SOFTWARE BASED ANALYSIS, DESIGN AND MODELING OF A MULTISTORY BUILDING

FINAL YEAR PROJECT UG 2017

BY

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Certification

This is to certify that the Thesis titled

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has been accepted towards the fulfillment of the requirements

For Bachelor's in Civil Engineering

____

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DEDICATED

TO

OUR BELOVED PARENTS

FOR THEIR UNWAVERING SUPPORT

AND ENCOURAGEMENT

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1. Abstract

Analysis design and modeling of a multistory structure is a design-oriented project. The aim of this project was Structural design and detailing of multi-story residential/commercial building using essential civil engineering software. The First software used was AUTOCAD. It was used to have a layout of the building including all the architectural maps and all the components of building which were to be assigned. ETABs was used for the analysis and design of the building. First the grid was assigned and then all the components were defined. The live load and dead load was calculated and then all the components were assigned. Finally analysis and design was done and the loads were collected which then were to be applied on the foundation for its design. The codes (name of codes) were used as a reference material for design. All the detailing was done using CSI details and finally the foundation was designed using CSI SAFE.

ACKNOWLEDGEMENTS

We are thankful to ALLAH ALMIGHTY for all his blessings and bestowing us with the strength and skills necessary for the task. We would like to show gratitude to Sir Ather Ali for providing us with the opportunity to perform this project and guide us in the completion of the project. We would like to thank our Head of CIVIL Department of SCEE and Principal of NICE whose support has been crucial to us for the completion of our venture. We would like to thank our teachers who helped us with dedication and commitment at NUST. We would also like to acknowledge the support of the Department of Civil Engineering for providing us adequate resources and work space within the premises of university to accomplish our task efficiently. We are also grateful to our families who have supported us morally and financially at every step. Last but not the least I would like to thank my friends especially M.Shazeb Khan and Uzair Azhar for their unconditional support during the tenure of our degree.

2. Introduction

The purpose of this project is to use our civil engineering knowledge and apply it by learning different civil engineering software like ETABS, SAFE, AUTOCAD, REVIT and 3Ds max and using them to create an economical and industry level design with complete structural drawings of a multistory building. This project will help us be familiarized with all the codes which were used during this project to get us ready for industrial level design. Using all the software we have all the design steps required to perfect a multistory building design.

3. Background

To select our multi story building we searched for a building which has a higher level of complexity compared to usual multistory residential building. After some research we selected Kaur Complex for our project which is in Peshawar, KPK. Kaur Complex is a dedicated project for families living in Peshawar which provides a secured gated community with 600+ apartments in total exclusively state of the art international standard apartments and condominiums, shops, and luxury penthouses. This multistory building was recently built, and it contains components like Residential and commercial area within the same floor, Elevators, Penthouse containing swimming pools, Water tank and basements. We referred to building codes for our design consideration. We started our project using ETABS. ETABS is the revolutionary ultimate integrated software package used to analyze and design structure. It can be used to design buildings of 1 story up to a skyscraper with variable level of complexity. It was developed by Computers and Structures, Inc. This software was used for analysis and design of our multistory building considering all the components in the design. Using the data from our design from ETABS, we use the software SAFE for our foundation design. SAFE is the ultimate tool for designing concrete floor and foundation systems. From framing layout to detail drawing production, SAFE integrates every aspect of the engineering design process in one easy and intuitive environment. SAFE provides unmatched productivity to the engineer with its truly unique combination of power, comprehensive capabilities, and ease-of-use. Laying out models is quick and efficient with the sophisticated drawing tools or uses one of the import options to bring in data from CAD, spreadsheet, or database programs. Slabs or foundations can be of any shape and can include edges shaped with circular and spline curves. Models can have columns, braces, walls, and ramps connected from the floors above and below. Walls can be modeled as either straight or curved.

4. Methodology:

AUTOCAD:

For Kaur complex we have drawings for each floor including all the details and components. All the dimensions required are in the drawings. We have 2 basements which are used for underground parking. The ramp starts from ground floor and goes to lower basement. Ground floor and the First floor houses residential and commercial area. About 50% area is commercial and 50% is residential divided by a wall. From 2nd floor till 9th floor, the area is residential and on the 9th floor there is a penthouse containing swimming pools and other luxuries. The roof contains Overhead Water tank. The building includes Elevators and stairs. All these components are to be accounted for in design.

ETABS:

First, we will be initializing model and define codes we will be using. The codes used were (ACI 3.18-14

1. **Defining Grid and Story Data:**
   By using architectural plan, we have defined grid. And we have assigned all the floors which were taken from architectural plans. The height of basement is 10.75 and rest of the floors are 11.75. The Elevations are assigned and -5ft is taken for foundation under basement and the rest of the elevations are according to the floor heights.
2. **Defining material:**
   We have defined 4 types of materials. These were Concrete Fc 4000psi, Concrete Fc 3000psi, Steel Gr60, Steel Gr50 for walls we have assigned Masonry of 3000psi. All these materials were assigned as we are using hit and trial method and we will be taking the material accordingly. We modify our material property. The properties of material are selected by ETABS automatically and Unit weight of concrete is takes as 150 lb./ft^2 and the unit weight of Steel is taken as 480 lb/ft^2.
3. **Defining Columns:**
   We have given 3 types of columns. Outside Columns are taken as 30"x30". For interior columns we have selected circular columns for aesthetic purpose with 30" diameter. We use 4000 psi concrete. We modify our stiffness value using ACI 318-19, the moment of inertia taken is of 0.7Ig as they are weak in tension than in compression. Then we modify our rebar. Referring to the code we have selected 1.5" cover and we change reinforcement configuration as rectangular and circular accordingly.
4. **Defining Beams**:
   We have selected rectangular beam of 12"x20". Again, we changed our stiffness modifiers using ACI 319-19 we selected moment of inertia to be 0.35Ig. The Beam was assumed to be unsuitable for torsion, so the value was assigned a factor of 0.01. The cover given was of 2" for both top and bottom bars.
5. **Defining Slab:**
   We selected a 6" shell thin slab as we assume shear stresses to be 0. The stiffness modifiers are taken from the code. Modifying stiffness modifiers from ACI 318-19 we took moment of inertia to be 0.25Ig.
6. **Defining Loads:**
   First, we assigned our load patterns. ETABS calculates Dead load by itself, so the multiplier is 1. Then we have calculated super imposed deal load. All the loads are accommodated including Floor load was taken as 36psf, masonry wall of 9" as 990 psf. Masonry Wall of 4.5" as 445 psf and Concrete wall of 6" as 825 psf. For live load all the live loads ae taken from the code ASCE 7-16 (Enter code table).

After defining all the components, we assigned all the components on the ETABS.

7. **Assigning Frames:**
   In frame we have all the beams and columns. First, we placed our columns using (enter Command). We have all the gridlines we need to map our columns accordingly placing rectangular corner columns and circular columns interior columns. Then we placed our beams between our columns using (enter command).
8. **Assigning Slabs:**

After setting up our frame we place our slabs on our frames. For trial we have taken slabs of a 6”. The opening is left for elevator which follows from basement to last floor. We have left one slab of 7” on roof for support of elevator connection.

9. **Assigning Elevator walls:**
Walls of Elevators were created using (enter command). We enter all the dimensions required to create shear walls. There is one passenger lift and one cargo lift.
10. **Assigning staircase:**
We have added Landing of the staircase in the form of a resting slab by introducing a reference plane to add a slab in between 2 floors. Next, mini ramps were added from one landing to another.

Assigning load

In assigning the loads the load was applied on slabs, Live load and superimposed dead load of floor finishes was applied on slabs, and load of walls was applied on beams manually while the dead load calculation of all members was done by CSI Etabs itself. Those labs which lie in a residential part of the building, the residential live load was applied on those buildings, similarly, those slabs which lie in the commercial part of the building live load was applied on them accordingly. Transference of load from slabs to beam and beams to the column was done by Etabs.

Analysis

Then analysis of the building was performed by CSI Etabs, in analysis of the building Etabs produced the SFD and BMD of the members of the building and calculated the forces that were being applied to the building and the reactions which were resisting the loading. In this way, all the applied loadings and reactions were obtained.

Design

In the design phase, the first stage frames were designed i.e., beams and columns on the Etabs. And in the results, Etabs produced the rebar percentage of top and bottom bars separately of beams.

Similarly, the design of columns which was done by the Etabs obtained the amount of steel needed in columns.

After the design of the frames, the design of the slab was started and performed by the Etabs, the rebar percentage needed for the slab was obtained, and then the design of the shear wall was also performed on Etabs.

Design of Retaining wall

Retaining wall cannot be designed in Etabs, retaining wall was designed manually on excel sheet considering all the parameters of design, to verify the design all the checks were applied on the designed retaining wall, all the checks were passed indicating that design was appropriate.

SAFE SOFTWARE PART

Results of analysis produced by Etabs were imported into this software and the design of the foundation was started. The material for the foundation was defined in software for designing purpose which includes the strength of concrete in terms of Psi, grade of steel, and then the slab for the foundation which is raft foundation was defined to the software. We initially started with a small thickness of slab of raft foundation and kept on increasing the thickness/depth until the design was satisfied, and then applied both the checks required for foundation design which were settlement check and bearing capacity check and punching shear check all of which were satisfied against the design, while the allowable settlement that was 50mm from ACI-318 and the building capacity of soil that is 1800 lb/ft^2 and the factor of safety equal to 3 was known from the soil profile. The punching shear check was the problem because the foundation was failing in punching shear again and again, to overcome this failure, the depth of the foundation was increased and extended with an offset a bit more than the outer line of the column. And the punching shear value for all the columns was less than 1, the check was passed. SAFE software generated the results for a foundation giving the results in in2/ft.

Detailing

After the designing phase detailing of the members was performed, detailing of each slab column beam elevator and the foundation present in the building was prepared by the software. In the detailing generated by the software, the number of bars used as reinforcement and the number of bars used as stirrups along with the spacing required for each member on each floor were obtained. As the floor changed, the loads on each member was also changed so the design and software-generated detailing of each member was obtained according to its load applied and members capacity to bear it. This means the software did not design all the members for the same load.

Excel sheets

Design excel sheets were also prepared.

- Retaining Wall
- Slabs

All the ACI checks were also applied on those manually designed members, to counter verify the pertinence of design.

