Design of a Reinforced-Concrete Ware House

A Thesis

1920

by R. Nebolsine
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Preface

The object of this thesis is the design of a reinforced concrete Warehouse 86'x65' in size. There are to be 3 stories each 13' high & a basement 11' below the first floor.

Throughout the design - the Author has followed the Recommendations laid down in the Final Report of the Joint Committee appointed by the American Society of Civil Engineers.

Flat slab system of floors has been adopted for this building - as this type of construction is now generally conceded to be the most suitable for Warehouse & there high live loads.
Roof.

Roof Drainage:

According to the recommendations of Mr. A.M. Wolfe (Eng. News May 11 1916) — a) 1" of conductor area is required for 75-100 sq ft of roof. b) Diameter of downspout should not be less than 3¾". c) Slope of roof to insure proper drainage

\[ \frac{1}{4} - \frac{3}{4} \text{" per ft.} \]

Use: a) 4 downspouts b) 4" dia c) Slope of roof 3/8" per ft

Conductor box shown in figure 1.

Description of Roof:

Cinder filling—shall be placed on the concrete roof slab of 3" min. thickness and varying in depth to secure the necessary slope of the roof surface.

Maximum depth of cinder fill = \( 23 \times \frac{3}{8} + 3 = 11\frac{5}{8} \) " say 12"

Average " — " — " say = 8"

Mortar Coating — 1½" in thickness shall be placed on cinder fill
Felt and Gravel - roof covering shall be placed on the mortar coating; the roof covering shall comply to the specifications of the American Railway Engineering Association (1910)

Flashing - as shown in fig 3 shall be used

Parapet walls - shall be of reinforced concrete construction as shown in fig 3; the parapet wall must be provided with overflow openings to prevent flooding of the roof.

Provision for Expansion of the cinder fill and mortar coating should be made as shown in fig 3
Fig 1.
Fig 2.
Fig. 3
**ROOF SLAB.**

**Description:**
Two way system flat slab - without drop panels
Dia. of Capitals = .225 x 22 = 4.95' say 5'0" W 60°

**Loading:**

- Live Load (Snow) 40
- Felt & gravel covering 5
- 1½" Mortar coating 18
- 8" Grider fill @ 75#/ft 50
- Assume 9½" slab 232#/6

**Thickness of Slab:**

\[ t = 0.024 \times L \times \sqrt{W} + 1 \frac{1}{2} \]

\[ t = 0.024 \times 21 \times \sqrt{232} + 1 \frac{1}{2} = (7.7 + 1.5) \text{ say 9} \frac{1}{2} " \]

**Design of Outer Panel:**

**Outer panel positive B.M.**

Total B.M. = \( \frac{1}{25} \times W \times L (l-\frac{2}{3}c)^2 + 20\% = \)

\[ = 1.2 \left[ \frac{1}{25} \times 232 \times 22 \left( 22 - \frac{2}{3} \times 5 \right)^2 \right] = 1.2 \times \frac{5110}{25} \times 18.67^2 = \]

\[ = 85200 \# = 1022\,000''\# \]
Assume 35% taken by inner section.
" 65% " "(c) outer section.

**Interior section:**

\[ \text{B.M.} = 0.35 \times 1022000 = 3577000 \ " \# \]

\[ A_s = \frac{3577000}{16000 \times 2 \times 8.0} = 3.20 " \]

\[ d = 9.5 - 1.5 = 8.0 \quad \text{Use 17} - \frac{1}{2} \ " \# \]

\[ f_c = \text{O.K. as } p < .0077. \]

**Outer section:**

\[ \text{B.M.} = 0.65 \times 1022000 = 664000 \ " \# \]

\[ A_s = \frac{664000}{16000 \times 2 \times 8.0} = 5.92 " \]

\[ \text{Use 14} - \frac{3}{4} " \# \]

\[ f_c = \text{O.K. as } p < .0077 \]

**Outer panel Neg B.M. (at wall)**

Total B.M. = \( \frac{1}{15} \) W L \( (l - \frac{2}{3} c) \) =

\[ \frac{1}{15} \times 232 \times 22 \times 18.67^2 = 118500 \ " \# = 1423000 \ " \# \]

Assume 25% taken by Mid section
" 75% " " Column head "

