UNIVERSITY OF CALIFORNIA, SAN DIEGO

SE140B Professional Issues and Design of Civil Structures II

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Project 01: Two-Way Slab Design
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1. INTRODUCTION

SLOTH Architects has ordered the design of a 8-story vacation/office building. The objective of this project is to design the reinforced concrete floor system of one interstory level. The floor system consists of 3 two-way RC slabs and 2 girders, one interior and one exterior, both with fixed-fixed end conditions. Full analysis and design is to be conducted for the slabs and girders using the strip method and the yield line method. However, lateral loading is not considered as columns and beams are not part of the LFRS.

1.1 Description, Materials and Preliminary Dimensions

The reinforced concrete slab is made of normal weight concrete and ASTM A615 Grade 60 steel reinforcements. Material properties are specified in the Project 01 brief (Palermo, 2026). The compressive strength of the concrete, f'_c , is 4.k ksi with k being the last digit of our student PID. Hannah Ahn's PID is A18582629 so the compressive strength of concrete used is 4.9 ksi.
The beam and slab dimensions were also determined through the Project 01 brief with the slab sizing being dependent on our student PID (Palermo, 2026). The width of the slab is 32'-6" because the third to last digit of Hannah's PID is 6. The slab length is 30'-2" because the second to last digit of Hannah's PID is 2.

Table 1.1.1 Material Properties and Preliminary Dimensions

Description	Variable	Value
Reinforced Concrete and Steel		
Compression Resistance of Concrete	f_c	4.9 [ksi]
Young's Modulus	E_c	3,990 [ksi]
Weight per unit volume	γ_c	0.15 [kip/ft^3]
Reinforcement Steel		
Yield Resistance of Steel bars	f_y	60 [ksi]
Young's Modulus	E_s	29,000 [ksi]

Table 1.1.2 Dead and Live Loads Used

Description	Value	Units
Dead Loads		
Slab self-weight (normal-weight RC)	150	[pcf]
Superimposed dead load (partitions, finishes, MEP)	25	[psf]
Perimeter line dead load (glass facade along slab edges)	250	[plf]
Live Loads		
Typical lobby slabs (Grids 5-7 and E-F)	100	[psf]
Other slabs (Grids 7-8 and E-F)	250	[psf]

Table 1.1.3 Cross-sectional dimensions of beams

Element	Dimensions	
	Height h (in)	Thickness b_w (in)
Internal beam (Girder 7)	36	24
External beam (Girder 8)	36	24

Table 1.1.4 Lateral dimensions of slabs (Plan View)

Element	Length of span	
	X-direction l_{sx} (ft)	Y-direction l_{sy} (ft)
Slab #1	32.5	30.167
Slab #2	32.5	30.167
Slab #3	32.5	30.167

2. PRELIMINARY SLAB GEOMETRY DESIGN

Before beginning a slab thickness design, a minimum slab thickness calculation was performed, as specified in ACI 318-19 Table 8.3.1.2. The effective width of the T-beams (interior) and L-beams (exterior) were calculated using the average flexure stiffness ratios between the beams and the slabs. For each panel, the average slab stiffnesses were calculated. Since all the stiffness ratios values were found to be greater than 2 and they each have the same β value, the minimum thickness value was found to be 8.899 in for all the slabs. The proposed slab thickness of 10 in was determined to ensure conservative compliance with code requirements, while remaining relatively light.

Table 2.1 Preliminary data of slabs

Parameters	Geometric Parameters		
	Slab #1	Slab #2	Slab #3
Ratio of longer to shorter clear spans (β)	1.082	1.082	1.082
Average flexure stiffness ratio (α)	3.095	3.23	3.095
Required minimum slab thickness (h_{min})	8.899 [in]	8.899 [in]	8.899 [in]
Slab thickness proposed (h)	10 [in]	10 [in]	10 [in]

3. METHODS OF ANALYSIS

3.1 Strip Line Method Applied to Slabs

3.1.1 Internal Forces in Slabs

The internal forces in the slabs were determined using the strip method, where each slab panel is divided into equivalent beam strips in both principal directions. Factored loads were calculated using the governing load combinations from ASCE 7-16. For the dead load for all three slabs, a self-weight of 150 pcf and a superimposed dead load of 25 psf were used. For Slab #1 live load, an area load of 250 psf was used. For Slabs #2 and #3 live loads, an area load of 100 psf was used. Since the length and width of the slabs are not 1:1, a γ value of 0.6 was applied to the shorter length (y-direction). It is, thusly, assumed that the y-direction loads will be greater than that of the x-direction, except for Slab 2, which has a special case. The loading in both directions for Slabs #1 and #3 were considered fixed-pinned, as the inner sides are rigidly fixed to the rest of the slab. For Slab #2, the y-direction loads were considered fixed-fixed, as Slabs #1 and #3 do not allow it to move in any direction. In the x-direction, Slab #2 has a 7' cantilever overhang, which actually reduces deflection in the slab and causes the moments to be lower. There is a glass facade load which was assumed to not act on the overhang as it extends past the building face. To calculate the internal slab forces, structural analysis and statics were performed in Excel. To take the cantilever into consideration, the x-direction strip for Slab #2 bending diagram was calculated in Hurmet, providing a maximum positive and negative moment and a maximum shear. The initial assumption that the y-direction loads are higher than the x-direction loads except for Slab #2 turned out to be true, as seen below in Table 3.1.1.

The calculation process for the slab loads generally followed the same design method. First, the ultimate load was calculated for each slab using a load combination of the maximum of 1.4*DL or 1.2*DL + 1.6*LL. This gave a maximum load of 0.58 klf for Slab #1 and 0.34 klf for Slabs #2 and #3. The γ-factor was then applied in each direction to find the loads. ASCE 7-22 beam diagrams and formulas were used to calculate shear and negative and positive moments.

Table 3.1.1 Bending moment and shear demands in slabs in x-x (horizontal) and y-y (vertical)

Element	Strip Method		
	Positive Moment (kip.ft/ft)	Negative Moment (kip.ft/ft)	Shear Force (kip.ft/ft)
Slab #1 (x-x)	17.23	30.63	4.71
Slab #1 (y-y)	22.27	39.59	7.07
Slab #2 (x-x)	8.51	16	2.58
Slab #2 (y-y)	7.74	15.47	3.32
Slab #3 (x-x)	10.1	17.96	2.76
Slab #3 (y-y)	13.05	23.21	4.14

3.1.2 Shear and Flexural Design Capacity

The flexural and shear capacities of the slabs are calculated using reinforced concrete design principles in accordance with ACI 318-19. The required reinforcement area is obtained from the bending moment demand using strength design equations.

The first step of finding the flexural capacity of a slab in either direction was to find the depth of the compression stress block. Using an iterative value for this depth, a_{iter}, and the required tensile steel, A_s, given this value of a_{iter}, a required value of a_{req} was able to be calculated. The value of a_{iter} was changed continuously until a_{iter} and a_{req} converged to the same value. After finding the required A_s, some amount of #6 bars were chosen to meet this requirement. Then, an actual value of the compression stress block was calculated, which was used to calculate the nominal moment, which is required to be larger than the ultimate moment of the strip divided by a ϕ-factor of 0.9. Several checks needed to be performed, such as ensuring the section is tension-controlled, the minimum A_s value was met, and the minimum and maximum spacing was met, of which all of the slabs in either direction were satisfied.

Shear capacity was evaluated considering the contribution of concrete and minimum reinforcement requirements. The design ensures that the nominal capacity exceeds the factored demands with appropriate strength reduction factors. The shear capacity was calculated in accordance with the ACI code, using a ϕ-factor of 0.75. If there was any instance in which the slab itself could not provide enough shear strength on its own, stirrups were added. The spacing of the stirrups were then checked to ensure they met the minimum and maximum spacing requirements.

Table 6 Bending moment and shear capacity in slabs in x-x (horizontal) and y-y (vertical)

Element	Strip Method		
	Positive Moment (kip.ft/ft)	Negative Moment (kip.ft/ft)	Shear Force (kip.ft/ft)
Slab #1 (x-x)	35.08	50.87	5.03
Slab #1 (y-y)	35.08	50.87	5.03
Slab #2 (x-x)	18.12	26.74	3.99
Slab #2 (y-y)	18.12	18.12	3.49
Slab #3 (x-x)	18.12	26.47	3.99

Element	Strip Method		
	Positive Moment (kip.ft/ft)	Negative Moment (kip.ft/ft)	Shear Force (kip.ft/ft)
Slab #3 (y-y)	18.12	32.08	4.26

3.1.3 Longitudinal and Transversal Steel Bars

The top reinforcement is reinforced at the supports and resists negative moments. The bottom reinforcement reinforces the midspan and resists positive moments. #6 bars were used for all three slabs for ease of construction. The bottom positive reinforcement spacing was first determined with 6 inches going into the beam to satisfy ACI 318-19 §7.7.3.8.2. The same spacing of bars in the positive reinforcement was placed in the top negative reinforcement and ran through the whole slab. These go 21 inches into the beam to satisfy the 18 inch lap splice length required in ACI 318-19 §25.5.2.1 where the reinforcement from other beams overlap. The remaining reinforcement necessary to suffice for the moment demand was placed at the edges of the slab with peak negative moment. 18 inches extended into the beam to satisfy the development length and 9 inches extended further beyond the location of zero moment to satisfy the extension length.

Table 7 Reinforcement Steel Bars for Slab #1

Slab 1 Description	Variable	Value
Top steel bars		
Steel reinforcement (X-direction)	Ts_x	#6 bars @ 4” o.c.
Steel reinforcement (Y-direction)	Ts_y	#6 bars @ 4” o.c.
Bottom steel bars		
Steel reinforcement (X-direction)	Bs_x	#6 bars @ 6 o.c.
Steel reinforcement (Y-direction)	Bs_y	#6 bars @ 6 o.c.

Table 8 Reinforcement Steel Bars for Slab #2

Slab 2 Description	Variable	Value
Top steel bars		
Steel reinforcement (X-direction)	Ts_x	#6 bars @ 8 o.c.
Steel reinforcement (Y-direction)	Ts_y	#6 bars @ 12 o.c.
Bottom steel bars		
Steel reinforcement (X-direction)	Bs_x	#6 bars @ 12 o.c.
Steel reinforcement (Y-direction)	Bs_y	#6 bars @ 12 o.c.

Table 9 Reinforcement Steel Bars for Slab #3

Slab 3 Description	Variable	Value
Top steel bars		
Steel reinforcement (X-direction)	Ts_x	#6 bars @ 8 o.c.
Steel reinforcement (Y-direction)	Ts_y	#6 bars @ 6 o.c.
Bottom steel bars		
Steel reinforcement (X-direction)	Bs_x	#6 bars @ 12 o.c.
Steel reinforcement (Y-direction)	Bs_y	#6 bars @ 12 o.c.

3.2 Yield Line Method applied to slabs

3.2.1 Shear and Flexural design capacity

The yield line method is used to estimate the ultimate load-carrying capacity of the slabs by assuming collapse mechanisms defined by plastic hinge lines. Different yield line patterns are considered based on slab geometry and boundary conditions. Using the principle of virtual work, the internal work along yield lines is equated to the external work done by applied loads, allowing the determination of collapse load and corresponding moment capacity.

The first step of the yield line method is to find both the internal and external work and set them equal to each other in order to find the distributed load. Next, the equation is simplified to have the distributed load divided by the moment capacity, which is represented by the variable k. By minimizing the function k and solving it as a system of equations, the length l_1, l_2, and l_3 were found. After plugging those values back into the function k and solving for the distributed load, the moment capacity was calculated. The moment capacity and lengths were then used to solve for the positive and negative moments.

Table 10 Moment and shear capacity of slabs (x-x, y-y differentiation if using different plastic moments)

Level	Yield Line Method	
	Positive Moment (kip.ft/ft)	Negative Moment (kip.ft/ft)
Slab #1	2034	1017

3.2.2 Longitudinal and Transversal Steel Bars

Reinforcement design based on the yield line method is performed by relating the plastic moment capacity to the required steel area. Reinforcement is placed perpendicular to the expected yield lines to effectively resist plastic rotations.

The first step was to calculate the elastic section modulus, which was then used to find the cracking bending moment at midspan. The assumed depth of the compression block was repeatedly used until it matched the depth of Whitney's compression block, giving the required cross-section area of steel bars. Based on that value, the number of reinforcement bars and their diameter were selected appropriately. After solving for the bar spacing, the next step was to check the moment capacity of the slab as well as the minimum and maximum steel ratio and area of steel reinforcement. For the serviceability criteria, the minimum and maximum bar spacing was found, finally confirming the steel reinforcement in both directions, top and bottom.

Table 11 Reinforcement Steel Bars for Slab #1

Description	Variable	Value
Top steel bars		
Steel reinforcement (X-direction)	Ts_x	#6 @ 12"
Steel reinforcement (Y-direction)	Ts_y	#6 @ 12"
Bottom steel bars		
Steel reinforcement (X-direction)	Bs_x	#6 @ 12"
Steel reinforcement (Y-direction)	Bs_y	#6 @ 12"

3.3 Analysis and Design of reinforced concrete beams

3.3.1 Internal forces

Girders 7 and 8 were analyzed and designed according to the slab reactions that are directly transferred to the girders through the strip method (Method A). Both beams were modeled with fixed ends, as specified in the project statement, and the appropriate structural analysis equations for moment and shear were utilized accordingly.

Prior to the design of the beams, it was necessary to determine the amount of load transferred from the slabs to the beams. Rather than simply using a 50/50 tributary area estimation, our group used a more accurate analysis, taking the reactions of the slabs along the y-direction. Girder 8 experienced a factored uniform load from Slab 1 of 3.937 klf, while Girder 7 experienced loads from both Slabs 1 and 2, totaling 9.638 klf. In addition to these slab loads, the beam self-weight was considered as well as the glass facade load for the edge beam G8. The loads were factored according to two load combinations: LC 1 (1.4D + Slab Loads) and LC 2(1.2D + 1.6L + Slab Loads). The slab loads were not factored because they were already factored in the slab calculations, which means LC 1 governed since the only additional loads were dead loads. It was determined that Girder 7 experiences a factored load of 10.898 klf while Girder 8 experiences a factored load of 5.547 klf.

From there, the flexure and shear demands were calculated using structural analysis. Girder 7 experiences a maximum positive moment of 479.63 k-ft, a maximum negative moment of 959.25 k-ft, and a maximum shear of 177.09 kips. Girder 8 experiences a maximum positive moment of 244.13 k-ft, a maximum negative moment of 488.25 k-ft, and a maximum shear of 90.14 kips. From here, it became apparent that Girder 7 would require significantly more steel at the top of the beam, as well as more closely spaced stirrups.

Table 14 Required bending moment and shear in beams

Element	Positive Moment	Negative Moment	Shear Force
Internal beam (Girder 7)	479.63 [kip.ft]	959.25 [kip.ft]	177.09 [kip]
External beam (Girder8)	244.13 [kip.ft]	488.25 [kip.ft]	90.14 [kip]

3.3.2 Shear and Flexural design capacity

Before designing the beams, a couple of assumptions were made. For the analysis, a #8 bar was assumed for the longitudinal bars and #4 bar for shear stirrups since these are some of the most common rebar values for the average beam. A beam depth of 33.5 in was also assumed to account for 1.5 in of cover, 0.5 in of #4 stirrups, and 0.5 in to the center of a #8 longitudinal rebar.

Based on these assumptions, a certain number of tension reinforcements was chosen for the beams, accounting for positive and negative moment demands. Taken together, the moment and shear capacity of the beams are displayed below.

Table 15 Moment and shear capacity of beams

Element	Positive Moment	Negative Moment	Shear Force
Internal beam (Girder 7)	571.1 [kip.ft]	1100.43 [kip.ft]	184.38 [kip]
External beam (Girder 8)	460.23 [kip.ft]	571.1 [kip.ft]	96.36 [kip]

3.3.3 Longitudinal and transversal steel bars

Longitudinal reinforcement is designed to resist both positive and negative bending moments, with top reinforcement concentrated near supports and bottom reinforcement at mid-span.
Transverse reinforcement (stirrups) is designed to resist shear forces and provide confinement. Bar sizes and spacing are selected to satisfy strength requirements and detailing provisions from ACI 318-19.

With these assumed values, moment design began with a calculation of extension length, development length, and lap splice length. From there, an iterative process was used to determine the preliminary required value of the steel area. The compression block depth was assumed and entered into the required steel area equation. Based on the required steel area value, another compression block value was calculated. Using the "Goal Seek" function in Excel, the initial compression block value was changed until the initial and final compression blocks matched, resulting in the final required steel area. This iteration was performed for all the girders. Rounding up from the required steel area helped to determine the number of #8 tension bars needed for the positive and negative moments for Girders 7 and 8. The nominal moment capacity was then calculated based on the number of steel rebars.

However, after the beams were designed for flexure, the beam had to undergo four moment design checks: flexure check, minimum area check, max area check, and bar spacing check. Since the beams had all been designed to meet the maximum moment demand, all of the beams passed the first check. However, Girder 8 had to increase the number of steel bars for positive moment from 3 to 4 due to the minimum area requirement. DCR values were calculated for each check, ensuring that they all remained below 1.

During moment design, it was discovered that Girder 7 would require 9 tension bars for negative moment due to the high moment demand of 959.25 k-ft. Initially, all of the #8 bars were going to be placed in a single row to stay consistent with the assumed beam depth of 33.5 in. However, after calculating for spacing, we found that 9 bars placed side to side would result in a tight, yet technically ACI-legal spacing. However, considering how wider spacing better accommodates concrete vibrators to consolidate freshly poured concrete, our group designed for two rows of #8 bars, spaced 2 in apart center-to-center between the top and bottom row. This, of course, lowered the depth from 33.5 in to 32.5 in, causing a slight decrease in the moment capacity. Although it remained within the acceptable range, an extra bar was added to remain conservative, bringing the total number of tension bars for Girder 7 to 10. This worked out well since the top (5) #8 bars can remain continuous throughout the length of the beam, while the bottom row of bars could be discontinued once no longer necessitated by the development length, according to ACI 318-19 § 25.4.

For Girder 8's negative moment reinforcement design, it was found that it required only (4) #8 bars to run continuously through the beam. However, it felt more conservative to just have the beam run an additional #8 bar continuously through the beam. It did not feel worth cutting a single bar off early, since it would only save a microscopic amount of money.

Shear design began by determining the nominal concrete strength of the girders. Then the concrete strength was subtracted from the ultimate shear value to determine the required shear strength of the steel. A maximum stirrup spacing was calculated using ACI 318-19 Table 9.7.6.2.2. Based on this value, our group came up with a spacing value that would meet the maximum spacing requirements. The nominal shear resistance of steel was then calculated using the assumed spacing value. The final nominal shear capacity was determined by adding the shear resistance of steel to the nominal concrete strength, resulting in a value of 184.38 kips for Girder 7 and 96.364 kips for Girder 8. The shear design was then checked with the rest of the requirements: maximum stirrup spacing and minimum area check.