5. Results.

➢ Column

The column layout

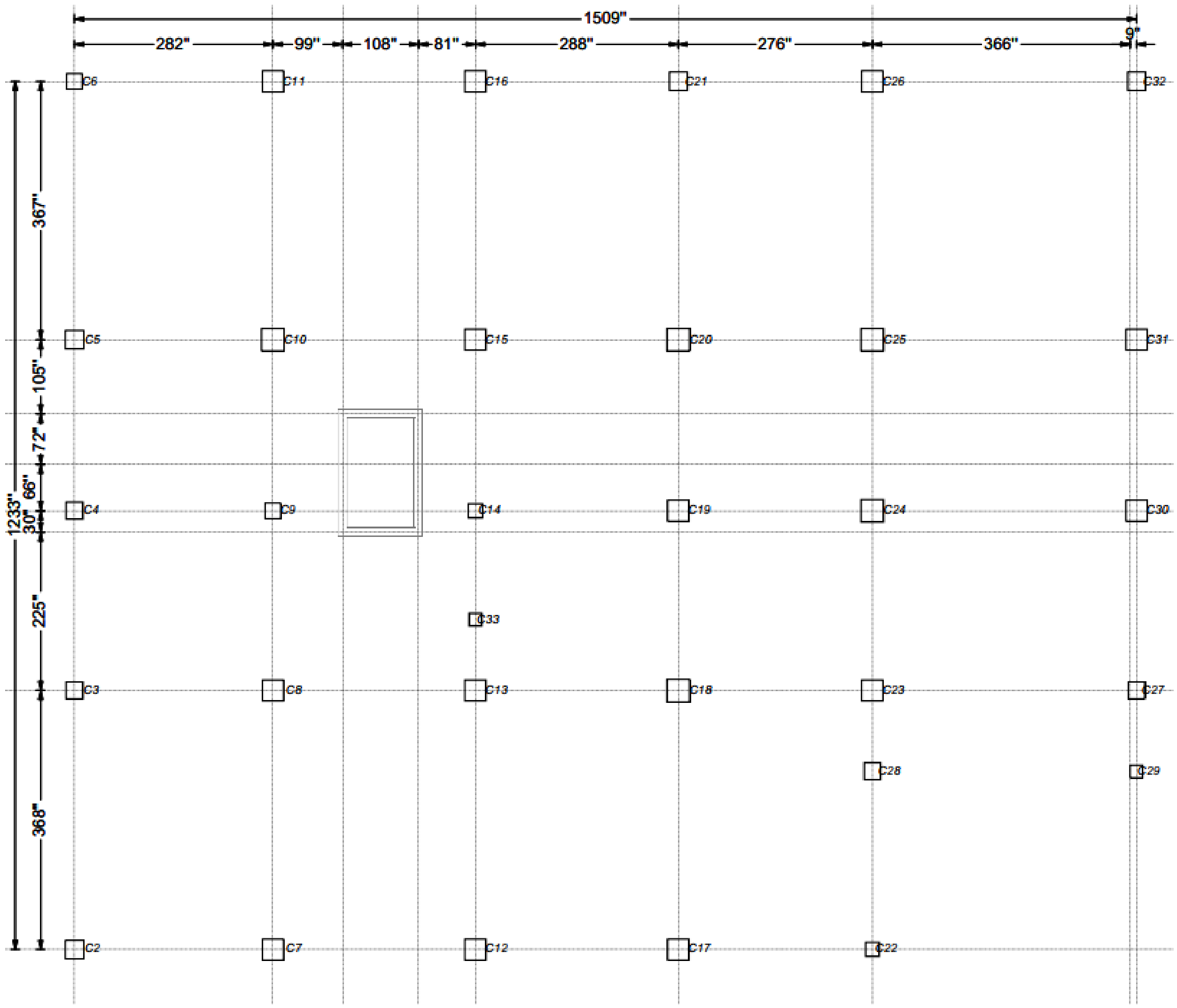


Figure 1

Complete Detailing of one column

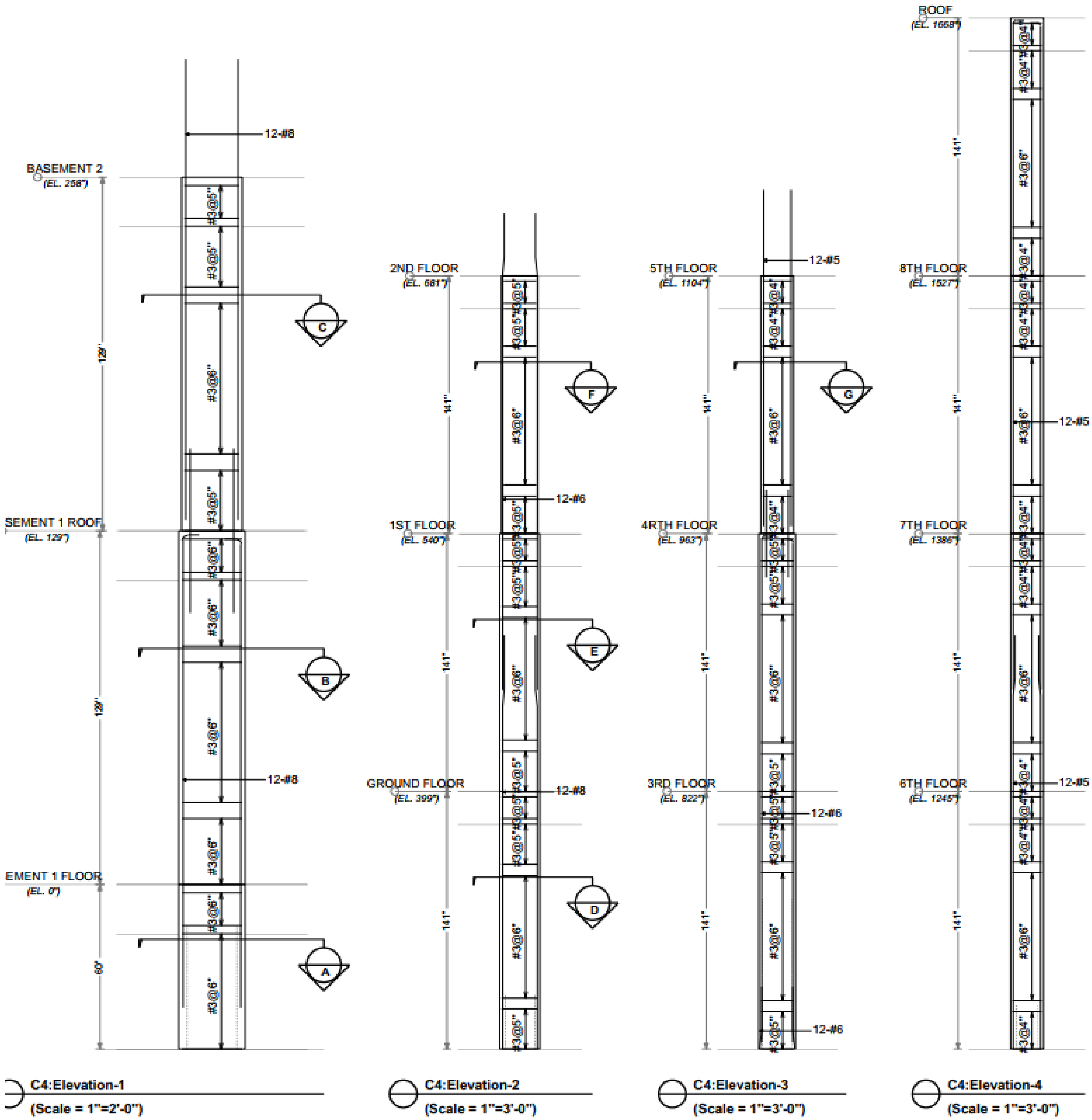


Figure 2

As we can see there are **A, B, C, D,E,F and G** sections in which detailing, and dimension of our column is different.

