Depth Study

The two-way flat-plate system for the Upper Campus Housing Project was designed using ADOSS. The flat-plate system will be 10" with no drop panels of normal weight concrete with strength of 4000psi and a steel strength of 60,000psi. The original depth for the system was determined using ACI 318 Table 9.5(c) an exterior panel without edge beams or drop panels, $t_{min} = \ell n/30 = (27ft – 2ft)(12in/ft)/30 = 10"$. ACI 318 also specifies the minimum reinforcement in the slab as 0.0018Ag. Therefore, $As_{min} = 0.0018(10")(12") = 0.216\ in^2/ft$ (#5 at 12"). The columns for this system were designed by using interaction diagrams with a given moment and axial force. A starting size for the columns came from CRSI Handbook for shear requirements. This size is 26" x 26". The minimum reinforcement from ACI 10.16.8.6 for the columns is equal to 0.01Ag. Therefore, Asmin = 0.01(26")(26") = $6.76in^2$ which is 12-#7. There is also a maximum reinforcement ratio for columns of 0.08Ag.

Loading

The gravity loads that were used to design the two-way flat-plate system were: dead, live, snow and roof live. For simplification of the design, the lateral loads were assumed to be taken by the shear walls.

Gravity Loads	
Dead	*Computed by ADOSS
Superimposed Dead	25psf
Live	80psf
Roof/Snow	30psf

Two-Way Slab Design

The following is part of the ADOSS output for a typical bay in the North/South direction. The program will design the reinforcement, but for the purpose of this design the following information was used to make a more consistent design based on 12" segments of slab.

N E G A T I V E   R E I N F O R C E M E N T

COLUMN NUMBER	PATT NO.	LOCATION @COL FACE	TOTAL DESIGN (ft-k)	COLUMN AREA (sq.in)	STRIP WIDTH (ft)	MIDDLE AREA (sq.in)	STRIP WIDTH (ft)
1	4	|| R	229.4	6.15	13.5	2.92	13.5
2	4	L ||	-485.8	10.22	13.0	3.24	14.0
3	4	L ||	-197.2	5.26	13.0	3.02	14.0

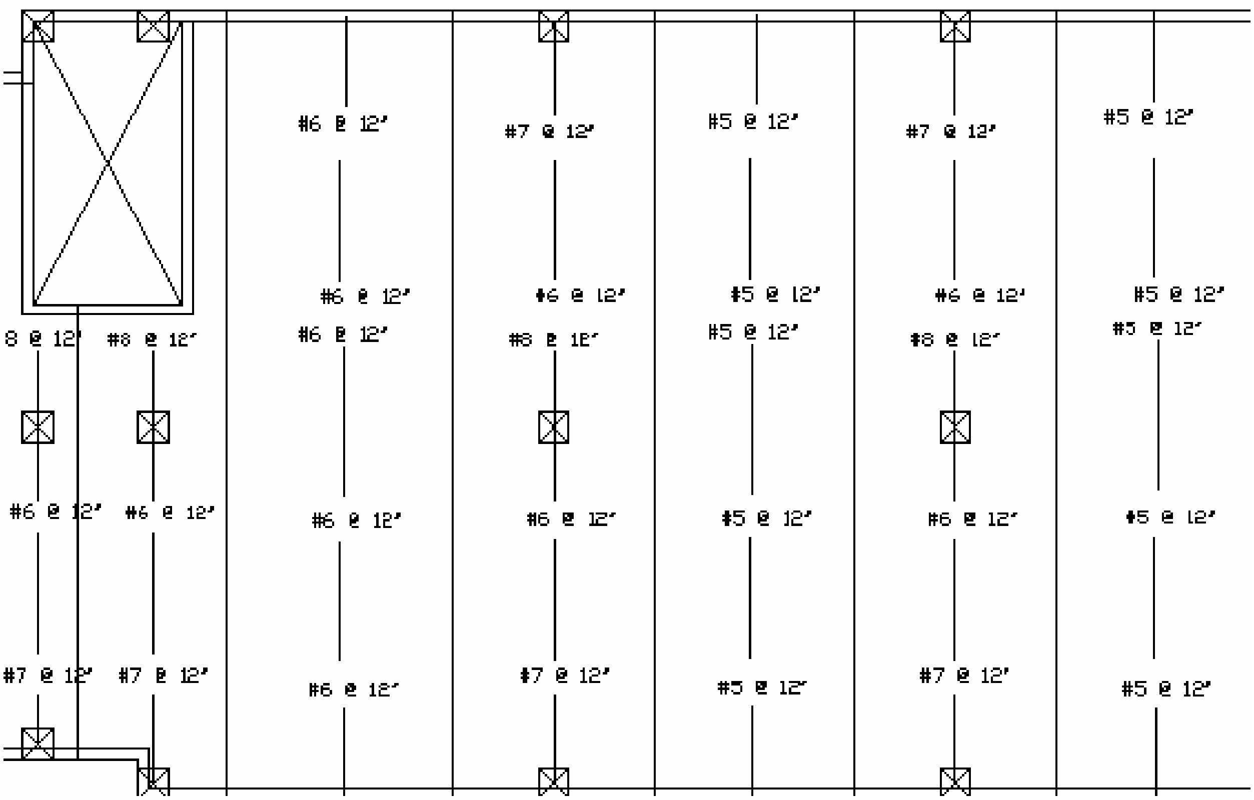
P O S I T I V E   R E I N F O R C E M E N T

