DESIGN CHECK OF REINFORCED CONCRETE OFFICE BUILDING

Thesis for the Degree of B. S.
MICHIGAN STATE COLLEGE

John R. Evans

1941

DESIGN CHECK OF REINFORCED CONCRETE OFFICE BUILDING

A Thesis Submitted to

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by

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ACKNOWLEDGEMENT

Theobject of this thesis was to acquaint the author with practical applications of theory studied in the design courses and to obtain a knowledge of the requirements of a complete design. It was also to provide an opportunity to explore a phase of reinforced concrete that was not discussed in classes- that of flat slab floors.

The building under consideration is the Michigan State Health Department Office Building, located on DeWitt Road in the Northwest section of Lansing. It is to be a four story structure with an additional story covering but part of the roof. This is referred to in the plans as the penthouse.

The author wishes to acknowledge his indebtedness to Mr. C.A. Miller, Assistant Professor in the CivilEngineering Department at Michigan State College for his many valuable suggestions and to the architects, Lee and Kenneth Black for the plans and specifications.

Bibliography

Reinforced Concrete Design

by Sutherland and Clifford

Reinforced Cnocrete Structures

by Peabody

Building Regulations for Reinforced Concrete

(A.C.I. 501-36T)

Concrete- Plain and Reinforced

Taylor, Thompson and Smulski

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Floor Slabs

The floors of this building are flat slabs. The term flat slabs refers to concrete slabs without beams or girders to carry the load to the supporting member and reinforced with bars extending in two or four directions. Teh moment distribution and slab thicknesses specified are for a series of rectangular panels of approximately uniform size arranged in three or more rows of panels ineach direction and in which the ratio of length to width of panel is not more than 1,5o.

Panel Strips and Prinicpal Design Sections

(a) A flat slab shall be considered as consisting of strips in each direction as follows:

Amiddle strip½ a panel in width symmetrical about the panel centerline and extending througn the panel in the direction in which the moments are to be considered.

A column strip ½ a panel in width occupying the two panel areas outside the middle strip.

(b) Crtical Sections

Sections for negative moments shall be taken along the edges of the panel on lines joining the column centers except that they follow the column capital instead of passing through it.

Sections for positive moments- These shall be taken on the centerline of the panel.

Floor Slabs(cont.)

The floors of tis building have no dropped panels and the columns have no enlarged capitals. The elimination of capitals decreases the subtractive term $\frac{2c}{L}$ in the moment formula and thereby increased the moment. However, it was thought better to have the entire ceiling smooth and increase the thickness of the slab slightly. The relatively small value for c which would be substituted in the thickness formula gives a value of t (thickness) of 10.15". The mimimum thickness allowed is .375L. This gives a value of t equal to 6". The 10.1o was disregarded and the moment thickness of 7½" was taken as the depth.

Themimimum loads a s specified by the Lansing Building code are as follows:

Office building space, first floor	120#/sq.ft.
" " " other "	80#/sq.ft.
Flat roofs	30#/sq.ft.

The central portion of each floor is designated as vault space. This space on the first floor is to carry a live load of 200#/sq.ft. and the vaults on the other floors are to carry a live load of 100#/sq.ft. The rest of the sturcture is designed according to the building code.

The equation for moment M_o, which is the numerical sum of the positive and negative moments in the direction of either side of and interior rectangular panel, is given below.

$$M_o = .09WL\left(1-\frac{2}{3}\frac{C}{L}\right)^2$$

W = Total live and dead load uniformly distributed on 1 panel

L = Span of the panel from center to center of the panel

C = Diameter of the column capital in feet

Slab Computations

Live load equals 200#/sq.ft. Panel dimensions 16"x16" ft.

Dead " " 90#/sq.ft. W equals 16x16x290 = 742,000

Total " 290 #/sq. ft.

M_o equals $.09 \times 742{,}000(1-\frac{2}{3}\times 16)^2$

M_o " 96,000 ft.pounds

Moments to be used in the design of interior panel

Two-way system without dropped panel

	Negative	Positive
Column strip	$.46M_o$	$.22M_o$
Middle strip	$.16M_o$	$.16M_o$

Maximum negative moment equals .46x96,000 = 45,000'#

d equals $\sqrt{\frac{M}{Rb}}$ R = constant determined by f_s & f_c

d = effective depth

b = breadth of section

d equals $\sqrt{\frac{45{,}000 \times 12 \times 1.15}{200 \times 96}}$ equals $\begin{matrix} 5.74" \\ \underline{1.50"} \\ 7.24 \end{matrix}$

say $7\frac{1}{4}$" is effective depth

Minimum thickness .575L equals 6"

CHECK SHEAR:

Special column heads take sheatr and eliminate dropped

panel. The column heads consist of car channels crossing over the top the column. (see detail)

v equals $\frac{V}{bjd}$

Area of column head
16.75 sq.ft.

Perimeter of column head
17,5 ft.

v equals unit shear
V " total shear
B " breadth
j " ratio of distance between centroid of compression and centroid of tension to depth
d equals depth

v equals $\frac{290(206-16.75)}{17,5x12x.866x5.74}$

v " 56.8#/sq.ft.