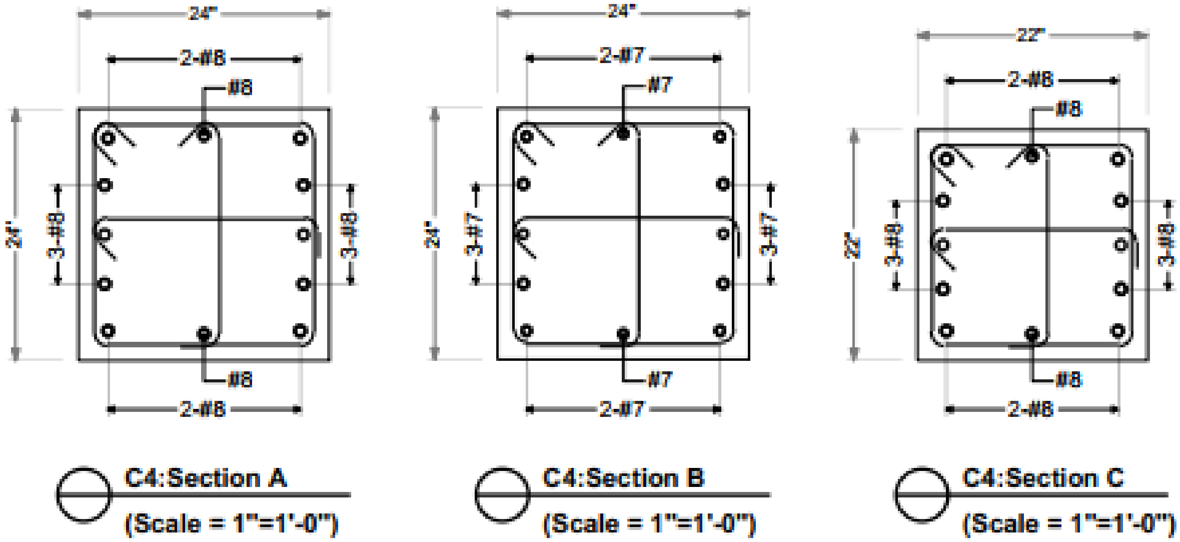


Figure 3

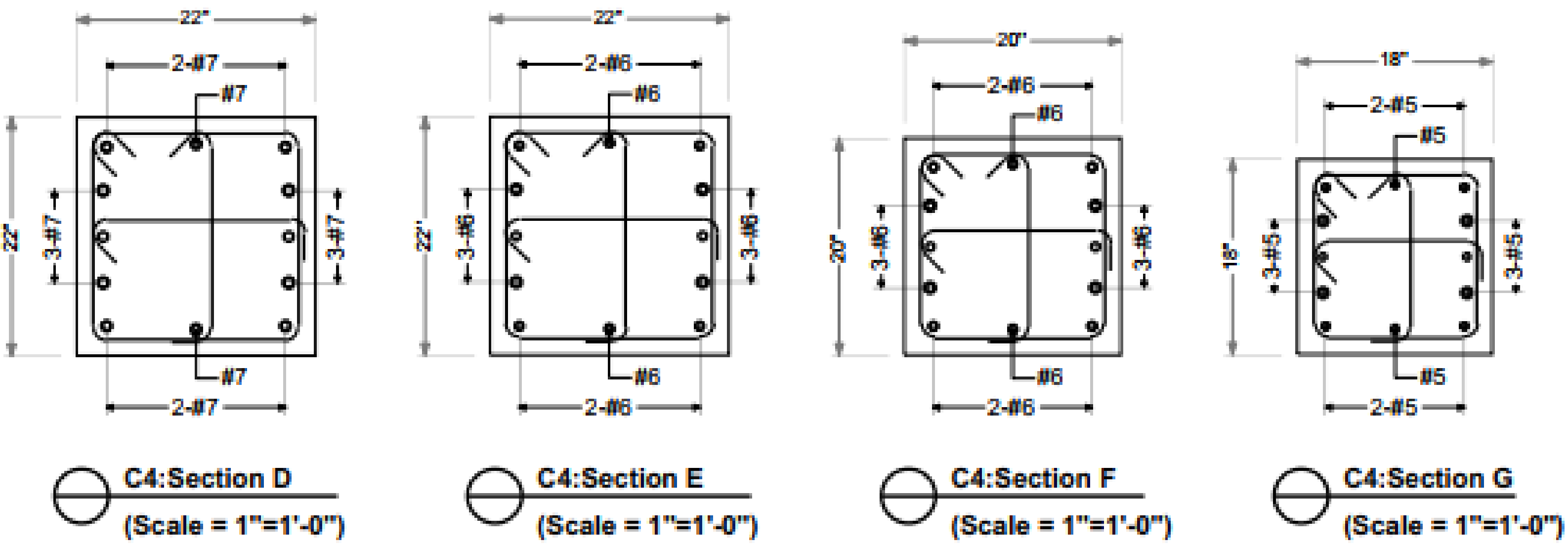


Figure 4

➢ Beams

Beam Framing Plan

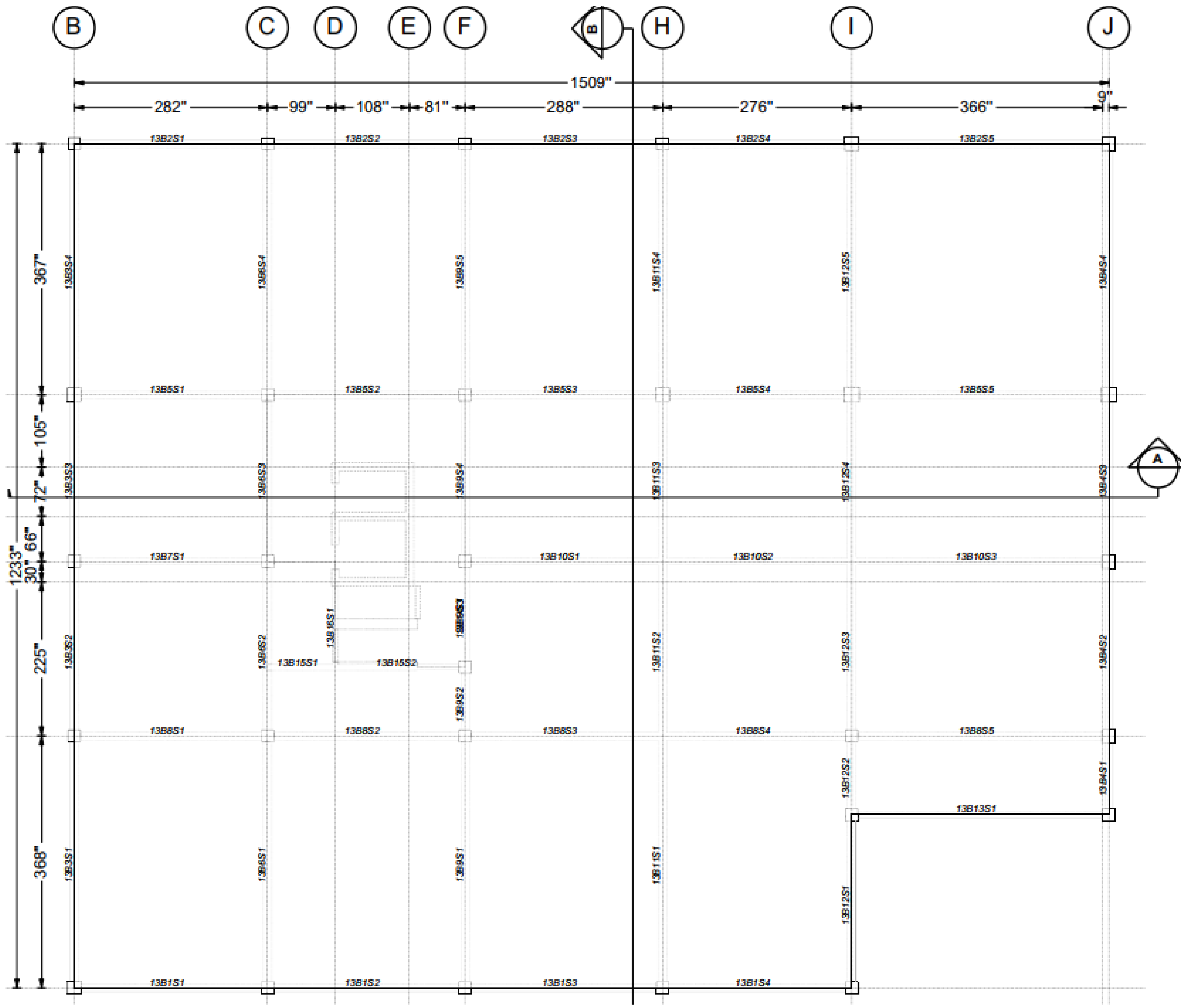


Figure 5

Typical Concrete Beam Elevation

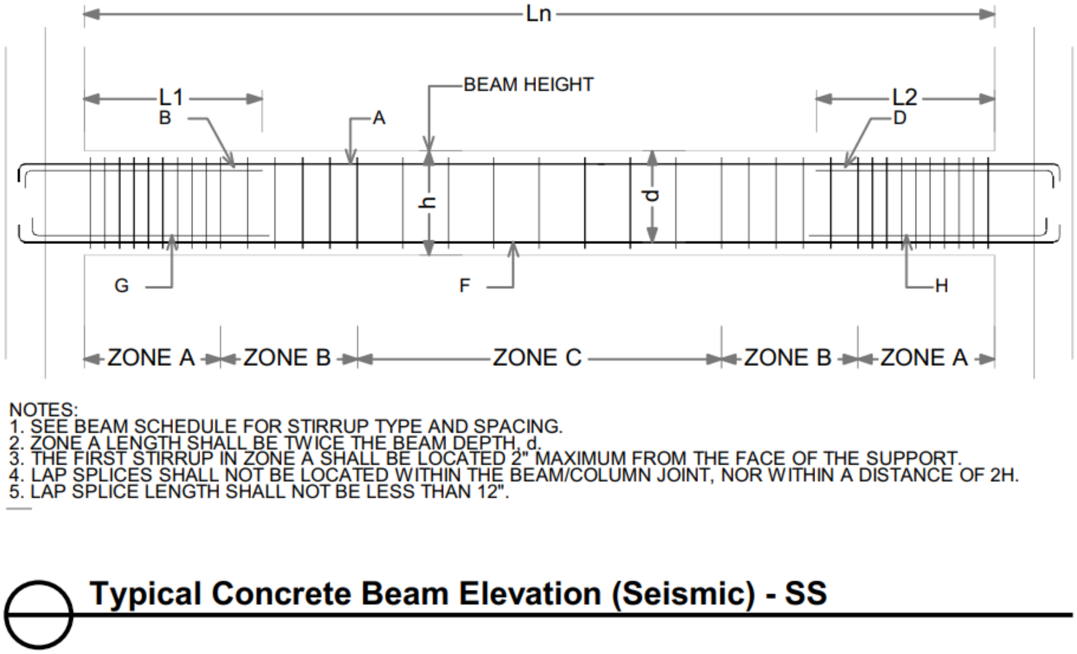


Figure 6

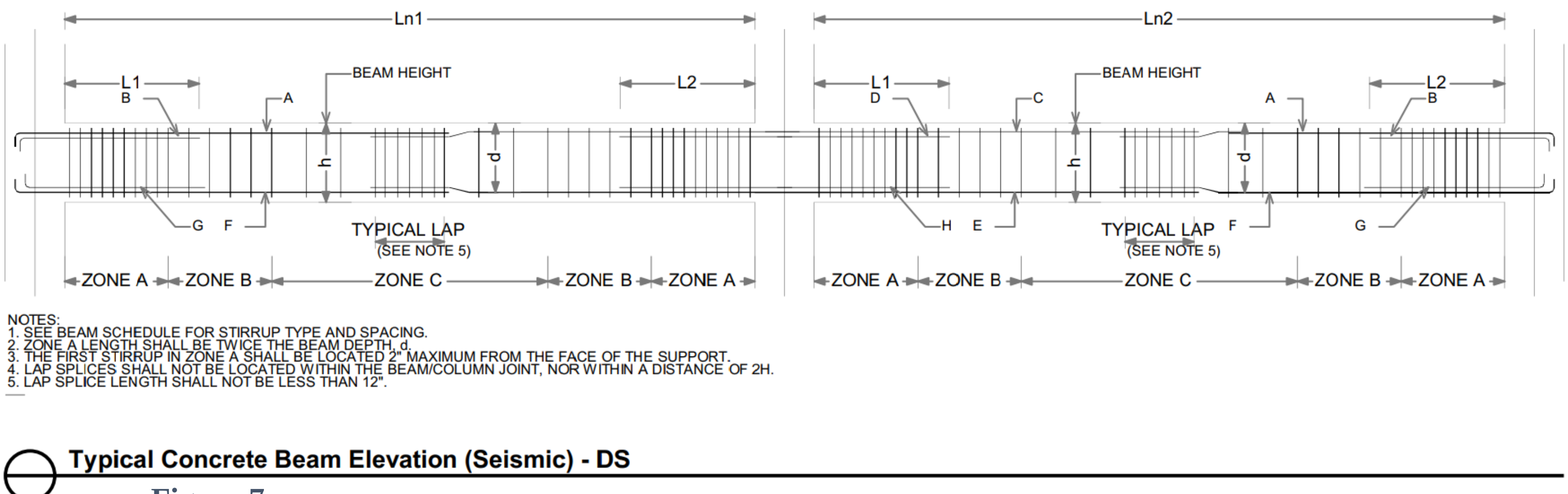


Figure 7

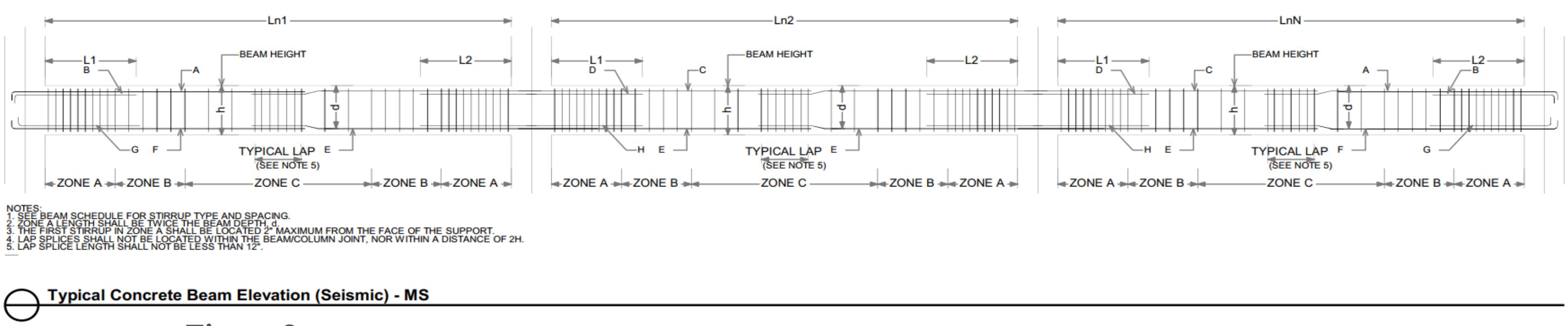


Figure 8

Complete Detailing of one beam

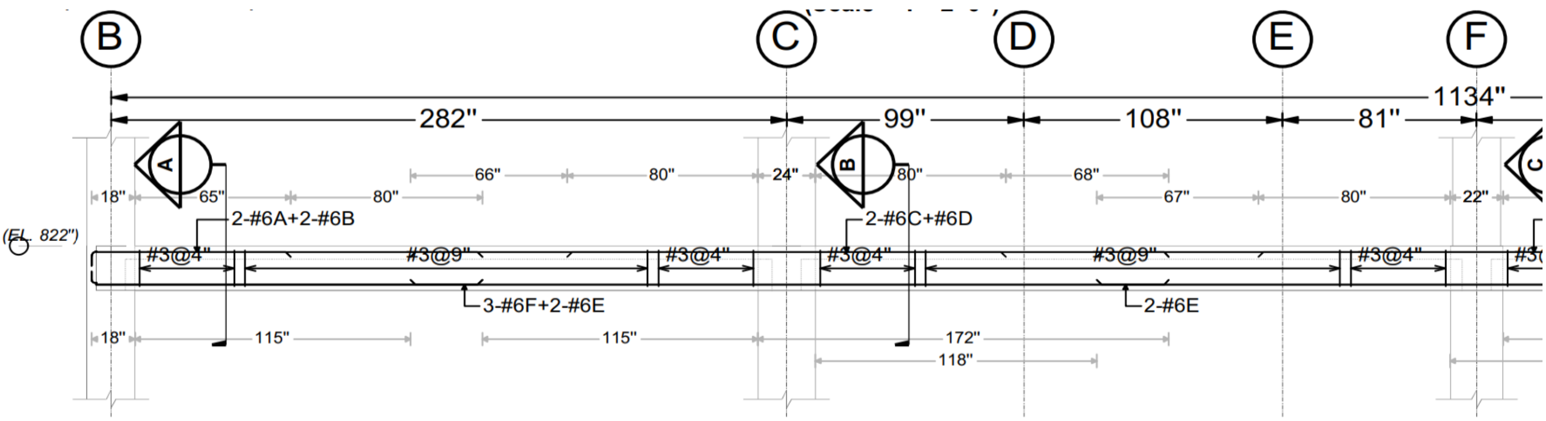


Figure 9

