = 1.6$ for girders supporting joists)
$= 1.6(118/31.4)^{1/4}(20) = 44.6\ ft < \frac{2}{3}(3 \times 30) = 60'$ ∴ ok ✓

$W_g = (w_g/L_j)B_gL_g = (1160/30)(44.6)(20) = 34.5^k$

Combined

$L_g < B_j \longrightarrow \Delta_g' = \frac{L_g}{B_j}\Delta_g = \frac{20}{25.4}(0.15) = 0.118\ in$

$f_n = 0.18\sqrt{g/(\Delta_j + \Delta_g')} = 0.18\sqrt{386/(0.30 + 0.118)} = 5.47\ Hz$

$W = \frac{\Delta_j}{\Delta_j + \Delta_g'}W_j + \frac{\Delta_g'}{\Delta_j + \Delta_g'}W_g = \frac{0.30}{0.30 + 0.118}(42.8) + \frac{0.118}{0.30 + 0.118}(34.5)$
$W = 40.5^K$

$\beta W = 0.05(40.5) = 2023\ lbs$ ($\beta = 0.05$ for full height partitions)

Walking Evaluation
$P_o = 65\ lbs$ $\frac{a_p}{g} = \frac{P_o \exp(-0.35 f_n)}{\beta W} = \frac{65\exp[-0.35(5.47)]}{2023} = 0.47\%$ of g

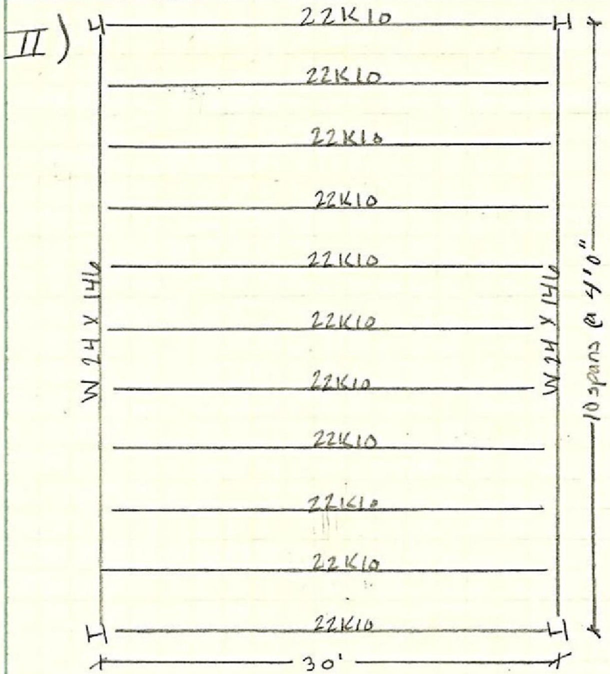
0.47% < a_o/g limit of 0.5%

Floor Stiffness Evaluation ⟶ 5.47 Hz < 9 Hz ∴ acceptable

Final Evaluation ⟶ Floor system is acceptable
0.47% < 0.5% and 5.47 Hz < 9 Hz ∴ ok ✓

Marissa Delozier | AE Senior Thesis | Gravity System Redesign | 1

II)



Deck

$w_c = 145$ pcf $f'_c = 3000$ psi

thickness = 3 1/2"

slab + deck wt = 37 psf

Joists

22K10

Wt = 12.6 plf

D = 22"

$I_{chords} = 269\ in^4$

$A = 2.22\ in^2$

$y_c = 11"$

*joist sizing, spacing, length, etc. did not change from configuration I, ∴ all values found for joists will remain the same

$I_j = 470\ in^4$ $w_j = 225$ plf

$\Delta_j = 0.30"$ $f_j = 6.46$ Hz

$D_s = 3.8\ in^4/ft$ $D_j = 118\ in^4/ft$

$B_j = 25.4'$ $W_j = 42.8^k$

Girders

W24X146

$A = 43 in^2$

$I_x = 4580\ in^4$

d = 24.7 in

$w_{eff} = 0.4L_g = 0.4(40)(12) = 192" < L_j = 360"$

$d_c = 3"$

$$\bar{y} = \frac{43(0.5+3.5+24.7/2) - (192/7.1)(3)(3/2)}{43 + (192/7.1)(3)} = 4.68" \text{ below}$$

$$I_g = 4580 + 43(0.5+3.5+(24.7/2) - 4.68)^2 + (192/7.1)(3)^3/12 + (192/7.1)(3)(4.68+1.5)^2 = 13{,}595\ in^4$$

$I_{grad} = 4580 + (13595 - 4580)/4 = 6834\ in^4$

$w_g = 40(225/4) + 146 = 2396$ plf

$$\Delta_g = \frac{5(2396)(40)^4(1728)}{384(29\times10^6)(6834)} = 0.70"$$

$f_g = 0.18\sqrt{386/0.7} = 4.23$ Hz $D_g = 6834/30 = 228\ in^4/ft$

$B_g = 1.6\,(118/228)^{1/4}(40) = 54' < 60'$ ∴ ok ✓

$W_g = (2396/30)(54)(40) = 173$ k

Combined

$L_g > B_j \longrightarrow f_n = 0.18\sqrt{g/(\Delta_j+\Delta_g)} = 0.18\sqrt{386/(0.30+0.70)} = 3.54$ Hz

$$W = \frac{0.3}{0.3+0.7}(42.8) + \frac{0.7}{0.3+0.7}(173) = 134^k$$

$\beta W = 0.05(134) = 6700$ lbs

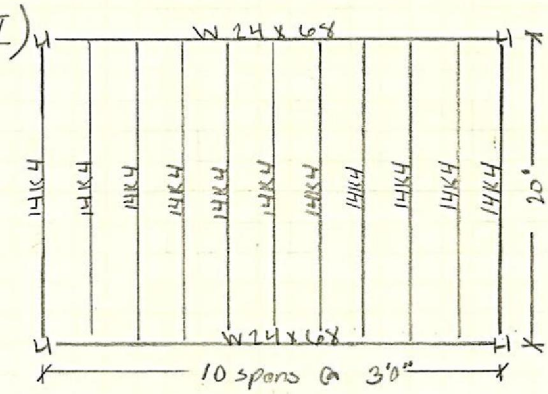
Walking Evaluation

$$\frac{a_p}{g} = \frac{65\exp[-0.35(3.54)]}{6700} = 0.28\%\ \text{of}\ g < 0.5\%\ \therefore \text{ok} ✓$$

Marissa Delozier | AE Senior Thesis | Gravity System Redesign | 1

II) (cont) Final Evaluation → Floor System is acceptable
$0.28\% < 0.5\%$ and $3.54\ Hz < 9\ Hz$ ∴ OK ✓

III)



Deck
$W_c = 145$ pcf $f'_c = 3000$ psi
thickness = 2 1/2" + 9/16" ≈ 3"
slab + deck wt = 35 psf

Joists
14K4
wt = 6.7 plf
D = 14"

$I_{chords} = 26.767(287)(20-0.33)^3(10^{-6}) = 58.5\ in^4$

$A = 58.5/(14/2)^2 = 1.19\ in^2$

$y_c = 7''$

$E_c = 3025$ ksi $n = 7.1$

$$\bar{y} = \frac{1.19(0.5+7) - (36/7.1)(2.5)(2.5/2)}{1.19 + (36/7.1)(2.5)} = 0.5''$$

$$I_{comp} = 58.5 + 1.19(0.5+7+0.5)^2 + \frac{(36/7.1)(2.5)^3}{12} + (36/7.1)(2.5)(2.5/2 - 0.5)^2 = 148\ in^4$$

since $6 \le L/d = (20 \times 12)/14 = 17.1 \le 24 \rightarrow C = 0.9\left(1 - e^{-0.282(17.1)}\right)^{2.8} = 0.88$

$\gamma = 0.14$ $I_j = \dfrac{1}{\frac{0.14}{58.5} + \frac{1}{148}} = 109\ in^4$

$W_j = (36/12)(11 + 35 + 5) + 6.7 = 160$ plf

$\Delta_j = \dfrac{5(160)(20)^4(1728)}{384(29 \times 10^6)(109)} = 0.18''$ $f_j = 0.18\sqrt{386/0.18} = 8.34\ Hz$

$D_{slab} = 12(2.75)^3/(12)(7.1) = 2.93\ in^4/ft$ $D_j = 109/3 = 36.3\ in^4/ft$

$B_j = 2(2.93/36.3)^{1/4}(20) = 21.3' < 60'$ ∴ OK ✓

$W_j = (160/3)(21.3)(20) = 22.7^K$

Girders
W24 x 68
$A = 20.1\ in^2$
$I_x = 1830\ in^4$
$d = 23.7$ in

$W_{eff} = 0.4(30)(12) = 144'' < L_j = 20 \times 12 = 240''$

$d_e = 2.75''$

$$\bar{y} = \frac{20.1(0.25 + 3 + 23.7/2) - (144/7.1)(2.75)(2.75/2)}{20.1 + (144/7.1)(2.75)} = 2.99'' \approx 3''$$

$$I_g = 1830 + 20.1(0.25 + 3 + 23.7/2 - 3)^2 + (144/7.1)(2.75)^3/12 + (144/7.1)(2.75)\left(3 - \frac{2.75}{2}\right)^2 = 5876\ in^4$$

$I_{gred} = 1830 + (5876 - 1830)/4 = 2842\ in^4$

$W_g = 30(160/3) + 68 = 1668$ plf

$\Delta_g = \dfrac{5(1668)(30)^4(1728)}{384(29 \times 10^6)(2842)} = 0.369''$

$f_g = 0.18\sqrt{386/0.369} = 5.82\ Hz$

Marissa Delozier | AE Senior Thesis | Gravity System Redesign | /

III) (cont) $D_j = 36.3\ in^4/ft$ $D_g = 2842/20 = 142\ in^4/ft$

$B_g = 1.6\,(36.3/142)^{1/4}(30) = 34.1' < \frac{2}{3}(3 \times 20) = 40'$ ∴ ok ✓

$W_g = (1668/20)(34.1)(30) = 85.3^K$

<u>Combined</u>

$L_g > B_j \longrightarrow f_n = 0.18\sqrt{386/(0.18+0.369)} = 4.77\,Hz$

$W = \frac{0.18}{0.18+0.369}(22.7) + \frac{0.369}{0.18+0.369}(85.3) = 64.8^K$

$\beta W = 0.05(64.8) = 3240\ lbs$

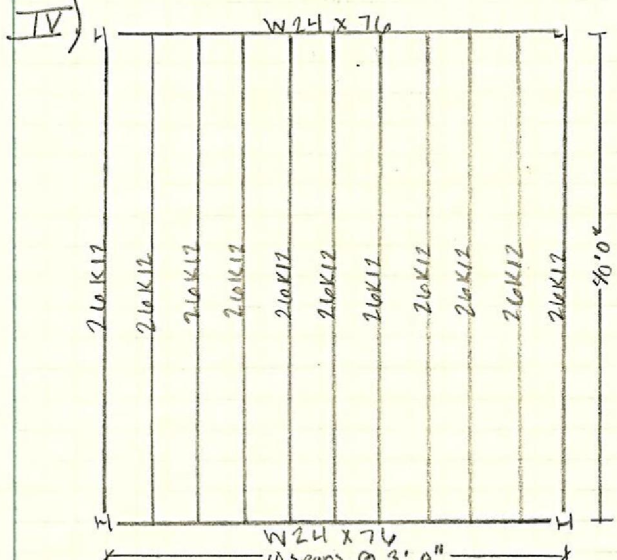
<u>Walking Evaluation</u>

$\frac{a_p}{g} = \frac{65\exp[-0.35(4.77)]}{3240} = 0.38\% < 0.5\%$ ∴ ok ✓

<u>Final Evaluation</u> ⟶ Floor System is <u>acceptable</u>

$0.38\% < 0.5\%$ and $4.77\,Hz < 9\,Hz$ ∴ ok ✓

IV)



<u>Deck</u>

$W_c = 145\ pcf$ $f'_c = 3000\ psi$

thickness $= 2\frac{1}{2}" + \frac{1}{2}" = 3"$

slab + deck wt = 35 psf

<u>Joists</u>

26K12

wt = 16.6 plf

D = 26"