Allowable V equals 75#/sq.ft. O.K.

STEEL: interior panel

M equals $A_s f_s jd$

A_s equals steel area
F_s " allow. steel tensile stress

A_s equals $\frac{45,000x12}{20,0000x,866x5.74}$ equals 5.40sq.in. Req'd

12-1" round plus 10-$\frac{5}{8}$" round bars equals 5.42 (Have)

Second Floor Slab

Resisting Moments

For location of coordinates see print of floor plan in pocket in back of thesis

	A	B	C	D
1.	12,000	5,770	22,300	5,770
2.	8,750	11,550	155,00	11,550
3.	13,750	10,600	25,700	11,550
4.	8,750	9,620	15,500	11,550
5.	13,750	9,620	27,400	11,550
6.	8,750	9,260	15,500	11,550
7.	13,750	9,620	28,400	11,550
8.	8,750	9,620	15,500	11,550
9.	13,750	9,620	27,400	11,550
10.	8,750	9,620	15,500	11,550
11.	13,750	10,600	25.700	11,550
12.	8,750	11,550	15,500	11,550
13,	12,000	5,770	22,300	5,770

Rows Aand C are column strips

Rows Band D are middle "

Even numbers are positive moments

Odd " " negative "

Second Floor Slab

Resisting Moments

For location of coordinates see print of floor plan in pocket in back of thesis.

A		F		G		H	
1.	24,100	1.	6,740	1.	24,100	1.	577,0
2.	18,900	2.	15,480	2.	18,900	2.	11,550
3.	31,000	3.	15,480	3.	31,000	3.	11,550
4.	15,750	4.	12,320	4.	15,750	4.	11,550
5.	32,300	5.	7,700	5.	32,300	5.	11,550
6.	20.650	6.	14,400	6.	20,650	6.	11,550
7.	30,300	7.	15,500	7.	30,300	7.	13,480
8.	20,650	8.	14,400	8.	20,650	8.	14,440
9.	32,300	9.	7,700	9.	37,100	9.	10,400
10.	15,500	10.	15,500	10.	15,500	10.	9,620
11.	28,400	11.	10,400	11.	29,200	11.	10,400
12.	15,500	12.	9,630	12.	15,500	12.	9,630
13.	22,300	13.	4,815	13.	22,300	13.	4,815

Rows E and G are column strips

Rows F " H " middle strips

Even numbers are positivemoments

Odd numbers are negative moments

Second Floor Slab

Resisting Moments

For location of coordinates see print of floor plan in pocket in back of thesis.

I	J	K	L
1. 22,300	1. 5,770	1. 22,300	1. 5,770
2. 155,00	2. 11,550	2. 155,00	2. 11,550
3. 25,700	3. 11,550	3. 25,700	3. 10,600
4. 15,500	4. 11,550	4. 15,500	4. 9,260
5. 27,400	5. 11,550	5. 27,400	5. 9,260
6. 15,500	6. 11,550	6. 15,500	6. 9,260
7. 27,400	7. 11,550	7. 27,400	7. 9,260
8. 15,500	8. 11,550	8. 15,500	8. 9,260
9. 27,400	9. 11,550	9. 27,400	9. 9,260
10. 15,500	10. 11,550	10. 15,500	10. 9,260
11. 25,700	11. 11,550	11. 25,700	11. 10,600
12. 15,500	12. 11,550	12. 15,500	12. 11,550
13. 22,300	13. 5,770	13. 22,300	13. 5,770

Rows I and K are column strips

Rows J and L " Middle strips

Even numbers are positive moments

Odd " " negative "

Second Floor Slab

Resisting Moments

For location of coordinates see print of floor plan in pocket in back of thesis.

M	F8	G'
1. 12,000	10. 15,500	10. 9,640
2. 13,750	11. 29,300	11. 10,400
3. 8,370	12. 15,500	12. 9,630
4. 13,750	13. 22,300	13. 4,815
5. 8,370		
6. 13,750		
7. 8,370		
8. 13,750		
9. 8,370		
10. 13,750		
11. 8,750		
12. 13,750		
13. 12,000		

Rows M and F8 are column strips

Row G' is a middle strip

Even numbers are positive moments

Odd numbers are negative moments

Second Floor Slab

Resisting Moments

For location of coordinates see print of floor plan in pocket in back of thesis.

2	3	4	1
A. 5,760	A. 22,300	A. 5,570	A. 12,000
B. 11,550	B. 15,500	B. 11,550	B. 8,580
C. 10,600	C. 25,700	C. 11,500	C. 13,750
D. 9,360	D. 15,500	D. 11,550	D. 8,580
E. 9,360	E. 27,400	E. 9,640	E. 13,750
F. 9,360	F. 15,500	F. 6,740	F. 8,580
G. 9,360	G. 27,400	G. 7,740	G. 13,750
H. 9,360	H. 15,500	H. 14,400	H. 8,580
I. 9,360	I. 27,500	I. 13,500	I. 13,750
J. 9,360	J. 15,500	J. 11,550	J. 8,580
K. 10,600	K. 25,700	K. 11,550	K. 13,750
L. 11,550	L. 15,500	L. 11,550	L. 8,580
M. 5,780	M. 22,300	M. 5,770	M. 12,000

Rows 1 and 3 are column strips

Rows 2and 4 are middle "

B,D,G, etc. are positive moments

A,C,F, etc, are negative "

Second Floor slab

Resistng Moments

For location of coordinates see print of floor planin pocket in back of thesis.