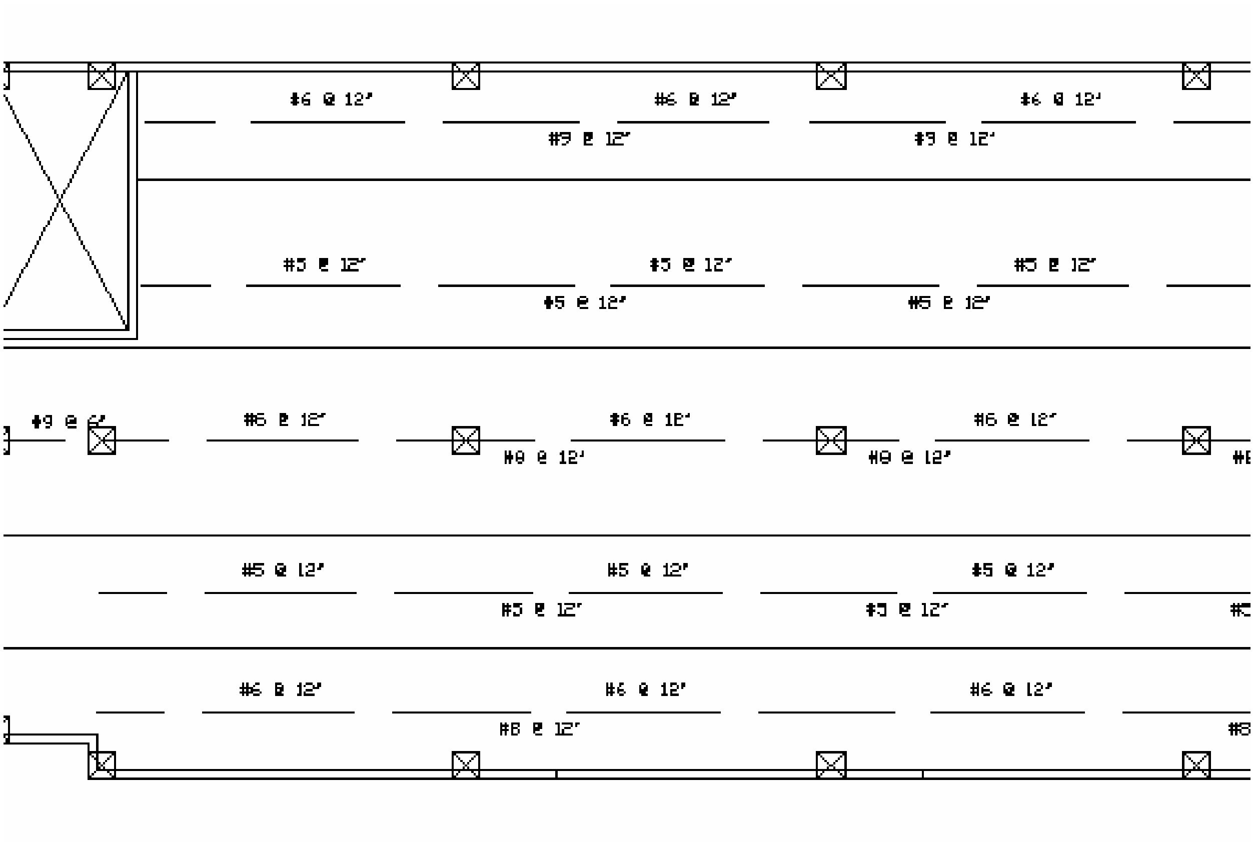
SPAN NUMBER	PATT NO.	LOCATION FROM LEFT (ft)	TOTAL DESIGN (ft-k)	COLUMN AREA (sq.in)	STRIP WIDTH (ft)	MIDDLE AREA (sq.in)	STRIP WIDTH (ft)
2	4	12.8	333.4	5.42	13.5	3.57	13.5
3	4	14.9	304.4	4.94	13.0	3.25	14.0