$I_{chords} = 26.767(269)(40-0.33)^3(10^{-6})$
$= 450\ in^4$

$A = 450/(26/2)^2 = 2.66\ in^2$

$y_c = 13"$

$E_c = 3025\ ksi$

$n = 7.1$

$\bar{y} = 2.66(0.25+13) - (36/7.1)(2.5)(2.5/2) / [2.66 + (36/7.1)(2.5)] = 1.26"$

$I_{comp} = 450 + 2.66(13.25-1.26)^2 + (36/7.1)(2.5)^3/12 + (36/7.1)(2.5)(1.26 - 2.5/2)^2$
$= 919\ in^4$

$6 \le L/d = (40 \times 12)/26 = 18.5 \le 24 \rightarrow C = 0.9\left(1 - e^{-0.282(18.5)}\right)^{2.8} = 0.89$

$\gamma = \frac{1}{0.89} - 1 = 0.12$ $I_j = \frac{1}{\frac{0.12}{450} + \frac{1}{919}} = 738\ in^4$

$w_j = 3(11+35+5) + 16.6 = 170\ plf$

$\Delta_j = \frac{5(170)(40)^4(1728)}{384(29 \times 10^6)(738)} = 0.458"$ $f_j = 0.18\sqrt{386/0.458} = 5.23\,Hz$

$D_s = 2.93\ in^4/ft$ $D_j = 738/3 = 246\ in^4/ft$

Marissa Delozier | AE Senior Thesis | Gravity System Redesign

IV) (cont.) $B_j = 2(2.93/246)^{1/4}(40) = 26.4' < 60'$ ∴ ok ✓

$W_j = (170/3)(26.4)(40) = 59.8^k$

Girders

W24x76

A = 22.4

$I_x = 2100$

d = 23.9

$W_{eff} = 144''$

$d_c = 2.75''$

$$\bar{y} = \frac{22.4(3.25 + 23.9/2) - (144/7.1)(2.75)(2.75/2)}{22.4 + (144/7.1)(2.75)} = 3.37''$$

$$I_g = 2100 + 22.4(0.25 + 3 + 23.9/2 - 3.37)^2 + (144/7.1)(2.75)^3/12 + (144/7.1)(2.75)(3.37 + \tfrac{2.75}{2})^2 = 6526\ in^4$$

$I_{g\,red} = 2100 + (6526 - 2100)/4 = 3207\ in^4$

$W_g = 30(170/3) + 76 = 1776$ plf

$$\Delta_g = \frac{5(1776)(30)^4(1728)}{384(29\times10^4)(3207)} = 0.35''$$ $f_g = 5.98$ Hz

$D_j = 246\ in^4/ft$ $D_g = 3207/40 = 80.2\ in^4/ft$

$B_g = 1.6(246/80.2)^{1/4}(30) = 63.5' < 80'$ ∴ ok ✓

$W_g = (1776/40)(63.5)(30) = 84.6^k$

Combined

$L_g > B_j \rightarrow f_n = 0.18\sqrt{386/(0.458 + 0.35)} = 3.93$ Hz

$$W = \frac{0.458}{0.458 + 0.35}(59.8) + \frac{0.35}{0.458 + 0.35}(84.6) = 56.5^K$$

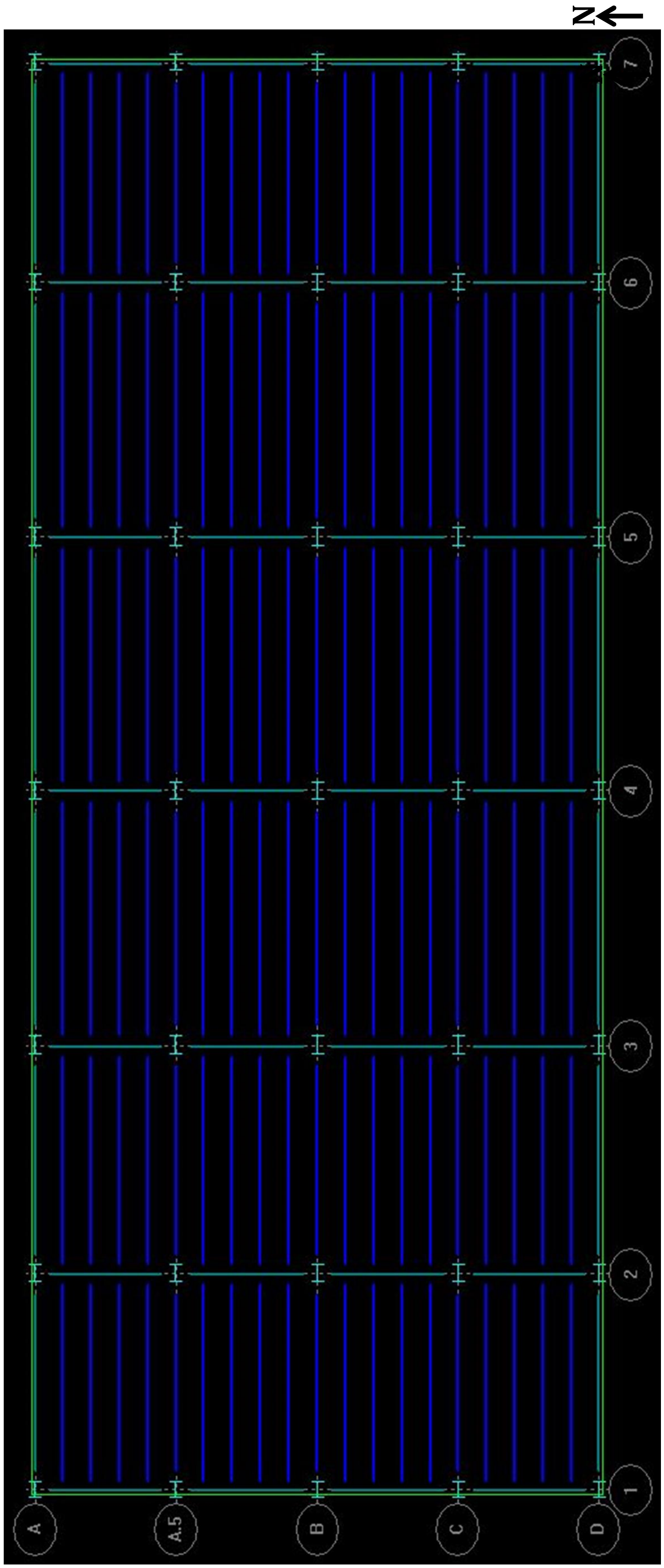
$\beta W = 0.05(56.5) = 2825$ lbs

Walking Evaluation

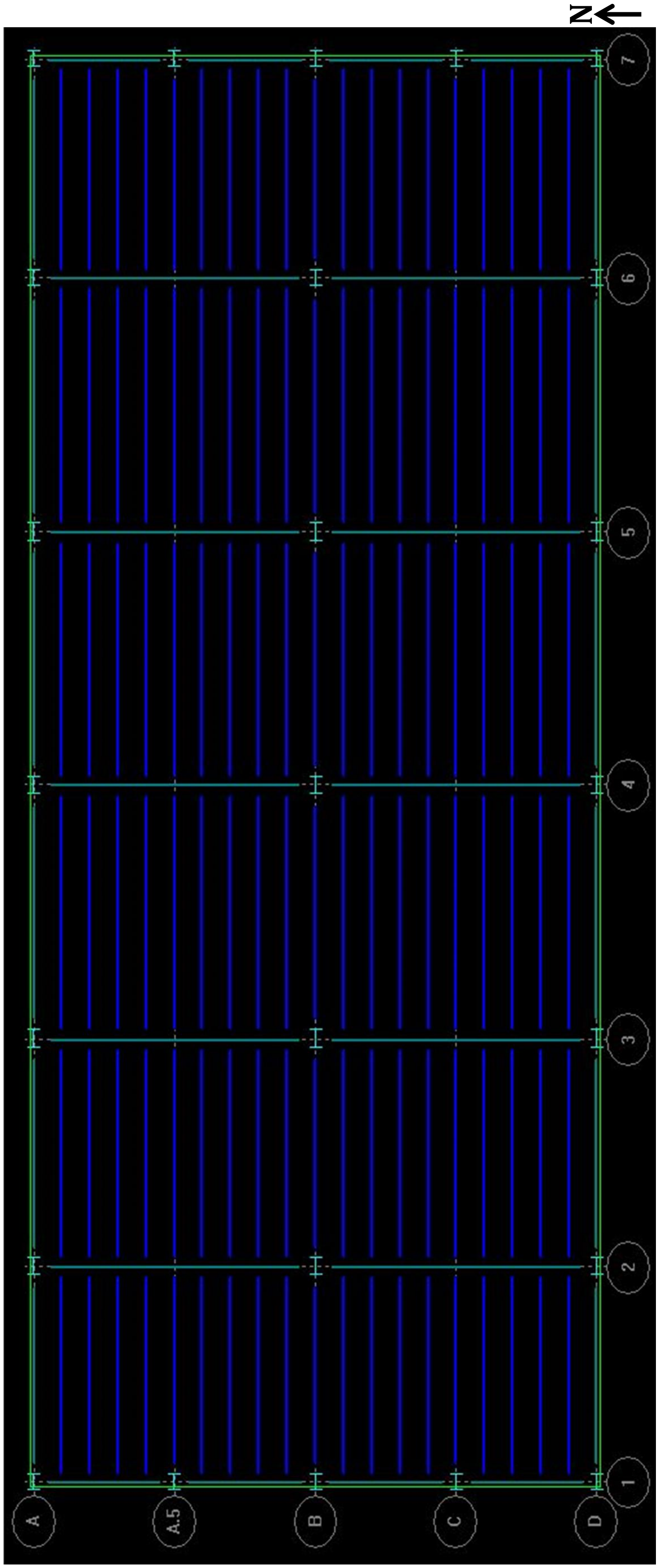
$$\frac{a_p}{g} = \frac{65\exp[-0.35(3.93)]}{2825} = 0.58\% > 0.5\%$$ ∴ NOT OK

Final Evaluation → this Floor System is adequate but not acceptable by comfort standards

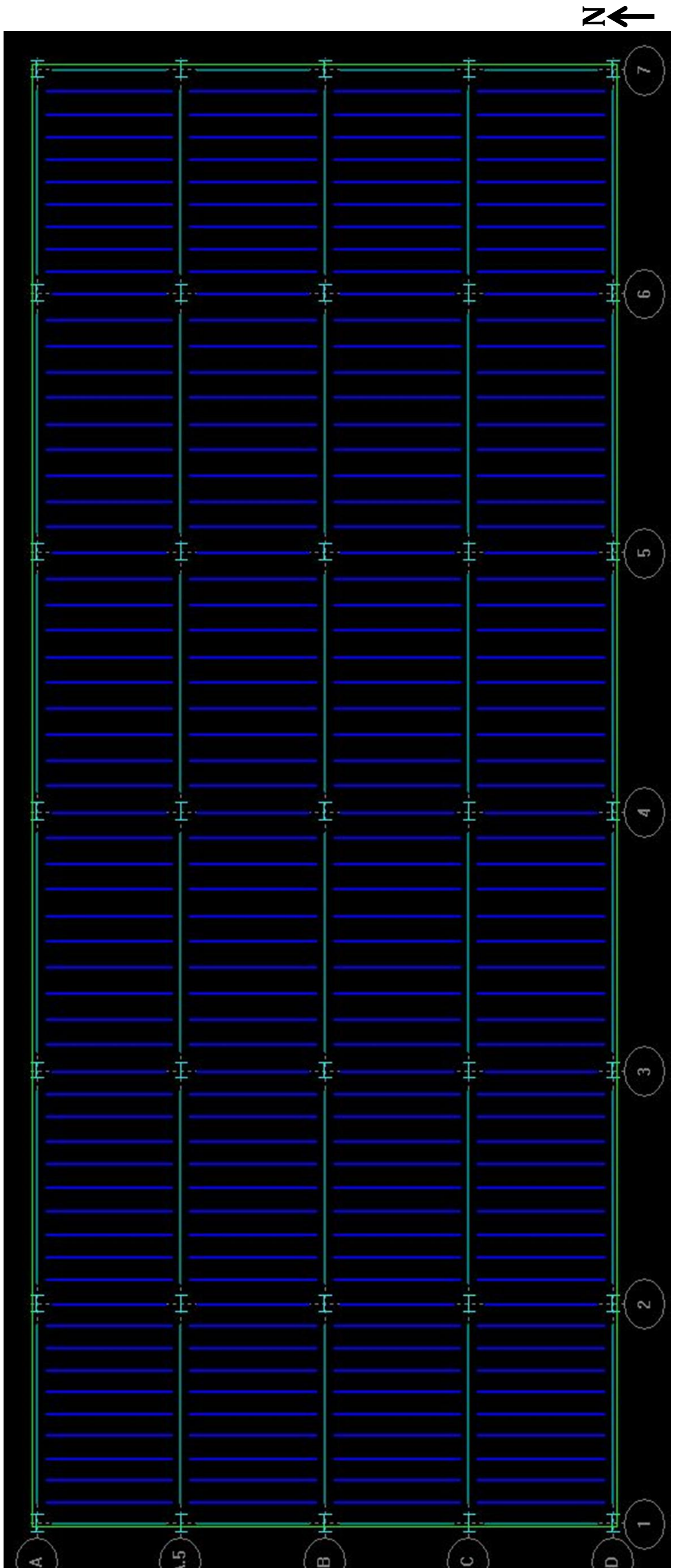
- utilizing Figure 2.1 in AISC Design Guide 11, the Floor system is at the brink of unacceptable with a peak acceleration of 0.58% g and a frequency of 3.93 Hz