5	6	7	8
A. 22,500	A. 5,770	A. 22,500	A. 5,770
B. 15,500	B. 11,550	B. 15,500	B. 11,550
C. 26,400	C. 10,600	C. 25,700	C? 10,600
D. 15,500	D. 9,260	D. 155,00	D. 9,260
E. 30,550	E. 10,600	E. 32,650	E. 10,600
F. 10,520	F. 11,550	F. 17,150	F. 11,500
G. 32,300	G. 11,550	G. 34,300	G. 11,550
H. 20,700	H. 11,500	H. 17,100	H. 11,550
I. 33,100	I. 11,550	I. 34,300	I. 11,550
J. 17,150	J. 11,550	J. 17,100	J. 11,550
K. 31,000	K. 11,550	K. 31,000	K. 11,550
L. 15,500	L. 11,550	L. 15,500	L. 11,500
M. 22,300	M. 5,770	M. 22,300	M. 5,770

Odd numbers are column strips

Even letters (B, D, etc.) are positive moments

Second Floor Slab

Resisting Moments

For location of coordinates see print of floor plan in pocket in back of thesis.

9	11	10	12
A. 22,300	A. 22,300	A. 5,770	A. 5,780
B. 15,500	B. 15,550	B. 11,550	B. 11,550
C. 27,400	C. 25,700	C. 11,550	C. 10,600
D. 15,500	D. 15,500	D. 11,550	D. 9,630
E. 30,500	E. 24,950	E. 5,780	E. 9,630
F. 10,320	F. 15,500	F. 4,830	F. 9,630
G. 18,900	G. 24,950	G. 5,780	G. 9,630
H. 10,320	H. 15,500	H. 4,830	H. 9,630
I. 30,900	I. 24,950	I. 11,800	I. 9,630
J. 17,150	J. 15,500	J. 11,550	J. 9,630
K. 31,000	K. 25,700	K. 11,550	K. 10,600
L. 15,500	L. 15,500	L. 11,550	L. 11,550
M. 22,300	M. 22,300	M. 5,770	M. 5,780
	F' 24,950	F' 5,780	F' 9,639
	G' 15,500	G' 4,830	G' 9,639

Rows 9 and 11 are column strips

" 10 " 12 " middle "

Even letters are posttive moments(B,D,etc.)

Odd letters are negative " (AC,etf.)

Second Floor Resisting

Moments (Slab)

	13
A.	12,000
B.	8,080
C.	13,750
D.	8,080
E.	13,750
F.	8,080
G.	13,750
H.	8,080
I.	13,740
J.	8,080
K.	13,750
L.	8,080
M.	12,000
F'	9,630
G'	9,630

Row 13 is a column strip

Even letters are positive moments(B, D, etc,)

Odd letters are negative moments (A, C, etc.)

First Floor Slab

Resisting Moments

	A	B	C	D
1.	10,600	11,450	20,500	11,450
2.	9,280	11,450	16,750	11,450
3.	13,000	11,450	29,700	13,550
4.	7,580	10,400	16,750	14,620
5.	13,000	10,400	33,500	14,620
6.	7,580	10,400	16,750	14,620
7.	13,000	10,400	33,500	14,620
8.	7,580	10,400	16,750	14,620
9.	13,000	10,400	33,500	14,620
10.	7,580	10,400	16,750	14,620
11.	13,000	11,450	29,700	13,550
12.	9,280	11,450	16,750	11,450
13.	10,600	11,450	20,500	11,450

Bending Moments are in foot pounds.. The even numbers are for positive moments, B and D are middle strips. A and C are column strips

First Floor Slab

Resisting Moments

	E	F	F'	G
1.	20,000	14,020	16,750	20,500
2.	18,750	13,050	30,700	18,070
3.	31,650	14,630	16,750	31,650
4.	14,090	7,500	18,050	14,890
5.	34,900	9,060		34,900
6.	25,400	17,700		25,400
7.	31,300	18,750		31,300
8.	25,400	17,700		25,400
9.	34,950	9,060		46,000
10.	14,650	10,400		7,380
11.	29,700	10,400		12,800
12.	16,750	10,400		16,750
13.	18,550	10,400		20,650

Rows E, F', and G are column strips

Row F is a middle strip

The even numbers are positive and the odd numbers are negative moments

First Floor Slab

Resisting Moments

	H	G'	I	J
1.	11,450	10,400	20,800	11,450
2.	11,450	10,400	16,680	11,450
3.	13,550	10,400	33,420	13,550
4.	14,630	10,400	40,000	14,630
5.	14, 630		40,800	14,620
6.	14,630		40,000	14,620
7.	13,550		40,800	14,620
8.	17,700		40,000	14,620
9.	9,550		33,420	12,520
10.	14,670		12,750	10,400
11.	14,750		9,150	13,550
12.	10,450		16,680	11,450
13.	10,400		20,800	11,450