Once the initial shear design was complete, it was still necessary to determine the acceptable range along the beam for the design reinforcement (near the supports) and the acceptable range for the minimum reinforcement (near the midspan). Although the analysis worked with a center-to-center assumption, the shear technically involves the clear span, making the ultimate shear demands more conservative. According to ACI 318-19 § 9.6.3, where the nominal concrete capacity is less than the ultimate shear value, shear reinforcement with required spacing is needed., where the nominal concrete capacity is less than the ultimate shear value, shear reinforcement with required spacing is needed. Everywhere else, design reinforcement is necessary. Using the beam's shear diagram and similar triangles, the required distances were found. However, the spacing and ranges had to be adjusted across numerous iterations to make sure that the spacing resulted in whole numbers, that the ranges were divisible by the spacing values, and that the stirrups remained within the acceptable limits determined by the calculation. The final design for Girder 7 is #4 bars at 12 in O.C. from 42” < x < 318” (minimum stirrup design) and #4 bars at 4 in O.C. from 2” < x < 42” and 318” < x < 358” (regular stirrup design). The final design for Girder 8 is #4 bars at 14 in O.C. from 82” < x < 278” (minimum stirrup design) and #4 bars at 10 in O.C. from 2” < x < 82” and 278” < x < 358” (regular stirrup design).

The design reinforcement bar values are listed below.

Table 16 Design Reinforcement Steel Bars

Description	Variable	Value
Internal Beam (Girder 7)		
Longitudinal steel reinforcement (Top)	Li_t	(10) #8 bars
Longitudinal steel reinforcement (Bottom)	Li_b	(5) #8 bars
Rebar size for stirrups and spacing	Ti_s	#4 bar @ 4 in O.C.
External Beam (Girder 8)		
Longitudinal steel reinforcement (Top)	Le_t	(5) #8 bars
Longitudinal steel reinforcement (Bottom)	Le_b	(4) #8 bars
Rebar size for stirrups and spacing	Te_s	#4 bar @ 10 in O.C.

Table 17 Minimum Reinforcement Steel Bars

Description	Variable	Value
Internal Beam (Girder 7)		
Longitudinal steel reinforcement (Top)	Li_t	(5) #8 bars
Longitudinal steel reinforcement (Bottom)	Li_b	(5) #8 bars
Rebar size for stirrups and spacing	Ti_s	#4 bar @ 12 in O.C.
External Beam (Girder 8)		
Longitudinal steel reinforcement (Top)	Le_t	(5) #8 bars
Longitudinal steel reinforcement (Bottom)	Le_b	(4) #8 bars

Description	Variable	Value
Rebar size for stirrups and spacing	Te_s	#4 bar @ 14 in O.C.

4. CONCLUSION AND RECOMMENDATIONS

Provides final thoughts based on the analysis and offers suggestions for design or future improvements.

Strip Method

- The strip method was employed to calculate loads using a statics and structural analysis approach. It allowed for methodical, step-by-step analysis which started from finding the loads acting on the beam in each direction, then using beam formulas to find the maximum negative and positive moment. By assuming a ballpark gamma-factor, the y-direction strips experience a larger portion of the slab loads. This makes sense because load tends to gravitate towards the shorter direction. There tended to be a higher maximum negative moment because the negative moment was at a fixed end, which has to resist the most bending and deflection.
  Reinforcements were designed from the moment diagrams found using the strip method.
- The bottom reinforcements were designed to resist cracking caused by positive moment at midspan and the top reinforcements resist negative moment at the supports. The positive bottom reinforcements were first designed to withstand the maximum positive moment. Since positive moments occur in the middle of the strip, the bottom ends of the strip technically do not need to be reinforced since there is no positive moment there. For this reason, the bottom bars only extend 6 inches into the beams at the ends as there is enough to account for the extension length required at the points of zero moment. The negative top reinforcements have two components: continuous through bars and discontinuous end bars at high negative moments. The same reinforcement spacing in the bottom is placed in the top through the entire length of the slab. These are continuous through all three of the slabs with lap splices at the ends of the slabs in the beam. This is necessary as the highest negative moment occurs at the edges of the slab so abrupt cuts could lead to high stress and failure. Short discontinuous bars were placed in areas where the continuous bars were not sufficient for resisting negative moments. This was on the edges of the beams and they extended into the beam to satisfy the development length because the reinforcement ended at areas of maximum moment. Hooks were designed for top reinforcements in Slab 2 on the edge with an overhang to secure the ends of the bars with high negative moment.
- A big challenge for the strip method was managing the calculations. Since it was created on Excel, it was hard to see the formulas and sometimes confusing tracing dependents due to the overwhelming amount of variables. There were also a lot of parts to manage, having to create calculations for positive moment, negative moment, shear, and ACI checks for each direction. Moving forward, it would definitely help to create calculations on a program that allows the equations to be written so it can be seen what variables are going into it.

Beam Design

- Using the slab loads from the strip method and additional relevant self-weights, the beam was designed to be fixed at each end. Structural analysis was utilized to determine the maximum positive moments, maximum negative moments, and maximum shear loads. Some assumptions were made about the depth of the reinforcements as well as the size of the rebars at the beginning of the design, but were adjusted at each iteration to match reality. This is to ensure that the beam design process remains conservative yet efficient. We also aimed to simplify the rebar layout for the construction team by utilizing the same #8 rebars for longitudinal reinforcement and #4 stirrups for transverse reinforcement.

- One improvement we can make in our slab and beam design process is thinking more practically. It was easy to get lost in the numbers and forget that the spacings between the rebars should ideally be whole numbers or "simple" numbers rather than irrational ones. This makes it easy for the contractor and makes the drawings easier to understand. Another lesson learned through the design process is "garbage in, garbage out." Sometimes the calculations made no sense but we realized that it was really because we had improperly defined the initial conditions. For instance, a small assumption about the size of a column or an Excel formula can make or break a design, which means all calculations must be double checked. Lastly, to improve beam design in the future, we would try to aim for a lower DCR for the shear design. Even though shear is heavily penalized, using a factor of 0.75 rather than 0.9, given the suddenness and uncertainty of shear failure, it is more conservative to aim for a design with a DCR below 0.9 if possible rather than a DCR of 0.96, which is what we had. For future designs, we would either upsize the bar size and increase the spacing or decrease the spacing if possible.

Yield Line Method

- To calculate the load on the slab using the yield line method, the internal and external work were calculated and set equal to each other. Through minimization, the lengths l_1, l_2, and l_3 were able to be calculated, which provided all the necessary values in order to solve for the required moment capacity. After obtaining the required moment capacity, it was used to calculate the positive and negative moment of each segment of the slab, in turn solving for the entire slab. The required moment capacity was also used in order to design the flexural reinforcement for the concrete slab by first using it to determine the required cross-section area of steel bars. Based on the required cross-section area of steel bars the number and size of steel bars was selected. After selecting the number and size of bars the bar spacing was determined. In order to confirm these selections all of the necessary checks were conducted including minimum and maximum bar spacing as well as the minimum and maximum area of reinforcement steel. All in all, one design improvement could be to design the reinforcement differently for the top and bottom of the slab since the negative moment was significantly less than the positive moment.

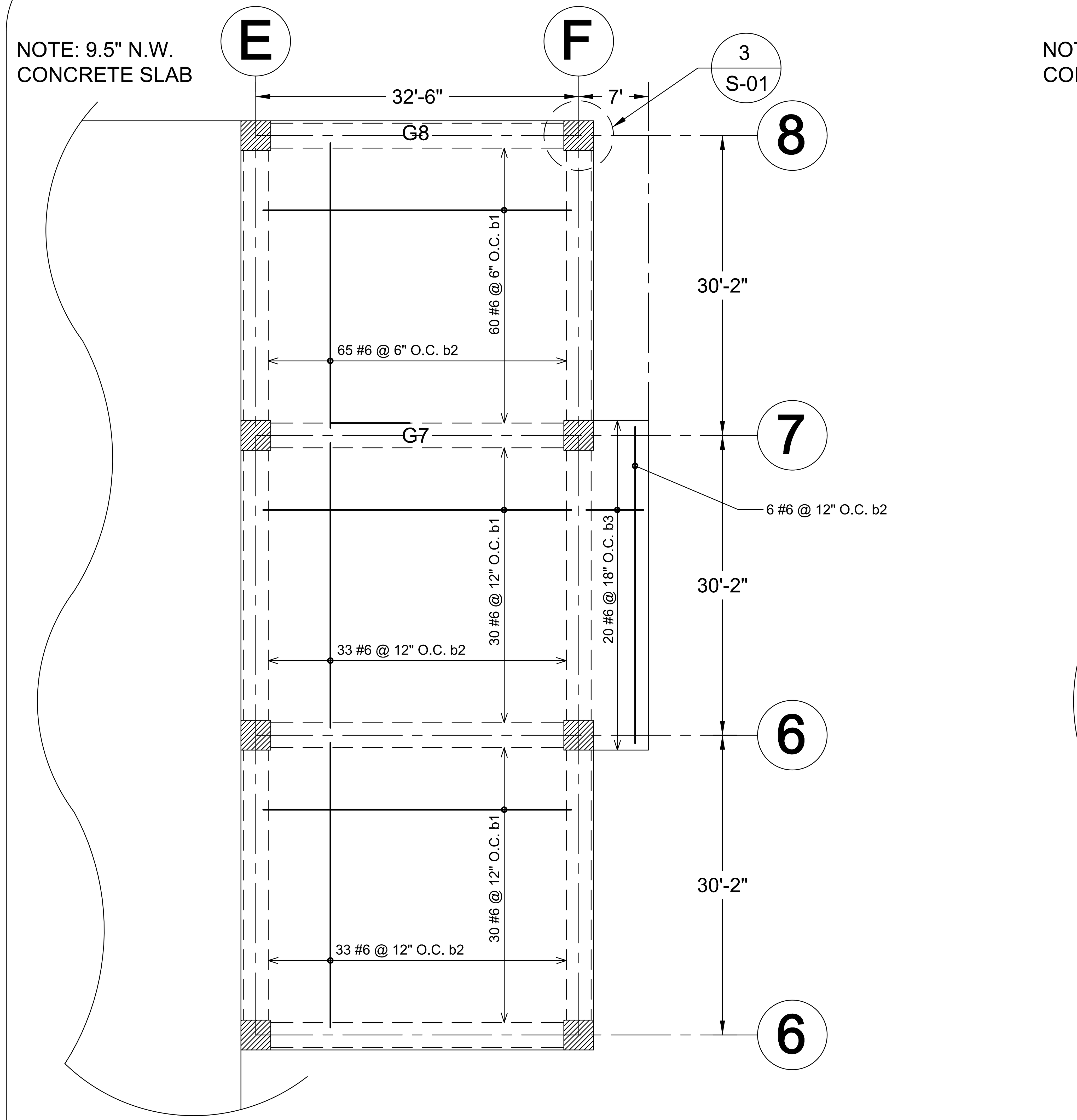
This in-depth slab design project helped our team gain a holistic understanding of slab design through the strip method and yield line method. We were able to compare the difference in the Strip and Yield Line Methods. Critical thinking was also necessary to design the reinforcements in both the slabs and beams and make decisions that prioritize ease of construction and cost. Designing the slabs also allowed us to see the differing demands caused by varying supports with the overhanging portion in Slab 2 reducing the moment demand. This project allowed us to test our engineering intuition with real life calculations and design choices.

5. REFERENCES

ACI Committee 318. (2019). *Building code requirements for structural concrete (ACI 318-19) and commentary (ACI 318R-19)*. American Concrete Institute.

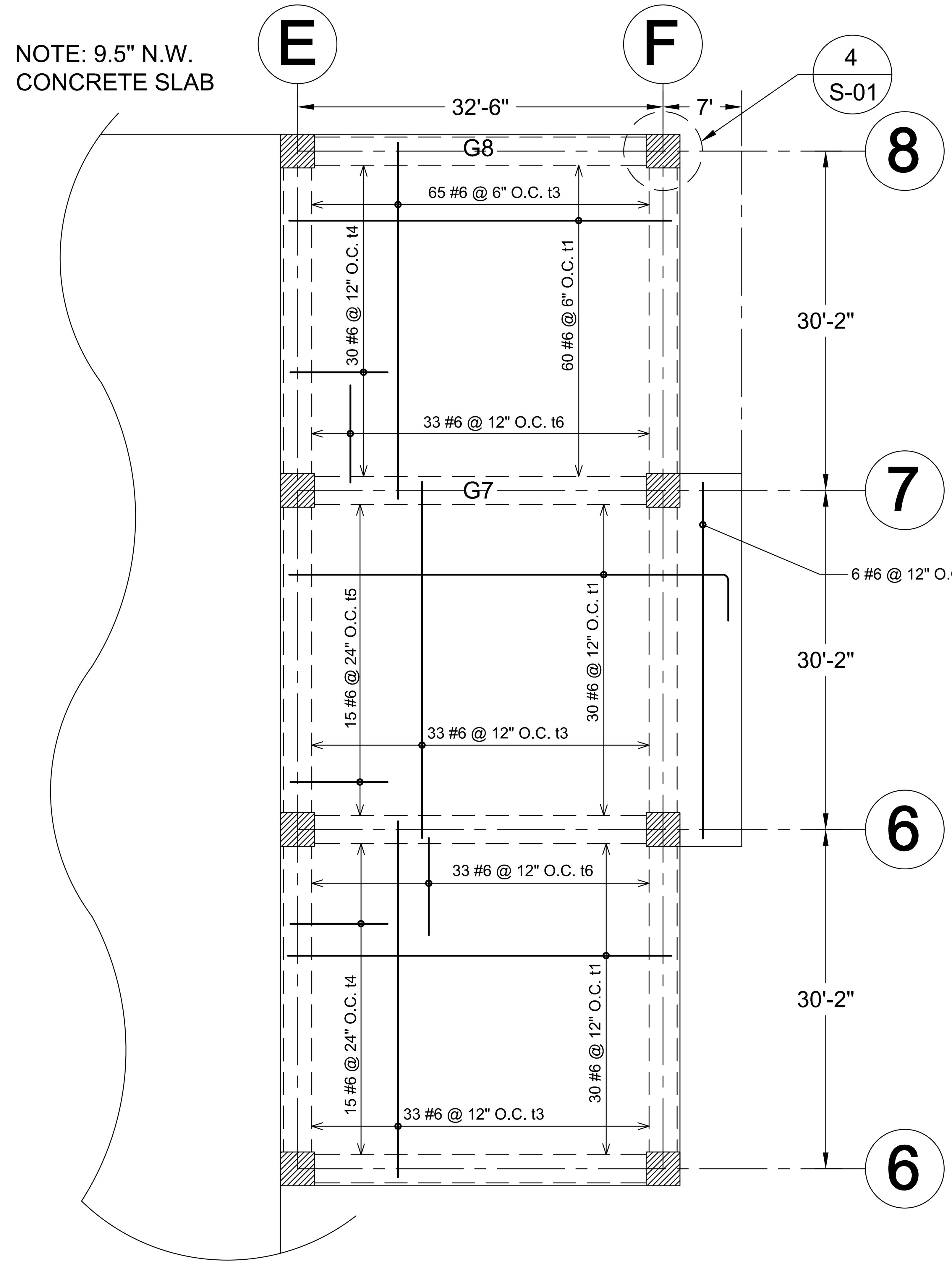
American Society of Civil Engineers. (2022). *Minimum design loads and associated criteria for buildings and other structures* (ASCE/SEI 7-22). https://doi.org/10.1061/9780784415788

APPENDIX A – Technical drawings



1 | BOTTOM SLAB REINFORCEMENT PLAN VIEW BY STRIP METHOD

S-01 | 1/8" - 1'-0"



2 | TOP SLAB REINFORCEMENT PLAN VIEW BY STRIP METHOD

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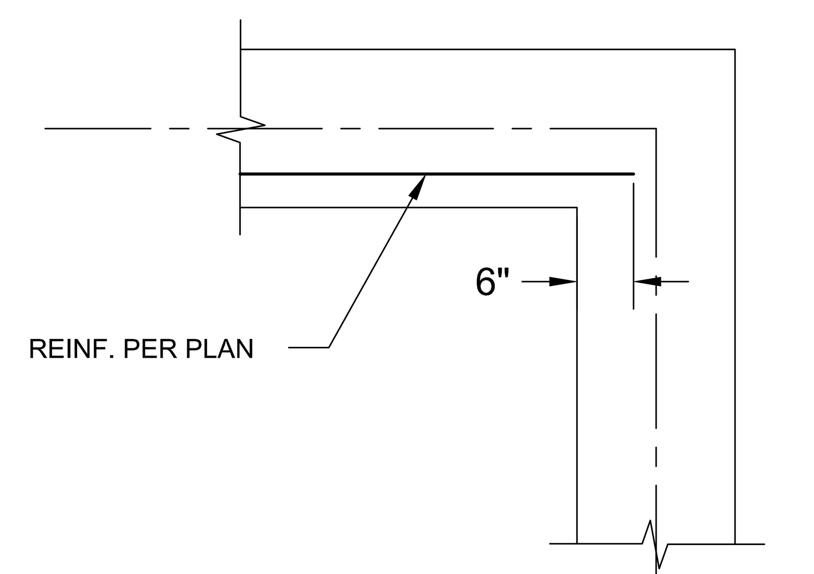
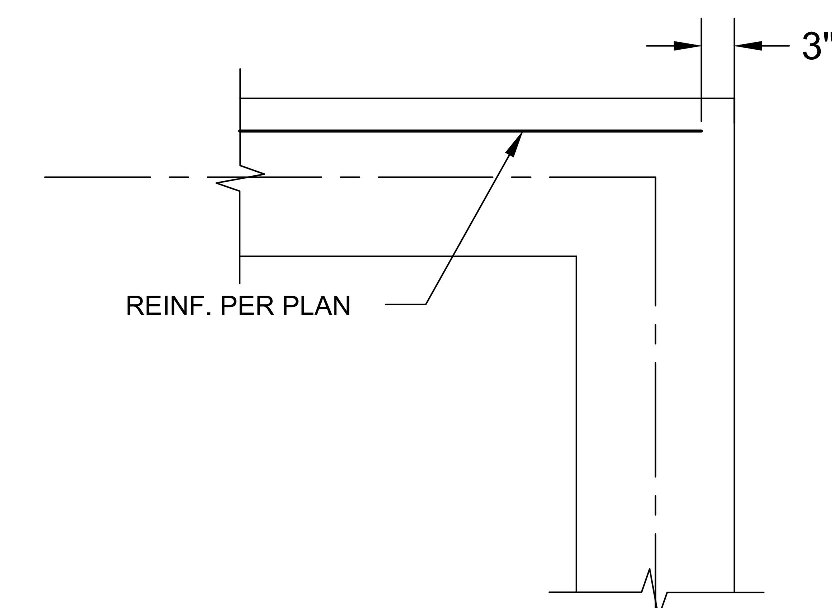