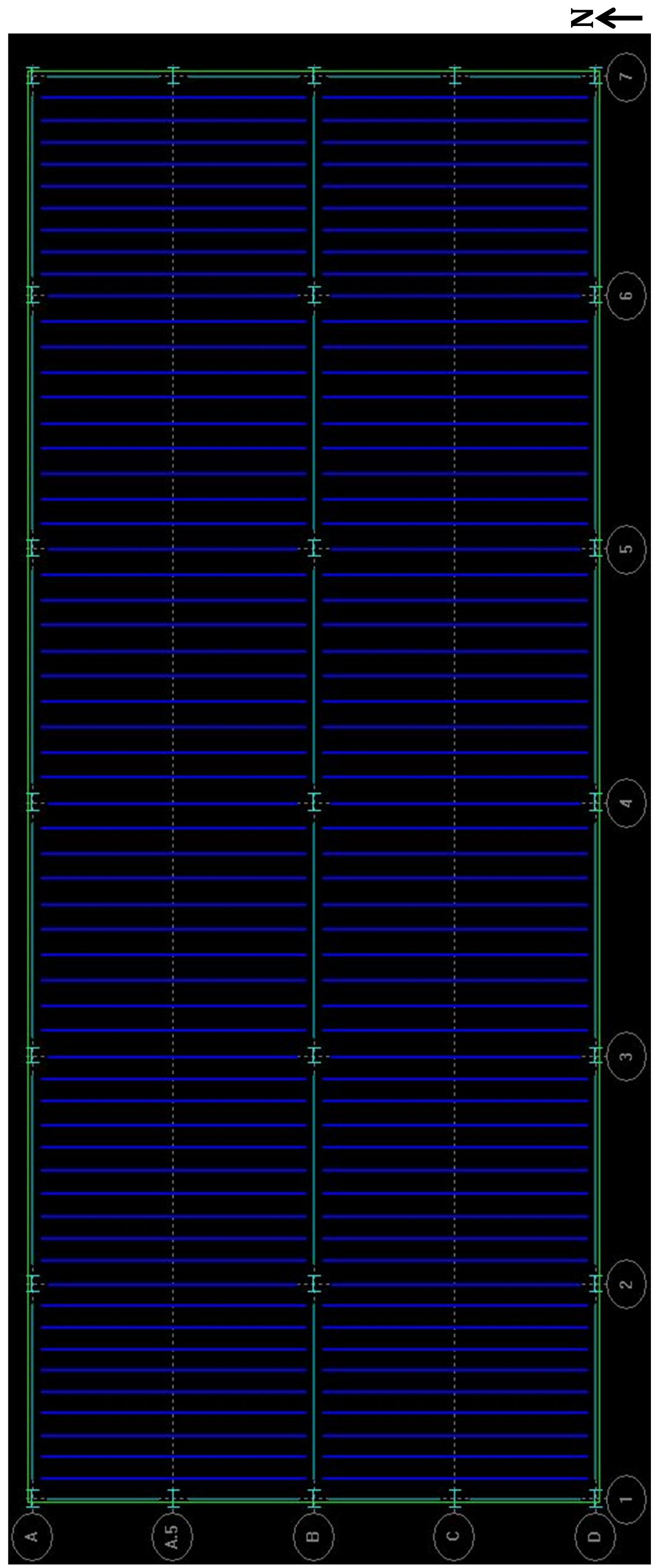
Gravity System Redesign – Configuration I
(30' x 20' Bay with Joists Traveling in the 30' Direction, East-West)



Gravity System Redesign – Configuration II
(30' x 40' Bay with Joists Traveling in the 30' Direction, East-West)



Gravity System Redesign – Configuration III
(30' x 20' Bay with Joists Traveling in the 20' Direction, North-South)



Gravity System Redesign – Configuration IV
(30' x 40' Bay with Joists Traveling in the 40' Direction, North-South)

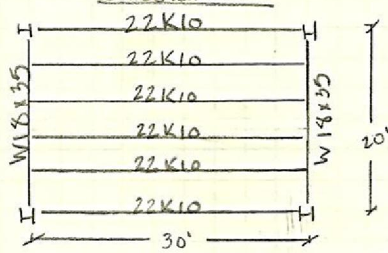
Marissa Delozier | AE Senior Thesis | Gravity System Redesign | 1

Comparison to RAM Design

Objective: Compare detailed hand calculations to RAM Design output for frame size, layout, and loads. Confirm both are similar to check not only hand calculations but also application of RAM program

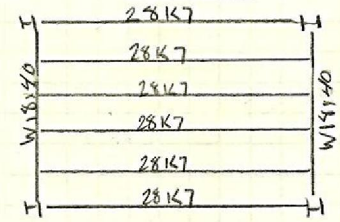
I. 30' x 20' Bay (w/ joists traveling in 30' direction)

Calculations



LL = 80 psf
DL = 10 psf
1.0 C24 Deck
37 psf
3 1/2" thick

RAM



Properties

W18x35 : $\phi M_n = 249$ ft·k
$I = 510$ in^4

W18x40 : $\phi M_n = 294$ ft·k
$I = 612$ in^4

22K10 : Load Capacity = 825 lb/ft
w for $l/360$ = 385 lb/ft
wt = 12.6 lb/ft

28K7 : Load Capacity = 796 lb/ft
w for $l/360$ = 486 lb/ft
wt = 11.8 lb/ft

Check

28K7 → 738 lb/ft + (11.8 lb/ft)(1.2) = 752 < 796 ∴ ok ✓
w for $l/240$ = 486(1.5) = 729 > 508 ∴ ok ✓
W18x40 → ok ✓ (so similar to selection → ∴ will pass requirements)

Comparison

Joists → 22K10 vs 28K7

	22K10	28K7
Weight	—	✓
Depth	✓	—
Load Capacity	✓	

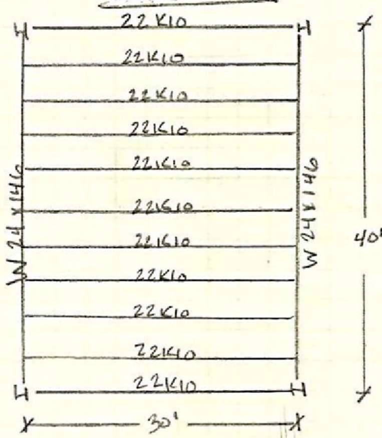
Final Evaluation? → 22K10 is economical choice

Girders → W18x40 is accurate, economical selection

Marissa Delozier | AE Senior Thesis | Gravity System Redesign

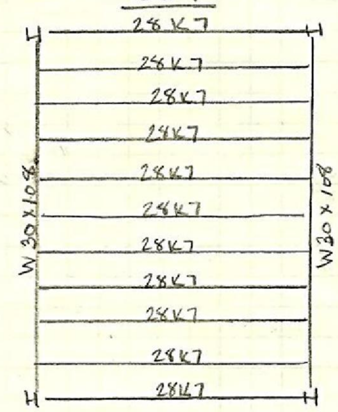
II. 30' x 40' Bay (w/ joists traveling in 30' direction)

Calculations



LL = 80 psf
DL = 10 psf
1.0C24 Deck
37 psf
3 1/2" thick

RAM



Properties

W24x146: $\phi M_n = 1570$ ft-k
$I = 4580$ in^4

W30x108: $\phi M_n = 1300$ ft-k
$I = 4470$ in^4
camber = 1/2"

W22K10: Load Capacity = 825 lb/ft
w for $l/360$ = 385 lb/ft
Wt = 12.6 lb/ft

W28K7: Load Capacity = 796 lb/ft
w for $l/360$ = 486 lb/ft
Wt = 11.8 lb/ft

Check

28K7 → still acceptable (same properties/values as I.)

W30x108 → $M_u = 1476$ ft-k $\phi M_n = 1300 < 1476$ ∴ NOT OK
$\Delta_{LL} = 1.33"$ $I \geq 3584$ $I = 4470 > 3584$ ∴ OK ✓

Comparison

Joists →

	22K10	vs	28K7
Weight	—		✓
Depth	✓		—
Load Capacity	✓		—

Final Evaluation → 22K10 is still most economical option

Girders →

	W24x146	vs	W30x108
Weight	—		✓
Depth	✓		—
ϕM_n	✓		—
I	✓		—
Max Load	✓		—

Final Evaluation? → First, explore options between W24x146 & W30x108

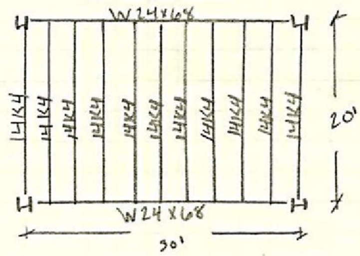
	W24x146	vs	W30x116	W24x146	vs	W30x124
Weight	—		✓	—		✓
Depth	✓		—	✓		—
ϕM_n	✓		—	—		✓
I	—		✓	—		✓
Max Load	✓		—	✓		—

Final Evaluation? → use W30x124, $\phi M_n = 1530 > 1476$ $I = 5360 > 3584$

Marissa Delozier | AE Senior Thesis | Gravity System Redesign | 1

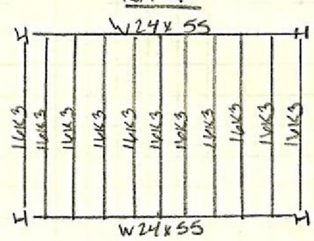
III. 30' x 20' Bay (w/ joists traveling in the 20' direction)

Calculations



LL = 80 psf
DL = 10 psf
0.6C24 Deck
35 psf
3" thick

RAM



Properties

W24x68: ϕM_n = 664 ft·k
I = 1830 in⁴
14K4: Load Capacity = 642 lb/ft
w for L/360 = 287 lb/ft
wt = 6.7 lb/ft

W24x55: ϕM_n = 503 ft·k
I = 1350 in⁴
16K3: Load Capacity = 615 lb/ft
w for L/360 = 330 lb/ft
wt = 6.3 lb/ft

Check

16K3 → 546 + (6.3)(1.2) = 554 < 615 ∴ ok ✓
w for L/240 = 330(1.5) = 495 > 375 ∴ ok ✓

W24x55 → M_u = 614 ft·k ϕM_n = 503 ft·k < 614 ∴ NOT OK
Δ_{LL} = 1" $I \geq 1006$ in⁴ 1350 > 1006 ∴ ok ✓