Rows H and J are middle strips

Row I is a column strip

Row G' is a middle strip

Even numbers are positive bending moments

Odd numbers are negative bending moments

First Floor Slab

Resisting Moments

	A	L	M
1.	20,300	11,450	10,800
2.	16,750	11,450	9,280
3.	29,700	11,450	15,000
4.	16,750	10,400	7,380
5.	30,300	10,400	15,000
6.	16,750	10,400	7,380
7.	30,300	10,400	15,000
8.	16,750	10,400	7,380
9.	30,300	10,400	15,000
10.	16,750	10,400	7,380
11.	29,700	11,450	15,000
12.	16,750	11,450	9,280
13.	20,300	11,450	10,800

Rows A and M are column strips

Row L is a middle strip

Even numbers are positive bending moments

Odd numbers are negative bending moments

First Floor Slab

Resisting Moments

	1	2	3	4
A.	10,800	11,450	20,300	11,450
B.	9,280	11,450	17,100	11,450
C.	15,000	11,450	30,100	12,320
D.	7,360	10,400	17,100	11,450
E.	15,000	10,400	30,800	10,400
F.	7,360	10,400	17,000	7,300
G.	15,000	10,400	30,800	9,360
H.	7,360	10,400	17,000	17,700
I.	15,000	10,400	30,800	16,700
J.	7,360	10,400	17,000	14,600
K.	15,000	11,450	30,100	13,300
L.	9,280	11,450	17,000	11,450
M.	10,800	11,450	20,300	11,450

Rows one and three are column strips

Rows two and four are middle strips

B, D, E, H, J, and L are positive moments

A, C, E, G, I, K, and M are negative moments

First Floor Slab

Resisting Moments

5	6	7	8
A. 20,000	11,450,	20,500	11,450
B. 16,100	11,450	16,680	11450
C. 31,700	11,450	29,700	11,450
D. 16,190	10,400	16,680	10,400
E. 36,700	12,520	37,100	12,550
F. 11,000	14,500	20,900	14,600
G. 40,400	14,500	40,900	14,600
H. 22,000	14,500	20,500	14,600
I. 40,600	14,500	40,500	14,600
J. 20,500	14,500	20,500	14,600
K. 38,100	13,450	38,900	13,850
L. 16,190	11,450	16,600	11,450
M. 20,500	11,450	20,500	11,450

Rows five and seven are column strips

Rows sixand eight are middle strips

A, C, E, G, I, K, and M are negative moments

B, D, F, H, J, and L are positive moments

Moments are all in foot pounds

First Floor Slab

Resisting Moments

5	6	7	8
A. 20,300	11,450	20,300	11,450
B. 16,100	11,450	16,680	11450
C. 31,700	11,450	29,700	11,450
D. 16,190	10,400	16,680	10,400
E. 36,700	12,520	37,100	12,550
F. 11,000	14,300	20,900	14,600
G. 40,400	14,300	40,900	14,600
H. 22,300	14,300	20,300	14,600
I. 40,800	14,300	40,300	14,600
J. 20,300	14,300	20,300	14,600
K. 36,100	13,450	36,900	13,550
L. 16,190	11,450	16,600	11,450
M. 20,300	11,450	20,300	11,450

Rows five and seven are column strips

Rows six and eight are middle strips

A, C, E, G, I, K, and M are negative moments

B, D, F, H, J, and L are positive moments

Moments are all in foot pounds

First Floor Slab

Resisting Moments

9	10	11	12
A. 20,000	11,400	20,500	11,400
B. 16,700	11,400	16,720	11,400
C. 31,600	12,000	29,700	11,400
D. 16,700	11,400	16,700	10,400
E. 30,700	9,000	27,800	10,400
F. 11,100	5,000	16,720	10,400
G. 20,000	6,170	16,720	10,400
H. 11,100		16,720	10,400
I. 30,000	7,200	16,000	10,400
J. 20,000	14,000	16,720	10,400
K. 29,000	10,000	31,000	11,400
L. 16,700	11,400	16,720	11,400
M. 20,000	11,400	20,500	11,400
F'.	6,100	27,000	10,400
G'.	5,200	16,720	10,400

Rows nine and eleven are column strips

Rows ten and twelve are middle strips

A, C, E, F', G, I, K, and M are negative moments

B, D, F, H, J, L, and G', are positive moments

All moments are in foot pounds

First Floor Slab

Resisting Moments

15

A. 10,800

B. 9,280

C. 13,000

D. 7,380

E. 10,800

F. 7,380

G. 10,800

H. 7,380

I. 10,800

J. 7,380

K. 13,000

L. 9,380

M. 10,800

F' 10,800

G' 7,380

Now thirteen is one-half a column strip

A, C, E, F', G, I, K, and M are negative moments

B, G', D, F, H, J, and L are positive moments

All moments are in foot pounds

BEAM COMPUTATIONS

Beam B-5

Load to be carried by the marginal beam equals the load directly imposed upon it plus a uniform load equal to $\frac{1}{4}$ of the total live and dead panel load.