**Mid section:**

\[ \text{B.M.} = 0.25 \times 1423000 = 3557500 \ " \]
\[ A_s = \frac{3.55 \times 10^3}{1600 \times \frac{7}{8} \times 8.0} = 3.17'' \]

Use 17-\( \frac{1}{2}'' \) fy

\[ f_c = 0.07 \] as \( \rho < 0.0077 \)

Column head section:

\[ B.M. = 0.75 \times 1423000 = 1069000''# \]

\[ A_s = \frac{1069000}{1600 \times \frac{7}{8} \times 8.0} = 9.55'' \]

Use 22-\( \frac{3}{4}'' \) fy

\( \rho > 0.0077 \) so that to keep \( f_c \leq 650 \)
wel must have compression steel.

From examination of the following case that has been worked out provide say: \( A_s' = 6.0'' \)

Use 14-\( \frac{3}{4}'' \) fy at bottom.

Outer panel Negative B.M. (at first column away from wall)

Total B.M. = \( \frac{1}{15} \) W L (\( e - \frac{2}{3} e \))^2 + 20% =

\[ = 1.20 \left[ \frac{1}{15} \times 232 \times 22 \times 18.67^2 \right] = 141200''# = 1693000''# \]

Assume 25% taken by Mid section

\[ 75\% \] " " " Column head " 
Mid section:

\[ B.M = 0.25 \times 1693000 = 423000 \text{"} \]
\[ A_5 = \frac{423000}{16000 \times 2 \times 8.0} = 3.77 \text{"} \]

Use 20 - \( \frac{1}{2} \) " \( y \)

\[ f_c = 0.1K \text{ as } p < 0.0077 \]

Column head section:

\[ B.M = 0.75 \times 1693000 = 1270000 \text{"} \]
\[ A_5 = \frac{1270000}{16000 \times 2 \times 8.0} = 11.34 \text{"} \]

Use 26 - \( \frac{3}{4} \) " \( y \)

but \[ p = \frac{A_5}{bd} = \frac{11.34}{11 \times 12 \times 8.0} = 0.111 > 0.0077 \]

so that to keep \( f_c \leq 650 \) we must have compression steel

\[ B.M \text{ to be carried} = 1270000 \]

\[ B.M = 0.077 \times 132 \times 8.0 \times 16000 \times 2 \times 8 = 925000 \]

\[ \frac{345000}{4880 \times 6.2} = 925000 \text{"} \]

\[ d = 8" \text{ : } kd = \frac{3\times 8}{8} = 3" \]
\[ d' = 1\frac{1}{2}" \text{ : } f_{\text{c}} = 15 \times \frac{650}{30} = 4880" \]

\[ A_5' = \frac{345000}{4880 \times 6.2} = 10.9 \text{"} \]

Use 25 - \( \frac{3}{4} \) " \( y \)

\[ : \text{Covered } A_5 = p \cdot bd + \frac{4.83 \times 10.9}{18} = \]

\[ = 8.24 + 3.33 = 11.57 \text{"} \text{ have 0.K} \]
Design of Interior Panel

**Int. panel pos. B.M.**

Total B.M. = \( \frac{1}{25} \) w.l. \((l - \frac{2}{3} c)^2 = \)

= \( \frac{1}{25} \) 232 \( \times \) 21 \( \times \) 17.67^2 = 60750'\# = 729000'\#

Assume 35% taken by Int. section

" 65% " " Outer "

**Int. section:**

B.M. = .35 \( \times \) 729000 = 255000'\#

\( A_s = \frac{255000}{16000 \times \frac{7}{8}} = 2.28 \) 0''

Use 12 - \( \frac{1}{2} \)' 4

\( f_c = 0.K. \) as \( p < .0077 \)

**Outer section:**

B.M. = .65 \( \times \) 729000 = 474000'\#

\( A_s = \frac{474000}{16000 \times \frac{7}{8}} = 4.23 \) 0''

Use 10 - \( \frac{3}{4} \)' 4

\( f_c = 0.K. \) as \( p < .0077 \)
Int panel Neg B.M.

