APPENDIX B

Structural Slab Design
Design calculations and tables are derived from *Concrete Reinforcing Steel Institute Design Handbook*, 2002.

**Slab Design**

Typical Bay Size: 30’ x 30’  
Average Column Size: 24” x 24”

Live Load: 100 PSF  
Dead Load:
- Ceiling: 10 PSF  
- Sarnatherm XPS Insulation: 0.69 PSF  
- Sarnafelt NWP-HD Separation Layer: 0.13 PSF  
- Sarnafil G476-15 Waterproofing Membrane: 0.33 PSF  
- Drainage Panel 900: 0.23 PSF  
- Saturated Growth Media and Plants: 48 PSF

\[ w_u = 1.4 \times 60 \text{ PSF} \times 1.7 \times 100 \text{ PSF} = 254 \text{ PSF} \]

Clear span between the column and interior beam is conservatively estimated to be 13’-6”. Clear span between columns is 28'-0”. Therefore the clear span between column line and interior beam is likely even smaller than 13’-6” given that the beam design will likely yield a beam width of greater than 1'-0”. Assuming a larger clear span value is a conservative estimate for the slab thickness design.

The minimum allowable slab thickness is \( \frac{t}{28} = \frac{15'}{28} = 6.4' \). Therefore, a minimum slab thickness of 6.5” will be used.

Based on the Solid One-Way Slab tables in Chapter 7 of the CRSI Handbook, the minimum amount of reinforcement that can be used in a 6.5” slab based on a factored load of 254 PSF is \( \rho \approx 0.0050 \). End span and interior span tables located on pages 7-12 and 7-17, respectively, are used. End span loading is most critical in determining slab thickness because of the increased shear in these regions.

**End Spans:** See Table 1.

\[ w_u = 312 \text{ PSF capacity} > 254 \text{ PSF} \]

- Top Bars, #5 @ 11”
- Bottom Bars, #5 @ 12”
- Top Bars at Free End, #4 @ 12”
- Temperature Bars, #4 @ 17”

**Interior Spans:** See Table 2.

\[ w_u = 355 \text{ PSF capacity} > 254 \text{ PSF} \]
Serviceability Check

1. Deflection - Maximum deflection occurs in the end span.

Service Load = \[ \left( \frac{1}{1.7} \right) w_u = \left( \frac{1}{1.7} \right) (232 \text{ PSF}) = 136.5 \text{ PSF} \]

Live Load Deflection = \[ \frac{L}{Service} \left( \frac{l \times 12 \text{ in}}{360} \right) \frac{j}{360} \]

\[ = \left( \frac{100 \text{ PSF}}{136.5 \text{ PSF}} \right) \left( \frac{13.5 \times 12 \text{ in}}{360} \right) \frac{15^\circ}{360} \]

\[ = 0.33" < 0.50" \quad \text{OK!} \]

2. Crack Control – Based on ACI 10.6.4, for 3/4" concrete cover, bar spacing is limited to 12". Bar spacing in design is satisfactory.

Beam Design

Live Load: 100 PSF
Dead Load:
- Ceiling .......................................................... 10 PSF
- 6-1/2” Concrete Slab ......................................... 81 PSF
- Sarnatherm XPS Insulation ............................... 0.69 PSF
- Sarnafelt NWP-HD Separation Layer .............. 0.13 PSF
- Sarnafil G476-15 Waterproofing Membrane .... 0.33 PSF
- Drainage Panel 900 ......................................... 0.23 PSF
- Saturated Growth Media and Plants ............. 48 PSF

140.38 PSF \approx 141 \text{ PSF}

Strength Design

\[ w_u = 1.4 \text{ Dead Load} \times 1.7 \text{ Live Load} \]

\[ w_u = 1.4 \times (141 \text{ PSF}) \times 1.7 \times (100 \text{ PSF}) \]

\[ w_u = 368 \text{ PSF} \]

Estimate end and interior span beam stem to be b=18", h=22". It was later determined that the interior spans could be designed with a beam width of 16" and larger reinforcing steel but for consistency in formwork and constructability, the interior span beams were left with a depth of 22" and a width of 18"

Beam Stem Estimate: \[ [18" \times (22"-6.5")][\frac{150 \text{ PCF}}{144 \text{ in}^2/\text{ft}^2} \times (1.4)] = 407 \text{ PLF} \]

Area Factored Load: \[ 368 \text{ PSF} \times 15' = 5,520 \text{ PLF} \]

Total Factored Load, \[ w_u: \]

\[ 5,927 \text{ PLF} \]
Determine load capacity of beams. See Tables 3 and 4 for end span and interior span load capacities.