Dead beam load equals $\frac{8x18}{144}$ x150 equals 150#/'

Live & dead panel load " 1159#/'

1309#/'

Moment equals $\frac{wL^2}{10}$ equals $\frac{1309x14.66^2}{10}$

" 28,100'#

d equals $\sqrt{\frac{M}{Rb}}$

d " $\sqrt{\frac{28,000x12}{208x8}}$ equals 14.5 plus 1.5

" 16"

In beam schedule beam is 8"xL8"

Allowable steel moment (positive)

M equals $A_s f_s jd$

M " 1.27x20,000x.866x15.75 equals 34,600'#

Actual moment 28,000'#

Clear dist, should not be greater than 32 times the least width of the compression flange.

8x32 equals 256"

Clear dist. 192" O.K.

CHECK SHEAR:

V equals 1309x8 equals 10,440

v " $\frac{10,440}{8x.866x15.75}$ equals 67.1#/sq.in.

allowable 150#/sq.in.

CHECK BOND

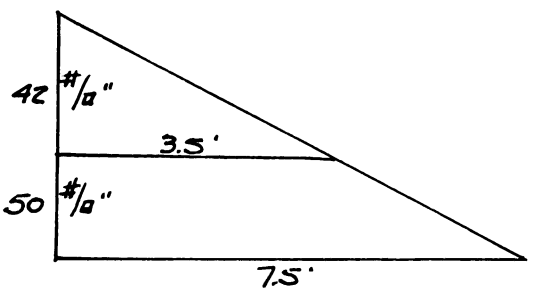
u equals $\frac{V}{Pjd}$ P equals the sum of perimeters of bars

1" rd. plus $1\frac{1}{8}$"sq. equals 7.64"

u equals $\frac{1309x7.85}{7.64x.866x16.5}$ equals 87 lb. per sq.in.

Allowable equals 125 lb. per sq.in.

STIRRUPS B-29



V_1 equals 42 psi

S equals 5.5 ft.

b " 10 d equals 18"

Use $\frac{3}{8}$ " rd. stirrups

Tables from Reinforced Concrete Design

Max $\frac{1}{s}$ equals $\frac{42x10}{4400}$ equals.0955

Index equals $\frac{1.0x3.5}{.0955}$ equals 55

N equals 6x5.5x.0955 equals 12

2 Stirrups at 12"

2 " at 9"

6 required in Beam Schedule

BEAM DATA

Beam	Load (#/it.)	Act. Mom. (Ft. Kips)	All.Mom. (Ft.Kips.)	Shear #/sq.in.)
B-1	1809	32.1	36.4	66.4
B-2	1259	25.6	14.9	33.8
B-3	1809	28.1	36.4	66.4
B-4	1826	40.8	40.1	92.3
B-5	1809	2851	36.4	66.4
B-6	1809	32.1	36.4	66.4
B-7	1292	3.46	28.3	29.0
B-21	1809	32.1	36.4	66.4
B-22	1259	3.86	14.9	33.8
B-23	1809	28.1	36.4	66.4
B-24	1826	40.8	46.1	92.3
B-25	1809	28.1	36.4	66.4
B-26	1809	32.1	36.4	66.4
B-27	1292	3.46	28.3	29.0
B-28	1772	40	32.8	92
B-29	1772	33.3	32.8	92
B-30	1772	33.3	32.8	92

BEAM DATA

Beam	Bond ($\bar{u}$/sq. in)	Steel (Ft. kips)
B-1	100.1	42.8
B-2	101.3	13.3
B-3	83.2	48.2
B-4	481.2	68.7
B-5	87	49.4
B-6	100.1	42.8
B-7	107	18.6
B-21	100.1	42.8
B-22	101.3	13.3
B-23	83.2	48.2
B-24	81	68.3
B-25	87	49.4
B-26	100.1	42.8
B-27	107	18.6
B-28	146	37.8
B-29	133.2	33.2
B-30	83.2	48.2

Beam Conclusions

B-27 and B-7 which frame the elevator shaft, show shear stresses which do not exceed the allowable unit stresses for concrete. Stirrups are required in the beam schedule. Due to the fact that the details for the stairways and the elevator shaft were not available, the precise value for shear is not known, The unit shear is 69 p.s.i. and therefore a greater load can be applied before stirrups are required. However in this case where the loads cannot be accurately determined when the elevator is in operation, it is best to be on the safe side and allow for unexpected stresses.

In each case the number of stirrups required in the beam schedule is greater than the number calculated. A maximum spacing on 10" would increase the number of stirrups

COLUMN COMPUTATIONS

1. Principal columns shall have a mimimum diameter or thickness of 10" and a minimum gross area of 120 sq.in.

2. Longitudinal reinforcement shall consist of at least 4bars of minimum diameter of $\frac{5}{8}$".

3. Lateral ties shall be at least $\frac{1}{4}$" in diameter and shall be spaced apart not over 16 bar diameter, 48 tie diameters or the least dimension of the column. When there are more than 4 vertical bars, additional ties shall be provided so thate every longitudinal bar is held firmly in its designed position.