Total B.M. = \( \frac{1}{15} \times W \cdot l \cdot (l - \frac{2}{3}c)^2 = \frac{1}{15} \times 232 \times 17.67^2 = \)

= 101400' # = 1220 000'' #

Assume 25% taken by Mid section

" 75% " " Col. head "

Mid section:

B.M. = .25 \times 1220 000 = 305 000'' #

\( A_s = \frac{305 000}{16000 \times \frac{7}{8} \times 3.0} = 2.73 \) #

Use 14 - \( \frac{1}{2} \) " #

\( f_c = 0.1 \) as \( \rho < 0.0077 \)

Col. head section:

B.M. = .75 \times 1220 000 = 915 000' #

\( A_s = \frac{915 000}{16000 \times \frac{7}{8} \times 8} = 8.16 \) #

Use 19 - \( \frac{3}{4} \) " #

\( f_c = 0.1 \) as \( \rho = \frac{8.16}{10.5 \times 12 \times 8} = 0.0081 \approx 0.0077 \) very nearly
FLOOR SLAB

Description
Two way system flat slab - with drop panels
Dia of Capital 60" as before
Length of drop panel = .4 l = .4 x 21 say 8' 6"
Drop = 4"

Loading
L.L. 200
9" Slab

Thickness of Slab (minimum)
\[ t = 0.02 \cdot l \cdot \sqrt{w} + 1.0 \]
\[ t = 0.02 \times 21 \sqrt{313} + 1.0 = 8.45 \text{ say } 8 \frac{1}{2} " \]

Design of Outer Panel

Outer panel pro. B.M

Total B.M. = \[ \frac{1}{25} \omega l (l - \frac{2}{3}e)^2 + 20 \% \]
= 1.2 \[ \left[ \frac{1}{25} \times 313 \times 22 \times 18.67^2 \right] = 115,000' = 1380,000'' \]
Assume 30% taken by interior section
70% " " outer"
Interior section:

\[ B.M = 0.30 \times 1380000 = 414000" \#
\]

\[ A_s = \frac{414000}{16000 \times 7.25} = 4.07" \#
\]

Use 21 - \( \frac{1}{2} \)"

\[ f_c = 0.6 \quad \text{as} \quad \rho < \rho_{cr}
\]

Outer section:

\[ B.M = 0.70 \times 1380000 = 966000" \#
\]

\[ A_s = \frac{966000}{16000 \times 7.25} = 9.52" \#
\]

Use 22 - \( \frac{3}{4} \)"

But \( \rho = \frac{A_s}{\rho bd} = \frac{9.52}{10.5 \times 12 \times 7.25} = 0.0096 > 0.0077 \) so that to keep \( f_c \leq 650" \), we must have comp. steel.

Provide \( \rho A_s' = 7.0" \quad \text{Use} \quad 16 - \frac{3}{4}"

Outer panel negative B.M (at wall)

\[ \text{Total B.M} = \frac{1}{15} w L (L - \frac{2}{3}c)^2 = \frac{1}{15} 313 \times 22 \times 18.67^2 = 1900000" \#
\]

Assume 20% taken by Mid section

" 80%  "  " Col. head  "
Mid section:

\[ B.M. = 0.20 \times 1900000 = 380000"^# \]

\[ A_s = \frac{380000}{16000 \times 7.25} = 3.74 \text{"} \]

Use 19-\(\frac{1}{2}\)"p

\[ f_c = 0.9 \quad \text{as} \quad p < 0.0077 \]

Col. head section:

\[ B.M. = 0.80 \times 1900000 = 1520000"^# \]

\[ A_s = \frac{1520000}{16000 \times 10.75} = 10.00 \text{"} \]

Assume \(d = 12.5 - 1.0 - 7.5 = 10.75"\) to compensate for the \(8\frac{1}{2}"\) thickness of parts of the col. head section

Use 23-\(\frac{3}{4}\)"p

\[ f_c = 0.9 \quad \text{as} \quad p < 0.0077 \]

Outer panel req. B.M. (at first col. is away from wall)

Total B.M. = \(\frac{1}{15} \text{w} \times (l - \frac{3}{2}c)^2 + 20\% \) =

\[ = 1.20 \left(\frac{1}{15} \right) 313 \times 2 \times 2 (22 - 3.33)^2 \right) = 190 000"^# = 2 280 000"^# \]

Assume 20% taken by mid section

" 80% "  " col. head "

Mid section:

\[ B.M. = 0.20 \times 2 280000 = 456000"^# \]
\[ A_5 = \frac{456,000}{16,000 \times \frac{7}{8} \times 7.25} = 4.50 \text{ in.} \]

Use 2\(\frac{3}{4}\)" y

\[ f_c = 0.0 \text{ K as } p < 0.0077 \]