Comparison

Joists →

	14K4	vs 16K3
Weight	—	✓
Depth	✓	—
Load Capacity	✓	—

Final Evaluation → 14K4 is most economical choice

Girders →

	W24x68	vs W24x55
Weight	—	✓
Depth	—	—
ϕM_n	✓	—
I	✓	—
Max Load	✓	—

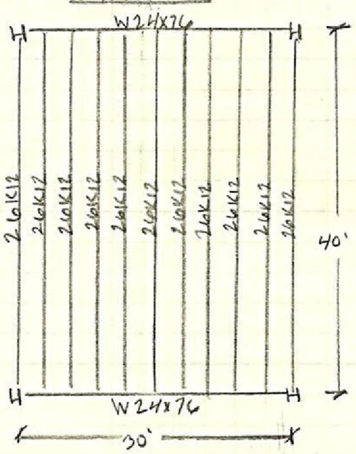
	W24x68	vs W21x68
Weight	—	—
Depth	—	✓
ϕM_n	✓	—
I	✓	—
Max Load	✓	—

Final Evaluation → W24x68 is most economical choice

Marissa Delozier | AE Senior Thesis | Gravity System Redesign | 1

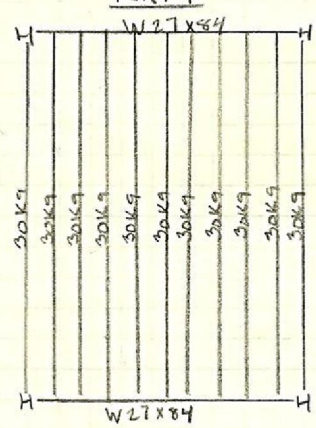
IV. 30'x 40' Bay (w/ joists traveling in the 40' direction)

Calculations



LL = 80 psf
DL = 10 psf
0.6C24 Deck
35 psf
3" thick

RAM



Properties

W24x76: ϕM_n = 750 ft·k
I = 2100 in⁴

26K12 : Load Capacity = 657 lb/ft
w for L/360 = 269 lb/ft
Wt = 16.6 lb/ft

W27x84: ϕM_n = 915 ft·k
I = 2850 in⁴

30K9 : Load Capacity = 576 lb/ft
w for L/360 = 278 lb/ft
Wt = 13.4 lb/ft

Check

30K9 ⟶ 546 + 13.4(1.2) = 562 lb/ft < 576 lb/ft ∴ ok ✓
w for L/240 = 278(1.5) = 417 lb/ft > 375 lb/ft ∴ ok ✓

W27x84 ⟶ M_u = 614 ft·k ϕM_n = 915 ft·k > 614 ∴ ok ✓
Δ_{LL} = 1"   I ≥ 2011 in⁴   2850 > 2011 ∴ ok ✓

Comparison

Joists ⟶

	26K12	vs 30K9
Weight	—	✓
Depth	✓	—
Load Capacity	✓	—

Final Evaluation ⟶ 26K12 is most economical choice

Girders ⟶

	W24x76	vs W27x84
Weight	✓	—
Depth	✓	—
ϕM_n	—	✓
I	—	✓
Max Load	—	✓

	W24x76	vs W24x84
Weight	✓	—
Depth	—	—
ϕM_n	—	✓
I	—	✓
Max Load	—	✓

Final Evaluation ⟶ use W24x84 girders

Appendix C: Lateral System Redesign

Velocity Pressures at Heights Above Ground Level		
Height Above Ground Level (ft)	K_{zt}	q_z (psf)
0 – 15	0.57	11.5
20	0.62	12.5
25	0.66	13.4
30	0.70	14.2
40	0.76	15.4
50	0.81	16.4
60	0.85	17.2
70	0.89	18.0
80	0.93	18.8
90	0.96	19.4
100	0.99	20.0
120	1.04	21.0
140	1.09	22.1
160	1.13	22.9
180	1.17	23.7
200	1.21	24.5

Windward Wind Pressures – X-Direction (East-West)			
Floor	Height Above Ground Level (ft)	q_z (psf)	p (psf)
2	14.667	11.5	16.6
3	29.333	14.2	20.5
4	44	15.8	22.8
5	58.667	17.1	24.6
6	73.333	18.3	26.4
7	88	19.3	27.8
8	102.67	20.1	28.9
9	117.33	20.9	30.1
10	132	21.7	31.2
11	146.67	22.4	32.2
12	161.33	22.9	33
13	176	23.5	33.8
Roof	196	24.3	35
Parapet	200.67	24.5	35.3

Windward Wind Pressures – Y-Direction (North-South)			
Floor	Height Above Ground Level (ft)	q_z (psf)	p (psf)
2	14.667	11.5	7.82
3	29.333	14.2	9.66
4	44	15.8	10.7
5	58.667	17.1	11.6
6	73.333	18.3	12.4
7	88	19.3	13.1
8	102.67	20.1	13.7
9	117.33	20.9	14.2
10	132	21.7	14.8
11	146.67	22.4	15.2
12	161.33	22.9	15.5
13	176	23.5	16
Roof	196	24.3	16.5
Parapet	200.67	24.5	16.7

Calculated Dead Loads By Floor							
Floor	DL (psf)				Ext. DL (psf)		Total DL (psf)
	Misc.	Slab/Deck	Framing	Insul.	Panel	Glass	
1	10	0	3.5	0	-	-	15
2	10	37	3.2	2	22	11	90
3	10	37	8	2	45	5	107
4	10	37	7.7	2	45	5	107
5	10	37	7.5	2	33	8	98
6	10	37	7.2	2	33	8	98
7	10	37	7.2	2	33	8	98
8	10	37	7	2	33	8	97
9	10	37	6.7	2	33	8	97
10	10	37	6.5	2	33	8	97
11	10	37	6.3	2	33	8	97
12	10	37	6.1	2	33	8	97
13	10	37	6.2	2	33	8	97
Roof	10	2.5	4	3	66	0	86

Seismic Forces By Floor – Both X & Y-Directions (E-W & N-S)					
Floor	Dead Load (psf)	Weight (k)	Height (ft)	wh^k	Force (k)
2	90	1370	14.667	131720	0.9
3	107	1630	29.333	508982	3.5
4	107	1630	44	1014044	7
5	98	1492	58.667	1513695	10.4
6	98	1492	73.333	2211963	15.2
7	98	1492	88	3015709	20.7
8	97	1477	102.67	3879833	26.6
9	97	1477	117.33	4868496	33.4
10	97	1477	132	5947798	40.8
11	97	1477	146.67	7114767	48.8
12	97	1477	161.33	8365848	57.4
13	97	1477	176	9699560	66.5
Roof	86	1310	196	10330150	70.9
	W (k) =	19,278	$\sum wh^k$ =	58,602,565	

Comparison of Wind & Seismic Loads – Story Shears (k)				
Floor	Wind (X, E-W)	Wind (Y, N-S)	Seismic	Wind or Seismic Controls
Roof	9.8	44.3	70.9	Seismic
13	42.6	115.1	137	Seismic
12	69.9	182.4	195	Seismic
11	96.7	247.9	244	Wind
10	122.9	313.4	284	Wind
9	148.4	377.1	318	Wind
8	172.9	439.1	344	Wind
7	196.8	499.3	365	Wind
6	219.8	557.7	380	Wind
5	241.8	614.3	391	Wind
4	262.5	667.4	398	Wind
3	281.4	717	401	Wind
2	299.2	764.8	402	Wind

Comparison of Wind & Seismic Loads – Base Shear (k) & Overturning Moment (ft-k)				
	Wind (X, E-W)	Wind (Y, N-S)	Seismic	Wind or Seismic Controls
Base Shear (k)	300	765	402	Wind (Y, N-S)
Overturning Moment (ft-k)	31,800	81,500	333,500	Seismic

Center of Mass & Center of Rigidity		
	X	Y
C.o.M.	88	43.5
C.o.R.	91	39
X +e	88	48
X –e	88	39
Y +e	91	43.5
Y –e	85	43.5

Drift Calculations – Wind Loads – Case 1					
Floor	X-Direction (E-W)		Y-Direction (N-S)		Allowable Drift
	X Disp.	X Drift	Y Disp.	Y Drift	
Roof	3.69	0.12	4.35	0.41	0.6
13	3.57	0.12	3.94	0.31	0.44
12	3.45	0.17	3.63	0.34	0.44
11	3.28	0.21	3.29	0.35	0.44
10	3.06	0.26	2.93	0.37	0.44
9	2.81	0.30	2.56	0.38	0.44
8	2.51	0.33	2.18	0.39	0.44
7	2.18	0.36	1.79	0.38	0.44
6	1.82	0.40	1.41	0.37	0.44
5	1.42	0.42	1.03	0.34	0.44
4	1.00	0.42	0.69	0.30	0.44
3	0.57	0.38	0.39	0.24	0.44
2	0.20	0.20	0.15	0.15	0.44

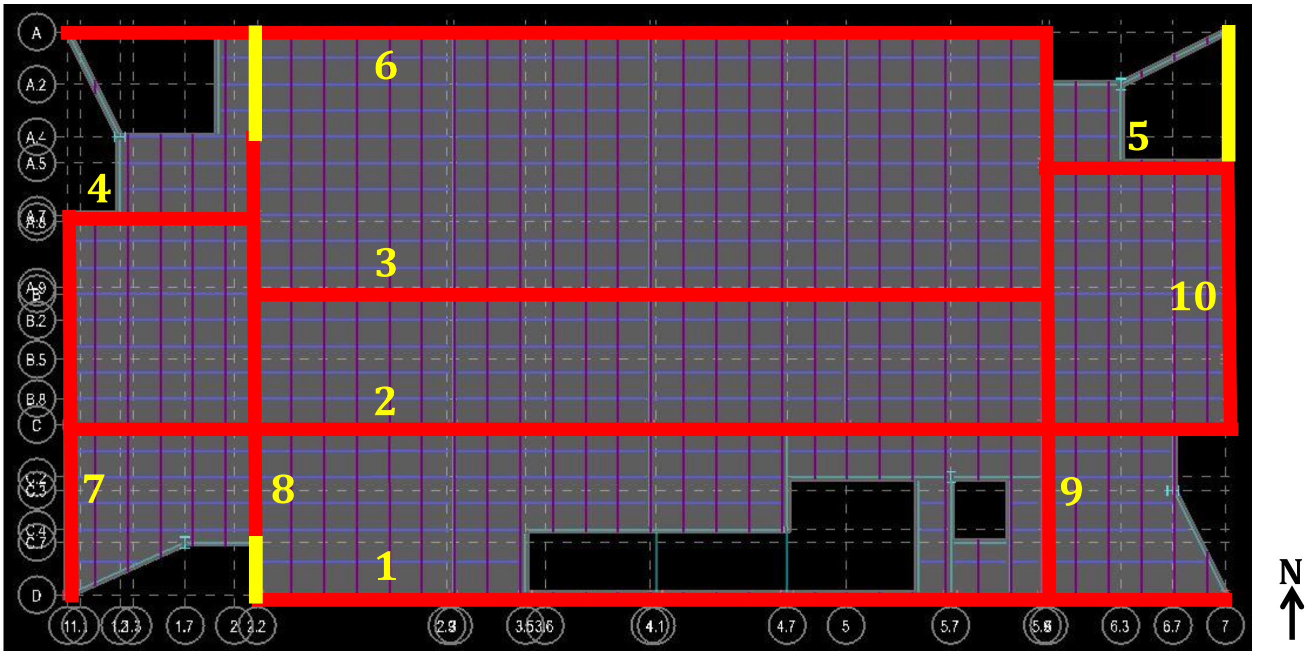
Drift Calculations – Wind Loads – Case 2									
Floor	X-Direction (E-W) (+/-e)				Y-Direction (N-S) (+/-e)				Allowable Drift
	X Disp.	X Drift	X Disp.	X Drift	Y Disp.	Y Drift	Y Disp.	Y Drift	
Roof	2.80	0.09	2.74	0.09	3.24	0.31	3.28	0.30	0.6
13	2.71	0.09	2.65	0.09	2.93	0.23	2.98	0.23	0.44
12	2.61	0.13	2.56	0.13	2.70	0.25	2.74	0.26	0.44
11	2.48	0.16	2.44	0.16	2.45	0.27	2.49	0.27	0.44
10	2.32	0.20	2.28	0.19	2.18	0.28	2.22	0.28	0.44
9	2.12	0.22	2.09	0.22	1.90	0.28	1.94	0.29	0.44
8	1.90	0.25	1.87	0.24	1.62	0.29	1.65	0.30	0.44
7	1.65	0.27	1.63	0.27	1.33	0.29	1.35	0.29	0.44
6	1.37	0.30	1.36	0.30	1.04	0.28	1.07	0.28	0.44
5	1.07	0.32	1.06	0.32	0.76	0.26	0.79	0.26	0.44
4	0.75	0.32	0.75	0.32	0.51	0.22	0.53	0.23	0.44
3	0.43	0.28	0.33	0.28	0.29	0.18	0.30	0.18	0.44
2	0.15	0.15	0.15	0.15	0.11	0.11	0.12	0.12	0.44