Use Transformed Area Method

Penthouse Roof To Main Roof Column-32

Size equals 12x12 Steel equals 4-$\frac{5}{8}$" rd. bars

A_g 12x12 equals 144 f'_c equals 2500

A'_s equals (1.23)(12-1) equals $\frac{13.33}{157.53}$

f_s equals 20,000

n " 12

f_c " 625

P_a equals 157.53(625) equals 98500 lbs (Allowable)

Column 32 MAIN ROOF TO THIRD FLOOR

Size 16"x16" Steel 4-$\frac{3}{4}$" rd.

Concrete Area equals 16x16 equals 256 256

Tranformed Steel Area equals (12-1)(1.77) $\frac{19.47}{275.47}$

f_c equals 625

n " 12

P_a equals 275.47x625 equals 172,000'# (allowable)

THIRD FLOOR*-SECOND FLOOR

Size 16"x16" Steel 4-$\frac{5}{8}$" Rd. bars

Concrete area equals 16x16 equals 256sq.in.

Transformed steel area " 26.5 "
282.5 sq.in.

P equals 282.5x256 equals 176,500#(allowable)

SECOND FLOOR TO FIRST FLOOR

Size 16x16" steel equals 8-1" Rd. bars

Concrete area equals 16x16 equals 256 sq.in.

Transformed steel area equals (10-1)6.3 56.6 "
312.6 sq.in.

fc equals 3,000#/sq.in.

n " 10

f_c " 750#/sq.in.

P equals 750x 312.6 equals 234,500 # (allowable)

FIRST FLOOR TO FOOTING

Size 18"x18" Steel 8-1" sq. bars

Concrete area equals 18x18 equals 324 sq.in.

Transformed steel area equals(10-1)8 equals 72 sq.in.
Total area " 396sq.in.

P equals 396x750 equals 297,000#(allowable)

Comparison between actual and allowable column loads

PENTHOUSE ROOF TO MAIN ROOF

75# 6" penthouse roof

50# live load
125# Lansing building code recommends 30# per sq.ft. for live load

125x256 equals 32,000# Total panel load
1,500 Column load
33,500# Actual "
98,500# Allowable

COLUMN SUPPORTING MAIN ROOF

256x185 equals	34,550	main roof
	2,670	column
	33,500	from floor above
	70,720#	actual
	172,000#	allowable

COLUMN SUPPORTING THIRD FLOOR

256x185 equals	47,400	third floor
	2,670	column
	70,720	From floor above
	120,790 #	actual load
	176,500#	allowable

COLUMN SUPPORTING SECOND FLOOR

256x185	47,400	second floor
	120,790	from floor above
	2,670	column
	170,860#	actual
	254,200#	allowable

COLUMN SUPPORTING FIRST FLOOR

290x 256	74,200#	first floor
	5,480	column
	170,860	from floor above
	248,580#	actual
	297,000#	allowable

In determining the load on each columnn, it was assumed that the column supported the slab halfway to the next column in four directions. The corner columns were assumed to carryone half a panel load. The columns in every case appear to be over designed. In some instances the actual load was slightly greater than one half the allowable.load.

Column Data

Columns	Size	Floor	Steel	Allow. Load (Kips)	Actual Load (Kips)
52,54,56	10x16	P-R	4-$\frac{5}{8}$"	108.5	9.02
	10x16	R-5	4-$\frac{3}{4}$"	112	21.10
	10x16	5-2	4-$\frac{3}{4}$"	112	54.29
	10x16	2-1	4-$\frac{7}{8}$"	136	71.48
	12x16	1-F	4-1"	160	104.68
53-55	10x16	P-R	4-$\frac{5}{8}$"	108.5	9.02
	10x16	R-5	4-$\frac{3}{4}$"	112	21.10
	10x16	5-2	4-$\frac{3}{4}$"	112	54.29
	10x16	2-1	4-$\frac{7}{8}$"	136	71.48
	12x16	1-F	4-1" sq.	171	104.68
16,17	12x12	R-5	4-$\frac{5}{8}$"	98.5	30.75
	12x24*	5-2	6-$\frac{5}{8}$"	222.8	75.47
	12x24*	2-1	6-$\frac{3}{4}$"	268	116.19
	12x24*	1-F	6-$\frac{7}{8}$"	294	150.70
15-18	12x12	R-5	4-$\frac{5}{8}$"	98.5	30.75
	12x28*	5-2	6-$\frac{5}{8}$"	177.5	61.03
	12x28*	2-1	6-$\frac{3}{4}$"	210.5	91.39
	12x30*	1-F	6-$\frac{7}{8}$"	250.2	119.35

All bars are round unless sesignated as square by mark sq.