An example calculation for the reinforcement is as follows for the column strip negative reinforcement at column #1:

As = 6.15in^2/13.5ft = 0.456 in2/ft (#7 at 12")

This calculation was done for each column strip and middle strip. The reinforcement was then distributed evenly throughout each strip. Below is an example of the floor reinforcement layout. All floors and directions are located in the Appendix page 75.


#6 @ 12"
#7 @ 12"
#5 @ 12"
#7 @ 12"
#5 @ 12"
#6 @ 12"
#6 @ 12"
#5 @ 12"
#6 @ 12"
#5 @ 12"
8 @ 12"
#8 @ 12"
#6 @ 12"
#8 @ 12"
#5 @ 12"
#8 @ 12"
#5 @ 12"
#6 @ 12"
#6 @ 12"
#6 @ 12"
#6 @ 12"
#5 @ 12"
#6 @ 12"
#5 @ 12"
#7 @ 12"
#7 @ 12"
#6 @ 12"
#7 @ 12"
#5 @ 12"
#7 @ 12"
#5 @ 12"



Long and short bar extensions were completed by ADOSS which complies with ACI Figure 13.3.8.

The following design criterion was used in ADOSS to complete the design of the slabs:

Distance from reinforcement to tension face = 1.5"

Minimum Bar Size = #4

Minimum Clear Bar Spacing = 6"

100% Column Fixity

Column Design

The columns for the Upper Campus Housing Project were designed using interaction diagrams from the Design of Concrete Structures textbook. Using an excel spreadsheet an axial force and moment on each column was determined. Interaction diagrams were then used to find a reinforcement ratio. Each axial force was computed using the tributary area of the column and floor gravity loads. The axial force and the moment were then put into the following equations to get a reinforcement ratio needed for each column.

$$K_n = \frac{P_u}{\phi f'_c(A_g)} \qquad R_n = \frac{M_u}{\phi f'_c(A_g)h}$$

The interaction diagram used for this design is located in the Appendix on page 90. The lateral ties for each column were designed based on the following spacing requirements: 16 x diameter of the longitudinal bars (14"), 48 x diameter of the tie (48.375"), and the least dimension of the column (26"). Therefore, the lateral ties will be spaced at 14".

The following are design criteria for the design of the concrete columns for a two-way flat-plate system:

Minimum Concrete Cover = 1.5"