3 | BOTTOM SLAB BAR PENETRATION

S-01 | NTS



4 | TOP SLAB BAR PENETRATION

S-01 | NTS

BAR SCHEDULE					
ID	BAR #	NO. BARS	LENGTH	NOTES	SCHEDULE
b1	#6	120	31'-6"		
b2	#6	137	29'-2"		
b3	#6	20	6'-6"		

BAR SCHEDULE					
ID	BAR #	NO. BARS	LENGTH	NOTES	SCHEDULE
t1	#6	90	34'-0"		
t2	#6	30	40'-1"	9" HOOK	
t3	#6	137	31'-8"		
t4	#6	45	10'-5"		
t5	#6	15	10'-1"		
t6	#6	66	9'-10"		

General Notes

SLAB DESIGN BY STRIP METHOD

No.	Revision/Issue	Date

Firm Name and Address

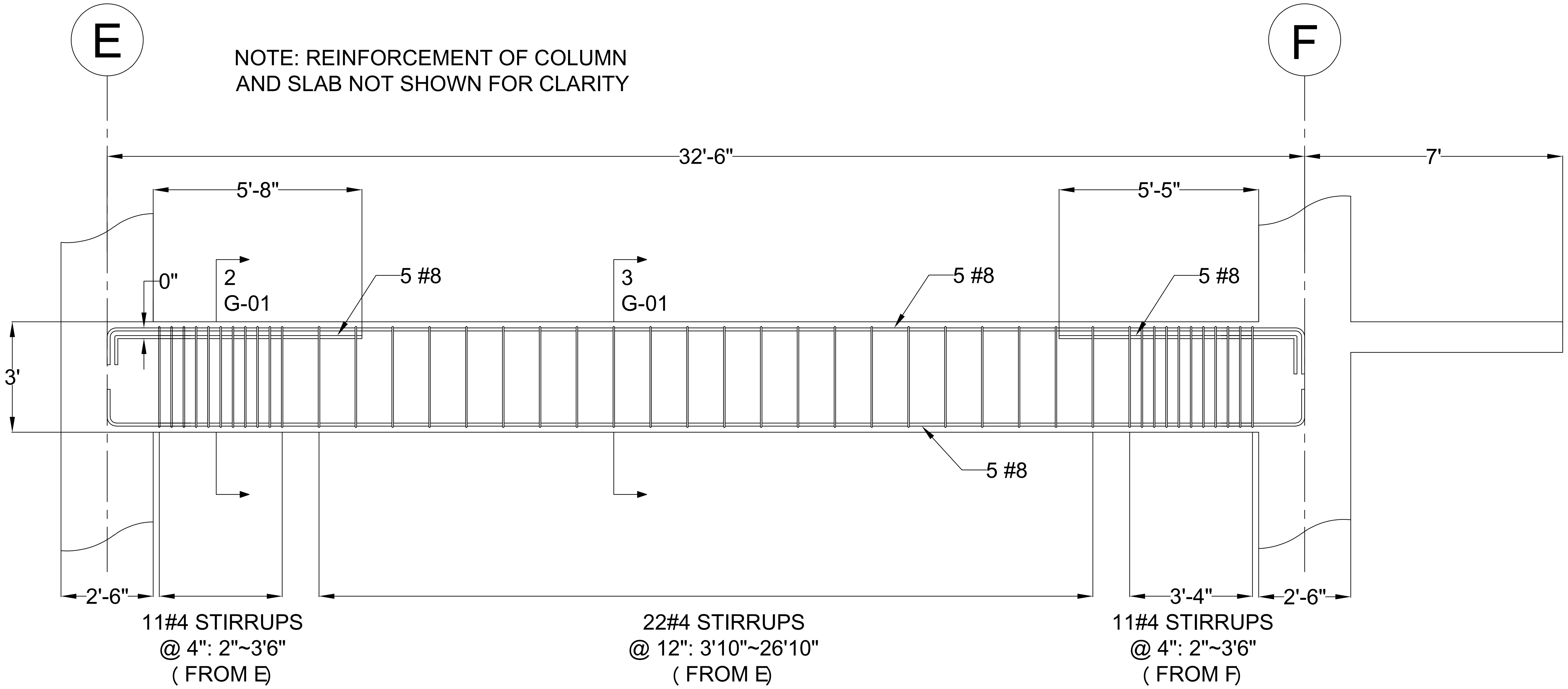
Project Name and Address

Project: SE 140B Project 1

Date: 4/25/2026

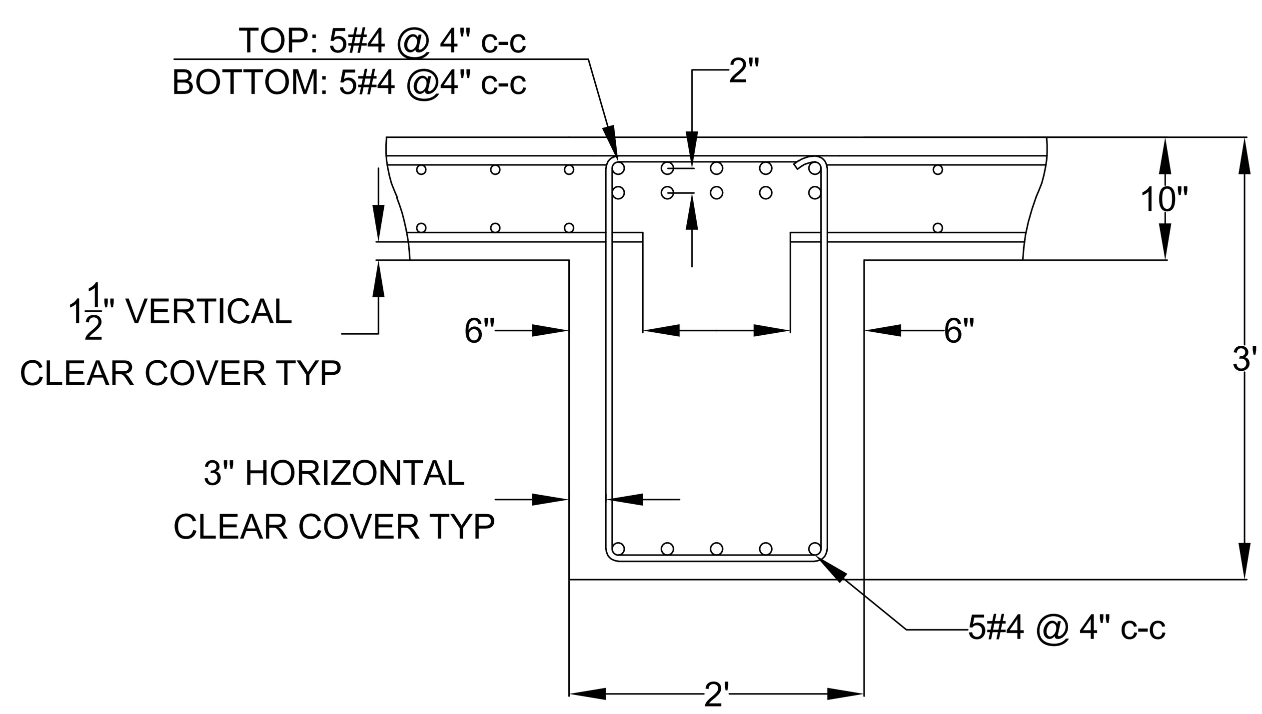
Scale: As Noted

Sheet: S-01



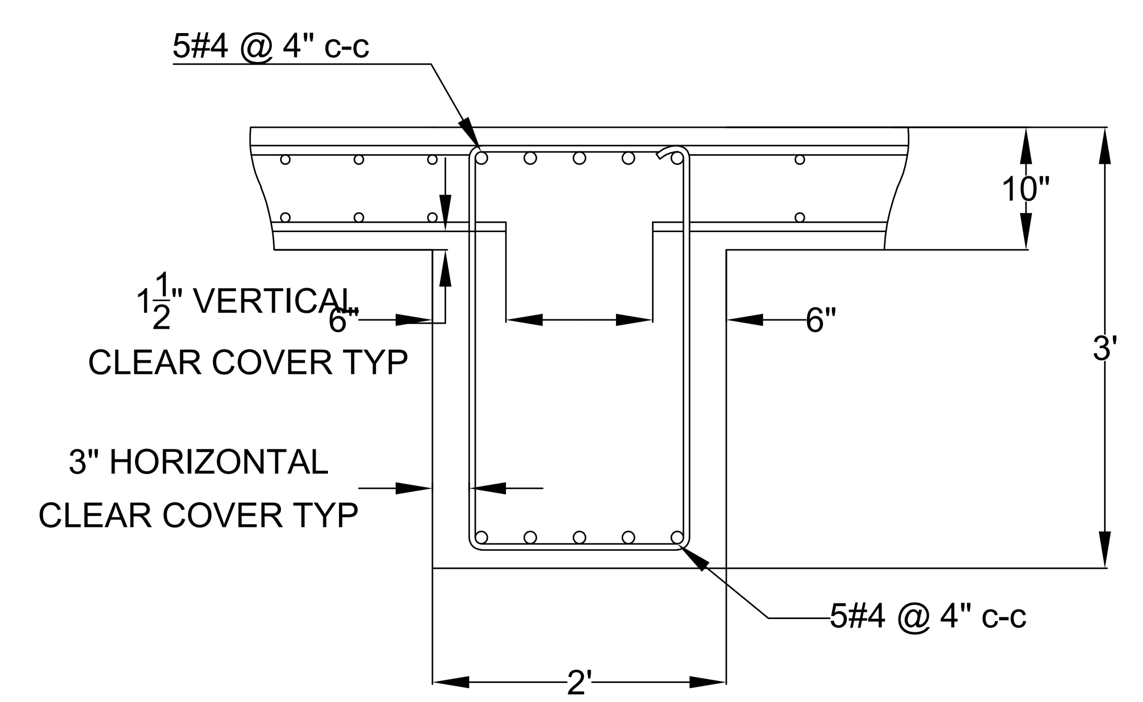
GIRDER G7 ELEVATION

1
G-01
1/16" - 1'-0"



GIRDER G7 CROSS SECTION

2
G-01



GIRDER G7 CROSS SECTION

3
G-01
1/16" - 1'-0"

General Notes

Girder G7 Design

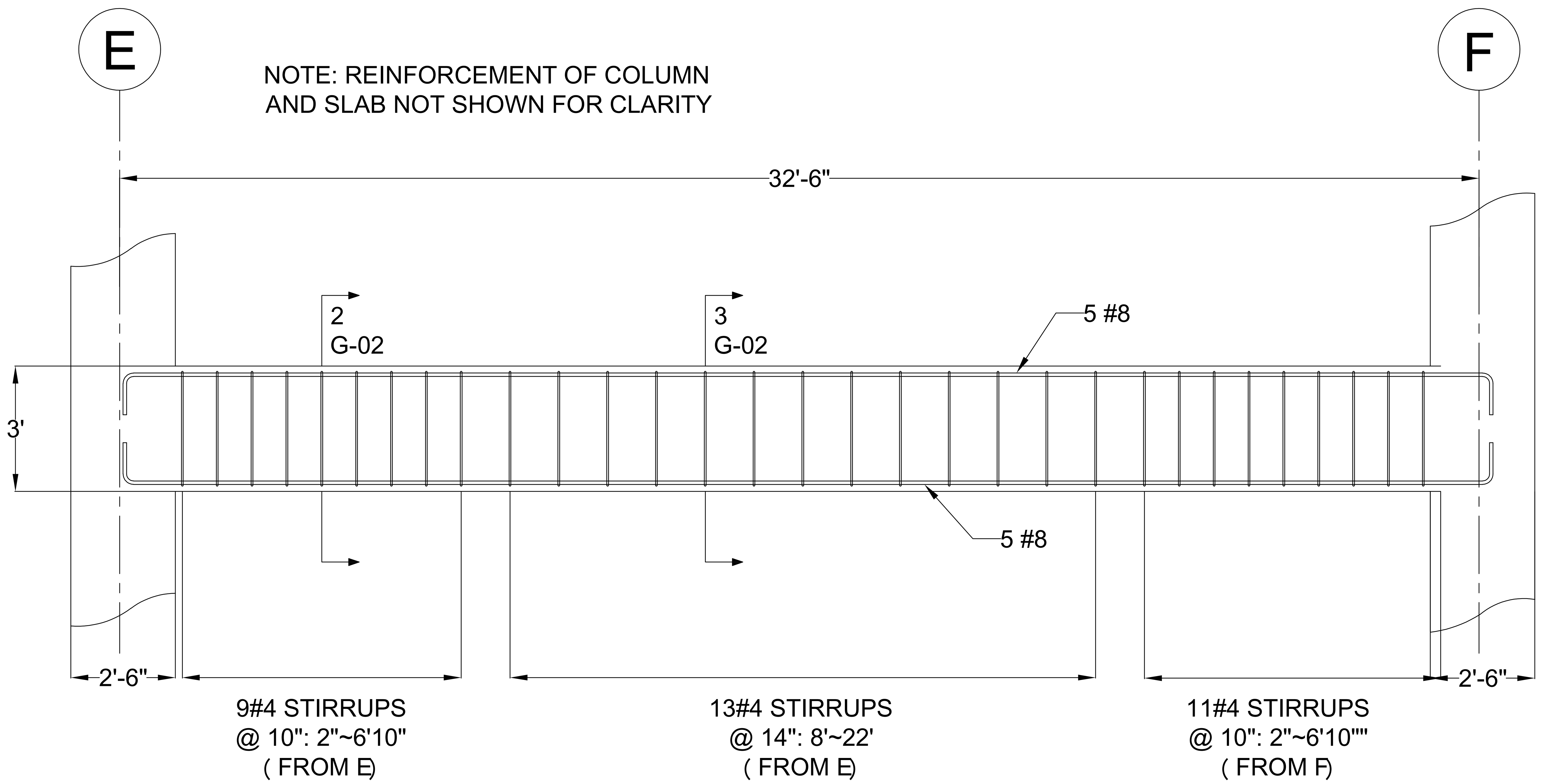
No.	Revision/Issue	Date

Firm Name and Address

Project Name and Address

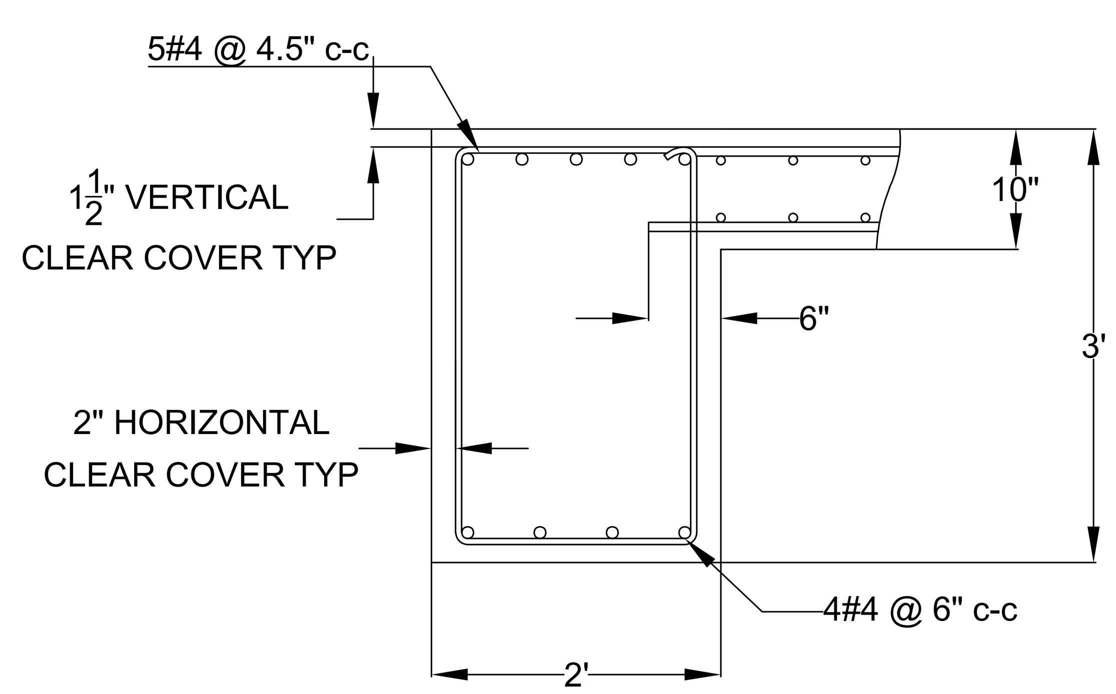
Value
Value
Value

Project: SE 140B PROJECT 1
Date: 5/3/2026
Scale: As Noted
Sheet: G-01



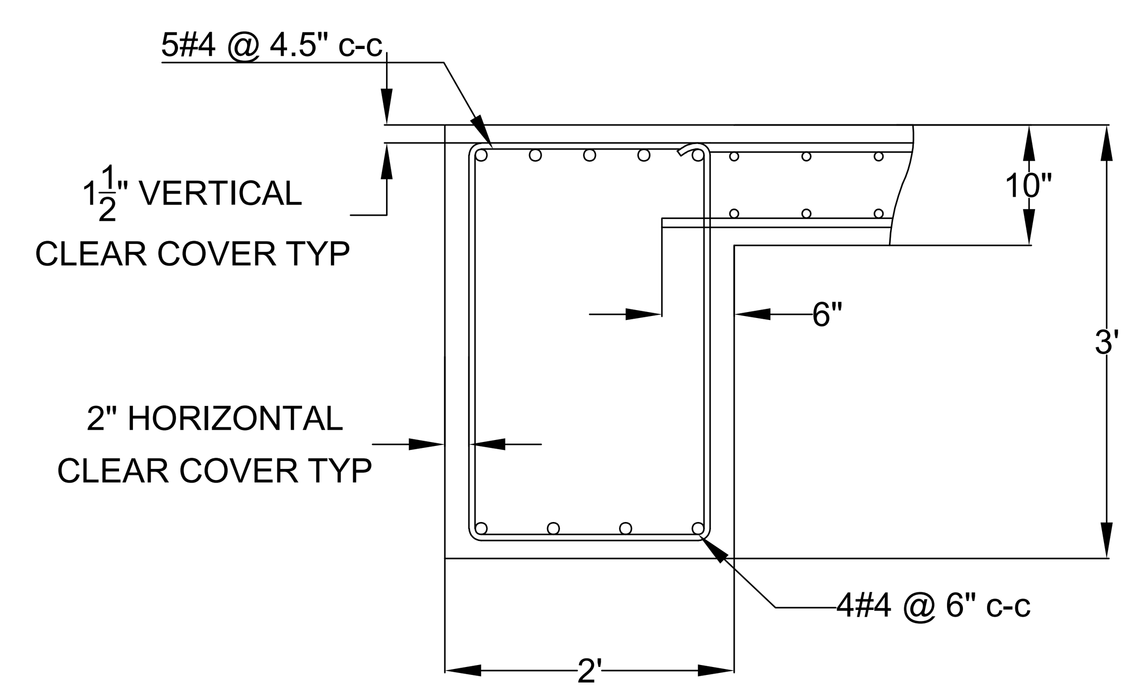
GIRDER G8 ELEVATION

1
G-02
1/16" - 1'-0"



GIRDER G8 CROSS SECTION

2
G-02
1/16" - 1'-0"



GIRDER G8 CROSS SECTION

3
G-02
1/16" - 1'-0"

General Notes

Girder G8 Design

No.	Revision/Issue	Date

Firm Name and Address

Project Name and Address
Value
Value
Value

Project
SE 140B PROJECT 1
Date
5/3/2026
Scale
As Noted
Sheet
G-02

APPENDIX B – Step-by-Step calculations

1. MINIMUM SLAB THICKNESS CALCULATIONS

Initial Values

$f'_c = 4900\ psi$ (Concrete compressive strength)