R designates roof

P designates penthouse

Column Data

Columns	Size	Steel	Floor	Allow. Load (Kips)	Actual Load (Kips)
38,43	16x16	4-$\frac{5}{8}$"	P-R	108.5	25.67
	16x16	4-$\frac{3}{4}$"	R-5	172	57.35
	16x16	4-$\frac{3}{4}$"	5-2	172	90.18
	16x16	4-1"sq	2-1	219	130
	16x16	4-$\frac{1}{4}$"sq	1-F	285	170
34, 42, 44	16x16	4-$\frac{5}{8}$"	P-R	108.5	13.15
	16x16	4-$\frac{3}{4}$"	R-5	172	56.34
	16x16	4-$\frac{3}{4}$"	5-2	172	89.17
	16x16	4-$\frac{7}{8}$"	2-1	208	133.05
	16x16	4-1"	1-F	264.2	170.6
48,49	16x16	4-$\frac{5}{8}$"	P-R	108.5	11.79
	16x16	4-$\frac{5}{8}$"	R-5	168.5	43.64
	16x16	4-$\frac{3}{4}$"	5-2	172	86.96
	16x16	4-$\frac{7}{8}$"	2-1	204	79.27
	16x16	4-$\frac{3}{4}$"	1-F	204	104.98

All bars are round unless designated as square by mark sq.

R designates roof

P designates penthouse

Column Data

Columns	Size	Steel	Floor	Allow Load (Kips)	Actual Load (Kips)
1,17 18,21	12x12	4-$\frac{5}{8}$"	R-5	98.5	19.1
	14x14	"	5-2	132.5	48.6
	16x16	4-$\frac{3}{4}$"	2-1	204	78.2
	22x22*	"	1-F	204	108.6
2-6 14-19 8-12 21-25	12x12	4-$\frac{5}{8}$"	R-5	98.5	27.4
	12x14	"	5-2	113.4	65.1
	12x16	4-$\frac{3}{4}$"	2-1	156	101.7
	12x32*	"	1-F	204.5	155.9
26-31 38,36 40-41 30-31	16x16	4-$\frac{5}{8}$"	R-5	168.2	32.1
	16x16	4-$\frac{3}{4}$	5-2	172	69.4
	16x16	"	2-1	204	109.8
	16x16	"	1-F	204	148.5
32,37 38,39	12x121	4-$\frac{5}{8}$"	P-R	98.5	33.5
	18x16	4-$\frac{3}{4}$"	R-5	172	70.7
	16x16	4-$\frac{7}{8}$	5-2	176.5	120.79
	16x16	8-1"	2-1	234.2	170.7
	16x16	8-1"sq.	1-F	297	248.54

All bars are round unless designated as square by mark sq.

R designates roof

P designates penthouse

Footings

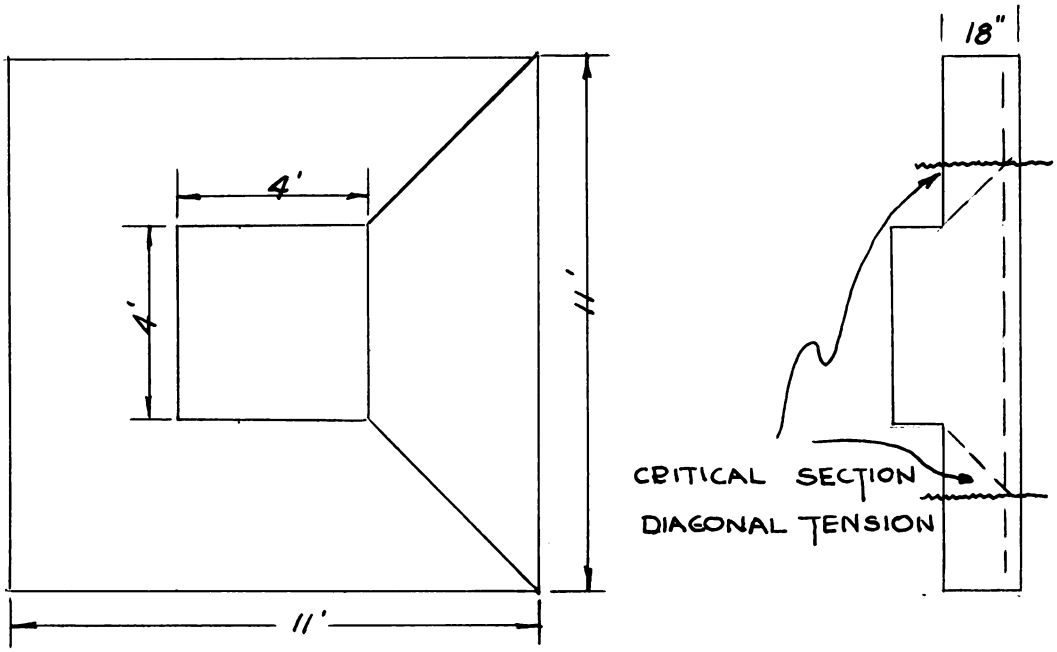
(a) The critical section for bending moment in a concrete footing which supports a concrete column, wall, or pesdestal, shall be considered to br at the face of the column, wall. or pesdestal. For footing under masohry walls, the critical section shall be assumed to be halfway between the edge and the middle of the walk.