Strength Reduction Factor = 0.65

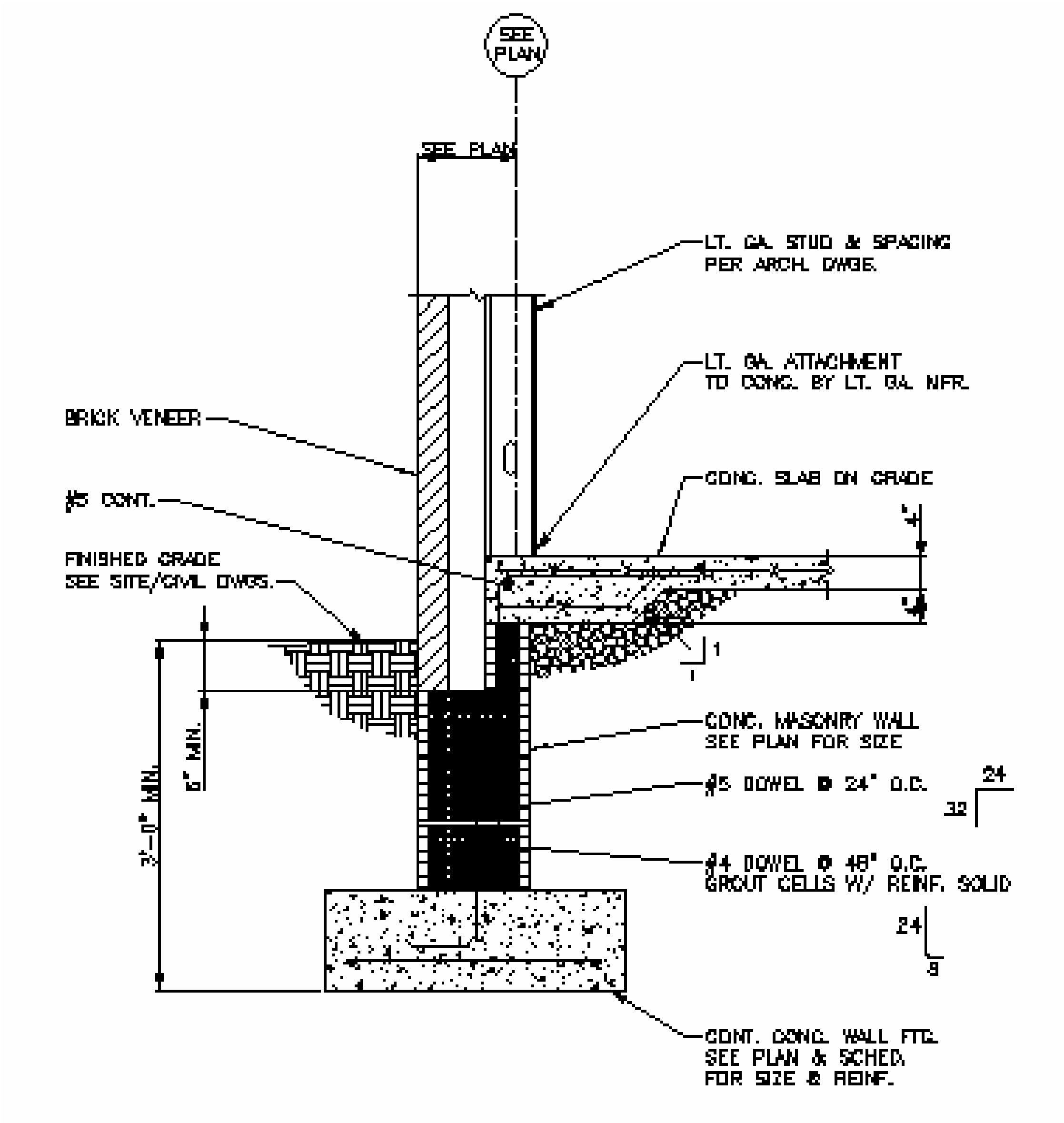
Lateral ties for <#10 bars = #3

Shown on the next page is the column schedule for the roof columns. Complete column schedules can be viewed in the Appendix page 91.