$f_y = 60000\ psi$ (Steel Yield Strength)

$l_{sx} = 32.5\ ft$ (Span in X-Direction)

$l_{sy} = 30\ ft + \frac{2\ ft}{12} = 30.167\ ft$ (Span in Y-Direction)

$E_c = 57000 * \sqrt{f'_c} = 3990000\ psi^{0.5}$ (Young's Modulus of Concrete)

$E_s = 29000\ ksi$ (Young's Modulus of Steel)

$h_x = 36\ in$ (height of beam x)

$b_{wx} = 24\ in$ (width of beam x)

$h_y = 36\ in$ (height of beam y)

$b_{wy} = 24\ in$ (width of beam y)

1. Ratio of Longer to Shorter Clear Spans

$$\beta = \frac{Max\left(l_{sx} - b_{wx}, l_{sy} - b_{wy}\right)}{Min\left(l_{sx} - b_{wx}, l_{sy} - b_{wy}\right)} = 1.083$$

(Ratio of Long to Short Clear Spans)

2. Effective Width of T-Beam (Interior)

$k_x = 0.3$ (Ratio of h_f / h)

$k_y = 0.3$ (Ratio of h_f / h)

$$b_{sx,T} = Min\left(b_{wx} + 2 * \left(1 - k_x\right) * h_x, b_{wx} + 8 * \left(k_x * h_x\right)\right) = 74.4\ in$$

(Effective Width of T-Beam in X-Direction)

$$b_{sy,T} = Min\left(b_{wy} + 2 * \left(1 - k_y\right) * h_y, b_{wy} + 8 * \left(k_y * h_y\right)\right) = 74.4\ in$$

(Effective Width of T-Beam in Y-Direction)

3. Effective Width of L-Beam (Exterior)

$$b_{sx,L} = Min\left(b_{wx} + \left(1 - k_x\right) * h_x, b_{wx} + 4 * \left(k_x * h_x\right)\right) = 49.2\ in$$

(Effective Width of L-Beam in X-Direction)

$$b_{sy,L} = Min\left(b_{wy} + \left(1 - k_y\right) * h_y, b_{wy} + 4 * \left(k_y * h_y\right)\right) = 49.2\ in$$

(Effective Width of L-Beam in Y-Direction)

4. Moment of Inertia of T-Beam (Interior)

$$c_{gx,T} = \frac{\left(b_{sx,T} - b_{wx}\right) * k_x * h_x * \left(\frac{k_x * h_x}{2}\right) + b_{wx} * h_x * \left(\frac{h_x}{2}\right)}{\left(b_{sx,T} - b_{wx}\right) * k_x * h_x + b_{wx} * h_x} = 13.130 \text{ in}$$ (C.O.G. from top fiber)

$$I_{1x,T} = \frac{\left(b_{sx,T} - b_{wx}\right) * \left(k_x * h_x\right)^3}{12} + \left(\left(b_{sx,T} - b_{wx}\right) * k_x * h_x\right) * \left(\frac{k_x * h_x}{2} - c_{gx,T}\right)^2 = 37816.005 \text{ in}^4$$

(Moment of Inertia of Flanges)

$$I_{2x,T} = \frac{\left(b_{wx}\right) * \left(h_x\right)^3}{12} + \left(b_{wx} * h_x\right) * \left(\frac{h_x}{2} - c_{gx,T}\right)^2 = 113802.885 \text{ in}^4$$ (Moment of Inertia of Center Web)

$$I_T = I_{1x,T} + I_{2x,T} = 151618.891 \text{ in}^4$$ (Total Moment of Inertia)

5. Moment of Inertia of L-Beam (Exterior)

$$c_{gx,L} = \frac{\left(b_{sx,L} - b_{wx}\right) * k_x * h_x * \left(\frac{k_x * h_x}{2}\right) + b_{wx} * h_x * \left(\frac{h_x}{2}\right)}{\left(b_{sx,L} - b_{wx}\right) * k_x * h_x + b_{wx} * h_x} = 14.982 \text{ in}$$ (C.O.G. from top fiber)

$$I_{1x,L} = \frac{\left(b_{sx,L} - b_{wx}\right) * \left(k_x * h_x\right)^3}{12} + \left(\left(b_{sx,L} - b_{wx}\right) * k_x * h_x\right) * \left(\frac{k_x * h_x}{2} - c_{gx,L}\right)^2 = 27632.382 \text{ in}^4$$

(Moment of Inertia of Flange)

$$I_{2x,L} = \frac{\left(b_{wx}\right) * \left(h_x\right)^3}{12} + \left(b_{wx} * h_x\right) * \left(\frac{h_x}{2} - c_{gx,L}\right)^2 = 101182.901 \text{ in}^4$$ (Moment of Inertia of Center Web)

$$I_L = I_{1x,L} + I_{2x,L} = 128815.282 \text{ in}^4$$ (Total Moment of Inertia)

6. Moment of Inertia of Slab

$$I_{sx,interior} = \frac{l_{sx} * \left(k_x * h_x\right)^3}{12} = 1.974 \text{ ft}^4$$ (Interior Moment of Inertia of Slab, X-Direction)

$$I_{sy,interior} = \frac{l_{sy} * \left(k_y * h_y\right)^3}{12} = 1.833 \text{ ft}^4$$ (Interior Moment of Inertia of Slab, Y-Direction)

$$I_{sx,exterior} = \frac{l_{sx} * \left(k_x * h_x\right)^3}{2 * 12} = 0.987 \text{ ft}^4$$ (Exterior Moment of Inertia of Slab, X-Direction)

$$I_{sy,exterior} = \frac{I_{sy} * \left(k_y * h_y\right)^3}{2 * 12} = 0.916\ ft^4$$ (Exterior Moment of Inertia of Slab, Y-Direction)

7. Stiffness Ratios

Flexure Stiffness Ratio (I_T to Slab)

$$\alpha_{T,sx} = \frac{I_T}{I_{sx,interior}} = 3.703$$ (Interior Flexure Stiffness Ratio, X-Direction)

$$\alpha_{T,sy} = \frac{I_T}{I_{sy,interior}} = 3.990$$ (Interior Flexure Stiffness Ratio, Y-Direction)

Flexure Stiffness Ratio (I_L to Slab)

$$\alpha_{L,sx} = \frac{I_L}{I_{sx,exterior}} = 6.293$$ (Exterior Flexure Stiffness Ratio, X-Direction)

$$\alpha_{L,sy} = \frac{I_L}{I_{sy,exterior}} = 6.780$$ (Exterior Flexure Stiffness Ratio, Y-Direction)

Average Stiffness Ratios

Slab 1: $\alpha_{fm1} = \text{Average}\left(\alpha_{T,sx}, \alpha_{T,sy}, \alpha_{L,sx}, \alpha_{L,sy}\right) = 5.191$

Slab 2: $\alpha_{fm2} = \text{Average}\left(\alpha_{T,sx}, \alpha_{L,sx}, \alpha_{T,sy}, \alpha_{T,sy}\right) = 4.494$

Slab 3: $\alpha_{fm3} = \text{Average}\left(\alpha_{T,sx}, \alpha_{T,sy}, \alpha_{L,sx}, \alpha_{L,sy}\right) = 5.191$

8. Thickness Value Calculations

$$h = \text{Max}\left(k_x * h_x, k_y * h_y\right) = 10.8\ in$$ (Assumed Slab Thickness)

$$\mathbf{h_{min} = Max\left(\frac{Max\left(l_{sx}, l_{sy}\right) * \left(0.8 + \frac{f_y}{200000\ psi}\right)}{36 + 9 * \beta}, 3.5\ in\right) = 9.378\ in}$$ (Minimum Slab Thickness)

USE 10" FOR MINIMUM SLAB THICKNESS

2. SLAB REACTIONS ON GIRDERS

$\text{format} = \text{h4}$

1. SLAB DIMENSIONS

$L_{x1} = 32.5\,\text{ft}$

$L_{x3} = L_{x1} = 32.5\ \text{ft}$

$L_{x2} = 39.5\,\text{ft}$

$L_{y1} = 30.167\,\text{ft}$

$L_{y2} = L_{y1} = 30.17\ \text{ft}$

$L_{y3} = L_{y1} = 30.17\ \text{ft}$

$h = 10\,\text{in}$

$b = 12\,\text{in}$

$d = h - 1.5 = (10\,) - 1.5 = 8.5\ \text{in}$

$\gamma = 0.6$

2. CONCRETE PROPERTIES

$f'_c = 4{,}900\,\text{psi}$, $f_y = 60{,}000\,\text{psi}$

$f_r = 7.5 * \dfrac{\sqrt{f'_c}}{1{,}000} = 7.5 * \dfrac{\sqrt{4{,}900}}{1{,}000} = 0.525\ \text{ksi}$

$E_c = 57{,}000 * \dfrac{\sqrt{f'_c}}{1{,}000} = 57{,}000 * \dfrac{\sqrt{4{,}900}}{1{,}000} = 3{,}990\ \text{ksi}$

$E_s = 29{,}000\,\text{ksi}$

$\varepsilon_{cmax} = 0.003$

$\phi_f = 0.9$

$\phi_s = 0.75$

3. LOAD COMBINATIONS

$$w_{\mathrm{SW}} = 150 * \frac{\frac{h}{12}}{1{,}000} = 150 * \frac{\frac{10}{12}}{1{,}000} = 0.125\ \mathrm{kip/ft^2}$$

$$w_{\mathrm{SD}} = 0.025\,\mathrm{kip/ft^2}$$

$$w_{\mathrm{D}} = w_{\mathrm{SW}} + w_{\mathrm{SD}} = (0.125) + (0.025) = 0.15\ \mathrm{kip/ft^2}$$

$$w_{\mathrm{Ltop}} = 0.25\,\mathrm{kip/ft^2}$$

$$w_{\mathrm{Lbot}} = 0.1\,\mathrm{kip/ft^2}$$

$$w_{\mathrm{U1}} = 1.4 * w_{\mathrm{D}} = 1.4 * (0.15) = 0.21\ \mathrm{kip/ft^2}$$

$$w_{\mathrm{U2top}} = 1.2 * w_{\mathrm{D}} + 1.6 * w_{\mathrm{Ltop}} = 1.2 * (0.15) + 1.6 * (0.25) = 0.58\ \mathrm{kip/ft^2}$$

$$w_{\mathrm{U2bot}} = 1.2 * w_{\mathrm{D}} + 1.6 * w_{\mathrm{Lbot}} = 1.2 * (0.15) + 1.6 * (0.1) = 0.34\ \mathrm{kip/ft^2}$$

$$w_{\mathrm{Utop}} = w_{\mathrm{U2top}} = 0.58\ \mathrm{kip/ft^2}$$

$$w_{\mathrm{Ubot}} = w_{\mathrm{U2bot}} = 0.34\ \mathrm{kip/ft^2}$$

4. REQUIRED BENDING MOMENT AND SHEAR IN THE SLABS

Slab #1 (y-direction)

$$R_{\mathrm{py1}} = \frac{3 * (\gamma * w_{\mathrm{Utop}} * b) * L_{\mathrm{y1}}}{8} = \frac{3 * \Big((0.6) * (0.58\ \mathrm{kip/ft^2}) * (12\,\mathrm{in}) \Big) * (30.167\,\mathrm{ft})}{8} = 3.937\ \mathrm{kip}$$

$$R_{\mathrm{fy1}} = \frac{5 * (\gamma * w_{\mathrm{Utop}} * b * L_{\mathrm{y1}})}{8} = \frac{5 * \Big((0.6) * (0.58\ \mathrm{kip/ft^2}) * (12\,\mathrm{in}) * (30.167\,\mathrm{ft}) \Big)}{8} = 6.561\ \mathrm{kip}$$

$$M_{\mathrm{fy1}} = -\frac{(\gamma * w_{\mathrm{Utop}} * b) * {L_{\mathrm{y1}}}^2}{8} = -\frac{\Big((0.6) * (0.58\ \mathrm{kip/ft^2}) * (12\,\mathrm{in}) \Big) * (30.167\,\mathrm{ft})^2}{8}$$
$$= -39.59\ \mathrm{kip{\cdot}ft}$$

Slab #1 (x-direction)

$$R_{\mathrm{px1}} = \frac{3 * ((1-\gamma) * w_{\mathrm{Utop}} * b) * L_{\mathrm{x1}}}{8} = \frac{3 * \Big(\big(1 - (0.6) \big) * (0.58\ \mathrm{kip/ft^2}) * (12\,\mathrm{in}) \Big) * (32.5\,\mathrm{ft})}{8}$$
$$= 2.828\ \mathrm{kip}$$

$$R_{\mathrm{fx1}} = \frac{5*((1-\gamma)*w_{\mathrm{Utop}}*b*L_{\mathrm{x1}})}{8} = \frac{5*\left(\ (1-(0.6))\ *(0.58\ \mathrm{kip/ft^2})*(12\,\mathrm{in})*(32.5\,\mathrm{ft})\right)}{8}$$
$$= 4.713\ \mathrm{kip}$$

$$M_{\mathrm{fx1}} = -\frac{((1-\gamma)*w_{\mathrm{Utop}}*b)*{L_{\mathrm{x1}}}^2}{8} = -\frac{\left(\ (1-(0.6))\ *(0.58\ \mathrm{kip/ft^2})*(12\,\mathrm{in})\right)*(32.5\,\mathrm{ft})^2}{8}$$
$$= -30.63\ \mathrm{kip{\cdot}ft}$$

Slab #2 (y-direction)

$$R_{\mathrm{fy2}} = \frac{\gamma*w_{\mathrm{Ubot}}*b*L_{\mathrm{y2}}}{2} = \frac{(0.6)*(0.34\ \mathrm{kip/ft^2})*(12\,\mathrm{in})*(30.17\ \mathrm{ft})}{2} = 3.077\ \mathrm{kips}$$

$$M_{\mathrm{fy2}} = -\frac{\gamma*w_{\mathrm{Ubot}}*b*{L_{\mathrm{y2}}}^2}{12} = -\frac{(0.6)*(0.34\ \mathrm{kip/ft^2})*(12\,\mathrm{in})*(30.17\ \mathrm{ft})^2}{12} = -15.47\ \mathrm{kip{\cdot}ft}$$

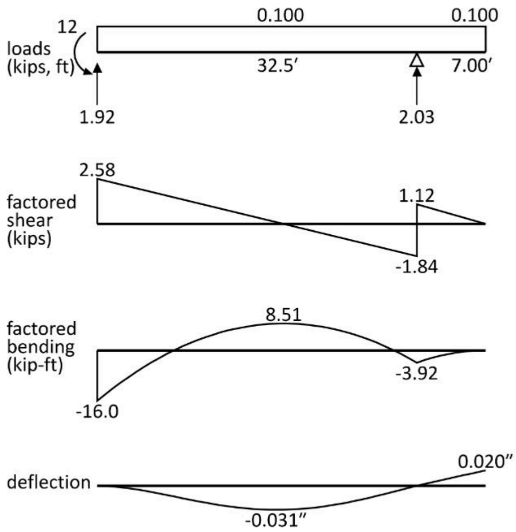
Slab #2 (x-direction)

beam =

item	value
plan	f 32.5′ △ 7′
E	29000 ksi
I	1000 in^4
dead	-0.06 kips/ft, 0:32.5 ft
live	-0.04 kips/ft, 0:32.5 ft
live	-0.1 kip/ft, 32.5:39.5 ft

loadFactors =

dead	live
1.4	0
1.2	1.6



Slab #3 (y-direction)

$$R_{py3} = \frac{3 * (\gamma * w_{Ubot} * b) * L_{y3}}{8} = \frac{3 * \left((0.6) * (0.34\ \mathrm{kip/ft^2}) * (12\ \mathrm{in}) \right) * (30.17\ \mathrm{ft})}{8} = 2.308\ \mathrm{kip}$$

$$R_{fy3} = \frac{5 * (\gamma * w_{Ubot} * b * L_{y3})}{8} = \frac{5 * \left((0.6) * (0.34\ \mathrm{kip/ft^2}) * (12\ \mathrm{in}) * (30.17\ \mathrm{ft}) \right)}{8} = 3.846\ \mathrm{kip}$$

$$M_{fy3} = -\frac{(\gamma * w_{Ubot} * b) * {L_{y3}}^2}{8} = -\frac{\left((0.6) * (0.34\ \mathrm{kip/ft^2}) * (12\ \mathrm{in}) \right) * (30.17\ \mathrm{ft})^2}{8} = -23.21\ \mathrm{kip{\cdot}ft}$$

Slab #3 (x-direction)

$$R_{px3} = \frac{3 * ((1-\gamma) * w_{Ubot} * b) * L_{x3}}{8} = \frac{3 * \left(\ (1-(0.6))\ * (0.34\ \mathrm{kip/ft^2}) * (12\ \mathrm{in}) \right) * (32.5\ \mathrm{ft})}{8}$$
$$= 1.657\ \mathrm{kip}$$

$$R_{fx3} = \frac{5 * ((1-\gamma) * w_{Ubot} * b * L_{x3})}{8} = \frac{5 * \left(\ (1-(0.6))\ * (0.34\ \mathrm{kip/ft^2}) * (12\ \mathrm{in}) * (32.5\ \mathrm{ft}) \right)}{8}$$
$$= 2.763\ \mathrm{kip}$$

$$M_{fx3} = -\frac{((1-\gamma) * w_{Ubot} * b) * {L_{x3}}^2}{8} = -\frac{\left(\ (1-(0.6))\ * (0.34\ \mathrm{kip/ft^2}) * (12\ \mathrm{in}) \right) * (32.5\ \mathrm{ft})^2}{8}$$
$$= -17.96\ \mathrm{kip{\cdot}ft}$$