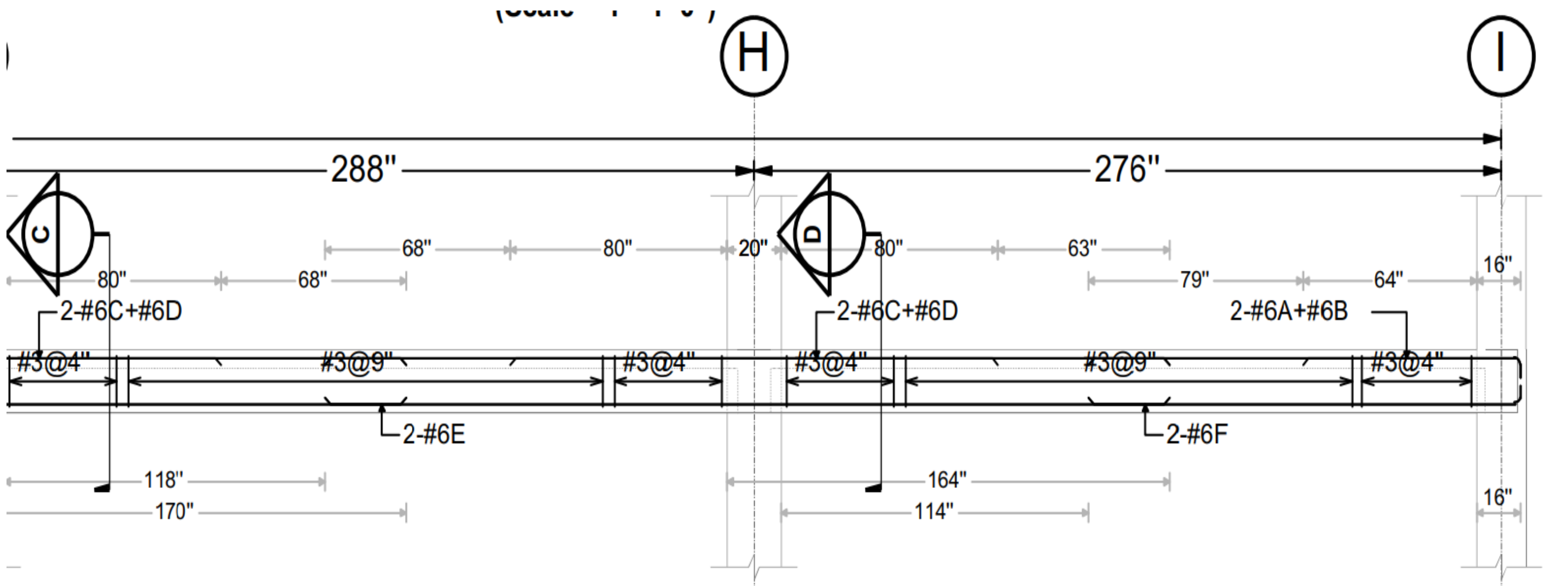
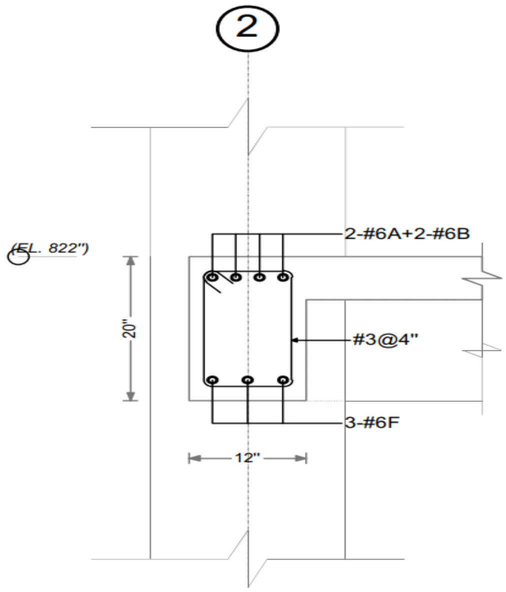
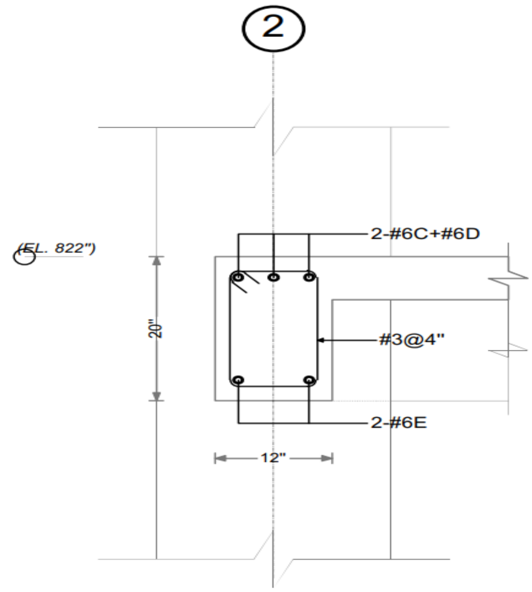


Figure 10

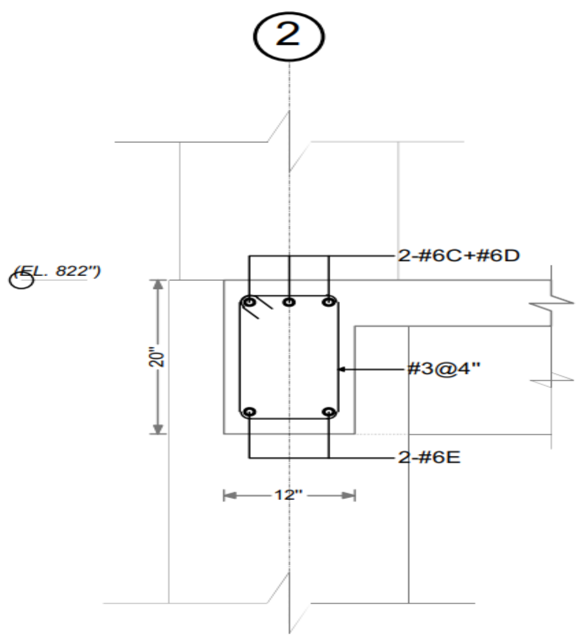
Detailing of sections



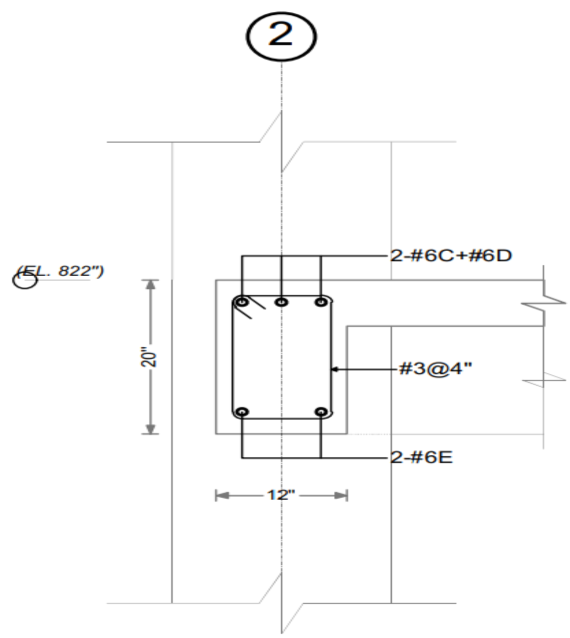
7B1:Section A
(Scale = 1"=1'-0")



7B1:Section B
(Scale = 1"=1'-0")



7B1:Section C
(Scale = 1"=1'-0")



7B1:Section D
(Scale = 1"=1'-0")

Figure 12

Figure 11

➢ Slab

We Designed slab by using strip-based Method.