Column	A_{trib} (ft^2)	P (lb)	M_{max}	Size (in x in)	Reinfor.	Ties
A-6	378	72576	241.7	26 X 26	12-#7	#3 @ 14'
A-6.5	135	25920	355.2	26 X 26	12-#7	#3 @ 14'
B.3-0	0	0	0	26 X 26	-	-
B-1	75	14400	245.7	26 X 26	12-#7	#3 @ 14'
B-2	280	53760	245.7	26 X 26	12-#7	#3 @ 14'
B-3	405	77760	244.9	26 X 26	12-#7	#3 @ 14'
B-4	405	103680	239.5	26 X 26	12-#7	#3 @ 14'
B-5	405	103680	244.9	26 X 26	12-#7	#3 @ 14'
B.6-6.5	-	50000	355.2	26 X 26	12-#7	#3 @ 14'
B.7-6	168	32256	344	26 X 26	12-#7	#3 @ 14'
B.8-0	0	0	0	26 X 26	-	-
C.3-6.2	-	50000	355.2	26 X 26	12-#7	#3 @ 14'
C.4-0.3	0	0	0	26 X 26	-	#3 @ 14'
C-1	75	14400	344.4	26 X 26	12-#7	#3 @ 14'
C-2	680	130560	485.8	26 X 26	12-#7	#3 @ 14'
C-3	702	134784	485.8	26 X 26	12-#7	#3 @ 14'
C-4	702	179712	485.8	26 X 26	12-#7	#3 @ 14'
C-5	702	179712	485.8	26 X 26	12-#7	#3 @ 14'
C-6	304	58368	360.6	26 X 26	12-#7	#3 @ 14'
D-0.6	0	0	0	26 X 26	-	-
D-1	0	0	0	26 X 26	-	-
E-2	175.5	33696	197.2	26 X 26	12-#7	#3 @ 14'
E-3	336	64512	248.2	26 X 26	12-#7	#3 @ 14'
E-4	336	86016	228.2	26 X 26	12-#7	#3 @ 14'
E-5	336	86016	268.4	26 X 26	12-#7	#3 @ 14'
E-6	312	59904	197.2	26 X 26	12-#7	#3 @ 14'
E.5-6.8	84	16128	355.2	26 X 26	12-#7	#3 @ 14'
F-6.8	90	17280	355.8	26 X 26	12-#7	#3 @ 14'
F-7	67.5	12960	245.7	26 X 26	12-#7	#3 @ 14'
F-8	405	77760	244.5	26 X 26	12-#7	#3 @ 14'
F-9	405	77760	244.9	26 X 26	12-#7	#3 @ 14'
F-10	240	46080	241.7	26 X 26	12-#7	#3 @ 14'
F-11	285	54720	245.7	26 X 26	12-#7	#3 @ 14'
F.2-12	0	0	0	26 X 26	-	-
F.5-6.8	90	17280	355.2	26 X 26	12-#7	#3 @ 14'
F.6-12	0	0	0	26 X 26	-	-
G-7	81	15552	344.4	26 X 26	12-#7	#3 @ 14'
G-8	702	134784	485.8	26 X 26	12-#7	#3 @ 14'
G-9	702	134784	485.8	26 X 26	12-#7	#3 @ 14'
G-10	420	80640	485.8	26 X 26	12-#7	#3 @ 14'
G-11	280	53760	344.4	26 X 26	12-#7	#3 @ 14'
G.1-6.8	90	17280	355.2	26 X 26	12-#7	#3 @ 14'
G3-11.7	0	0	0	26 X 26	-	-
G.6-6.8	84	16128	355.2	26 X 26	12-#7	#3 @ 14'
H-11	0	0	0	26 X 26	-	-
H-11.5	0	0	0	26 X 26	-	-
I-7	204	39168	220.4	26 X 26	12-#7	#3 @ 14'
I-8	336	64512	268	26 X 26	12-#7	#3 @ 14'
I-9	336	64512	246	26 X 26	12-#7	#3 @ 14'
I-10	97.5	18720	220.4	26 X 26	12-#7	#3 @ 14'

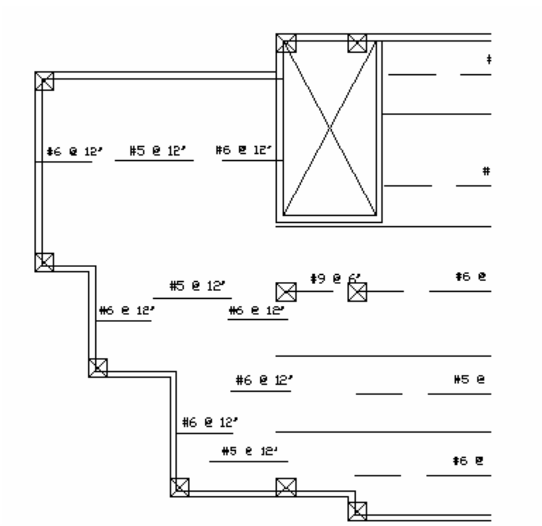
Foundations

The new foundation system for the Upper Campus Housing Project will be square footings under each column. The foundation shown below is the curtain wall down to the wall footing.