Drift Calculations – Wind Loads – Case 3									
Floor	X + Y				X – Y				Allowable Drift
	X Disp.	Y Disp.	X Drift	Y Drift	X Disp.	Y Disp.	X Drift	Y Drift	
Roof	2.73	3.24	0.08	0.30	2.81	-3.28	0.09	-0.31	0.6
13	2.64	2.93	0.09	0.23	2.71	-2.97	0.10	-0.24	0.44
12	2.56	2.70	0.12	0.25	2.62	-2.74	0.13	-0.26	0.44
11	2.43	2.45	0.16	0.26	2.49	-2.48	0.16	-0.27	0.44
10	2.27	2.19	0.19	0.28	2.32	-2.21	0.20	-0.28	0.44
9	2.09	1.91	0.22	0.28	2.13	-1.93	0.23	-0.29	0.44
8	1.87	1.63	0.24	0.29	1.90	-1.64	0.25	-0.30	0.44
7	1.62	1.33	0.27	0.28	1.65	-1.35	0.27	-0.29	0.44
6	1.36	1.05	0.29	0.28	1.37	-1.06	0.30	-0.28	0.44
5	1.06	0.77	0.32	0.25	1.07	-0.78	0.32	-0.26	0.44
4	0.75	0.52	0.32	0.22	0.75	-0.52	0.32	-0.23	0.44
3	0.43	0.22	0.28	0.18	0.43	-0.29	0.28	-0.18	0.44
2	0.15	0.11	0.15	0.11	0.15	-0.11	0.15	-0.11	0.44

Drift Calculations – Wind Loads – Case 4 – CW									
Floor	X + Y CW				X – Y CW				Allowable Drift
	X Disp.	Y Disp.	X Drift	Y Drift	X Disp.	Y Disp.	X Drift	Y Drift	
Roof	2.17	2.44	0.08	0.22	2.23	-2.45	0.09	-0.23	0.6
13	2.09	2.22	0.08	0.17	2.15	-2.21	0.08	-0.18	0.44
12	2.02	2.05	0.10	0.19	2.07	-2.04	0.11	-0.19	0.44
11	1.91	1.86	0.13	0.20	1.96	-1.85	0.14	-0.20	0.44
10	1.78	1.66	0.15	0.21	1.82	-1.65	0.16	-0.21	0.44
9	1.63	1.45	0.18	0.21	1.66	-1.43	0.18	-0.22	0.44
8	1.45	1.23	0.20	0.22	1.48	-1.22	0.20	-0.22	0.44
7	1.26	1.01	0.21	0.21	1.28	-1.00	0.22	-0.22	0.44
6	1.05	0.80	0.23	0.21	1.06	-0.78	0.23	-0.21	0.44
5	0.82	0.59	0.24	0.19	0.83	-0.57	0.25	-0.19	0.44
4	0.57	0.40	0.24	0.17	0.58	-0.38	0.25	-0.17	0.44
3	0.33	0.23	0.22	0.14	0.33	-0.21	0.22	-0.13	0.44
2	0.11	0.09	0.11	0.09	0.11	-0.08	0.11	-0.08	0.44

Drift Calculations – Wind Loads – Case 4 – CCW									
Floor	X + Y CCW				X – Y CCW				Allowable Drift
	X Disp.	Y Disp.	X Drift	Y Drift	X Disp.	Y Disp.	X Drift	Y Drift	
Roof	1.92	2.41	0.05	0.23	1.98	-2.48	0.06	-0.23	0.6
13	1.87	2.18	0.05	0.17	1.92	-2.25	0.06	-0.18	0.44
12	1.81	2.01	0.08	0.19	1.86	-2.07	0.09	-0.19	0.44
11	1.73	1.82	0.10	0.20	1.78	-1.88	0.11	-0.20	0.44
10	1.63	1.63	0.13	0.21	1.66	-1.68	0.13	-0.21	0.44
9	1.50	1.42	0.15	0.21	1.53	-1.46	0.16	-0.22	0.44
8	1.35	1.21	0.17	0.22	1.37	-1.25	0.18	-0.22	0.44
7	1.18	0.99	0.19	0.21	1.20	-1.02	0.20	-0.22	0.44
6	0.99	0.78	0.21	0.21	1.00	-0.81	0.22	-0.21	0.44
5	0.78	0.57	0.23	0.19	0.79	-0.59	0.23	-0.19	0.44
4	0.55	0.38	0.23	0.16	0.55	-0.40	0.24	-0.17	0.44
3	0.31	0.21	0.21	0.13	0.32	-0.23	0.21	-0.14	0.44
2	0.11	0.08	0.11	0.08	0.11	-0.09	0.11	-0.09	0.44

Drift Calculations – Seismic Loads									
Floor	X-Dir. +e		X-Dir. -e		Y-Dir. +e		Y-Dir. -e		Allowable Drift
	X Disp.	X Drift	X Disp.	X Drift	Y Disp.	Y Drift	Y Disp.	Y Drift	
Roof	6.31	0.36	6.26	0.35	3.67	0.40	3.67	0.41	2.9
13	5.96	0.30	5.91	0.30	3.26	0.30	3.27	0.30	2.9
12	5.65	0.39	5.61	0.38	2.96	0.32	2.96	0.33	2.9
11	5.27	0.46	5.21	0.45	2.64	0.33	2.64	0.33	2.9
10	4.81	0.51	4.78	0.51	2.30	0.34	2.31	0.34	2.9
9	4.30	0.56	4.27	0.55	1.97	0.33	1.97	0.33	2.9
8	3.74	0.58	3.72	0.58	1.63	0.33	1.63	0.33	2.9
7	3.16	0.60	3.15	0.59	1.30	0.31	1.30	0.31	2.9
6	2.56	0.61	2.55	0.61	1.00	0.29	1.00	0.29	2.9
5	1.95	0.62	1.94	0.62	0.71	0.25	0.71	0.25	2.9
4	1.33	0.59	1.32	0.59	0.46	0.21	0.46	0.21	2.9
3	0.74	0.49	0.74	0.49	0.25	0.16	0.25	0.16	2.9
2	0.25	0.25	0.25	0.25	0.09	0.09	0.09	0.09	2.9



Frame Participation - % by Floor Level – X-Direction (East-West)						
Frame #	1	2	3	4	5	6
Roof	11.1	41.4	30.1	4.8	3.0	9.6
13	19.5	33.3	21.6	3.8	3.9	17.9
12	19.4	32.7	21.8	4.1	4.3	17.8
11	19.8	33.5	21.3	4.2	4.3	16.9
10	19.9	33.8	21.1	4.2	4.4	16.4
9	19.9	34.1	21.0	4.2	4.5	16.2
8	19.9	33.4	20.9	4.4	4.4	16.9
7	19.5	33.3	20.1	4.8	4.4	18.0
6	19.8	30.9	19.4	5.4	4.8	19.7
5	21.6	26.9	18.4	6.0	5.3	21.8
4	21.8	26.3	17.8	6.3	5.5	22.3
3	21.9	25.4	17.8	6.7	5.9	22.4
2	20.8	26.5	18.9	5.6	4.4	23.7
AVERAGE	19.6	31.7	20.8	5.0	4.6	18.4

Frame Participation - % by Floor Level – Y-Direction (North-South)				
Frame #	7	8	9	10
Roof	2.5	58.0	16.0	23.5
13	5.5	51.2	20.6	22.7
12	7.2	50.0	21.3	21.6
11	7.3	51.3	20.8	20.6
10	6.9	54.6	19.3	19.2
9	6.7	54.1	19.3	19.9
8	5.9	55.5	17.7	20.9
7	5.5	53.8	17.0	23.6
6	4.9	54.3	14.6	26.2
5	4.2	52.2	12.7	31.0
4	3.1	54.7	8.6	33.7
3	2.2	53.7	5.4	38.7
2	1.3	60.1	2.9	35.7
AVERAGE	4.9	54.1	15.1	26.0

Appendix D: Cost & Schedule Analysis (Breadth 1)

Composite Steel Beams & Girders – Original System – Short Bay					
Description	**Quantity**	**Unit**	**Material**	**Installation**	**Total**
Welded wire fabric, 6x6 – W2.1x2.1 (8x8) 30 lb/CSF	6	CSF	17.35	25.5	42.85
Structural Conc., LW, Ready Mix, 110 #/CF, 3000 psi	175	CF	2.51	0	2.51
Structural Conc., placing, elevated slab, less than 6" thick, pumped	175	CF	0	0.85	0.85
Conc. surface treatment, curing, sprayed membrane compound	6	CSF	8.05	5.95	14
Welded Shear Connectors, 3/4" diam., 3- 3/8" long	44	Each	0.53	1.36	1.89
Structural steel members, Beam or girder, W18x35	60	LF	50	5.87	55.87
Structural steel members, Beam or girder, W18x65	40	LF	93	6.25	99.25
Metal decking, steel, non-cellular composite decking, galvanized, 3" deep, 20 ga.	600	SF	2.21	0.59	2.8
Sprayed cementitious fireproofing, 1" thick on beams & girders	400	SF	0.53	0.69	1.22
	Total ($/SF)		**14.79**	**2.72**	**17.50**

Composite Steel Beams & Girders – Original System – Long Bay					
Description	**Quantity**	**Unit**	**Material**	**Installation**	**Total**
Welded wire fabric, 6x6 – W2.1x2.1 (8x8) 30 lb/CSF	12	CSF	17.35	25.5	42.85
Structural Conc., LW, Ready Mix, 110 #/CF, 3000 psi	350	CF	2.51	0	2.51
Structural Conc., placing, elevated slab, less than 6" thick, pumped	350	CF	0	0.85	0.85
Conc. surface treatment, curing, sprayed membrane compound	12	CSF	8.05	5.95	14
Welded Shear Connectors, 3/4" diam., 3- 3/8" long	104	Each	0.53	1.36	1.89
Structural steel members, Beam or girder, W18x35	60	LF	50	5.87	55.87
Structural steel members, Beam or girder, W18x211	80	LF	246	6.45	252.45
Metal decking, steel, non-cellular composite decking, galvanized, 3" deep, 20 ga.	1200	SF	2.21	0.59	2.8
Sprayed cementitious fireproofing, 1" thick on beams & girders	800	SF	0.53	0.69	1.22
	Total ($/SF)		**22.50**	**2.45**	**24.95**

Non-Composite Steel Joists on Girders – Redesign – Short Bay					
Description	**Quantity**	**Unit**	**Material**	**Installation**	**Total**
Welded wire fabric, 6x6 – W2.9x2.9 (6x6) 42 lb/CSF	6	CSF	22.5	27.5	50
Structural Conc., Normal Wt, Ready Mix, 3000 psi	125	CF	3.59	0	3.59
Structural Conc., placing, elevated slab, less than 6” thick, pumped	125	CF	0	0.85	0.85
Conc. Finishing, floors, bull float, manual float, & broom finish	600	SF	0	0.53	0.53
Conc. surface treatment, curing, sprayed membrane compound	6	CSF	8.05	5.95	14
Open web bar joist, K series, 30’ to 50’ span, 22K10, 12.6 lb/LF	180	LF	9	2.89	11.89
Structural steel members, Beam or girder, W18x40	40	LF	57	5.87	62.87
Metal decking, steel, slab form, 24 ga., 1” deep, galvanized	600	SF	1.75	0.47	2.22
Sprayed cementitious fireproofing, 1” thick on joists & girders	800	SF	0.53	0.69	1.22
	Total ($/SF)		**10.01**	**3.69**	**13.70**