3. STRIP METHOD CALCULATIONS

DESIGN PARAMETERS														
fc'	fy	Ec	Es	Lx	Ly	γ	h	b	d	β	ϕ (flexural)	ϕ (shear)	ε_cu	λ
(ksi)	(ksi)	(ksi)	(ksi)	(ft)	(ft)	(-)	(in)	(in)	(in)	(-)	(-)	(-)	(-)	(-)
4.9	60	3990	29000	32.5	30.16666667	0.6	10	12	8.5	0.805	0.9	0.75	0.003	1

SLAB 1			
LOADS			
wD	0.1500	kip/ft	
wL	0.25	kip/ft	
wu	0.58	kip/ft	
X-DIRECTION LOADS			
wu,x	0.232	kip/ft	
Mu,neg	30.63	kip-ft	
Mu,pos	17.23	kip-ft	
Mn,neg	34.03	kip-ft	
Mn,pos	19.14	kip-ft	
Vu	4.71	kips	
NEGATIVE FLEXURAL DESIGN			
Nominal Moment Capacity			
a (iteration)	1.023	in	
Required As	0.852	in^2	
a (required)	1.023	in	
Use (3) #6 bars			
As	1.32	in^2	
a	1.585	in	
ϕMn	50.87	kip-ft	OK!
Design Checks			
c	1.97	in	
ε_t	0.012		OK!
As,min	0.357	in^2	OK!
Spacing Checks			
# of bars	3		
s	4	in	
d_b	0.5	in	
d_agg	0.5	in	
s_min	1	in	OK!
s_max	18	in	OK!
POSITIVE FLEXURAL DESIGN			
Nominal Moment Capacity			
a (iteration)	0.559	in	
Required As	0.466	in^2	
a (required)	0.559	in	
Use (2) #6 bars			
As	0.88	in^2	
a	1.056	in	
ϕMn	35.08	kip-ft	OK!
Design Checks			
c	1.31	in	
ε_t	0.020		OK!
As,min	0.357	in^2	OK!
Spacing Checks			
# of bars	2		
s	6	in	
d_b	0.5	in	
d_agg	0.5	in	
s_min	1	in	OK!
s_max	18	in	OK!
SHEAR DESIGN			
ρ_w	0.01294		
ϕVc	10.06	kips	
0.5ϕVc	5.03	kips	OK!
No shear reinforcement necessary			
Y-DIRECTION LOADS			
wu,y	0.348	kip/ft	
Mu,neg	39.59	kip-ft	
Mu,pos	22.27	kip-ft	
Mn,neg	43.98	kip-ft	
Mn,pos	24.74	kip-ft	
Vu	6.56	kips	

SLAB 2			
LOADS			
w_D	0.1500	kip/ft	
w_L	0.1	kip/ft	
w_u	0.34	kip/ft	
X-DIRECTION LOADS			
Lo	7	ft	
P	2.68	kips	
M	10.43	kip-ft	
wu,x	0.136	kip/ft	
Mu,neg	16.00	kip-ft	
Mu,pos	8.51	kip-ft	
Mn,neg	18.50	kip-ft	
Mn,pos	9.46	kip-ft	
Vu	2.58	kips	
NEGATIVE FLEXURAL DESIGN			
Nominal Moment Capacity			
a (iteration)	0.540	in	
Required As	0.450	in^2	
a (required)	0.540	in	
Use (1.5) #6 bars			
As	0.66	in^2	
a	0.792	in	
ϕMn	26.74	kip-ft	OK!
Design Checks			
c	0.98	in	
ε_t	0.027		OK!
As,min	0.357	in^2	OK!
Spacing Checks			
# of bars	1.5		
s	8	in	
d_b	0.5	in	
d_agg	0.5	in	
s_min	1	in	OK!
s_max	18	in	OK!
POSITIVE FLEXURAL DESIGN			
Nominal Moment Capacity			
a (iteration)	0.271	in	
Required As	0.226	in^2	
a (required)	0.271	in	
Use (1) #6 bars			
As	0.44	in^2	
a	0.528	in	
ϕMn	18.12	kip-ft	OK!
Design Checks			
c	0.66	in	
ε_t	0.043		OK!
As,min	0.357	in^2	OK!
Spacing Checks			
# of bars	1		
s	12	in	
d_b	0.5	in	
d_agg	0.5	in	
s_min	1	in	OK!
s_max	18	in	OK!
SHEAR DESIGN			
ρ_w	0.00647		
ϕVc	7.98	kips	
0.5ϕVc	3.99	kips	OK!
No shear reinforcement necessary			
Y-DIRECTION LOADS			
wu,y	0.204	kip/ft	
Mu,neg	15.47	kip-ft	
Mu,pos	7.74	kip-ft	
Mn,neg	17.19	kip-ft	
Mn,pos	8.59	kip-ft	
Vu	3.32	kips	

SLAB 3			
LOADS			
w_D	0.1500	kip/ft	
w_L	0.1	kip/ft	
w_u	0.34	kip/ft	
X-DIRECTION LOADS			
wu,x	0.136	kip/ft	
Mu,neg	17.96	kip-ft	
Mu,pos	10.10	kip-ft	
Mn,neg	19.95	kip-ft	
Mn,pos	11.22	kip-ft	
Vu	2.76	kips	
NEGATIVE FLEXURAL DESIGN			
Nominal Moment Capacity			
a (iteration)	0.584	in	
Required As	0.486	in^2	
a (required)	0.584	in	
Use (1.5) #6bars			
As	0.66	in^2	
a	0.792	in	
ϕMn	26.74	kip-ft	OK!
Design Checks			
c	0.98	in	
ε_t	0.027		OK!
As,min	0.357	in^2	OK!
Spacing Checks			
# of bars	1.5		
s	8	in	
d_b	0.5	in	
d_agg	0.5	in	
s_min	1	in	OK!
s_max	18	in	OK!
POSITIVE FLEXURAL DESIGN			
Nominal Moment Capacity			
a (iteration)	0.323	in	
Required As	0.269	in^2	
a (required)	0.323	in	
Use (1) #6 bars			
As	0.44	in^2	
a	0.528	in	
ϕMn	18.12	kip-ft	OK!
Design Checks			
c	0.66	in	
ε_t	0.043		OK!
As,min	0.357	in^2	OK!
Spacing Checks			
# of bars	1		
s	12	in	
d_b	0.5	in	
d_agg	0.5	in	
s_min	1	in	OK!
s_max	18	in	OK!
SHEAR DESIGN			
ρ_w	0.00647		
ϕVc	7.98	kips	
0.5ϕVc	3.99	kips	OK!
No shear reinforcement necessary			
Y-DIRECTION LOADS			
wu,y	0.204	kip/ft	
Mu,neg	23.21	kip-ft	
Mu,pos	13.05	kip-ft	
Mn,neg	25.78	kip-ft	
Mn,pos	14.50	kip-ft	
Vu	4.14	kips	

NEGATIVE FLEXURAL DESIGN			
Nominal Moment Capacity			
a (iteration)	1.35	in	
Required As	1.124	in^2	
a (required)	1.350	in	
Use (3) #6 bars			
As	1.32	in^2	
a	1.585	in	
ϕMn	50.87	kip-ft	OK!
Design Checks			
c	1.97	in	
ε_t	0.012		OK!
As,min	0.357	in^2	OK!
Spacing Checks			
# of bars	3		
s	4	in	
d_b	0.5	in	
d_agg	0.5	in	
s_min	1	in	OK!
s_max	18	in	OK!
POSITIVE FLEXURAL DESIGN			
Nominal Moment Capacity			
a (iteration)	0.73	in	
Required As	0.608	in^2	
a (required)	0.730	in	
Use (2) #6 bars			
As	0.88	in^2	
a	1.056	in	
ϕMn	35.08	kip-ft	OK!
Design Checks			
c	1.31	in	
ε_t	0.020		OK!
As,min	0.357	in^2	OK!
Spacing Checks			
# of bars	2		
s	6	in	
d_b	0.5	in	
d_agg	0.5	in	
s_min	1	in	OK!
s_max	18	in	OK!
SHEAR DESIGN			
ρ_w	0.01294		
ϕVc	10.06	kips	
0.5ϕVc	5.03	kips	NG!
Assume #3 stirrups			
Av	0.22	in^2	
Vs	28.56	kips	
s_max	24	in	
s (Av,min)	20.95	in	OK!
Av,min	0.22	in^2	OK!
s	4.25	in	
Use #3 stirrups @ 4 in			
DEVELOPMENT LENGTH			
Ψt	1		
Ψe	1		
Ψg	1		
λ	1		
Ld,req	17.14	in	

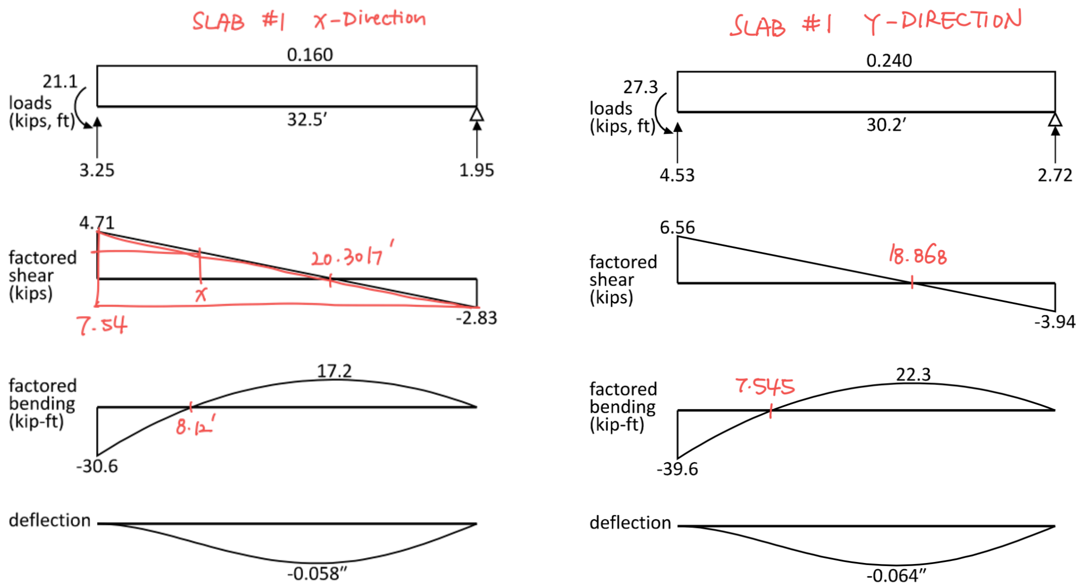
NEGATIVE FLEXURAL DESIGN			
Nominal Moment Capacity			
a (iteration)	0.5	in	
Required As	0.417	in^2	
a (required)	0.500	in	
Use (1) #6 bars			
As	0.44	in^2	
a	0.528	in	
ϕMn	18.12	kip-ft	OK!
Design Checks			
c	0.66	in	
ε_t	0.043		OK!
As,min	0.357	in^2	OK!
Spacing Checks			
# of bars	1		
s	12	in	
d_b	0.5	in	
d_agg	0.5	in	
s_min	1	in	OK!
s_max	18	in	OK!
POSITIVE FLEXURAL DESIGN			
Nominal Moment Capacity			
a (iteration)	0.246	in	
Required As	0.205	in^2	
a (required)	0.246	in	
Use (1) #6 bars			
As	0.44	in^2	
a	0.528	in	
ϕMn	18.12	kip-ft	OK!
Design Checks			
c	0.66	in	
ε_t	0.043		OK!
As,min	0.357	in^2	OK!
Spacing Checks			
# of bars	1		
s	12	in	
d_b	0.5	in	
d_agg	0.5	in	
s_min	1	in	OK!
s_max	18	in	OK!
SHEAR DESIGN			
ρ_w	0.00431		
ϕVc	6.97	kips	
0.5ϕVc	3.49	kips	OK!
No shear reinforcement necessary			
DEVELOPMENT LENGTH			
Ψt	1		
Ψe	1		
Ψg	1		
λ	1		
Ld,req	17.14	in	

NEGATIVE FLEXURAL DESIGN			
Nominal Moment Capacity			
a (iteration)	0.762	in	
Required As	0.635	in^2	
a (required)	0.762	in	
Use (2) #6 bars			
As	0.8	in^2	
a	0.960	in	
ϕMn	32.08	kip-ft	OK!
Design Checks			
c	1.19	in	
ε_t	0.022		OK!
As,min	0.357	in^2	OK!
Spacing Checks			
# of bars	6		
s	2	in	
d_b	0.5	in	
d_agg	0.5	in	
s_min	1	in	OK!
s_max	18	in	OK!
POSITIVE FLEXURAL DESIGN			
Nominal Moment Capacity			
a (iteration)	0.42	in	
Required As	0.350	in^2	
a (required)	0.420	in	
Use (1) #6 bars			
As	0.44	in^2	
a	0.528	in	
ϕMn	18.12	kip-ft	OK!
Design Checks			
c	0.66	in	
ε_t	0.043		OK!
As,min	0.357	in^2	OK!
Spacing Checks			
# of bars	1		
s	12	in	
d_b	0.5	in	
d_agg	0.5	in	
s_min	1	in	OK!
s_max	18	in	OK!
SHEAR DESIGN			
ρ_w	0.00784		
ϕVc	8.51	kips	
0.5ϕVc	4.26	kips	OK!
No shear reinforcement necessary			
DEVELOPMENT LENGTH			
Ψt	1		
Ψe	1		
Ψg	1		
λ	1		
Ld,req	17.14	in	

4. SLAB REINFORCEMENT LENGTHS:

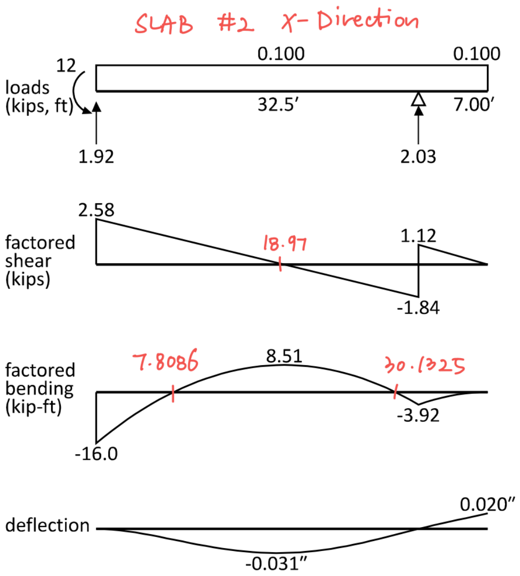
#6 Bars $d_b = 0.75"$
Extension Length: $l_o = max(d, 12d_b) = 9"$
Development Length: $l_d = 17.14" \rightarrow 18"$
Lap Splice Length: $l_{st} = max(1 * l_d, 12") = 18"$

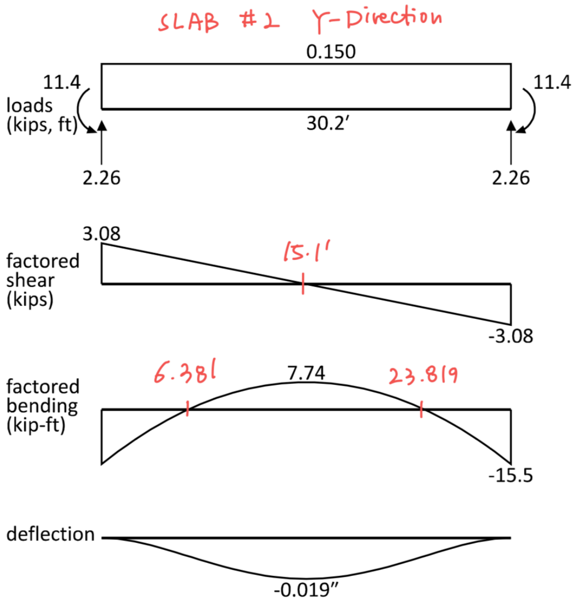
Slab 1 Moment Diagrams



Slab 1 Top
X-Direction:
Through Bars: 30'6" + 2(21") = 34"
Discontinuous Bars: 8.12' + 18" + 9" = 10.37' → 10'5"
Y-Direction:
Through Bars: 28'2" + 2(21") = 34" → 31'8"
Discontinuous Bars: 7.545' + 18" + 9" = 9.795' → 9'10"
Slab 1 Bottom
X-Direction: 30'6" + 2(6") = 31'6"
Y-Direction: 28'2" + 2(6") = 29'2"

Slab 2 Moment Diagrams





Slab 2 Top

<u>X-Direction:</u>

Through Bars: 30’6” + 21” + 6’10” = 40.083’ → 40’1”

Discontinuous Bars: 7.809’ + 18” + 9” = 10.059’ → 10’1”

<u>Y-Direction:</u>

Through Bars: 28’2” + 2(21”) = 34” → 31’8”

Discontinuous Bars: None. Negative moment satisfied by through bars

Slab 1 Bottom

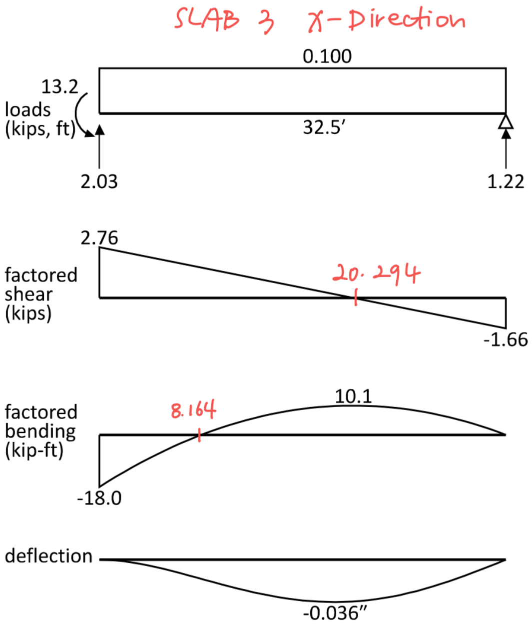
<u>X-Direction:</u> 30’6” + 2(6”) = 31’6”

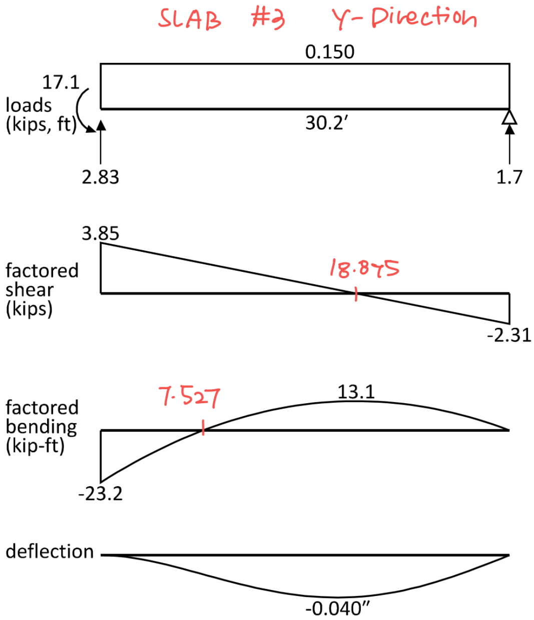
<u>Y-Direction:</u> 28’2” + 2(6”) = 29’2”