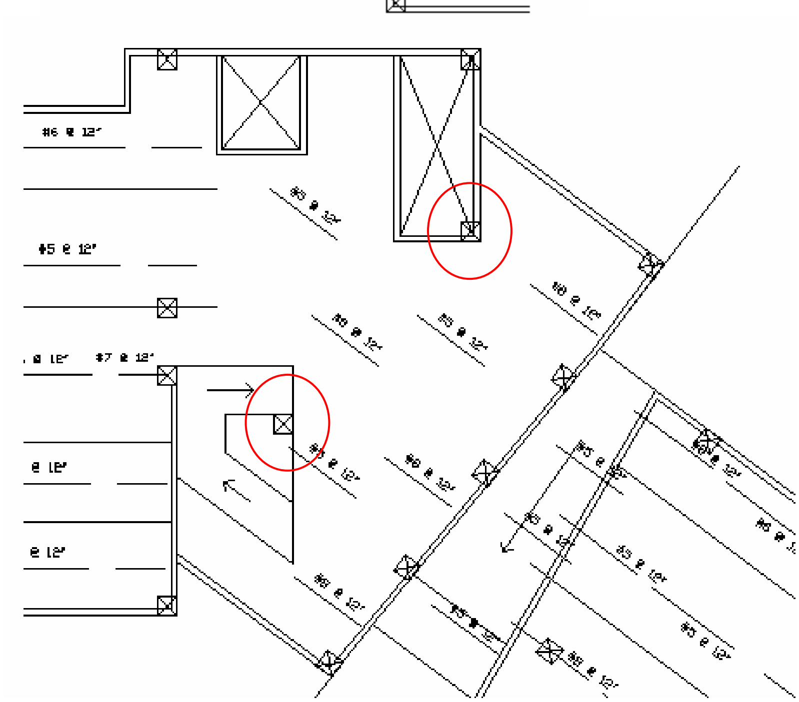


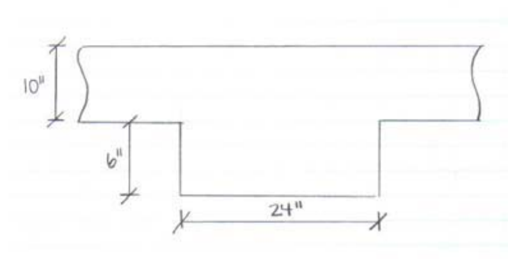
One-Way Design

The center section and the end sections of the floor plan (shown below) were designed as one-way systems. These one-way systems were also designed using ADOSS. They were checked with a manual calculation using a maximum moment of $wL^2/8$.



A beam was designed to span across the two columns circled below because the span was too high for the one-way system. The beam was designed by hand using a maximum moment of $wL^2/8$ also. It was designed as a T-beam for flexure and shear. The beam will have two rows of 5#8's for flexure and #3's for shear (1 at 2" and 18 at 9"). The beam calculations can be found in the Appendix on page 101. Also shown below is a picture of the beam designed.





Lateral Load Calculations (per ASCE7-02)

Seismic Use Group	I	Table 9.1.3
Site Classification	D	9.4.1.2.1
Ss	0.127	Figure 9.4.1.1a
S_1	0.054	Figure 9.4.1.1b
Fa	1.6	Table 9.4.1.2a
Fv	2.4	Table 9.4.1.2b
Seismic Design Category	A	
R	3	Table 9.5.2.2
I	1.0	Table 9.1.4