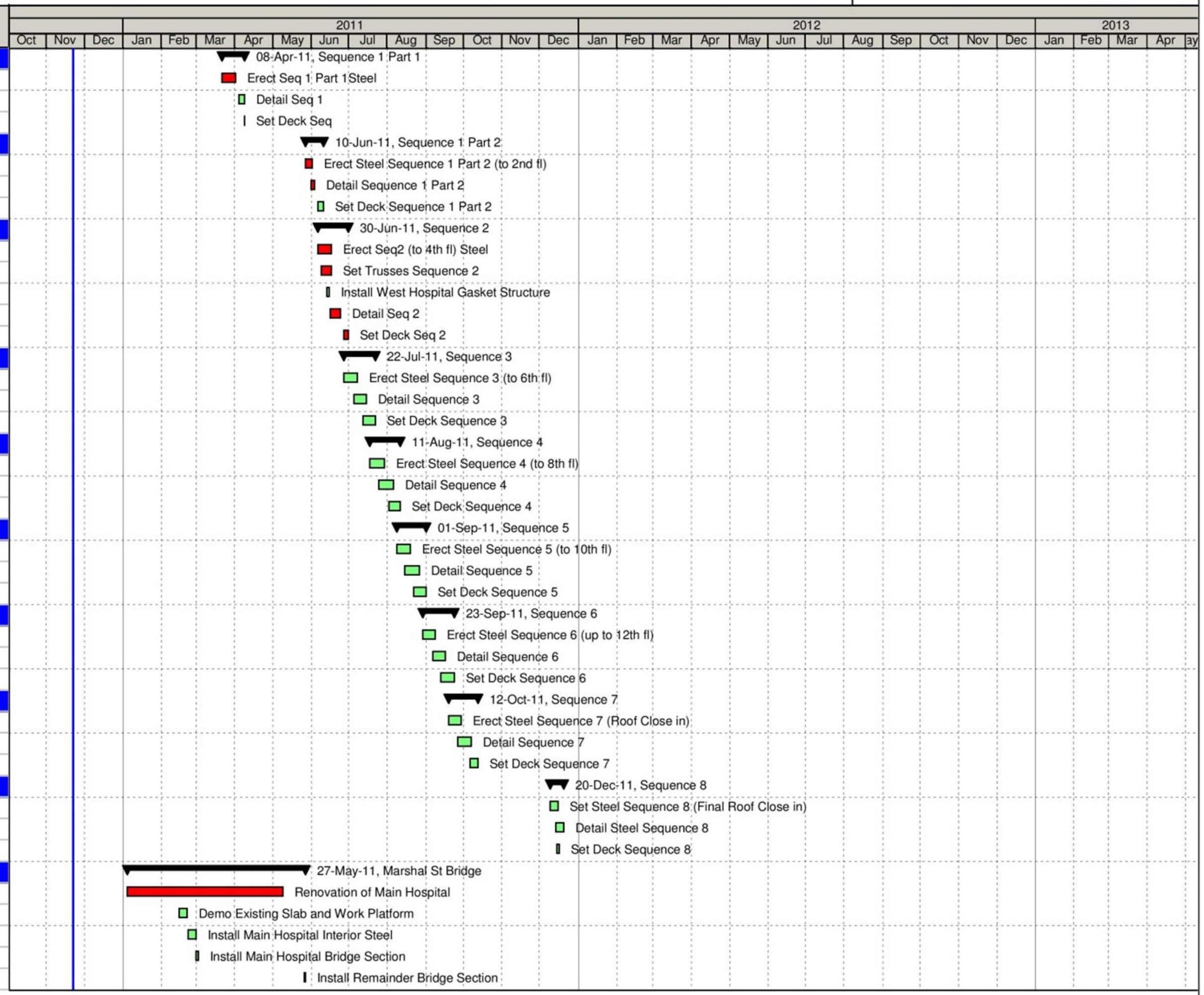
Non-Composite Steel Joists on Girders – Redesign – Long Bay					
Description	**Quantity**	**Unit**	**Material**	**Installation**	**Total**
Welded wire fabric, 6x6 – W2.9x2.9 (6x6) 42 lb/CSF	12	CSF	22.5	27.5	50
Structural Conc., Normal Wt, Ready Mix, 3000 psi	250	CF	3.59	0	3.59
Structural Conc., placing, elevated slab, less than 6” thick, pumped	250	CF	0	0.85	0.85
Conc. Finishing, floors, bull float, manual float, & broom finish	1200	SF	0	0.53	0.53
Conc. surface treatment, curing, sprayed membrane compound	12	CSF	8.05	5.95	14
Open web bar joist, K series, 30’ to 50’ span, 22K10, 12.6 lb/LF	330	LF	9	2.89	11.89
Structural steel members, Beam or girder, W30x124	80	LF	177.5	4.86	182.36
Metal decking, steel, slab form, 24 ga., 1” deep, galvanized	1200	SF	1.75	0.47	2.22
Sprayed cementitious fireproofing, 1” thick on joists & girders	1750	SF	0.53	0.69	1.22
	Total ($/SF)		**17.88**	**3.64**	**21.52**

Costs Associated with Spray Applied Fireproofing				
	Material ($/SF)	Installation ($/SF)	Total ($/SF)	Price Increase vs Original
Original System	0.35	0.46	0.81	–
Redesigned System	0.74	0.96	1.70	+ $0.90/SF (~ 4%)

Costs Associated with Shop/Spray Applied Fireproofing & Rated Ceilings – Redesigned System				
	Material ($/SF)	Installation ($/SF)	Total ($/SF)	Price Increase vs Original
Shop Applied	1.04	0	1.04	-
Spray Applied	0.20	0.26	0.46	-
Rated Ceilings	-	-	0.45	-
Total	**-**	**-**	**1.95**	**+ $1.15/SF (~ 5.5%)**

Print Date - 02-Dec-10 | Data Date - 22-Nov-10

Activity ID	Activity Name	Orig Dur	Start	Finish
Sequence 1 Part 1		15	21-Mar-11	08-Apr-11
5000	Erect Seq 1 Part 1Steel	10	21-Mar-11	01-Apr-11
5020	Detail Seq 1	5	04-Apr-11	08-Apr-11
5010	Set Deck Seq	1	08-Apr-11	08-Apr-11
Sequence 1 Part 2		10	27-May-11	10-Jun-11
5005	Erect Steel Sequence 1 Part 2 (to 2nd fl)	3	27-May-11	01-Jun-11
5015	Detail Sequence 1 Part 2	3	01-Jun-11	03-Jun-11
5025	Set Deck Sequence 1 Part 2	5	06-Jun-11	10-Jun-11
Sequence 2		19	06-Jun-11	30-Jun-11
5030	Erect Seq2 (to 4th fl) Steel	10	06-Jun-11	17-Jun-11
5060	Set Trusses Sequence 2	7	09-Jun-11	17-Jun-11
A1580	Install West Hospital Gasket Structure	3	13-Jun-11	15-Jun-11
5040	Detail Seq 2	7	16-Jun-11	24-Jun-11
5050	Set Deck Seq 2	4	27-Jun-11	30-Jun-11
Sequence 3		19	27-Jun-11	22-Jul-11
A1070	Erect Steel Sequence 3 (to 6th fl)	8	27-Jun-11	07-Jul-11
A1090	Detail Sequence 3	9	05-Jul-11	15-Jul-11
A1080	Set Deck Sequence 3	9	12-Jul-11	22-Jul-11
Sequence 4		19	18-Jul-11	11-Aug-11
A1100	Erect Steel Sequence 4 (to 8th fl)	10	18-Jul-11	29-Jul-11
A1120	Detail Sequence 4	10	25-Jul-11	05-Aug-11
A1110	Set Deck Sequence 4	8	02-Aug-11	11-Aug-11
Sequence 5		19	08-Aug-11	01-Sep-11
A1130	Erect Steel Sequence 5 (to 10th fl)	10	08-Aug-11	19-Aug-11
A1140	Detail Sequence 5	10	15-Aug-11	26-Aug-11
A1150	Set Deck Sequence 5	9	22-Aug-11	01-Sep-11
Sequence 6		19	29-Aug-11	23-Sep-11
A1160	Erect Steel Sequence 6 (up to 12th fl)	8	29-Aug-11	08-Sep-11
A1170	Detail Sequence 6	9	06-Sep-11	16-Sep-11
A1180	Set Deck Sequence 6	9	13-Sep-11	23-Sep-11
Sequence 7		18	19-Sep-11	12-Oct-11
A1190	Erect Steel Sequence 7 (Roof Close in)	9	19-Sep-11	29-Sep-11
A1200	Detail Sequence 7	10	26-Sep-11	07-Oct-11
A1210	Set Deck Sequence 7	5	06-Oct-11	12-Oct-11
Sequence 8		8	09-Dec-11	20-Dec-11
A1220	Set Steel Sequence 8 (Final Roof Clos...	5	09-Dec-11	15-Dec-11
A1230	Detail Steel Sequence 8	5	14-Dec-11	20-Dec-11
A1240	Set Deck Sequence 8	2	15-Dec-11	16-Dec-11
Marshal St Bridge		105	04-Jan-11	27-May-11
A1650	Renovation of Main Hospital	90	04-Jan-11*	09-May-11
A1610	Demo Existing Slab and Work Platform	5	15-Feb-11	21-Feb-11
A1620	Install Main Hospital Interior Steel	5	22-Feb-11	28-Feb-11
A1630	Install Main Hospital Bridge Section	2	01-Mar-11	02-Mar-11
A1640	Install Remainder Bridge Section	2	26-May-11	27-May-11



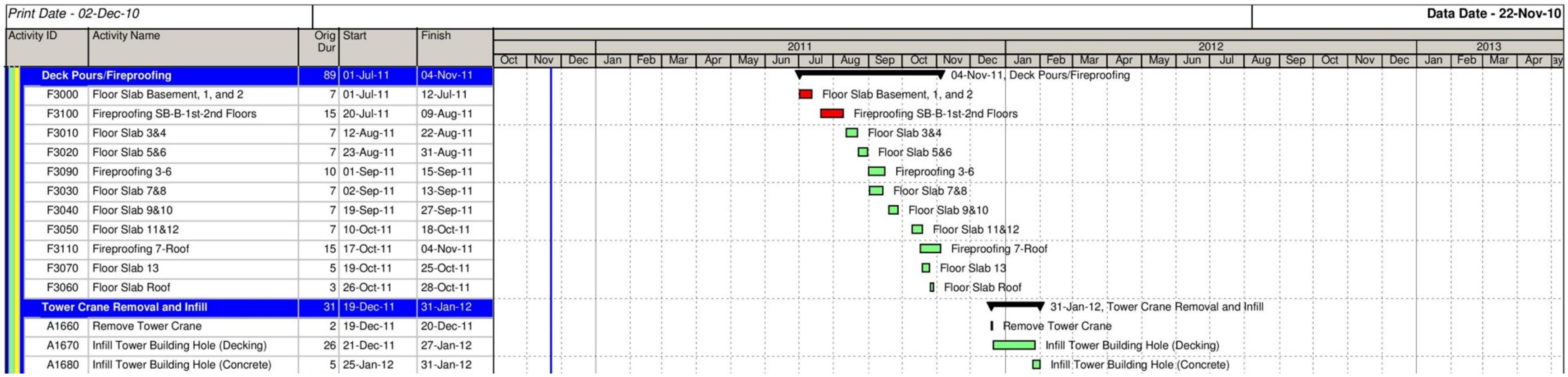
Remaining Level of Effort | Actual Work | Critical Remaining W... | Actual Level of Effort | Remaining Work | Summary Milestones