<u>Overhang X-Direction:</u> 6’ + 6” = 6’6”

<u>Overhang Y-Direction:</u> 28’2” + 2(6”) = 29’2”

Slab 3 Moment Diagrams





Slab 3 Top

X-Direction:

Through Bars: 30’6” + 2(21”) = 34”

Discontinuous Bars: 8.12’ + 18” + 9” = 10.37’ → 10’5”

Y-Direction:

Through Bars: 28’2” + 2(21”) = 34” → 31’8”

Discontinuous Bars: 7.527’ + 18” + 9” = 9.777’ → 9’10”

Slab 1 Bottom

X-Direction: 30’6” + 2(6”) = 31’6”

Y-Direction: 28’2” + 2(6”) = 29’2”

5. GIRDER 7 & 8 ANALYSIS: EXCEL

[SE 140B] Project 1

Codes: ACI 318-19, ASCE 7-22

Problem: Two-Way Slab Design

Geometry			
Lx	Slab Length in the x-direction	32.5	*ft*
Lnx	Clear Span Length in the x-direction	30.00	*ft*
Ly	Slab Length in the y-direction	30.17	*ft*
Lny	Clear Span Length in the y-direction	27.67	*ft*
h	Beam height	36	*in*
b	Beam width	24	*in*
d	Beam depth (effective): d = h_b - cc - db_stirrup - db_long. / 2 = 36 - 1.5 - 0.5 - 0.5	33.5	*in*
d (G7, Neg. Moment ONLY)	Beam depth (effective): d = h_b - cc - db_stirrup - db_long. / 2 = 36 - 1.5 - 0.5 - 0.5 - 2	32.5	*in*
t_s	Slab thickness	10	*in*
cc	Clear concrete cover to beam stirrups	1.5	*in*
Material Properties			
f'c	Specified compressive strength of concrete	4.9	*ksi*
β_1	Stress block factor → f'c ≤ 4 ksi → β_1 = 0.85	0.805	—
fy	Reinforcement yield strength (ASTM Grade 60)	60	*ksi*
fr	Rupture modulus = 7.5 * sqrt(f'c)	0.525	*ksi*
λ	Concrete density factor (normal-weight = 1.0)	1	—
Applied Loads			
w_u_ slab_G8	Factored Total Distributed Load from Slab 1 on G8	3.937	*k/ft*
w_u_ slab_G7	Factored Total Distributed lLoad from Slabs 1 and 2 on G7	9.638	*k/ft*
w_beam_sw	Beam Self Weight DL = (150 pcf) * b* h	0.9	*k/ft*
w_edge_perim.	Glass Facade DL = 250 plf =	0.25	*k/ft*
w_beam_G8_DL	Beam G8 DL = Beam Self Weight DL + Glass Facade DL	1.15	*k/ft*
w_beam_G7_DL	Beam G7 DL = Beam Self Weight DL	0.9	*k/ft*
w_beam_G_LL	LL already applied through slab reactions. No other LL applied.	0	*k/ft*

Load Cases				
		G8	**G7**	**Units**
LC1	1.4*(w_beam_DL) + w_u_slab	5.547	10.898	*k/ft*
LC2	1.2*(w_beam_DL) + 1.6*(w_beam_LL) + w_u_slab	5.317	10.718	*k/ft*
w_u	max(LC1, LC2)	5.547	10.898	*k/ft*

Beam — Demands				
		G8	**G7**	**Units**
M_pos	w_u * Lx ^2 / 24 @ supports	244.13	479.63	*k-ft*
M_neg	w_u * Lx ^2 / 12 @ supports	488.25	959.25	*k-ft*
V_u	w_u * Lx / 2 @ supports	90.14	177.09	*k*

Moment Design						
		G8		**G7**		**Units**
		M_pos (+)	**M_neg (-)**	**M_pos (+)**	**M_neg (-)**	
d_b	8/8 in (for #8 Bars)	1	1	1	1	*in*
l_extension	Extension Length = max(d, d_b)	33.5	33.5	33.5	32.5	*in*
l_development	Development Length = 34*d_b	34.00	34.00	34.00	34.00	*in*
ψ_e	Uncoated Reinforcement Factor = 1.0	1.0	1.0	1.0	1.0	
ψ_r	No.11 and Smaller Bars Factor = 1.0	1.0	1.0	1.0	1.0	
ψ_o	Side Cover Normal to Plane of Hook >= 2.5 in Factor = 1.0	1.0	1.0	1.0	1.0	
ψ_c	Concrete Strength Factor = f'c (psi) / 15000 + 0.6	0.927	0.927	0.927	0.927	
lambda	NWC = 1.0	1.0	1.0	1.0	1.0	
l_hooked	l_dh = roundup(max(fy*ψ_e*ψ_r*ψ_o*ψ_c/(55*λ*sqrt(f'c))*d_b^1.5, 8*d_b, 6 in))	15.00	15.00	15.00	15.00	
l_st	Lap Slices Length = max(1*d_b, 12 in)	12	12	12	12	*in*
a_it	Iterative value of compression block "a"	0.987	2.004	1.968	4.210	*in*
As_it	Iterative value of Steel Area = Mu / (0.9 * fy * (d - a_it /2))	1.644	3.339	3.278	7.013	*in^2*
a	True Depth of Whitney's Compression Block = As_it * fy / (0.85 * f'c * b)	0.987	2.004	1.968	4.210	*in*
Equilibrium	Equilibrium: a_it - a = 0; Iterate until this is true.	0.00	0.00	0.00	0.00	
Nb1	Number of #8 Tension Bars	4	5	5	10	*bars*
Nb2	Number of #8 Compression Bars	0	0	0	0	*bars*
ϕ_b1	Diameter of Tension Bars	1	1	1	1	*in*
ϕ_b2	Diameter of Compression Bars	0	0	0	0	*in*
c_c	Clear Cover = 1.5 in	1.5	1.5	1.5	1.5	*in*
s_bar	Bar Spacing = (b - 2*cc) / (Nb1 + Nb2 - 1)	7.00	5.25	5.25	2.33	
As	Area of Steel = Nb1 * pi * (ϕ_b1)^2 / 4 + Nb2 * pi * (ϕ_b2)^2 / 4	3.14	3.93	3.93	7.85	*in^2*
p_s	Reinforcement Ratio = As / (d*b)	0.0039	0.0049	0.0049	0.0098	
ϕ_f	Flexural Strength Reduction Factor	0.9	0.9	0.9	0.9	
w	Mechanical Steel Ratio	0.048	0.060	0.060	0.120	
ϕMn	**Nominal Moment Capacity = ϕ_f * b * d^2 * w * f'c * (1 - 0.59*w)**	**460.23**	**571.10**	**571.10**	**1100.43**	*k-ft*

Moment Design Checks

		G8		G7		Units	Status: DCR < 1? (G/NG)
		M_pos (+)	M_neg (-)	M_pos (+)	M_neg (-)		
1. Flexural Check	**DCR: Mu / ϕMn < 1?**	**0.53**	**0.85**	**0.84**	**0.87**		
Mu	Maximum Moment Demand	244.13	488.25	479.63	959.25	*k-ft*	
ϕMn	Nominal Moment Capacity	460.23	571.10	571.10	1100.43	*k-ft*	G
2. Minimum Area Check	**DCR: As_min / As < 1?**	**0.90**	**0.72**	**0.72**	**0.36**		
p_min	Minimum Reinforcement Ratio = max(0.35 * fr / fy, 3 * sqrt(f'c)/fy, 200/fy	0.0035	0.0035	0.0035	0.0035		
As_min	Minimum Steel Area = p_min * b * d	2.814	2.814	2.814	2.814	*in^2*	
As	Area of Steel	3.142	3.927	3.927	7.854	*in^2*	
Nb1_min	Min # Bars required everywhere = ROUNDUP(As_min / (0.79 in^2))	4	4	4	4	*bars*	
Nb1_additional	Additional Bars required = Nb1 - Nb1_min	0	1	1	6	*bars*	G
3. Max Area Check	**DCR: As / As_max < 1?**	**0.19**	**0.23**	**0.23**	**0.48**		
p_max	Max Reinforcement Ratio = 0.85 * B1 * f'c / fy * 0.003 / (0.008)	0.021	0.021	0.021	0.021		
As_max	Maximum Steel Area = p_max * b * d	16.848	16.848	16.848	16.345	*in^2*	
As	Area of Steel	3.142	3.927	3.927	7.854	*in^2*	G
4. Bar Spacing Check	**DCR: s_min / s < 1**	**0.14**	**0.20**	**0.20**	**0.50**		
s_bar	Spacing of Bars = (b - 2*cc) / (Nb1 + Nb2 - 1)	7.00	5.25	5.25	2.33	*in*	
s	Realistic spacing used	7	5	5	2	*in*	
s_min	max(1 in, max(ϕb1, ϕb2), 0.75*ϕag)	1	1	1	1	*in*	G

Shear Design

		G8		G7		Units
Vu	Ultimate Shear	90.14		177.09		*k*
λs	Size Effect Modification Factor = min(sqrt(2 / (1 +d/10)), 1)	0.6781		0.6860		
f_lms	Limited Material Strength = min(sqrt(f'c) , 100 psi)	70		70		
ϕ_s	Shear Strength Reduction Factor	0.75		0.75		
ϕV_nc	Nominal Concrete Strength = min (ϕs * (2*λs*b*d*f_lms), ϕs * (8*λs*ps^1/3 *b*d*f_lms))	36.064		38.130		*kips*
ϕVs	Required Shear Resistance of Stirrups = Vu - ϕV_nc	54.075		138.963		*kips*
x	ϕ_s * 4 * sqrt(f'c) * b * d	168.840		163.800		
s_max (if ϕVs < x)	Max Stirrup Spacing = min(d/2, 24 in)	16.75		16.250		*in*
s_max_design	User-Defined Max Spacing (given limit)	**14**		**12**		*in*
s	User-Defined Spacing	**10**		**4**		*in*
Stirrup Size	#4	#4		#4		
A_st	Shear Reinforcement Area = 2 * 0.20 in^2	0.400		0.400		*in^2*
A_st_min	Minimum Shear Reinforcement Area = max(0.75*sqrt(f'_c) * b* s / fy, 50 * b*s /fy	0.200		0.080		*in^2*
ϕ_s * (fy*A_st)	ϕ_s * (fy*A_st) < ϕ_s * (8*λ_s * b*d*f_lms) allows the use of the below equation for nominal shear resistance of reinforcing steel	18.000		18.000		
ϕ_s * (8*λ_s * b*d*f_lms)		228.968		231.647		*k*
ϕV_ns	Nominal Shear Resistance of Reinforcing Steel = ϕ_s * fy*A_st*d/s	60.300		146.250		*k*
ϕV_n	**TOTAL (CONC + STEEL) SHEAR RESISTANCE = ϕV_nc + ϕV_ns, where ϕV_nc < Vu**	**96.364**		**184.380**		*k*
	(STEEL) SHEAR RESISTANCE = ϕV_ns, elsewhere	**60.300**		**146.250**		*k*
Min. Reinforcement Range Req.	**ϕV_nc < Vu: d = (Lnx/ 2) * (ϕV_nc) / (Vu)**	72.017	287.983	38.756	321.244	*in*
	Left: 0 < x < [2" + (d1 = Lnx/2 - d)] **Right:** [d2 = Lnx/2 + d] < x < (Lnx)					
Design Reinforcement Range Req.	**ϕV_ns, elsewhere: d1 < x < d2**	73.00	287.00	39.00	321.00	*in*
FINAL Minimum Stirrup Design	**Range of minimum stirrup design was shrunk to accommodate spacing constraints**	**#4 @ 14" from [82" < x < 278"]**		**#4 @ 12" from 42"<x<318"**		*in*
FINAL Regular Stirrup Design	**Range of regular stirrup design was maximized to be conservative while also accommodating spacing constraints**	**#4 @ 10" O.C. from [2"<x<82"], [278"<x<358"]**		**#4 @ 4" O.C. from [2"<x<42"], [318"<x<358"]**		*in*

Shear Design Checks

		G8	G7	Units	Status: DCR < 1? (G/NG)
1. Flexural Check	**DCR: Vu / ϕVn < 1?**	**0.94**	**0.96**		
Vu	Maximum Shear Demand	90.14	177.09	*k*	
ϕVn	Nominal Shear Capacity	96.364	184.380	*k*	G
2. Max Stirrup Spacing	**DCR: s / s_max < 1?**	**0.60**	**0.25**		
s_max	Max Stirrup Spacing = min(d/2, 24 in)	16.75	16.250	*in*	
s	User-Defined Spacing	10	4	*in*	G
3. Minimum Area Check	**DCR: As_min / As < 1?**	**0.50**	**0.20**		
A_st_min	Minimum Shear Reinforcement Area = max(0.75*sqrt(f'_c) * b* s / fy, 50 * b*s /fy)	0.200	0.080	*in^2*	
A_st	Shear Reinforcement Area = 2 * 0.20 in^2	0.400	0.400	*in^2*	G

6. GIRDER 7 & 8 ANALYSIS: STEP-BY-STEP EXAMPLE CALCULATIONS

Initial Values

$f'_c = 4900$ psi (compressive strength)

$f_y = 60000$ psi (yielding resistance)

$f_r = 7.5 * \sqrt{f'_c} * 1\ psi^{0.5} = 525$ psi (rupture modulus)

$E_c = 57000 * \sqrt{f'_c} = 3990000\ psi^{0.5}$ (Young's Modulus of Concrete)

$E_s = 29000$ ksi (Young's Modulus of Steel)

$l_{sx} = 32.5$ ft (Center-to-Center Span in X-Direction)

$l_{sy} = 30$ ft + 2 in = 30ft 2in (Center-to-Center Span in Y-Direction)

$h_{beam} = 36$ in (height of beam)

$b_{beam} = 24$ in (width of beam)

$d_{beam} = h_{beam} - 1.5\ in - 0.5\ in - 1/2\ in = 33.5$ in (effective depth of beam)

1. Slab Loads (from Slab Reactions)

$w_{u,slab,G8} = 3.937$ klf (factored distributed load from Slab 1)

$w_{u,slab,G7} = 6.561$ klf + 3.077 klf = 9.638 klf (factored total distributed load from Slab 1 + Slab 2 on G7)

2. Beam Load Calculation

$w_{beam,sw} = (150\ pcf) * b_{beam} * h_{beam} = 0.9$ klf (self-weight of the beam)

$w_{edge,perimeter} = 250$ plf (glass facade dead load along slab edges)

$w_{beam,G8,DL} = w_{beam,sw} + w_{edge,perimeter} = 1.15$ klf (total unfactored beam G8 dead load)

$w_{beam,G7,DL} = w_{beam,sw} = 0.9$ klf (total unfactored beam G7 dead load)

$w_{beam,G8,LL} = 0$ klf (additional live load on beam G8)

$w_{beam,G7,LL} = 0$ klf (additional live load on beam G7)

$LC1_{G8} = 1.4 * (w_{beam,G8,DL}) + w_{u,slab,G8} = 5.547$ klf (Load Combo 1 for G8)

$LC2_{G8} = 1.2 * (w_{beam,G8,DL}) + 1.6 * (w_{beam,G8,LL}) + w_{u,slab,G8} = 5.317$ klf (Load Combo 2 for G8)

$LC1_{G7} = 1.4 * (w_{beam,G7,DL}) + w_{u,slab,G7} = 10.898$ klf (Load Combo 1 for G7)

$LC2_{G7} = 1.2 * \left(w_{beam,G7,DL}\right) + 1.6 * \left(w_{beam,G7,LL}\right) + w_{u,slab,G7} = 10.718\ klf$ (Load Combo 2 for G7)

Note: Slab loads are unfactored in the calcs because they've already been factored in slab calculations

$w_{u,G8} = Max\left(LC1_{G8}, LC2_{G8}\right) = 5.547\ klf$ (total factored beam G8 distributed load)

$w_{u,G7} = Max\left(LC1_{G7}, LC2_{G7}\right) = 10.898\ klf$ (total factored beam G7 distributed load)

3. Moment Demands

Moment Demands for Beam G8

$$M_{G8,pos} = \frac{w_{u,G8} * l_{sx}^{2}}{24} = 244.126\ kip * ft \quad @ \quad \frac{l_{sx}}{2} = 16.25\ ft$$ (Max positive moment center-span)

$$M_{G8,neg} = \frac{w_{u,G8} * l_{sx}^{2}}{12} = 488.252\ kip * ft \quad @\ ends$$ (Max negative moment at supports)

Moment Demands for Beam G7

$$M_{G7,pos} = \frac{w_{u,G7} * l_{sx}^{2}}{24} = 479.626\ kip * ft \quad @ \quad \frac{l_{sx}}{2} = 16.25\ ft$$ (Max positive moment center-span)

$$M_{G7,neg} = \frac{w_{u,G7} * l_{sx}^{2}}{12} = 959.251\ kip * ft \quad @\ ends$$ (Max negative moment at supports)

4. Moment Capacity Example: G8 (+)

$d_b = 8/8\ in$ (#8 bars used along span)

$l_{extension} = Max\left(d_{beam}, d_b\right) = 33.5\ in$ (extension length, measured from where $M(x) = 0$

$l_{development} = 34 * d_b = 34\ in$ (development length, measured from end support)

$l_{st} = Max\left(1 * d_b, 12\ in\right) = 12\ in$

$\psi_e = 1.0$ (uncoated reinforcement)

$\psi_r = 1.0$ (No. 11 and smaller bars)

$\psi_o = 1.0$ (side cover normal to plane of hook ≥ 2.5 in)

$$\psi_c = \frac{f'_c}{15000\ psi} + 0.6 = 0.927$$ (concrete strength)

lambda = 1.0 (NWC)

$$l_{dh} = \text{RoundUp}\left(\text{Max}\left(\frac{f_y * \psi_e * \psi_r * \psi_o * \psi_c * 1\ in^{2.5}}{\left(55 * lambda * \sqrt{\frac{f'_c}{1\ psi}} * d_b^{1.5}\right) * 1\ psi}, 8 * d_b, 6\ in\right)\right) = 15\ in$$