(b) The bending moment at the critical section in a square footing shall be computed from the load on the trapezoids bounded by the line of critical section for moment, the corresponding edge of the footing and the portions of the two diagonals. The load on the two corner triangles shall be considered as applied at a distance of six-tenths of the p projection of the footing from the line of critical section for moment.

(c) The critical section for diagonal tension in footings on soil shall be assumedas a vertical section at a distance (d) from the face of the column or pesdestal supported by the footing.

(d) The shearing unit stress on the critical section shall not exceed $.02f'_c$ for footings with straight bars nor $.03f'_c$ for footings with special anchorage of longitudinal steel.

FOOTING CALCULATIONS



Column load equals 248,040#

Footing weight " 29,650#

278,190# Gross load

$\frac{278,190}{11x11 \text{ (base area)}}$ equals 2500#/sq.ft.

2000#/sq.ft. Allowable

$\frac{248,040}{11x11}$ equals 2055#/sq.ft. Unit net pressure

Depth: Total punching shear

$248,040 - 2500x \frac{18x18}{144}$ equals 243,360#

18x18 equals column area

$v = \frac{V}{bjd}$ equals $\frac{234,460x8}{4x18x7x26}$ equals 148,4#/sq.in.

Allowable punching shear equals .05x3000 equals 150#/sq.in.

Diagonal tension:

Net pressure equals 2055#/sq.ft.

4 plus 2x 15" equals 4'-26" equals 6'-2"

121 sq.ft.(base area) -6.16^2 equals 82,9sq.ft.

82.9x2055 equals 170,000# equals V

v equals $\frac{V}{bjd}$ equals $\frac{170,000x8}{4x6.17x12x7x13}$ equals 50.4#/sq.in.

Allowable equals 50#/sq.in

Moment at the face of the cap;

4x5.5x20.5x2055 equals 590,000

5,5^{2}x 41 x.6x2055. " 617,000

1,207,000"#

d equals $\sqrt{\frac{1,207,000}{208x48}}$ equals $\sqrt{124.3}$ equals 11.12"

Weatherproofing 5"

16,12"

M equals $A_s f_s jd$

A_s " $\frac{M}{f_s jd}$ equals $\frac{1,207,000}{20,000x7x13}$ x8 equals 5.51sq.in.

Bond: Shear at face of cap

Total area - area of the cap

121sq." - 16sq." equals 105sq."

105x2055x.25 equals 54,000#

u equals $\frac{54,000 \times 8}{55.55 \times 7 \times 13}$ equals 154.2#/sq.in. O.K.

allowable equals 168#/sq.in.

FOOTING CONCLUSIONS

The thickness of the cap and base are proportionedas follows: the thickness of the cap is to be 0,4d and the base is to be 0.6d, where d is the combined thickness of

the base and cap. The soil borings revealed a wet sand for the foundations at the proposed site, thus a low allowable bearing pressure was adopted. The allowable soil pressure of 2000#/sq.ft. was exceeded but once- that being under the footing B2. The actual soil pressure in most cases was about 1600#/sq.ft. This would seem to indicate that the actual columns loads were low. HOwever every square foot of floor space and all the columns and beams were accounted for. There is obviously a discrepancy on the calculations somewhere although this author is at a to explain where The required depths at the face of the cap are practically without exception too high. Also the steel furnished is in excess of that required. There is no need for stirrups as the diagonal tension is below the allowable in every case.

Footing Data

Footing	Steel Req'd (sq.in.)	Steel Have (sq.in.)
1,17,13 20	2,08	3.69
23, 6,8 9,24,25 10-12,14 18,21-23	2,83	4.30
4,5,15, 18	2.63	4.30
26,29,30 31,35,36 40,41,45 46,51	3.05	4.30
16,17	3,59	4.09
32,37,38, 39	5.31	5.515.51
(27,32,34)	10.0	8.56
(28,55,33)	10.0	9.3
(45,56,50) (44,54,47)	10.9	9.3
(43,45)	19.4	21.1
48,49	2.49	3.06

Footing Data

Allowable soil pressure 2000#/sq.ft.

Footing	Unit Press.	Punch. Shear	Diagonal Tension	Depth at cap Req'd	Depth at cap Need
1,17,13, 20,	1530	82.4	34.4	12.6	16
					16
2,3,6,8, 10-12,14 9, 24,25 19,21-23	1610	99.3	41,6	13,3	
4,5,15, 18	1605	99.0	41,6	13.3	16
16,16	1758	85.4	44.7	13.3	16
40,41 26,29,30 42,46,51 51,53,56	1760	113.0	48.6	14.0	16
52,57,58 59	2300	148.4	50.4	16.2	18
(27,52,54)	1695	104.0	37.0	12.1	18
		85.5	37,0		
		106	37,0		
(38,55,55)	1609	104	39.5	12.4	18
		85.7	39.5		
		122.3	39.5		
(45,56,50) (44,54,47)	1740	106.5	35.5		16
		83.6	35.5		
		105.9	35.5		
(45-45)	1458	109.0	47.3	20.1	20
		85.9	47.3		
48,49	1965 (#/sq.ft.)	86.4 (#/sq.in.)	55.2 (#/sq.in.)	13.0 (in.)	14