VCU New SOM Master Schedule

Page 2 of 4

Gilbane

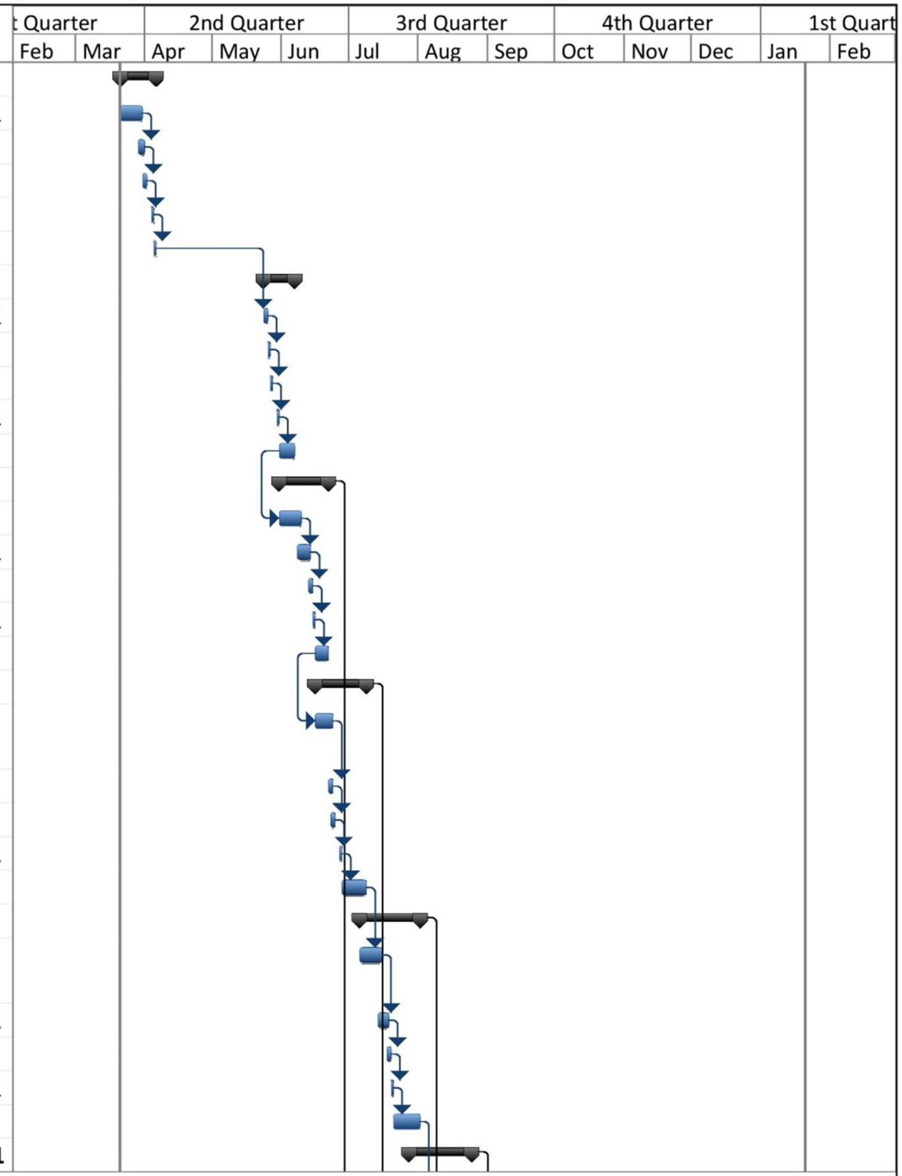
Original Floor Framing System Schedule (Provided by Gilbane Building Company)



Activity ID	Activity Name	Orig Dur	Start	Finish
Deck Pours/Fireproofing		89	01-Jul-11	04-Nov-11
F3000	Floor Slab Basement, 1, and 2	7	01-Jul-11	12-Jul-11
F3100	Fireproofing SB-B-1st-2nd Floors	15	20-Jul-11	09-Aug-11
F3010	Floor Slab 3&4	7	12-Aug-11	22-Aug-11
F3020	Floor Slab 5&6	7	23-Aug-11	31-Aug-11
F3090	Fireproofing 3-6	10	01-Sep-11	15-Sep-11
F3030	Floor Slab 7&8	7	02-Sep-11	13-Sep-11
F3040	Floor Slab 9&10	7	19-Sep-11	27-Sep-11
F3050	Floor Slab 11&12	7	10-Oct-11	18-Oct-11
F3110	Fireproofing 7-Roof	15	17-Oct-11	04-Nov-11
F3070	Floor Slab 13	5	19-Oct-11	25-Oct-11
F3060	Floor Slab Roof	3	26-Oct-11	28-Oct-11
Tower Crane Removal and Infill		31	19-Dec-11	31-Jan-12
A1660	Remove Tower Crane	2	19-Dec-11	20-Dec-11
A1670	Infill Tower Building Hole (Decking)	26	21-Dec-11	27-Jan-12
A1680	Infill Tower Building Hole (Concrete)	5	25-Jan-12	31-Jan-12

Original Floor Framing System Schedule Continued (Provided by Gilbane Building Company)

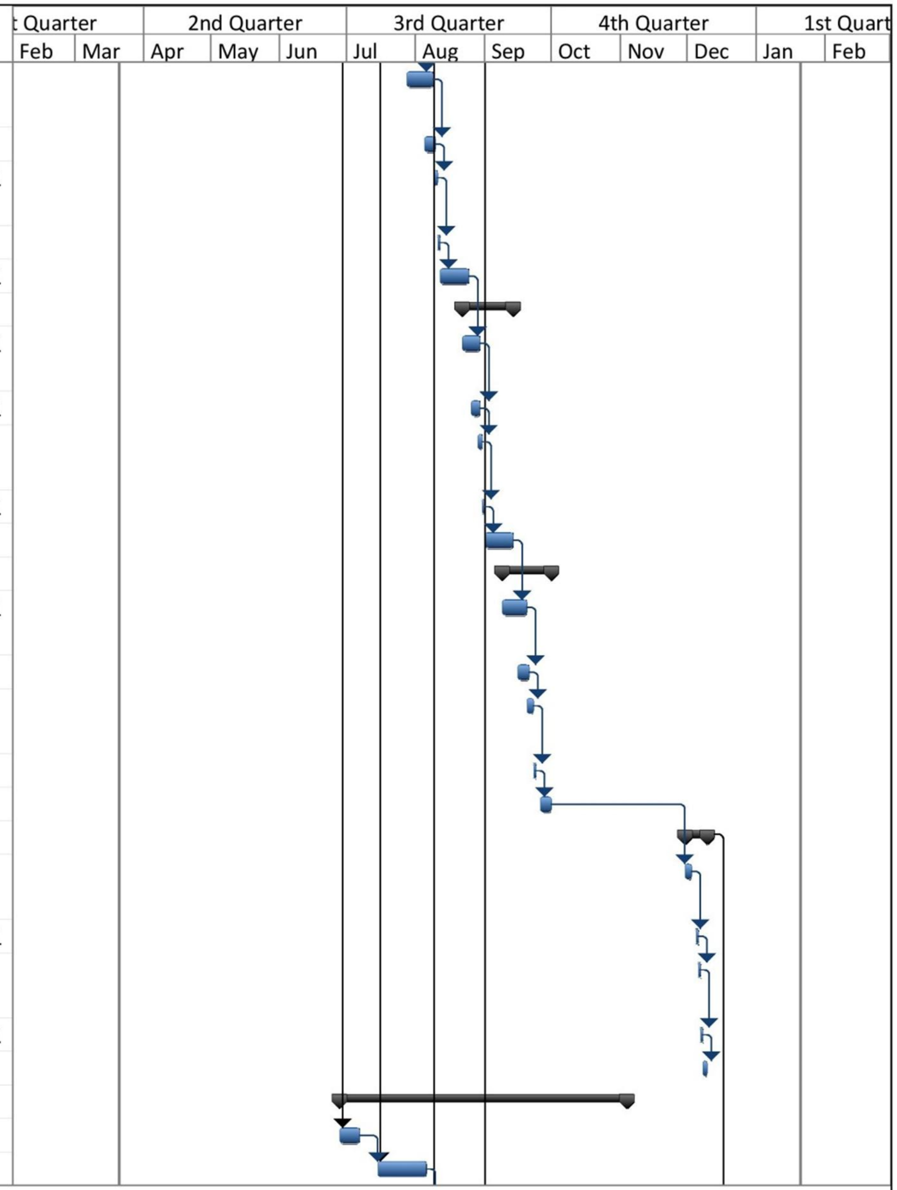
ID	Task Name	Duration	Start	Finish
1	**Sequence 1 Part 1**	**12 days**	**Mon 3/21/11**	**Tue 4/5/11**
2	Erect Steel	8 days	Mon 3/21/11	Wed 3/30/11
3	Detail Steel	3 days	Tue 3/29/11	Thu 3/31/11
4	Set Joists	2 days	Thu 3/31/11	Fri 4/1/11
5	Detail Joists	1 day	Mon 4/4/11	Mon 4/4/11
6	Set Deck	1 day	Tue 4/5/11	Tue 4/5/11
7	**Sequence 1 Part 2**	**10 days**	**Tue 5/24/11**	**Mon 6/6/11**
8	Erect Steel (to 2nd fl)	2 days	Tue 5/24/11	Wed 5/25/11
9	Detail Steel	1 day	Thu 5/26/11	Thu 5/26/11
10	Set Joists (to 2nd fl)	1 day	Fri 5/27/11	Fri 5/27/11
11	Detail Joists	1 day	Mon 5/30/11	Mon 5/30/11
12	Set Deck	5 days	Tue 5/31/11	Mon 6/6/11
13	**Sequence 2**	**16 days**	**Tue 5/31/11**	**Tue 6/21/11**
14	Erect Steel (to 4th fl)	8 days	Tue 5/31/11	Thu 6/9/11
15	Detail Steel	4 days	Wed 6/8/11	Mon 6/13/11
16	Set Joists (to 4th fl)	2 days	Mon 6/13/11	Tue 6/14/11
17	Detail Joists	1 day	Wed 6/15/11	Wed 6/15/11
18	Set Deck	4 days	Thu 6/16/11	Tue 6/21/11
19	**Sequence 3**	**17 days**	**Thu 6/16/11**	**Fri 7/8/11**
20	Erect Steel (to 6th fl)	6 days	Thu 6/16/11	Thu 6/23/11
21	Detail Steel	2 days	Wed 6/22/11	Thu 6/23/11
22	Set Joists (to 6th fl)	2 days	Thu 6/23/11	Fri 6/24/11
23	Detail Joists	1 day	Mon 6/27/11	Mon 6/27/11
24	Set Deck	9 days	Tue 6/28/11	Fri 7/8/11
25	**Sequence 4**	**19 days**	**Wed 7/6/11**	**Mon 8/1/11**
26	Erect Steel (to 8th fl)	8 days	Wed 7/6/11	Fri 7/15/11
27	Detail Steel	3 days	Thu 7/14/11	Mon 7/18/11
28	Set Joists (to 8th fl)	2 days	Mon 7/18/11	Tue 7/19/11
29	Detail Joists	1 day	Wed 7/20/11	Wed 7/20/11
30	Set Deck	8 days	Thu 7/21/11	Mon 8/1/11
31	**Sequence 5**	**20 days**	**Thu 7/28/11**	**Wed 8/24/11**