Floor framing plan of a typical floor.

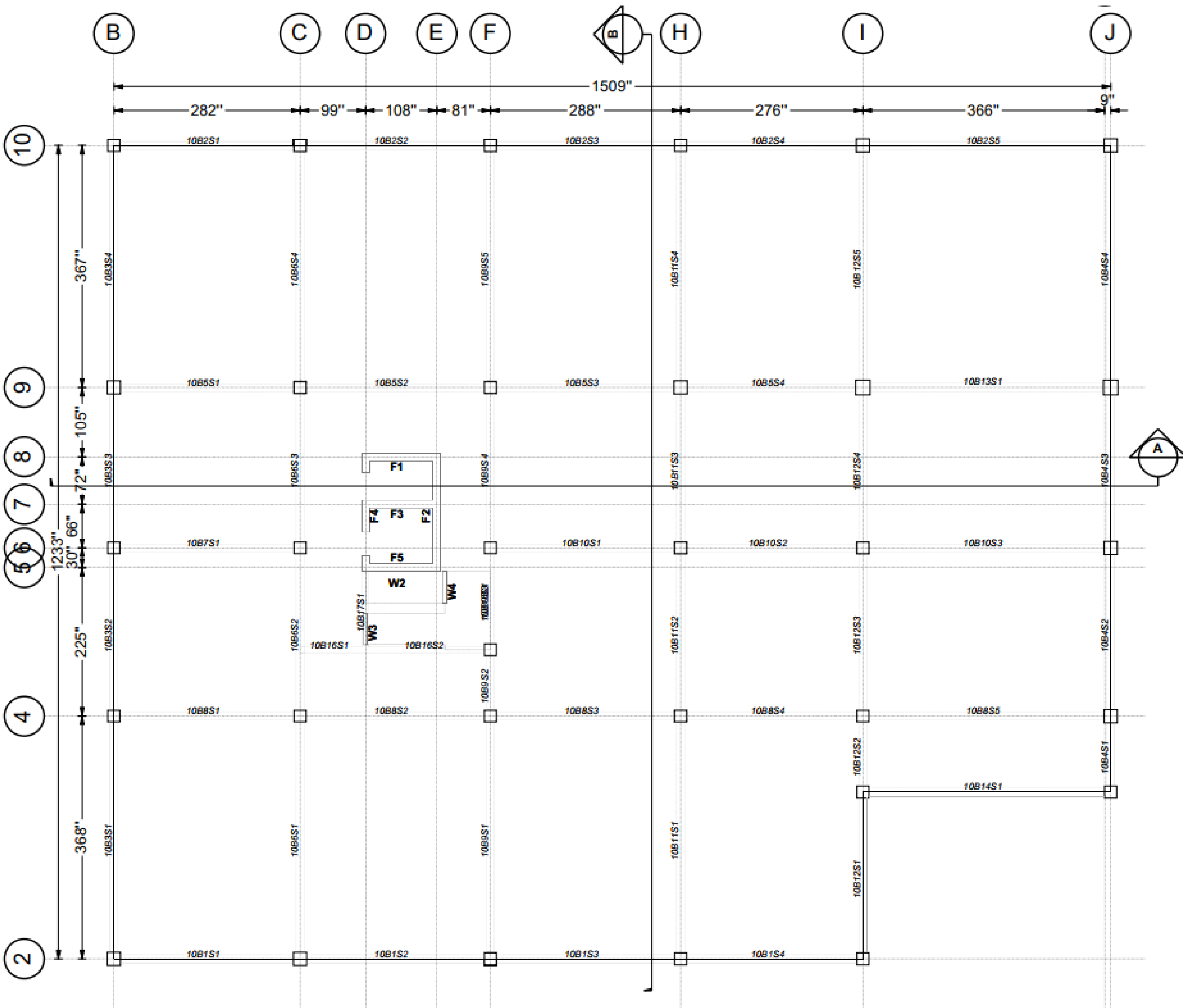


Figure 13

Close Detailing of one Section

1) Slab Top Rebar Plan

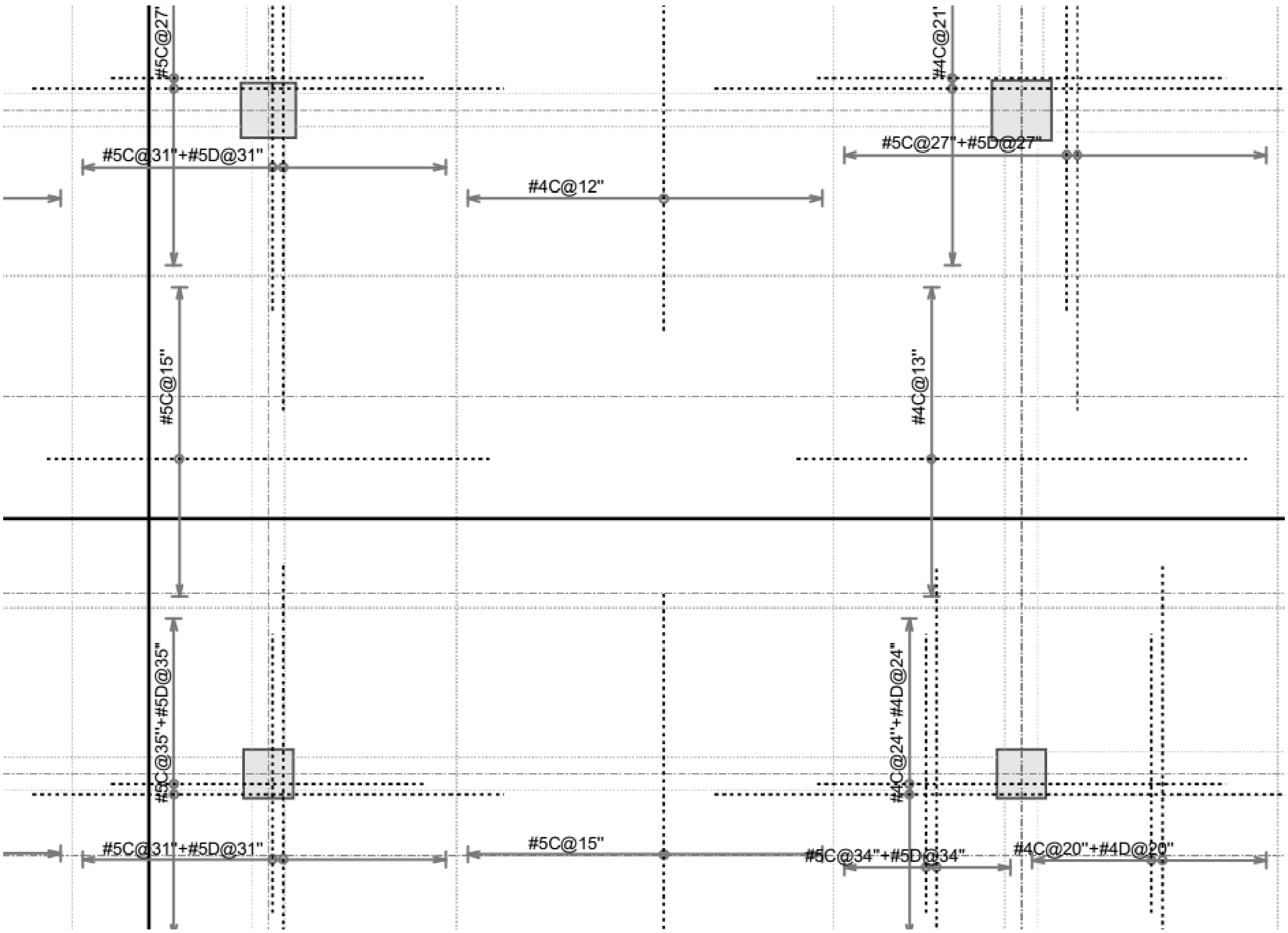


Figure 14

2) Bottom Rebar plan

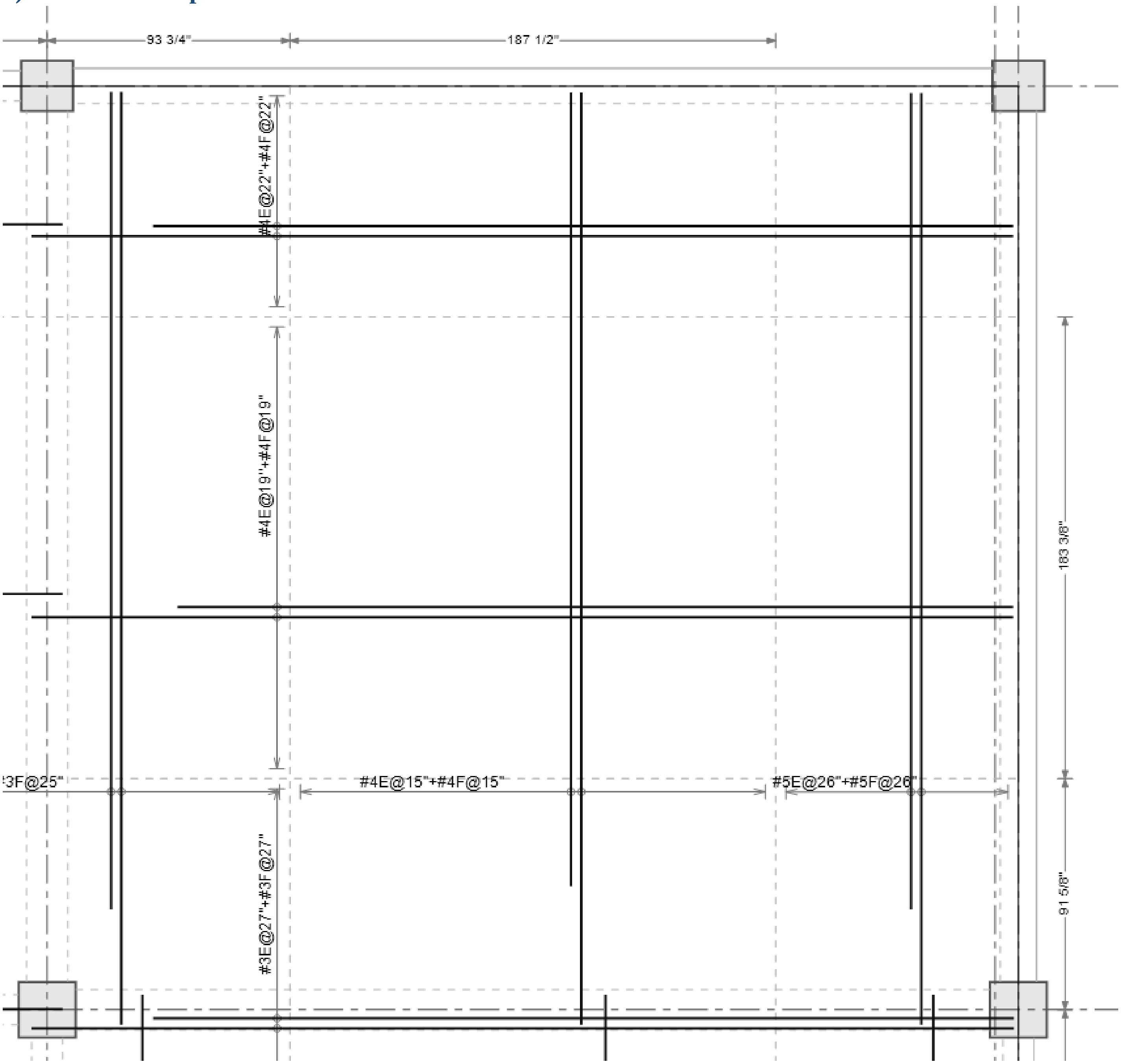


Figure 15

3) Slab Total Rebar plan

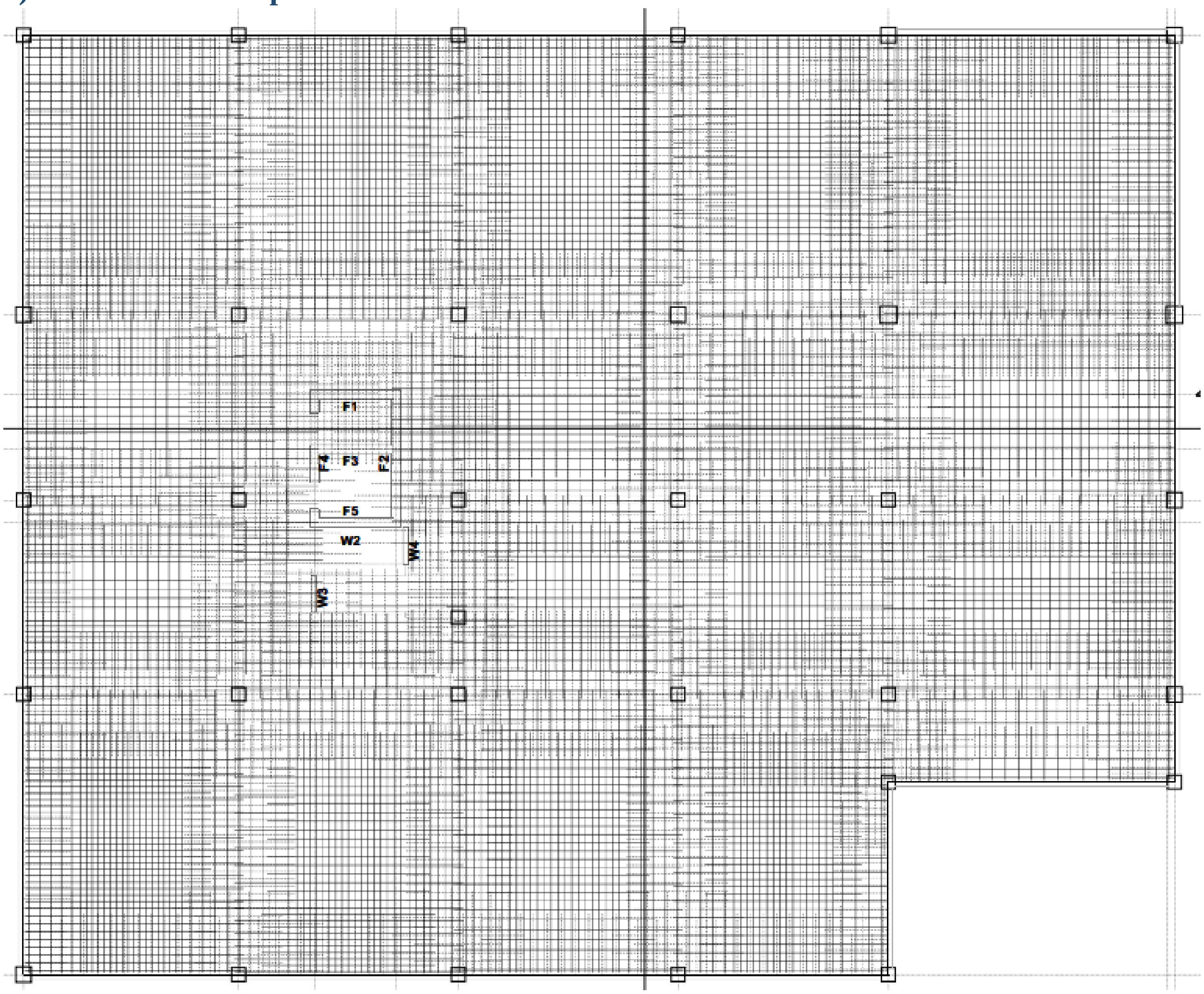


Figure 16

➢ Elevator

Detailing of Single Section

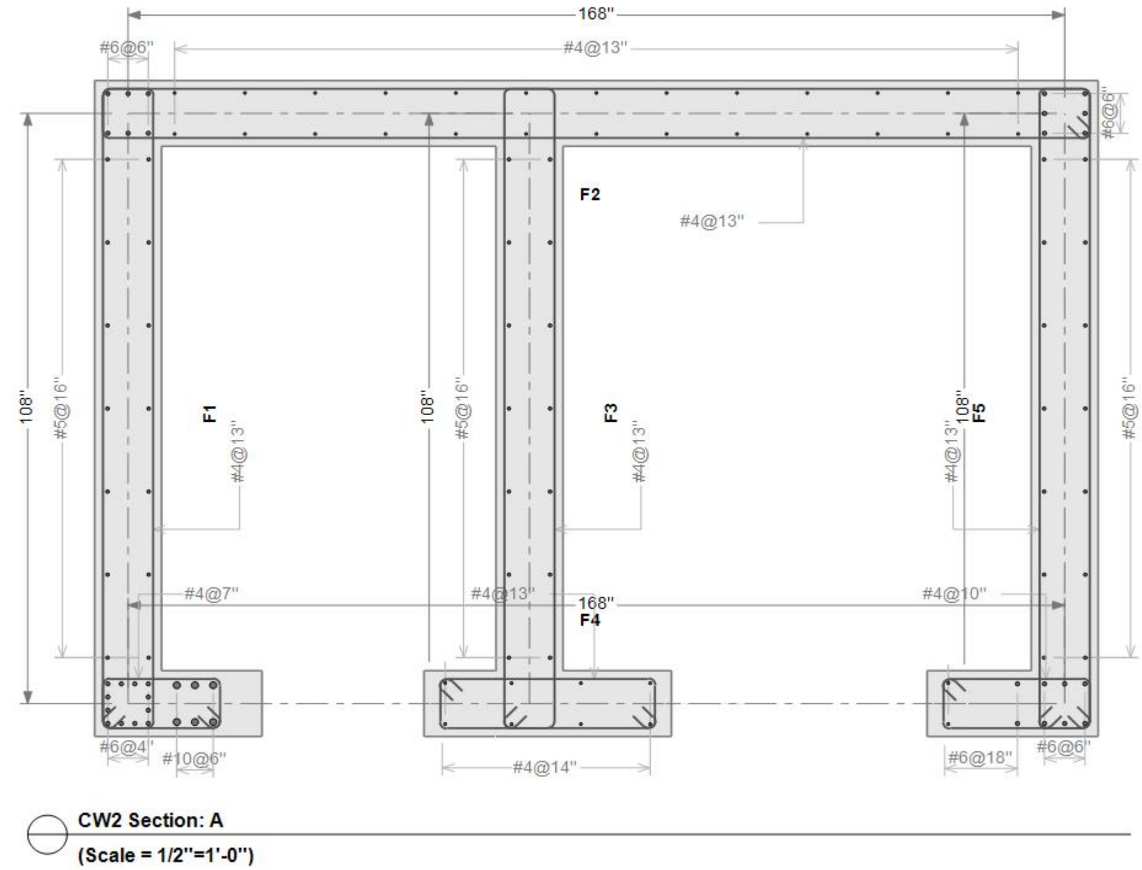


Figure 17