$Sms = FaSs = 1.6(0.127) = 0.203$

$Sm_1 = FvS_1 = 2.4(0.054) = 0.129$

$S_{DS} = (2/3)Sms = 0.135$

$S_{D1} = (2/3)\ Sm_1 = 0.086$

$T = Cthn^x = 0.02(100)^{0.75} = 0.632$

$Cs = S_{DS}/(R/I) = 0.045$

$Csmax = S_{D1}/(T(R/I)) = 0.045$

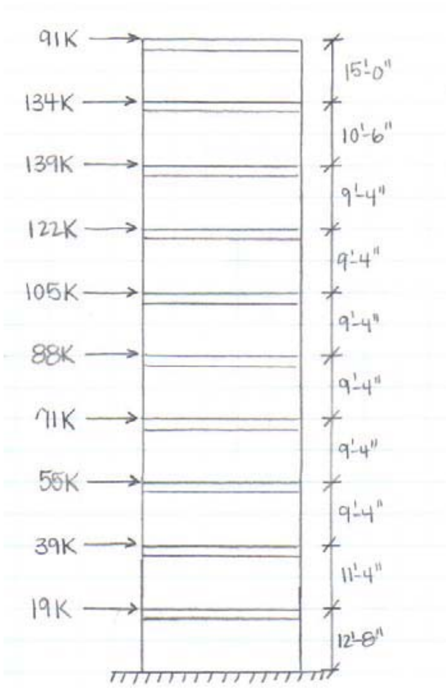
$Csmin = 0.044IS_{DS} = 0.006$

$V = CsW = 0.045(19875.5K) = 894.4K$

$K = 1 + ((0.632-0.5)/2) = 1.07$

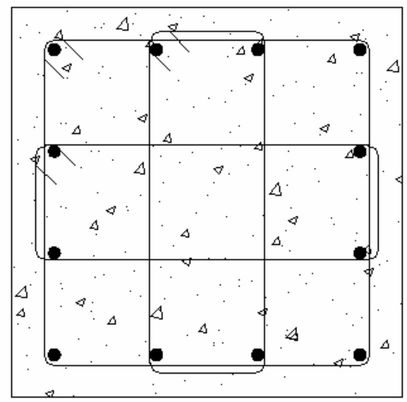
Lateral Design

The lateral shear walls for this structure were designed using a stiffness analysis using a procedure described in Chapter 3 of the PCI Design Handbook. The forces on the building were distributed to each shear wall accordingly based on the stiffness of that wall. Each wall is 10" thick reinforced concrete. The seismic load case was used because it controls the design for these walls. The distribution of the seismic load to each floor is shown below. The corresponding wind loading diagram is located in the Appendix on page 37. Because there is an expansion joint located where the building angles, the lateral design can be complete assuming that the building works as two separate halves. The reinforcement can be summarized as follows:

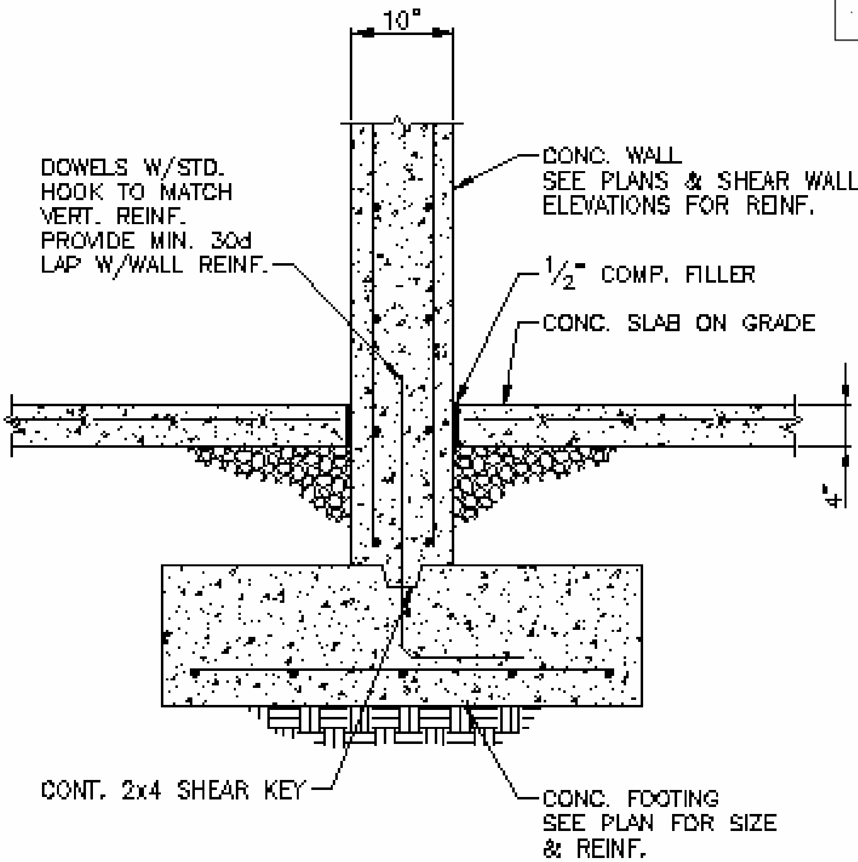


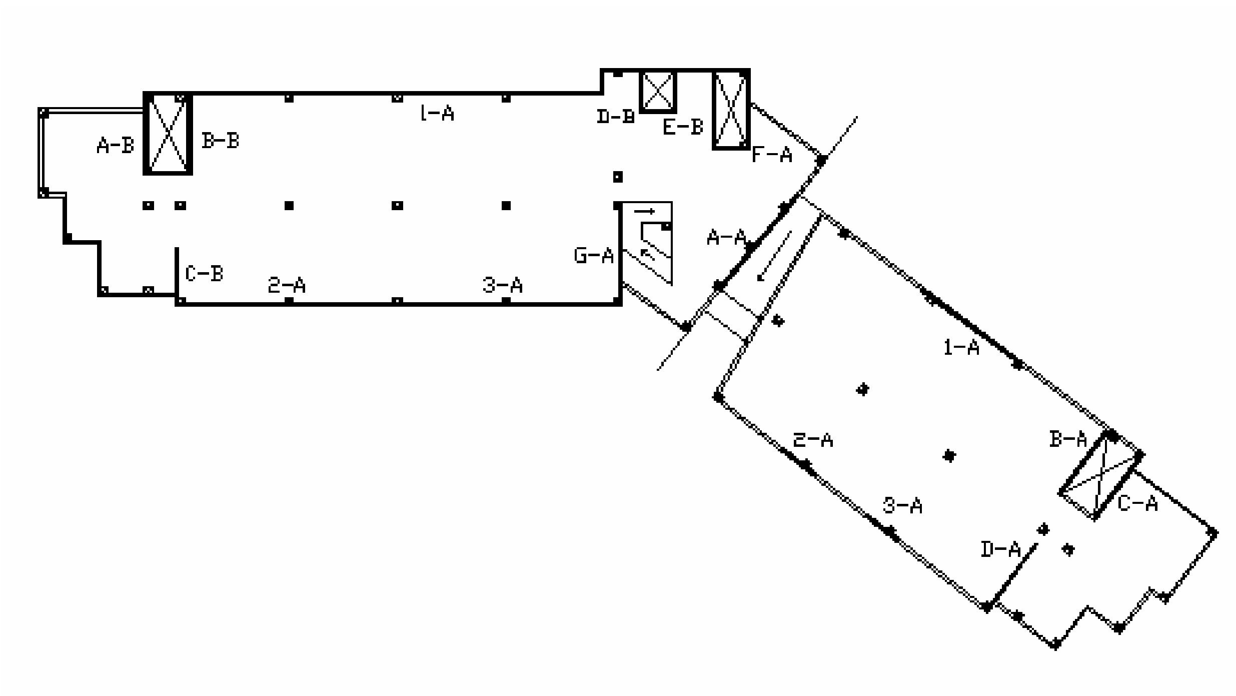
Shear Wall Design			
Type	Horizontal	Vertical (First and Last 12")	Vertical
A	#10 at 12"	20-#10's	#5 at 12"
B	#5 at 12"	20-#8's	#5 at 12"

The location and the types of shear walls are shown on the page 24. A complete design of the shear walls is located in the Appendix page 103.



The detail to the right is a column with 12 longitudinal bars and the required placement of lateral ties. The detail shown below is an example of how the shear wall will connect to the foundation.





Drift Check

$\Delta = (Ph^3/3EI)+(2.78Ph/AE)$

$E = 33(145pcf)^{1.5}(4000psi)^{0.5} = 3644ksi$

$\Delta_{allowable} = H/400 = 105.5ft(12in/ft)/400 = 3.165"$

Deflection calculations were done for each wall using an Excel spreadsheet. These calculations can be viewed on the next page. All deflections are less than the allowable limit. It is also important to note that the deflection at the expansion joint was considered for the two halves of the building hitting each other and is OK.

Left				
Wall	Length	Area	I	Deflection
A	237	2370	11093378	0.01883
B	237	2370	11093378	0.01883
C	171.96	1720	4237416	0.03113
D	60	600	180000	0.31538
E	60	600	180000	0.31538
F	216	2160	8398080	0.0216
G	312	3120	25309440	0.01296
1	336	3360	31610880	0.0118
2	120	1200	1440000	0.06113
3	120	1200	1440000	0.06113

Right				
Wall	Length	Area	I	Deflection
A	336	2370	31610880	0.01612
B	237	2370	11093378	0.01883
C	237	1720	11093378	0.02437
D	248.04	600	12716978	0.06153
1	216	3360	8398080	0.01586
2	120	1200	1440000	0.06113
3	120	1200	1440000	0.06113