Page 1

Redesigned Floor Framing System Schedule

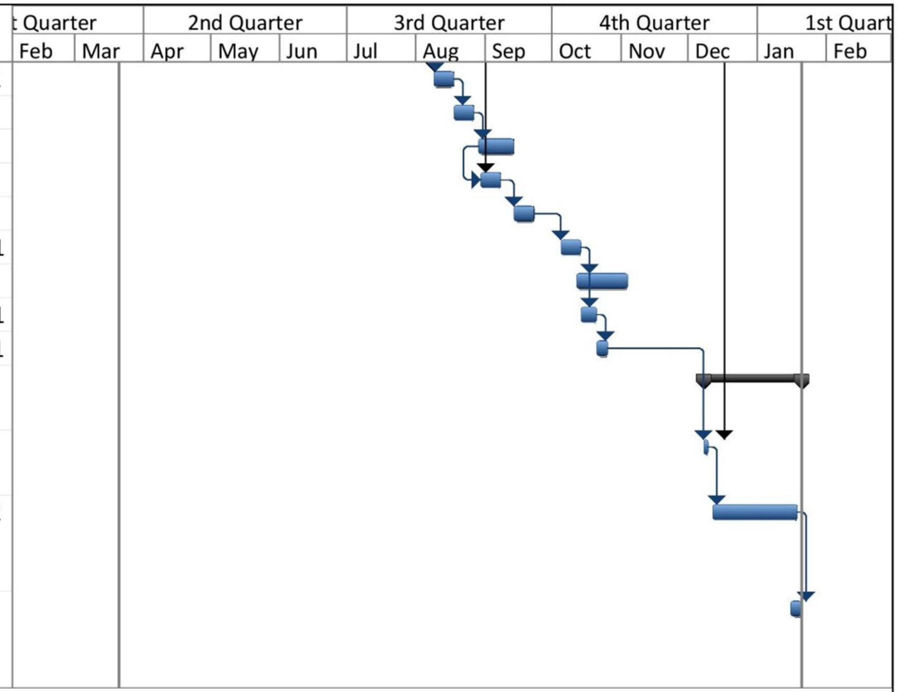
ID	Task Name	Duration	Start	Finish
32	Erect Steel(to 10th fl)	8 days	Thu 7/28/11	Mon 8/8/11
33	Detail Steel	3 days	Fri 8/5/11	Tue 8/9/11
34	Set Joists (to 10th fl)	2 days	Tue 8/9/11	Wed 8/10/11
35	Detail Joists	1 day	Thu 8/11/11	Thu 8/11/11
36	Set Deck	9 days	Fri 8/12/11	Wed 8/24/11
37	**Sequence 6**	**17 days**	**Mon 8/22/11**	**Tue 9/13/11**
38	Erect Steel (to 12th fl)	6 days	Mon 8/22/11	Mon 8/29/11
39	Detail Steel	2 days	Fri 8/26/11	Mon 8/29/11
40	Set Joists (to 12th fl)	2 days	Mon 8/29/11	Tue 8/30/11
41	Detail Joists	1 day	Wed 8/31/11	Wed 8/31/11
42	Set Deck	9 days	Thu 9/1/11	Tue 9/13/11
43	**Sequence 7**	**16 days**	**Fri 9/9/11**	**Fri 9/30/11**
44	Erect Steel (Roof Close-in)	7 days	Fri 9/9/11	Mon 9/19/11
45	Detail Steel	3 days	Fri 9/16/11	Tue 9/20/11
46	Set Joists (Roof Close-in)	3 days	Tue 9/20/11	Thu 9/22/11
47	Detail Joists	1 day	Fri 9/23/11	Fri 9/23/11
48	Set Deck	5 days	Mon 9/26/11	Fri 9/30/11
49	**Sequence 8**	**8 days**	**Wed 11/30/1**	**Fri 12/9/11**
50	Erect Steel (Final Roof Close-in)	3 days	Wed 11/30/11	Fri 12/2/11
51	Detail Steel	1 day	Mon 12/5/11	Mon 12/5/11
52	Set Joists (Final Roof Close-in)	1 day	Tue 12/6/11	Tue 12/6/11
53	Detail Joists	1 day	Wed 12/7/11	Wed 12/7/11
54	Set Deck	2 days	Thu 12/8/11	Fri 12/9/11
55	**Deck Pours/Fireproofing**	**93 days**	**Tue 6/28/11**	**Thu 11/3/11**
56	Floor Slab 1 & 2	7 days	Tue 6/28/11	Wed 7/6/11
57	Fireproofing 1-2	16 days	Fri 7/15/11	Fri 8/5/11



Page 2

Redesigned Floor Framing System Schedule

ID	Task Name	Duration	Start	Finish
58	Floor Slab 3 & 4	7 days	Tue 8/9/11	Wed 8/17/11
59	Floor Slab 5 & 6	7 days	Thu 8/18/11	Fri 8/26/11
60	Fireproofing 3-6	12 days	Mon 8/29/11	Tue 9/13/11
61	Floor Slab 7 & 8	7 days	Tue 8/30/11	Wed 9/7/11
62	Floor Slab 9 & 10	7 days	Wed 9/14/11	Thu 9/22/11
63	Floor Slab 11 & 12	7 days	Wed 10/5/11	Thu 10/13/11
64	Fireproofing 7-Roof	17 days	Wed 10/12/11	Thu 11/3/11
65	Floor Slab 13	5 days	Fri 10/14/11	Thu 10/20/11
66	Floor Slab Roof	3 days	Fri 10/21/11	Tue 10/25/11
67	**Tower Crane Removal & Infill**	**32 days**	**Thu 12/8/11**	**Fri 1/20/12**
68	Remove Tower Crane	2 days	Thu 12/8/11	Fri 12/9/11
69	Infill Tower Building Hole (Decking)	28 days	Mon 12/12/11	Wed 1/18/12
70	Infill Tower Building Hole (Concrete)	5 days	Mon 1/16/12	Fri 1/20/12



Page 3

Redesigned Floor Framing System Schedule

Comparison of Original Gravity System & Redesigned Gravity System Project Durations									
		Original			**Redesign**			**Comparison**	
		Dates	Dur	Total Dur	Dates	Dur	Total Dur	By Tasks	Total
Steel Erection	Seq 1 Part 1	3/21 -4/8	15	122 days	3/21 -4/5	12	114 days	Redesign	Redesign
	Seq 1 Part 2	5/27 -6/10	10		5/24 -6/6	10			
	Seq 2	6/6 -6/30	19		5/31 -6/21	16			
	Seq 3	6/27 -7/22	19		6/16 -7/8	17			
	Seq 4	7/18 -8/11	19		7/6 -8/1	19			
	Seq 5	8/8 -9/1	19		7/28 -8/24	20			
	Seq 6	8/28 -9/23	19		8/22 -9/13	17			
	Seq 7	9/19 -10/12	18		9/9 -9/30	16			
	Seq 8	12/9 -12/20	8		11/30 -12/9	8			
Deck Pours/ Fireproofing	Floor Slab 1-2	7/1 -7/12	7	89 days	6/28 -7/6	7	93 days	Original	
	Fireproofing 1-2	7/20 -8/9	15		7/15 -8/5	16			
	Floor Slab 3-6	8/12 -8/31	14		8/9 -8/26	14			
	Fireproofing 3-6	9/1 -9/15	10		8/29 -9/13	12			
	Floor Slab 7-12	9/2 -10/18	21		8/30 -10/13	21			
	Fireproofing 7-Roof	10/17 -11/4	15		10/12 -11/3	17			
	Floor Slab 13	10/19 -10/25	5		10/14 -10/20	5			
	Floor Slab Roof	10/26 -10/28	3		10/21 -10/25	3			
Tower Crane Removal & Infill	Remove Crane	12/19 -12/20	2	31 days	12/8 -12/9	2	31 days	Redesign	
	Infill Hole (Decking)	12/21 -1/27	29		12/12 -1/18	28			
	Infill Hole (Conc)	1/25 -1/31	5		1/16 -1/20	5			

Appendix E: Architectural Considerations (Breadth 2)

International Building Code 2006 [Ninth Printing]

A-3 Assembly uses intended for worship, recreation or amusement and other assembly uses not classified elsewhere in Group A including, but not limited to:

Amusement arcades
Art galleries
Bowling alleys
Places of religious worship
Community halls
Courtrooms
Dance halls (not including food or drink consumption)
Exhibition halls
Funeral parlors
Gymnasiums (without spectator seating)
Indoor swimming pools (without spectator seating)
Indoor tennis courts (without spectator seating)
Lecture halls
Libraries
Museums
Waiting areas in transportation terminals
Pool and billiard parlors

304.1 Business Group B. Business Group B occupancy includes, among others, the use of a building or structure, or a portion thereof, for office, professional or service-type transactions, including storage of records and accounts. Business occupancies shall include, but not be limited to, the following:

Airport traffic control towers
Animal hospitals, kennels and pounds
Banks
Barber and beauty shops
Car wash
Civic administration
Clinic—outpatient
Dry cleaning and laundries: pick-up and delivery stations and self-service
Educational occupancies for students above the 12th grade
Electronic data processing
Laboratories: testing and research
Motor vehicle showrooms
Post offices
Print shops
Professional services (architects, attorneys, dentists, physicians, engineers, etc.)
Radio and television stations
Telephone exchanges
Training and skill development not within a school or academic program

508.3.1 Accessory occupancies. Accessory occupancies are those occupancies subsidiary to the main occupancy of the building or portion thereof. Aggregate accessory occupancies shall not occupy more than 10 percent of the area of the story in which they are located and shall not exceed the tabular values in Table 503, without height and area increases in accordance with Sections 504 and 506 for such accessory occupancies.

Exceptions:

1. Accessory assembly areas having a floor area less than 750 square feet (69.7 m^2) are not considered separate occupancies.

TABLE 508.3.3
REQUIRED SEPARATION OF OCCUPANCIES (HOURS)

	A[e], E		I		R[d]		F-2, S-2[c,d], U[d]		B[b], F-1, M[b], S-1		H-1		H-2		H-3, H-4, H-5	
OCCUPANCY	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS
A[e], E[e]	N	N	1	2	1	2	N	1	1	2	NP	NP	3	4	2	3[a]
I	—	—	N	N	1	NP	1	2	1	2	NP	NP	3	NP	2	NP
R[d]	—	—	—	—	N	N	1	2	1	2	NP	NP	3	NP	2	NP
F-2, S-2[c,d], U[d]	—	—	—	—	—	—	N	N	1	2	NP	NP	3	4	2	3[a]
B[b], F-1, M[b], S-1	—	—	—	—	—	—	—	—	N	N	NP	NP	2	3	1	2[a]
H-1	—	—	—	—	—	—	—	—	—	—	N	NP	NP	NP	NP	NP
H-2	—	—	—	—	—	—	—	—	—	—	—	—	N	NP	1	NP
H-3, H-4, H-5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	NP

803.1 General. Interior wall and ceiling finishes shall be classified in accordance with ASTM E 84. Such interior finish materials shall be grouped in the following classes in accordance with their flame spread and smoke-developed indexes.

Class A: Flame spread 0-25; smoke-developed 0-450.

Class B: Flame spread 26-75; smoke-developed 0-450.

Class C: Flame spread 76-200; smoke-developed 0-450.

TABLE 803.5
INTERIOR WALL AND CEILING FINISH REQUIREMENTS BY OCCUPANCY[k]

GROUP	SPRINKLERED[l]			NONSPRINKLERED		
	Exit enclosures and exit passageways[a,b]	Corridors	Rooms and enclosed spaces[c]	Exit enclosures and exit passageways[a,b]	Corridors	Rooms and enclosed spaces[c]
A-1 & A-2	B	B	C	A	A[d]	B[e]
A-3[f], A-4, A-5	B	B	C	A	A[d]	C
B, E, M, R-1, R-4	B	C	C	A	B	C
F	C	C	C	B	C	C
H	B	B	C[g]	A	A	B
I-1	B	C	C	A	B	B
I-2	B	B	B[h, i]	A	A	B
I-3	A	A[j]	C	A	A	B
I-4	B	B	B[h, i]	A	A	B
R-2	C	C	C	B	B	C
R-3	C	C	C	C	C	C
S	C	C	C	B	B	C
U	No restrictions			No restrictions		

[F] 903.2.1.3 Group A-3. An automatic sprinkler system shall be provided for Group A-3 occupancies where one of the following conditions exists:

1. The fire area exceeds 12,000 square feet (1115 m^2).
2. The fire area has an occupant load of 300 or more.
3. The fire area is located on a floor other than the level of exit discharge.

Exception: Areas used exclusively as participant sports areas where the main floor area is located at the same level as the level of exit discharge of the main entrance and exit.