$a_{it} = 0.987\ in$ (assumed depth of compression block; iterative value)

$$A_{s,it} = \frac{M_{G8,pos}}{0.9 * f_y * \left(d_{beam} - \frac{a_{it}}{2}\right)} = 1.644\ in^2$$ (required cross-sectional area of steel bars)

$$a = \frac{A_{s,it} * f_y}{0.85 * f'_c * b_{beam}} = 0.987\ in$$ (true depth of Whitney's compression block)

$N_{b1} = 4$ $N_{b2} = 0$ (Number of reinforcement steel bars)

$\phi_{b1} = 8/8\ in$ $\phi_{b2} = 0/8\ in$ (Diameters of steel bars)

$c_c = 1.5\ in$ (Clear cover)

$$s_{bar} = \frac{b_{beam} - 2 * c_c}{\left(N_{b1} + N_{b2}\right) - 1} = 7\ in$$ (bar spacing)

$$A_s = \frac{N_{b1} * pi * \left(\phi_{b1}^{\ 2}\right)}{4} + \frac{N_{b2} * pi * \left(\phi_{b2}\right)^2}{4} = 3.142\ in^2$$ (Cross-sectional area of steel bars)

$$\rho_s = \frac{A_s}{d_{beam} * b_{beam}} = 0.00391$$ (Steel ratio)

$\phi_f = 0.9$ (Flexural Strength Reduction Factor)

$$\omega = \frac{\rho_s * f_y}{f'_c} = 0.0478$$ (Mechanical steel ratio)

$$\phi M_n = \phi_f * b_{beam} * d_{beam}^{\ 2} * \omega * f'_c * (1 - 0.59 * \omega) = 460.226\ kip * ft$$ (Nominal Moment Capacity of Beam)

$$\rho_{max} = \frac{0.85 * \left(0.805 * f'_c\right) * \left(\dfrac{0.003}{0.003 + \dfrac{f_y}{E_s} + 0.003}\right)}{f_y} = 0.0208$$ (maximum steel ratio)

$$A_{s,max} = \rho_{max} * b_{beam} * d_{beam} = 16.704\ in^2$$ (Maximum Area of Steel Reinforcement)

$$\rho_{min} = Max\left(\frac{0.35 * f_r}{f_y}, \frac{3 * \sqrt{\dfrac{f'_c}{1\ psi}} * 1\ psi}{f_y}, \frac{200 * 1\ psi}{f_y}\right) = 0.0035$$ (Minimum Reinforcement Steel Ratio of Rectangular Sections)

$$A_{s,min} = \rho_{min} * b_{beam} * d_{beam} = 2.814\ in^2$$ (Minimum Area of Steel Reinforcement)

Serviceability Criteria:

$\phi_{ag} = 0.5\ in$ (Maximum aggregate diameter size)

$$s_{b,min} = Max\left(1\ in, Max\left(\phi_{b1}, \phi_{b2}\right), 0.75 * \phi_{ag}\right) = 1\ in$$ (minimum bar spacing)

<u>#5. Shear Demands</u>

$w_{u,G8} = 5.547\ klf$ (total factored beam G8 distributed load)

$w_{u,G7} = 10.898\ klf$ (total factored beam G7 distributed load)

$$V_{u,G8} = \frac{w_{u,G8} * l_{sx}}{2} = 90.139\ kip$$ (Max Shear Demand for Beam G8)

$$V_{u,G7} = \frac{w_{u,G7} * l_{sx}}{2} = 177.093\ kip$$ (Max Shear Demand for Beam G7)

<u>#6. Shear Design Example: G8+</u>

$$\lambda_s = Min\left(\sqrt{\frac{2\ in}{1\ in + \dfrac{d_{beam}}{10}}}, 1\right) = 0.678$$ (Size Effect Modification Factor)

$$f_{lms} = Min\left(\sqrt{f'_c} * 1\ psi^{0.5}, 100\ psi\right) = 70\ psi$$ (Limit material strength used to compute the shear resistance)

$\phi_s = 0.75$ (shear factor)

$$\phi V_{nc} = Min\left(\phi_s * \left(2 * \lambda_s * b_{beam} * d_{beam} * f_{lms}\right), \phi_s * \left(8 * \lambda_s * \rho_s^{\left(\frac{1}{3}\right)} * b_{beam} * d_{beam} * f_{lms}\right)\right)$$

$= 36.064\ kip$ (Nominal Shear Strength of Concrete)

$\phi V_s = V_{u,G8} - \phi V_{nc} = 54.075\ kip$ (Required Shear Resistance of Stirrups)

X CONDITION:

$$x = \frac{\phi_s * 4 * \sqrt{f'_c} * b_{beam} * d_{beam} * 1\ lbf^{0.5}}{1\ in} = 168.84\ kip$$

(value that the nominal shear resistance must be less than in order to qualify for $s_{max} = Min\left(\frac{d}{2}, 24\ in\right)$

$$s_{max} = Min\left(\frac{d_{beam}}{2}, 24\ in\right) = 16.75\ in$$

(maximum spacing between stirrups)

$s_o = 10\ in$ (spacing defined by user)

$A_{st} = 2 * 0.20\ in^2 = 0.4\ in^2$ (Total area of shear reinforcement, given two vertical bars per stirrup)

$\phi_s * \left(f_y * A_{st}\right) = 18\ kip \quad < \quad \phi_s * 8 * \lambda_s * b_{beam} * d_{beam} * f_{lms} = 228.968\ kip$

Therefore:

$$\phi V_{ns} = \frac{\phi_s * f_y * A_{st} * d_{beam}}{s_o} = 60.3\ kip$$

(nominal shear resistance of reinforcing steel)

$\phi V_{nc} + \phi V_{ns} = 96.364\ kip > V_{u,G8} = 90.139\ kip$ G

7. YIELD LINE CALCULATIONS

Yield Line Method

$l_x := 32.5$ Clear span in X-direction [ft]

$l_y := 30.167$ Clear span in Y-direction [ft]

$$k(l_1, l_2, l_3) := -\frac{\dfrac{2 \cdot l_y}{l_1} + \dfrac{l_y}{l_2} + \dfrac{l_x}{l_3} - \dfrac{2 \cdot l_x}{l_3 - l_y}}{\dfrac{l_1 \cdot l_y}{6} + \dfrac{l_2 \cdot l_y}{6} - \dfrac{l_x \cdot l_y}{2}}$$

$l_1 := 1$

$l_2 := 1$

$l_3 := 1$

$$\frac{d}{dl_1} k(l_1, l_2, l_3) = 0$$

minimizing the function, we can compute the values of l_1, l_2, l_3

$$\frac{d}{dl_2} k(l_1, l_2, l_3) = 0$$

$$\frac{d}{dl_3} k(l_1, l_2, l_3) = 0$$

$$\begin{bmatrix} l_1 \\ l_2 \\ l_3 \end{bmatrix} := \textbf{Find}(l_1, l_2, l_3) = \begin{bmatrix} 18.323 \\ 12.956 \\ 12.496 \end{bmatrix}$$

$$k := -\frac{\dfrac{2 \cdot l_y}{l_1} + \dfrac{l_y}{l_2} + \dfrac{l_x}{l_3} - \dfrac{2 \cdot l_x}{l_3 - l_y}}{\dfrac{l_1 \cdot l_y}{6} + \dfrac{l_2 \cdot l_y}{6} - \dfrac{l_x \cdot l_y}{2}} = 0.036$$

$w_u := 0.58$ Ultimate Load [kip/ft^2]

$\phi m_n := \dfrac{w_u}{k} = 16.227$ Required Flexural Capacity [kip*ft/ft]

S_i = Yield Line

$S_1 := \phi m_n \cdot l_y = 489.525$

$S_2 := \phi m_n \cdot l_1 = 297.332$

$S_3 := \phi m_n \cdot l_1 = 297.332$

$S_4 := \phi m_n \cdot l_2 = 210.245$

$S_5 := \phi m_n \cdot l_2 = 210.245$

$S_6 := \phi m_n \cdot l_y = 489.525$

$S_7 := \phi m_n \cdot \left(l_x - l_1 - l_2\right) = 19.806$

$S_8 := \phi m_n \cdot \left(l_x - l_1 - l_2\right) = 19.806$

S = Positive Moment

$S := S_1 + S_2 + S_3 + S_4 + S_5 + S_6 + S_7 + S_8 = 2.034 \cdot 10^3$

P_i = Segment

$P_1 := \phi m_n \cdot l_y = 489.525$

$P_2 := \phi m_n \cdot l_1 = 297.332$

$P_3 := 0 = 0$

$P_4 := 0 = 0$

$P_5 := \phi m_n \cdot l_2 = 210.245$

$P_6 := 0 = 0$

$P_7 := \phi m_n \cdot \left(l_x - l_1 - l_2\right) = 19.806$

$P_8 := 0 = 0$

P = Negative Moment

$P := P_1 + P_2 + P_5 + P_7 = 1.017 \cdot 10^3$

DESIGN OF REINFORCED CONCRETE SLABS

1. General details

$f_c := 4900$	Compressive strength [lbf/in^2]
$f_y := 60$	Yielding resistance [kip/in^2]
$f_r := 7.5 \cdot \sqrt{f_c} = 525$	Rupture modulus [lbf/in^2]
$E_c := 57000 \cdot \frac{\sqrt{f_c}}{1000} = 3.99 \cdot 10^3$	Elasticity's modulus of concrete slab [kip/in^2], Sec.19.2.2.1
$E_s := 29000$	Elasticity's modulus of reinforcement steel [kip/in^2], Sec.20.2.2.2
$b := 12$	Strip Width [in]
$h := 10$	Total deep of slab [in], Sec.8.3.1.2
$d := h - 1.5 = 8.5$	Effective depth [in]
$\varepsilon_{cmax} := 0.003$	Maximum strain deformation of concrete slab [in/in], Sec.22.2.2
$\phi_f := 0.9$	Reduction factor by flexure, Sec.21.2.1
$\phi_s := 0.75$	Reduction factor by shear, Sec.21.2.1

2. Flexural Design

$M_u := 16$ Ultimate Bending Moment [kip*ft]

Cracking Bending Moment:

$S_o := \frac{b \cdot h^2}{6} = 200$ Elastic section modulus [in^3]

$\phi M_{cr} := \phi_f \cdot \frac{f_r}{1000} \cdot \frac{S_o}{12} = 7.875$ Cracking bending moment at midspan [kip*ft], Sec.24.2.3.5

Ultimate Bending Moment:

$M_u = 16$ Required moment strength [kip*ft]

$a_{it} := 0.518$ Assumed depth of compression block [in] (iterative value)

$$As_{it} := \frac{M_u \cdot 12}{\phi_f \cdot f_y \cdot \left(d - \frac{a_{it}}{2}\right)} = 0.431$$

Required cross-section area of steel bars [in^2]

$$a := \frac{As_{it} \cdot f_y}{0.85 \cdot \frac{f_c}{1000} \cdot b} = 0.518$$

Depth of Whitney's compression block [in]

$N_{b1} := 1$ $\quad N_{b2} := 0$

Number of reinforcement steel bars

$\phi_{b1} := \frac{6}{8}$ $\quad \phi_{b2} := \frac{0}{8}$

Diameter of steel bars [in'

$$s_{bar} := \frac{b}{N_{b1} + N_{b2}} = 12$$

Bar spacing [in]

$$A_s := N_{b1} \cdot \frac{\pi \cdot (\phi_{b1})^2}{4} + N_{b2} \cdot \frac{\pi \cdot (\phi_{b2})^2}{4} = 0.442$$

Cross-section area of steel bars [in^2]

$$\rho_s := \frac{A_s}{d \cdot b} = 4.331 \cdot 10^{-3}$$

Steel ratio

$$\omega := \rho_s \cdot \frac{f_y}{\frac{f_c}{1000}} = 0.053$$

Mechanical steel ratio

$$\phi M_n := \phi_f \cdot \frac{b}{12} \cdot d^2 \cdot \omega \cdot \frac{f_c}{1000} \cdot (1 - 0.59 \cdot \omega) = 16.37$$

Moment capacity of the slab [kip*ft]

Minimum and maximum tensile reinforcement in concrete beams and slabs:

$$\rho_{max} := \frac{0.85 \cdot (0.85 \cdot f_c)}{f_y} \cdot \left(\frac{\varepsilon_{cmax}}{\varepsilon_{cmax} + \frac{f_y}{E_s}}\right) \cdot \frac{1}{1000} = 0.035$$

Maximum Steel ratio

$$As_{max} := \rho_{max} \cdot b \cdot d = 3.562$$

Area of reinforcement Steel [in^2] (max.)

$$\rho_{min} := \max\left(0.35 \cdot \frac{\frac{f_r}{1000}}{f_y}, 0.0018\right) = 3.063 \cdot 10^{-3}$$

Minimum required steel ratio by Cracking Moment (rectangular sections)

$$As_{min} := \rho_{min} \cdot b \cdot d = 0.312$$

Area of reinforcement Steel [in^2] (min.)

Serviceability criteria:

For minimum bar spacing, use aggregate:

$\phi_{ag} := 0.5$

$S_{bmin} := \max\left(1, \max\left(\phi_{b1}, \phi_{b2}\right), \phi_{ag}\right) = 1$ Minimum bar spacing [in], Sec.8.7.2.1

For maximum bar spacing, use aggregate:

$S_{bmax} := min\left(2 \cdot h, 18\right) = 18$ Maximum bar spacing [in], Sec.8.7.2.2

Minimum concrete cover:

$t_{cov} := 0.75$ N°5 bar and smaller, Sec.20.5.1.3

Finally, the flexural design of the slab needs bars #6 @ 12 in

Note: This is for all steel reinforcement in both directions, top and bottom

APPENDIX C

Compass Activity (individual forms), team reflections (See Section 5 Design brief)

Compass Test Results: Hannah Ahn

Center for Collaborative Education

Quick Test to Identify Your Compass Point: Part 1

Are you more North or South?

For each set of words, circle the word that describes you more often than the other one (even though you may have both characteristics at times)

a. Confident b. Helpful	a. Goal-centered b. People-centered	a. Bold b. Supportive
a. Self-reliant b. Understanding	a. Initiator b. Listener	a. Productive b. Faithful
a. Fast-paced b. Easy-going	a. Determined b. Unselfish	a. Self-starter b. Volunteer
a. Independent b. Team player	a. Straightforward b. Patient	a. Opinionated b. Sensitive
a. Decisive b. Diplomatic	a. Results-focused b. Relationship-focused	a. Challenger b. Mediator
a. Assertive b. Non-confrontational	a. Hardworking b. Friendly	a. Doer b. Communicator
a. Competitive b. Cooperative	a. In-charge b. Generous	a. Deadline-driven b. Values-driven
a. Leader b. Loyal	a. Task-oriented b. Peace-oriented	a. Achiever b. Caregiver

Total # of A's circled: 9 (if this number is higher, you're more North)

Total # of B's circled: 15 (if this number is higher, you're more South)

Quick Test to Identify Your Compass Point: Part 2

Are you more East or West?
For each set of words, circle the word that describes you more often than the other one (even though you may have both characteristics at times)

c. Organized d. Creative	c. Factual d. Fun-loving	c. Cautious d. Open-minded
c. Structured d. Flexible	c. Analytical d. Cheerful	c. Finisher d. Motivator
c. Quality-centered d. Idea-centered	c. Consistent d. Versatile	c. Rule-follower d. Option-provider
c. Logical d. Visionary	c. Serious d. Humorous	c. Systematic d. Carefree
c. Reserved d. Innovative	c. Efficient d. Dreamer	c. Precise d. Inventive
c. Planner d. Spontaneous	c. Reliable d. Delegator	c. Persuasive d. Adventurous
c. Perfectionist d. Free-spirited	c. Detail-oriented d. Improvising	c. Accurate d. Adaptable
c. Traditional d. Risk-taker	c. Persistent d. Imaginative	c. Protocol-focused d. Methods-focused

Total # of C's circled: 21 (if this number is higher, you're more West)

Total # of D's circled: 3 (if this number is higher, you're more East)

Now that you have a number for each of the four types (North, South, East, West)...

This type has the highest number west (this is your Dominant Type)

This type has the second highest number South. (this is your Subdominant Type)

Dominant Compass Point Discussion

Once everyone has chosen a dominant compass point to join, spend 15 minutes answering the following questions as a group.

1. What are the strengths of your style? (4 adjectives)

organized, considerate, detailed, helpful.

2. What are the limitations of your style? (4 adjectives)

Indecisive, Rigid, slow, perfectionist

3. What style do you find most difficult to work with and why?

Fast paced people are difficult to work with if they're not thorough.

Spontaneous people are difficult if they're not dependable.

4. What do people from the other directions or styles need to know about you so you can work together effectively?

I appreciate clear communication on what has to be done and who is responsible for what part.

5. What do you value about the other 3 styles?

I'm slow so I appreciate North's direction & swiftness.

The creativity & free spiritedness of East is something I lack.

I sometimes rush so I appreciate South's thoroughness.

Compass Test Results: Isaac Kim

Isaac Kim

Center for Collaborative Education

Quick Test to Identify Your Compass Point: Part I

Are you more North or South?
For each set of words, circle the word that describes you more often than the other one (even though you may have both characteristics at times)

a. Confident
b. Helpful

a. Goal-centered
b. People-centered

a. Bold
b. Supportive

a. Self-reliant
b. Understanding

a. Initiator
b. Listener

a. Productive
b. Faithful

a. Fast-paced
b. Easy-going

a. Determined
b. Unselfish

a. Self-starter
b. Volunteer

a. Independent
b. Team player

a. Straightforward
b. Patient

a. Opinionated
b. Sensitive

a. Decisive
b. Diplomatic

a. Results-focused
b. Relationship-focused

a. Challenger
b. Mediator

a. Assertive
b. Non-confrontational

a. Hardworking
b. Friendly

a. Doer
b. Communicator

a. Competitive
b. Cooperative

a. In-charge
b. Generous

a. Deadline-driven
b. Values-driven

a. Leader
b. Loyal

a. Task-oriented
b. Peace-oriented

a. Achiever
b. Caregiver

Total # of A's circled: 16 (if this number is higher, you're more North)

Total # of B's circled: 8 (if this number is higher, you're more South)

Center for Collaborative Education

Isaac Kim

Quick Test to Identify Your Compass Point: Part 2

Are you more East or West?
For each set of words, circle the word that describes you more often than the other one (even though you may have both characteristics at times)

c. Organized
d. Creative

c. Structured
d. Flexible

c. Quality-centered
d. Idea-centered

c. Logical
d. Visionary

c. Reserved
d. Innovative

c. Planner
d. Spontaneous

c. Perfectionist
d. Free-spirited

c. Traditional
d. Risk-taker

c. Factual
d. Fun-loving

c. Analytical
d. Cheerful

c. Consistent
d. Versatile

c. Serious
d. Humorous

c. Efficient
d. Dreamer

c. Reliable
d. Delegator

c. Detail-oriented
d. Improvising

c. Persistent
d. Imaginative

c. Cautious
d. Open-minded

c. Finisher
d. Motivator

c. Rule-follower
d. Option-provider

c. Systematic
d. Carefree

c. Precise
d. Inventive

c. Persuasive
d. Adventurous

c. Accurate
d. Adaptable

c. Protocol-focused
d. Methods-focused

Total # of C's circled: 16 (if this number is higher, you're more West)

Total # of D's circled: 8 (if this number is higher, you're more East)

Now that you have a number for each of the four types (North, South, East, West)...