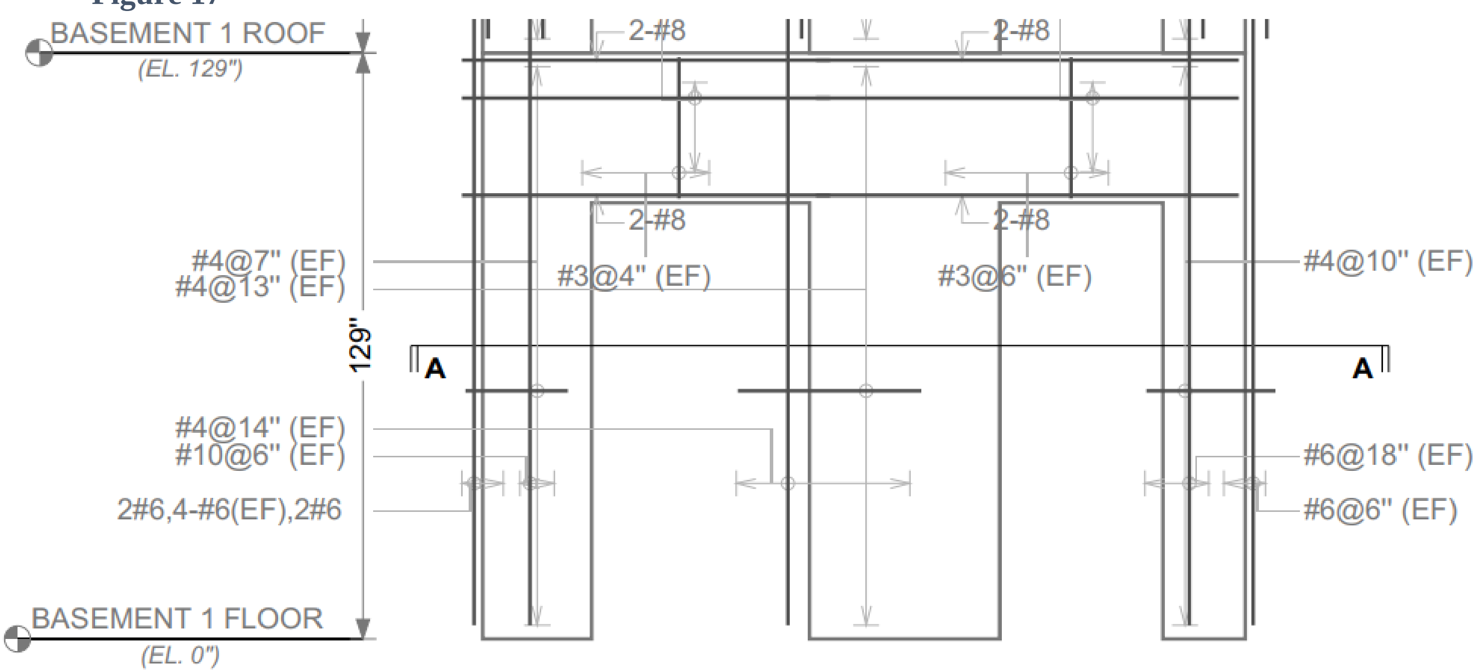


Figure 18

➢ Raft Design

✓ Checks

Settlement Check

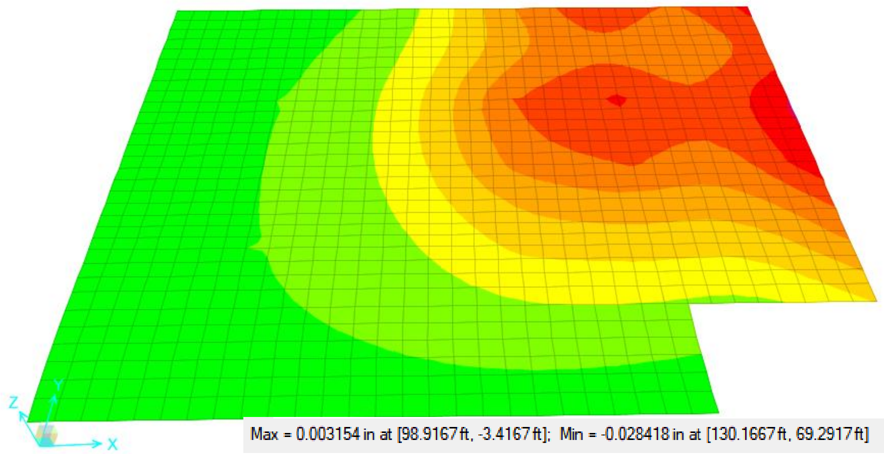


Figure 19

- ✓ 0.0284”<2”
- ✓ **Passed**

Bearing Capacity Check

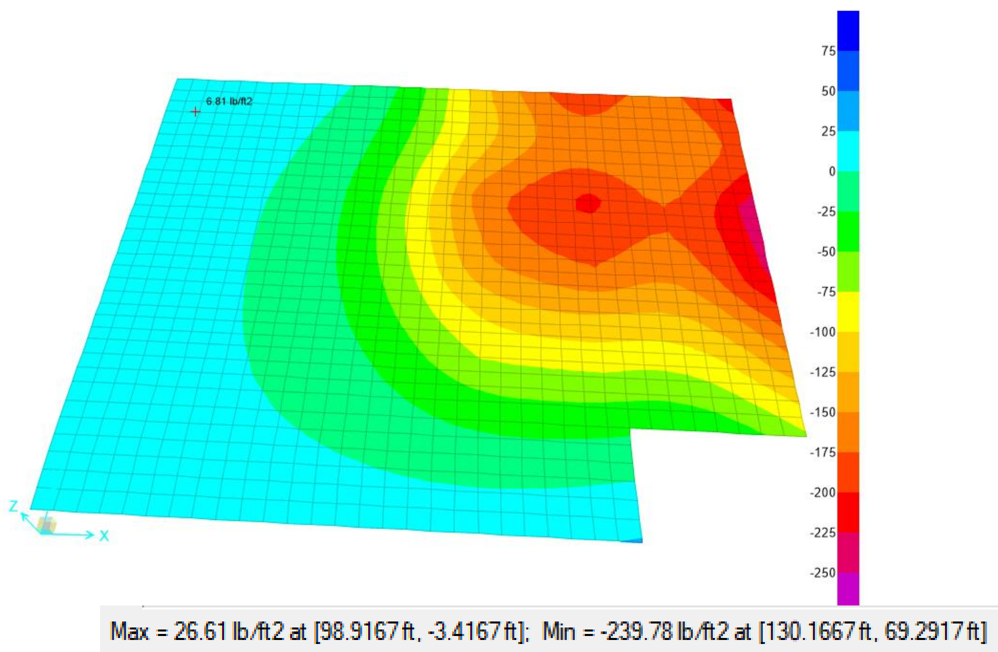


Figure 20

239.78<1800

- ✓ **Passed**

Punching Shear Check

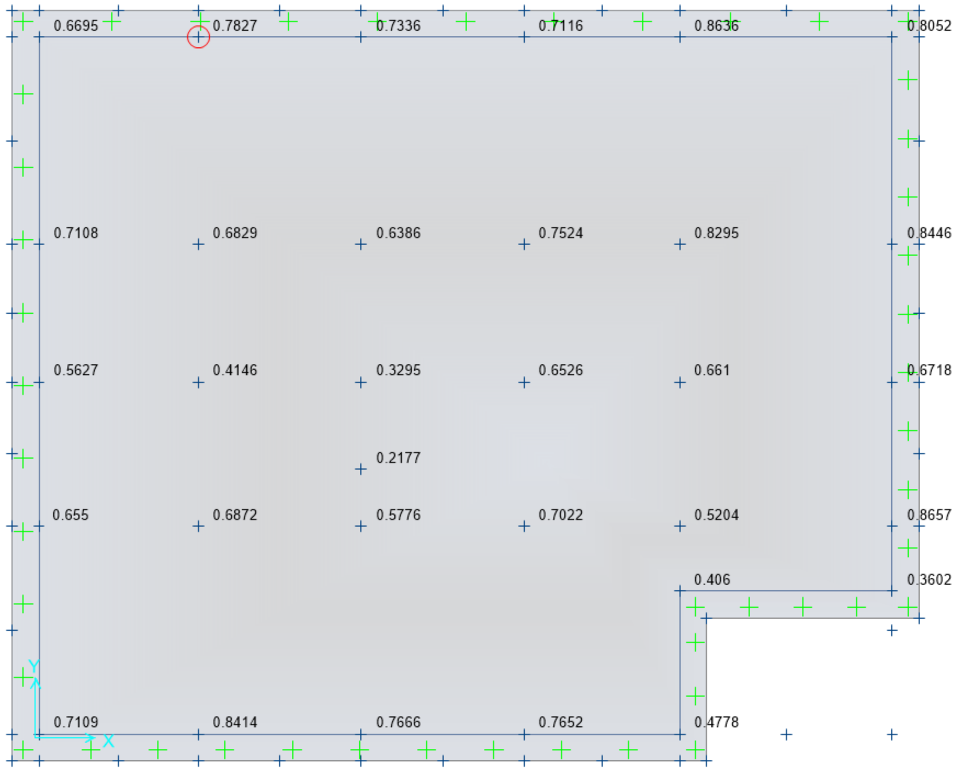


Figure 21

- ✓ **Passed**

Final Rebar Plan of Raft

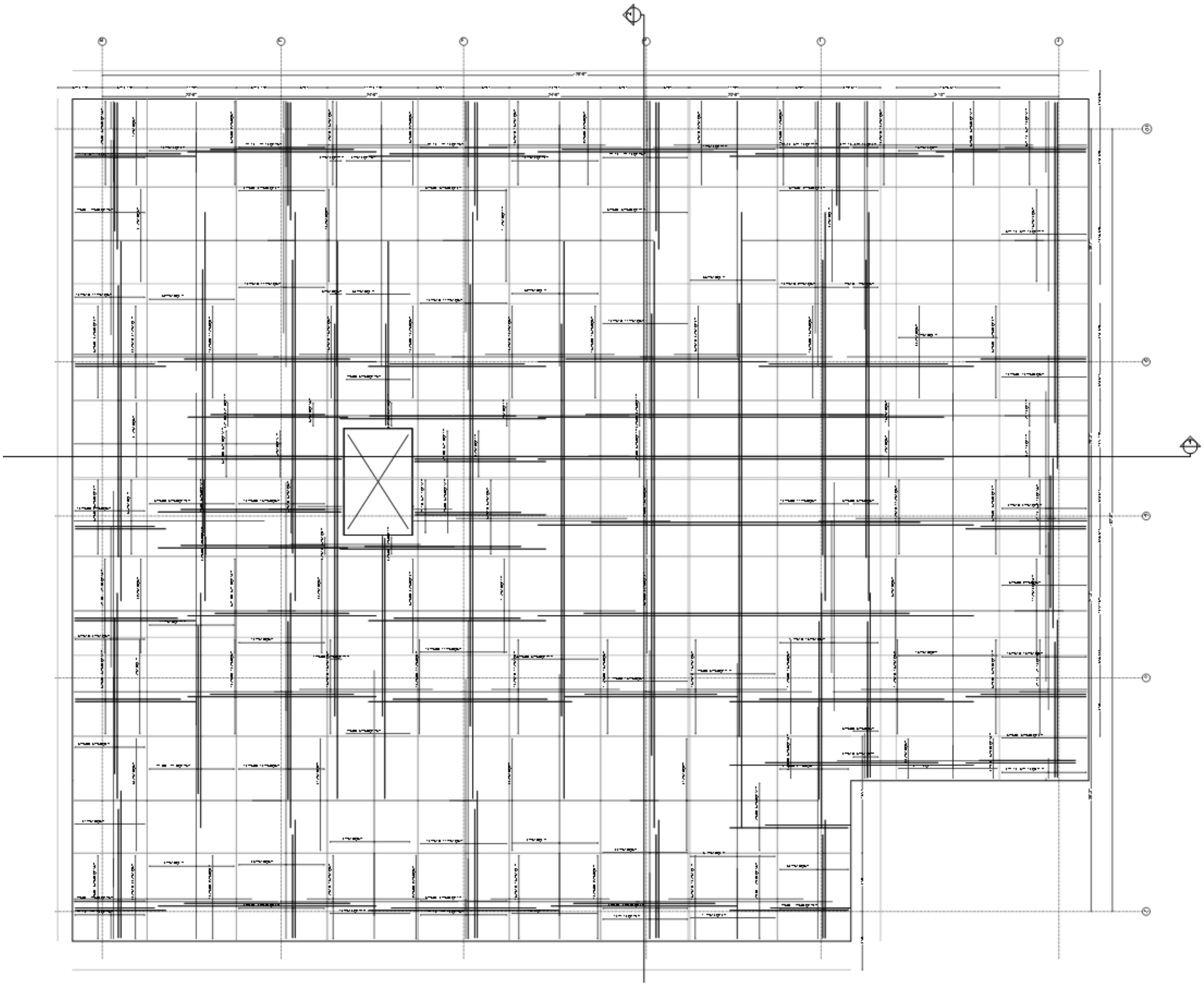


Figure 22

6. Design Sheet for Retaining Wall

Input Data			
Sr.No	f'_c	4	ksi
	f_y	60	ksi
	h	26.5	ft
	w_s	130	pcf
	w_c	150	pcf
	w_w	62.4	pcf
	Surcharge Load	200	psf
	Cover	1.5	in
	d_b	0.5	in
	L	26.25	ft
Lateral Earth Pressure			
	C_a	0	
	$P_a = C_a \omega h$	0	ksf
	H_a= 1/2 P_ah	0	K/ft
	Fram Base, H_a acts @	8.8333	ft
Surcharge Load			
	Surcharge Height, h_s	1.54	ft
	$P_s = C_a \omega h_s$	0	ksf
	H_s= P_sh	0	K/ft
	Fram Base, H_a acts @	13.25	ft