End Spans: See Table 3.
\[ w_u = 6.1 \text{ k/ft capacity} > 5.9 \text{ k/ft} \]

Bottom Bars, (2) \#14 \([\ell_n + 12"]\)
(1) \#14 \([0.875 \ell_n]\)
Top Bars, (3) \#14
Open Stirrups: Max Spacing at Exterior End, 195G: (19)#5: 1@2", 18@9"
Open Stirrups: Max Spacing at Interior End, 164G: (16)#4: 1@2", 15@9"

Interior Spans: See Table 4.
\[ w_u = 6.1 \text{ k/ft capacity} > 5.9 \text{ k/ft} \]

Bottom Bars, (2) \#10 \([\ell_n + 12"]\)
(1) \#10 \([0.875 \ell_n]\)
Top Bars, (3) \#14
Open Stirrups: Max Spacing at Each End, 164G: (16)#4: 1@2", 15@9"

Girder Design

Convert to uniform loads.

Concentrated load at center = 5.93 kips/ft (30 ft) = 177.9 kips

Estimate stem to be \(b=20"\), \(h=28"\).

\[
[20" \times (28"-6.5")](\frac{150 \text{ PCF}}{144 \text{ in}^2/\text{ft}^2})(1.4)= 627 \text{ PLF}
\]

Concentrated load factored moment, \[ M = \frac{(177.9 \text{ k} \times 28')}{8} = 622.65 \text{ ft-kips} \]

Equivalent uniform load, \[ w = \frac{11M}{h^2} = \frac{11(622.65' \text{ kips})}{(28')^2} = 8.74 \text{ kips/ft} \]

Total factored uniform load (for \(-M_u\)), \[ w_u = 8.74 \text{ kips/ft} + 0.63 \text{ kips/ft} = 9.37 \text{ kips/ft} \]

Factored positive moment, \[ +M_u = 622.5 \text{ ft-kips} + \frac{0.63 \text{ PLF} (28')^2}{16} = 653.4 \text{ ft-kips} \]

Equivalent uniform load (for \(+M_u\)), \[ w_u = \frac{16(622.65' \text{ kips})}{(28')^2} + 0.63 \text{ kips/ft} = 13.3 \text{ kips/ft} \]
Determine load capacity of girders. See Tables 5 and 6 for end span and interior span load capacities.

End Spans: See Table 5.
\[ w_u = 9.8 \text{ k/ft capacity} > 9.37 \text{ k/ft} \]
- Bottom Bars, (3) \#11 \([\ell_n + 12"]\)
  - (2) \#11 \([0.875 \ell_n]\)
- Top Bars, (4) \#12
- Open Stirrups: Max Spacing at Exterior End, 175FfE: (17)#5: 1@2", 6@8", 10@11”
- Open Stirrups: Max Spacing at Interior End, 155FeI: (15)#5: 1@2", 5@8", 9@11”

Interior Spans: See Table 6.
\[ w_u = 10.9 \text{ k/ft capacity} > 9.37 \text{ k/ft} \]
- Bottom Bars, (2) \#14 \([\ell_n + 12"]\)
  - (1) \#14 \([0.875 \ell_n]\)
- Top Bars, (4) \#14
- Open Stirrups: Max Spacing at Each End, 155FeI: (15)#5: 1@2”, 5@8”, 9@11”

Check Torsion.
Torsional moment capacity (with open stirrups) = 15 ft-kips.

Estimate \( T_u \) for the girder with live load on one side only.
\[ w_u (\text{live load}) = 0.17 \text{ KLF (15')} = 2.55 \text{ kips/ft} \]
\[ T_u = 1/11 x (2.55 \text{ kips/ft})(30'-1.67')^2 = 186.1 \text{ ft-kips} \]
\[ T_u \text{ in girder} = (60/1820)(186.1 \text{ ft-kips}) = 6.13 \text{ ft-kips} < 15 \]
Closed stirrups and additional longitudinal bars are not required.

Check Shear.
Max \( V = (177.9 \text{ kips/2}) + (0.63 \text{ KLF} \times 14') = 97.8 \text{ kips} \)
Equivalent \( w_u \) for shear = 97.8 kips / 14’ = 7.0 kips/ft
Initial stirrup spacing is ok.

Bottom Bar Check.
Equivalent \( w_u = 13.3 \text{ kips/ft} \)
\[ +M_u = 653.4 \text{ ft-kips} \]

For a 20” x 28” girder with a clear span of 28’-0” and (5)#11 bars, \( +M_u = 696 \text{ ft-kips}. \) OK!

Initial Stirrup Adjustment.
Adjust for equivalent \( w_u \) of 7.0 kips/ft over the full span. Based on Table 5, use stirrup spacing 155I, (15)#5’s: 1@2”, 14@11” at each end.
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**Table 1. End Span, Slab**
CRSI, Page 7-12

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**Table 2. Interior Span, Slab**
CRSI, Page 7-17
Table 3. End Span, Beams  
CRSI, Page 12-31

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Table 4. Interior Span, Beams  
CRSI, Page 12-61

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### Table 5. End Span, Girder
CRSI, Page 12-34

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### Table 6. Interior Span, Girder
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