This type has the highest number North (this is your Dominant Type)

This type has the second highest number West (this is your Subdominant Type)

SAME LEVEL

Isaac Kim

Center for Collaborative Education

Dominant Compass Point Discussion

Once everyone has chosen a dominant compass point to join, spend 15 minutes answering the following questions as a group.

1. What are the strengths of your style? (4 adjectives)

Assertiveness, organization, structure, detail

2. What are the limitations of your style? (4 adjectives)

Fast-paced (not compromising), can be easily put off when something isn't finished quickly, individualistic, sloppy

3. What style do you find most difficult to work with and why?

West-South people can be difficult if deadlines aren't met.

4. What do people from the other directions or styles need to know about you so you can work together effectively?

I value time and efficiency.

5. What do you value about the other ~~3~~ 2 (in my case) styles?

South-style people are very good at being team players, something I need to grow in.

East-style people are also very visionary, which can be very essential to coming up with creative solutions to difficult problems.

Compass Test Results: Brian Tran

Center for Collaborative Education

Quick Test to Identify Your Compass Point: Part I

Are you more North or South?
For each set of words, circle the word that describes you more often than the other one (even though you may have both characteristics at times)

a. Confident b. Helpful	a. Goal-centered b. People-centered	a. Bold b. Supportive
a. Self-reliant b. Understanding	a. Initiator b. Listener	a. Productive b. Faithful
a. Fast-paced b. Easy-going	a. Determined b. Unselfish	a. Self-starter b. Volunteer
a. Independent b. Team player	a. Straightforward b. Patient	a. Opinionated b. Sensitive
a. Decisive b. Diplomatic	a. Results-focused b. Relationship-focused	a. Challenger b. Mediator
a. Assertive b. Non-confrontational	a. Hardworking b. Friendly	a. Doer b. Communicator
a. Competitive b. Cooperative	a. In-charge b. Generous	a. Deadline-driven b. Values-driven
a. Leader b. Loyal	a. Task-oriented b. Peace-oriented	a. Achiever b. Caregiver

Total # of A's circled: 11 (if this number is higher, you're more North)

Total # of B's circled: 13 (if this number is higher, you're more South)

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Quick Test to Identify Your Compass Point: Part 2

Are you more East or West?
For each set of words, circle the word that describes you more often than the other one (even though you may have both characteristics at times)

c. Organized
d. Creative

c. Structured
d. Flexible

c. Quality-centered
d. Idea-centered

c. Logical
d. Visionary

c. Reserved
d. Innovative

c. Planner
d. Spontaneous

c. Perfectionist
d. Free-spirited

c. Traditional
d. Risk-taker

c. Factual
d. Fun-loving

c. Analytical
d. Cheerful

c. Consistent
d. Versatile

c. Serious
d. Humorous

c. Efficient
d. Dreamer

c. Reliable
d. Delegator

c. Detail-oriented
d. Improvising

c. Persistent
d. Imaginative

c. Cautious
d. Open-minded

c. Finisher
d. Motivator

c. Rule-follower
d. Option-provider

c. Systematic
d. Carefree

c. Precise
d. Inventive

c. Persuasive
d. Adventurous

c. Accurate
d. Adaptable

c. Protocol-focused
d. Methods-focused

Total # of C's circled: 9 (if this number is higher, you're more West)

Total # of D's circled: 15 (if this number is higher, you're more East)

Now that you have a number for each of the four types (North, South, East, West)...

This type has the highest number East (this is your Dominant Type)

This type has the second highest number South (this is your Subdominant Type)

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Dominant Compass Point Discussion

Once everyone has chosen a dominant compass point to join, spend 15 minutes answering the following questions as a group.

1. What are the strengths of your style? (4 adjectives)

Flexible, Creative, Friendly, Caring,

2. What are the limitations of your style? (4 adjectives)

Slow, Passive, Unstructured, Indecisive

3. What style do you find most difficult to work with and why?

West-North because they are almost completely opposite

4. What do people from the other directions or styles need to know about you so you can work together effectively?

I prefer to have work assigned to me, instead of being the one to divide the work

5. What do you value about the other 3 styles?

I tend to be more passive, so I value that the other styles are more assertive

Compass Test Results: Chris Liu

Center for Collaborative Education

Quick Test to Identify Your Compass Point: Part I

Are you more North or South?
For each set of words, circle the word that describes you more often than the other one (even though you may have both characteristics at times)

a. Confident
b. Helpful

a. Self-reliant
b. Understanding

a. Fast-paced
b. Easy-going

a. Independent
b. Team player

a. Decisive
b. Diplomatic

a. Assertive
b. Non-confrontational

a. Competitive
b. Cooperative

a. Leader
b. Loyal

a. Goal-centered
b. People-centered

a. Initiator
b. Listener

a. Determined
b. Unselfish

a. Straightforward
b. Patient

a. Results-focused
b. Relationship-focused

a. Hardworking
b. Friendly

a. In-charge
b. Generous

a. Task-oriented
b. Peace-oriented

a. Bold
b. Supportive

a. Productive
b. Faithful

a. Self-starter
b. Volunteer

a. Opinionated
b. Sensitive

a. Challenger
b. Mediator

a. Doer
b. Communicator

a. Deadline-driven
b. Values-driven

a. Achiever
b. Caregiver

Total # of A's circled: 6 (if this number is higher, you're more North)

Total # of B's circled: 18 (if this number is higher, you're more South)

Quick Test to Identify Your Compass Point: Part 2

Are you more East or West?
For each set of words, circle the word that describes you more often than the other one (even though you may have both characteristics at times)

c. Organized d. Creative	c. Factual d. Fun-loving	c. Cautious d. Open-minded
c. Structured d. Flexible	c. Analytical d. Cheerful	c. Finisher d. Motivator
c. Quality-centered d. Idea-centered	c. Consistent d. Versatile	c. Rule-follower d. Option-provider
c. Logical d. Visionary	c. Serious d. Humorous	c. Systematic d. Carefree
c. Reserved d. Innovative	c. Efficient d. Dreamer	c. Precise d. Inventive
c. Planner d. Spontaneous	c. Reliable d. Delegator	c. Persuasive d. Adventurous
c. Perfectionist d. Free-spirited	c. Detail-oriented d. Improvising	c. Accurate d. Adaptable
c. Traditional d. Risk-taker	c. Persistent d. Imaginative	c. Protocol-focused d. Methods-focused

Total # of C's circled: 21____ (if this number is higher, you're more West)

Total # of D's circled: 3_____ (if this number is higher, you're more East)

Now that you have a number for each of the four types (North, South, East, West)…

This type has the highest number C__________ (this is your Dominant Type)

This type has the second highest number B__________ (this is your Subdominant Type)

Center for Collaborative Education

Dominant Compass Point Discussion

Once everyone has chosen a dominant compass point to join, spend 15 minutes answering the following questions as a group.

1. What are the strengths of your style? (4 adjectives)

   friendly, caring, structured, detailed

2. What are the limitations of your style? (4 adjectives)

   rigid, not creative, easily distracted, indecisive

3. What style do you find most difficult to work with and why?

   I find it hardest to work with those with the North personality because they are too headstrong, fast-faced, assertive, and independent. It clashes a lot with how I like to work, which is more group-focused, accommodating, and inclusive.

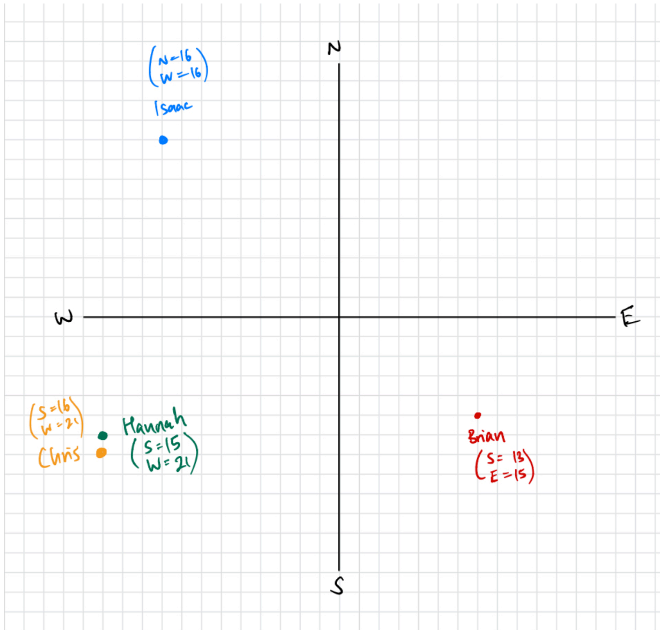
4. What do people from the other directions or styles need to know about you so you can work together effectively?

   They need to know that I like things to be organized and that everything has a structure. I also like things to be done efficiently.

5. What do you value about the other 3 styles?

   I value that the other styles can be assertive, decisive, creative, spontaneous, and competitive.

1. Group Initial Reflection



Looking at the distribution, our team naturally operates by complementing one anothers' strengths. Other than an overlapping West-South, our team is balanced with three of the four quadrants being filled. Having such diversity in the group is beneficial as each members' strengths are able to fill in for the weaknesses. Though there is no one in the North-East quadrant, we have a member in the North and another in the East so their collaboration will hopefully fill in that gap. In terms of our similarities, three out of the four of our members are South; this means that harmony and communication is a shared value among a majority of the group. This is beneficial for complex projects where collaboration is vital.

There are many strengths in our group's work style due to the diversity around the compass. Isaac is equally North as he is West so he exhibits the strengths of both North-West and West-North. According to the dominant-subdominant chart, the North-West person is assertive, decisive, structured, detailed, and organized. Similarly, the West-North person embodies the same characteristics but is also fast-paced instead of organized. Chris and Hannah are both West-South where friendliness, care, structure, detail, and organization are exhibited according to the dominant-subdominant compass. Detail, structure, and organization are commonalities between West-North and West-South. This is beneficial for aspects of the project where details are critical like the technical drawings. Brian is East-South which is described to be flexible, creative, friendly, caring, and cooperative according to the dominant-subdominant chart. East-South and West-South hold friendliness and care in common. Group harmony will be prioritized and this is a strength as communication and being on the same page is crucial for long term projects.

Being diverse in work styles can be a limitation at times despite the advantages it has. With such diversity, it can be easy to feel tension when members in the group are divided between North and South and also East and West. North desires for things to be done at a fast pace but South prefers to focus on detail and take it slow. East is more flexible, creative, and has a big picture outlook while West has a more rigid and detail focused approach. These differences in the approach to how the project should be completed could cause strain in the group because the speed at which we work and the areas we consider important to focus on are different. North-West and East-South are also on the complete opposite sides of the compass so their outlook on the project is the opposite. This will hopefully not be too big of an issue thanks to having two members in West-South which is the balance of the two

2. Individual Reflections

Chris Liu

My dominant compass point is West, with 21 points in that direction. I am detail-oriented, a careful thinker, analytical, organized, focused, logical, exact, and structured. I make sure I am clear on all the details before I start the project, otherwise, it is easy for me to become disorganized, distracted, and disoriented. I saw this style emerge positively when I was able to finish part of design quickly once I had all the information I needed. A downside was that I could not meaningfully start until I had all those details, so I felt a bit useless just waiting for information from my other teammates.

I found the North style most difficult to work with. They are assertive, impatient, fast-faced, decisive, and competitive. They work much too quickly for me, as my second-most dominant style is South, which is more slow-paced, non-confrontational, and patient. It would sometimes be hard to keep up with them and what they were asking for, as they tend to take leadership of the group. There weren't any big interpersonal conflicts, but we did struggle with divvying up the work. To navigate this, we each went over our strengths and skills—what we know we're good at—and split the work up as evenly as we could.

The most important thing about effective collaboration is taking time to understand and appreciate each direction for their strengths, weaknesses, and what they bring to the table. Every person has a little bit of each direction in them (unless they are on the extreme end of the spectrum), which means they have the capacity to embody certain traits of each direction. By understanding and learning about each direction, we can come to agreements that work for everyone.

Again, there were not any specific instances that caused tension within the group, but rather we learned how to work with each other and navigate the different styles. It was resolved by just being able to talk to one another and understand how each person operates and works. Moving forward, we will go over the project details, timelines, and deadlines as a group and ensure to assign tasks accordingly so that there is no confusion and everyone is clear on their tasks. We will also continue to have weekly meetings to report on our progress, ask questions, and help each other on areas we are struggling with.

Isaac Kim

My dominant Compass Point is North/West. I had an equal score for both North and West, which means I embody the characteristics of both: assertiveness, decisiveness, structure, detail, organization, and fast-paced nature. My desire for structure in the project pushed me to set up a project timeline with designated subtasks and member assignments. This helped to clarify who would be responsible for what and also kept us on track with completing things on time. My attribute of organization also inspired me to transfer my BlockPad (alternative to MathCad) calculations to Excel to have a cleaner UI when viewing calculations. This transfer was uncomfortable but in the end it was worth it because it cleaned up and shortened the beam calculations significantly. Although most of these attributes helped me to complete this project well, I found myself struggling with being “fast-paced.” When I work on individual homework assignments and projects, I tend to finish things quickly, refusing to correct small details even when I know them to be wrong. I felt the temptation to do the same for this group project, but I knew that wouldn’t be right, especially for a group project. I realized that although my desire to remain on track is a good thing, I shouldn’t allow this tendency to come at the expense of the quality of my work.

Thankfully, I didn’t find any member of my group difficult to work with. The only thing I could think of is how most of the group members like Hannah and Chris are more detail-oriented than I. Their review of my calculations forced me to often redo my designs. Then I would start to notice things that were incorrect in my calculations, causing me frustration since this clashed with my desire to get things done quickly. But honestly, I think it was a good thing because it taught me to balance out a fast pace with high-quality work by focusing on the details.

What do members from different directions need from each other to collaborate effectively? This first project showed me the value of clear communication. This looks different for different people. I’m used to texting long paragraphs, but noticing how some of my group members preferred quick phone calls or video calls, I decided to call more. I found how helpful this was when working on drawings or details that are much more easily explained via call, rather than text.

One instance where a teammate’s different work style caused tension is Hannah’s schedule. She is busy throughout the week with homework and club responsibilities, and she goes back to Orange County every weekend to serve at her church. It wasn’t just Hannah’s schedule, obviously, but we noticed how it was difficult in general for all of us to find a time to work at the same time and have a designated meeting since everyone is so busy. The way we resolved this tension is to have a short meeting in the beginning of the week and to text, call, and FaceTime for additional communication throughout the week. One thing that we’d do differently is to read the project statement and information altogether so that we can start off on the same page.

One concrete thing that I will do differently in my next team project is to spend more time working through initial hand calculations and hand drawings before moving into Blockpad or Excel, or AutoCAD. I find that jumping into the software immediately causes the concepts to remain murky in my mind. Toward the end of Project 1, I found quick calculations and drawings to be even more helpful. Another thing that I will do differently in the next team project is to double-check my calculations then triple-check them. During this project, I was too lazy to double check sometimes and that cost me precious time later down the line. For example, I designed the reinforcement spacing for Girder 7 instead of Girder 8 in the morning and only realized my mistake after I had sent the details to be fully drawn. Of course, I was able to fix it but it could’ve been avoided if I had done a simple check right after.

Hannah Ahn

West is organized, detailed, and logical. As my dominant Compass Point, this was helpful when figuring out the slab reinforcement sizing and locations because each slab has different demands and requirements that vary from the others. Being detail oriented was helpful for these details. A disadvantage to being so detailed was that the task took a long time as west is exact but careful when making choices so the work is slow paced. This was a good trait to have despite the difficulty in time because I was able to catch a lot of errors and mistakes that I had made as I continuously checked my work.

East was most difficult to work with because this is where I am the least inclined. I find people who are free-spirited to be difficult to work with at times because I like to know who is responsible for what and when things will get done. Continuous communication helped to eliminate this uncertainty so it was not an issue for our project team. Our team was structured in our approach to solving the problem statements and organized in our work so there was not much unwelcome spontaneity to work around. Rather, everyone knew what they were responsible for and we were

With differing compass directions, clear communication between team members was important so that personal needs and thoughts could be clearly conveyed. Our team was luckily not too different from one another so there were not many difficulties in working together and navigating the teamwork. I am grateful that each of my team members were committed to each of their responsibilities and were consistently present throughout the design process. Overall, I think clear communication about responsibilities and clarity throughout the project allowed us to collaborate effectively.

Our team opted to split up the work where one member does the first half of the design and another picks up the second half. There was difficulty in the process of completing things because team members were dependent on each other to even begin their responsibility. This did not cause tension but there was some lack of clarity about the process of the project that required some intentional communication halfway through the process. Communication was the key to this confusion.

For our next project, more thought and consideration as to how responsibilities and roles need to be divided is needed at the beginning of the project before any work is done. Making sure all our team members are on the same page and are clear about what the process of the project will look like is necessary for us to know what kind of timeline to expect and also so less confusion arises.

Brian Tran

My dominant Compass point is East. The characteristics of East are speculative thinker; Idea-centered; Creative; Innovative; Flexible; Visionary; Spontaneous; Enthusiastic; Free-spirited. The specific moments during this project did you notice this style emerging negatively was that East don’t get a project started until they are clear about the final product, which caused me to work slow. The specific moments during this project did you notice this style emerging positively was that East are free-spirited so I was open to any parts of the project assigned to me.

The style that was most difficult to work with was North. The characteristics of North are A leader; Goal-centered; Fast-paced; Task-oriented; Assertive; Decisive; Confident; Determined; Competitive; Independent. I found that the North worked too fast paced and I always felt behind and was playing catch up. There wasn’t a need to navigate this problem, because everyone in the group was understanding and never rushed each other to finish work and let each other work at our own pace.

Members from different directions need communication from each other to collaborate effectively. Some group members worked a lot faster, while others took their time and worked slower. By communicating our different work styles we were able to efficiently work together on the project.

There were no instances where a teammate's different work style created tension. There was no need to resolve it because we understood everyone had a unique style of work and brought something different to the table. Something I would do differently is try to respond faster to messages which would help us get started on different parts of the project faster.

One concrete thing I will do differently in my next team project as a result of this reflection is try to work faster. I was assigned to do the yield line calculations and since we learned about it later on in the project, it took me a while to actually get started on the calculations. Getting things done faster gives more time for my team to check my work and if they catch any mistakes we are not rushing to correct them at the last minute.