Lateral Water Pressure			
	C_a	1	
	$P_w = C_a \omega h$	1.6536	ksf
	H_w= 1/2 P_wh	21.9102	K/ft
	H'_W=H_w/2	10.9551	K/ft
	Fram Base, H'_w acts @	8.833	ft
Factored Loads			
	1.6H_a	0	K/ft
	1.6H_s	0	K/ft
	1.6H_w	35.05632	K/ft
	1.6H'_w	17.52816	K/ft
Moments & Shears (Uniform Load)			
	$M_{u(A)}$ due to Uniform Load	0.0000	K-ft
	$M_{u(C)}$ due to Uniform Load	0	K-ft
	Maximum Positive M_c from Base is @	9.9375	ft
	m=x/L, x=3L/8	0.375	ft
	Δ_x		
	Δ_{max}		
Moments & Shears (Triangular Load)			
	$M_{u(A)}$ due to Triangular Load	61.349	
	$M_{u(C)}$ due to Triangular Load	2.103	
	Maximum Positive M_c from Base is @		
Reactions			
	R_A=V_A	14.023	Kips
	R_B=V_B	3.505632	Kips

Analysis & Design for Negative Moment		
Steel %age =	1	%
R_u	443	psi
Effective Depth=d	11.768	in
Total Depth=h=d+cover+d_b/2	13.518	
Depth used=h	7.5	in
Effective Depth=d	5.75	
Ru	1856	psi
Steel Ratio=	0.0054	
Steel Area=A_s	0.3726	in^2
Minimum Steel=$A_{s,min}$	0.135	in^2
Steel for Flexure=$A_{s,f}$	0.2277	in^2
Steel Used=	0.3726	in^2
Steel Bar	4	#
Area of Bar=A_b	0.20	in^2
Spacing=S	6.32365671	in
Analysis & Design for Positive Moment		
Ru	504.506059	psi
Steel Ratio=	0.002	
Steel Area=A_s	0.14	in^2
Steel for Flexure=$A_{s,f}$	0.23	in^2
Steel Used=	0.23	in^2
Steel Bar	4	#
Area of Bar=A_b	0.20	in^2
Spacing=S	10.3478019	in
Longitudinal Reinfocement		
Steel Ratio=	0.002	
Steel Area=A_s	0.18	in^2
Steel Bar	4	#
Area of Bar=A_b	0.20	in^2
Spacing=S	13.09	in

7. Design Sheet for Slab

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1														
2		Design of Slab												
3														
4														
5														
6														
7														
8		INPUT DATA:												
9														
10	SLAB DIMESNIONS													
11														
12	Short span			lx	20	feet								
13	Long span			ly	25	feet								
14	Aspect ratio			m	0.8									
15	Thickness of slab (Minimum)			h(min)	6	inch	If your slab is supported on all 4 sides through beams h should not be less than 5 inch							
16	Thickness of slab (provided)			h	6	inch	ACI 9.5.3.2							
17							SLAB WITHOUT DROP PANEL H min = 5 inch							
18				da	5	inch	SLAB WITH DROP PANEL H min = 4 inch							
19				db	4.5	inch								
20														
21	END CONDTIONS													
22	Shoter span end confition			one edge conti and one disconti										
23	longer span end condition			one edge conti and one disconti										

24	coefficeint for shorter span		
25	coefficient of dead positive moments	Ca(+)D.L	0.039
26	coefficient of live positive moments	Ca(+)L.L	0.048
27	coefficient of negative moments	Ca(-)DL+LL	0.071
28			
29			
30	coefficeint for longer span		
31	coefficient of dead positive moments	Cb(+)D.L	0.016
32	coefficient of live positive moments	Cb(+)L.L	0.02
33	coefficient of negative moments	Cb(-)DL+LL	0.029
34			

35	APPLIED LOADING		
36	Self weight	75	psf
37	Service Dead Load	100	
38	Service Live Load	100	
39			
40	Load of water		
41	unit weight of water	62.43	lb/ft^3
42	Height of pool or tank	0	ft
43	Total weight of water	0	psf
44	For pool additional live load	10	psf
45			
46	**ultimate load of pool**	16	
47	Total actual load		
48	factored dead load	210	psf
49	factored live load	176	psf
50	Total ultimate Factored load	386	psf
51			

52	MATERIAL STRENGTH				
53	Concrete	fc	3		
54	steel	fy	60		
55					
56					
57	**LOADS**				
58	Total ultimate DL	WD.L		210	
59	Total ultimate LL	WL.L		176	
60	Total ultimate Factored load		Wu	386	
61					
62	DESIGN MOMENTS				
63	M(-ve) in shorter span DL+LL			10962.4	lb-ft
64	M(-ve) in longer span at DL+LL interior supports			6996.25	lb-ft
65	M(+ve) DL in shorter span at mid span			3276	lb-ft
66	M(+ve) DL in longer span at mid span			2100	lb-ft
67	M(+ve) LL in shorter span at mid span			3379.2	lb-ft
68	M(+ve) LL in longer span at mid span			2200	lb-ft
69	M(-ve) in shorter span at Discontinues edge			2218.4	lb-ft
70	M(-ve) in longer span at Discontinues edge			1433.33	lb-ft

73					
74	M(-ve) in shorter span DL+LL	10962.4	lb-ft	10.9624	k-ft
75	M(-ve) in longer span at DL+LL interior supports	6996.25	lb-ft	6.99625	k-ft
76	TOTAL M(+ve) in shorter span at mid span	6655.2	lb-ft	6.6552	k-ft
77	TOTAL M(+ve) in longer span at mid span	4300	lb-ft	4.3	k-ft
78	M(-ve) in shorter span at Discontinues edge	5872.53	lb-ft	5.87253	k-ft
79	M(-ve) in longer span at Discontinues edge	3765.42	lb-ft	3.76542	k-ft
80					
81					
82	**AREA OF STEEL REQUIRED**	**Ast = Mu/fy(0.9d)**			
83	for M(-ve) in shorter span interior	Ast	0.48722	in^2	
84	for M(-ve) in longer span at interior	Ast	0.34549	in^2	
85	for M(+ve) in shorter span at midspan	Ast	0.29579	in^2	
86	for M(+ve) in longer span at midspan	Ast	0.21235	in^2	
87	for M(-ve) in shorter span at Discontinues edge	Ast	0.261	in^2	
88	for M(-ve) in longer span at Discontinues edge	Ast	0.18595	in^2	
89					
90					

94									
95		number of bar selected			#	3		area of selected number of bar	0.110447
96	in^2								
97	in^2	Spacing	S	3.398365	inch	c/c			
98									
99	**ERIOR**								
100		number of bar selected			#	3		area of selected number of bar	0.110447
101	in^2								
102	in^3	Spacing	S	2.720267	inch	c/c			
103									
104	**CONTI**								
105		number of bar selected			#	3		area of selected number of bar	0.110447
106									
107		Spacing	S	12	inch	c/c			
108									
109	**ONG LONGER SPAN**								
110									
111		number of bar selected			#	3		area of selected number of bar	0.110447
112									
113		Spacing	S	6.241533	inch	c/c			
114									
115	**ERIOR**								
116		number of bar selected			#	3		area of selected number of bar	0.110447
117									
118		Spacing	S	3.836139	inch	c/c			
119									
120	**CONTI**								
121		number of bar selected			#	3		area of selected number of bar	0.110447
122									
123		Spacing	S	12	inch	c/c			
124									
125									
126									
127	nel	=	193	kips	**Lx * Ly* Wu**				
128									
129	tion ΦVc	=	5.58677	k/ft	0.85*2* (fc psi)^1/2 * b*d/1000				
130	de Vua	=	N.A						
131	le Vua	=	3.86	k/ft	(1*193) /	(2*ly)	<5.58677	ok	

8. Discussion:

The columns were designed by a hit and trial method. Nominal dimensions were selected, and the dimensions were increased until all the checks were passed. This way economical design was selected.

As for the beams, similar manual calculations were done to ensure and double check the accuracy of software calculations. The design was modified until all the checks were passed, final design and detailing was done.

Slabs were designed using stripped based method by software and to check the accuracy of software, manual calculations were done using design sheet of the slabs which conformed to the design of the slab using the software and ensures that all the checks were passed.

For the design of foundation, the dimensions were confirmed after making sure that punching shear check and bearing strength check were passed and finally the design of foundation was selected.

For the design of retaining wall, excel sheet was used. First, we analyzed the geotechnical soil site report and extracted all the necessary data of soil needed to be entered in the design sheet. According to our requirement we entered the steel percentage and all the required manual input to get all the data required and used it for the final design of retaining wall.

9. Conclusion:

With the help of Etabs software, design of all the members was conducted and all the checks were passed. Checks were performed by Etabs and manually as well. All the members passed the necessary ACI design checks. With this project, we got familiarized with the design procedure of a modern multistory building which included commercial and residential units inside the building. We also got familiarized with the Etabs software and we prepared manual design excel sheets of different structural elements of the building. In this project we learnt different parameters of the design which the software used.

10. References

- ✓ **https://www.csiamerica.com/products/etabs/videos**
- ✓ **https://www.csiamerica.com/products/safe/videos**
- ✓ **ACI 318-14**
- ✓ **ACI 318-18**
- ✓ **ASCE 7-10**
- ✓ **Design of Reinforced Concrete by Jack C. McCormack *and* Russell H**