Combination head section

> B.M. = 0.80 \times 2,280,000 = 1,830,000" #

\[ A_5 = \frac{1,830,000}{16,000 \times \frac{7}{8} \times 10.75} = 12.10 \text{ in.} \]

Use 2\(\frac{3}{4}\)" y

but \[ p = \frac{A_5}{bd} = \frac{12.1}{132 \times 10.75} = 0.0085 > 0.0077 \text{ so that} \]

to deep \[ f_c \leq 6.50\% \text{ provide } A'_5 \]

\[ d' = 1\frac{1}{2} " \quad kd = \frac{3}{8} \times 10.75 = 4.4 " \quad : \quad f'_5 = 650 \times \frac{2.2}{4.4} \times 15 = 6400 \]

B.M. to be carried \[ = 1,830,000 \]

\[ B.M. = 0.0077 \times 132 \times 10.75 \times 16,000 \times \frac{7}{8} \times 10.75 = 1,650,000 \]

\[ \text{taken by slab without compression} \quad \frac{180,000 "}{180,000 "} \# \]

\[ : \quad A'_5 = \frac{180,000}{6400 \times 9.25} = 3.04 \text{ in.} \]

Use 7\(\frac{3}{4}\)" y

\[ A_5 = p \cdot bd + A'_5 \times \frac{6.4}{16} = 10.18 + 1.22 = 11.40 \text{ in.} \]

hence O.K.
Design of Interior Panel

**Int Panel pos. B.M.**

Total B.M. = \( \frac{1}{25} \cdot w \cdot (l - \frac{2}{3}c)^2 \)

\[ = \frac{1}{25} \cdot 313 \times 21 \times (17.67)^2 = 82200 \text{#} = 986000" \#

Assume 30% taken by Int section

" 70% " " Outer "

**Int. section:**

B.M. = \( 0.30 \times 986000 = 296000" \#

\[ A_s = \frac{296000}{16000 \times \frac{3}{2} \times 7.25} = 2.91" \#

Use 15 - \( \frac{1}{2}" \) @ \( f_c = 0.8 \) K.

**Outer section**

B.M. = \( 0.70 \times 986000 = 690000" \#

\[ A_s = \frac{690000}{16000 \times \frac{3}{2} \times 7.25} = 6.79" \#

Use 16 - \( \frac{3}{4}" \) @ \( f_c = 0.8 \) K as \( p < .0077 \)

**Int panel negative B.M.**

Total B.M. = \( \frac{1}{15} \cdot w \cdot (l - \frac{2}{3}c)^2 = \)

\[ = \frac{1}{15} \times 313 \times 21 \times 17.67^2 = 1640000" \# \]
Assume 20% taken by Mid section
   " 80% " " Col. head "

Mid section:

B.M. = .20 \times 1640000 = 328000 \#

A_s = \frac{328000}{16000 \times \frac{3}{8} \times 7.25} = 3.24 \text{ in}^2

Use 17 - \frac{1}{2} \" P

f_c = 0.\text{K} \quad \text{as} \quad \rho < 0.0077

Col. head section:

B.M. = .80 \times 1640000 = 1310000 \#

A_s = \frac{1310000}{16000 \times \frac{3}{8} \times 10.75} = 8.65 \text{ in}^2

Use 20 - \frac{3}{4} \" P

f_c = 0.\text{K} \quad \text{as} \quad \rho < 0.0077
Third Story Interior Column

Description.

Round columns with 60" capitals

Least width \( \leq \frac{D}{12} \leq \frac{21}{12} \) (1.6')

Say 20" dia Column

Loading

Total Roof Load \( = 21 \times 21 \times 232 = 102,000 \)

D.W (of col head) \( = \frac{20 \times 10 \times 32 \times 17 \times 150}{1144} = 1,800 \)

D.W (of col itself) \( = \frac{\pi \times 20^2}{4 \times 1144} \times 13 \times 150 = 4,200 \)

Design

\[ \text{Total } P = \frac{102,000}{4} = 108,000 \text{ lb} \]

From Hoel's Tables—Try 20" dia (17" eff.) \( p = 1\% \)

\[ M = 0.022 w(l - \frac{3}{8} c) = 0.022 \times 40 \times 21 \times 17.67^2 = 69,300 \text{" lb} \]

From examination of cases that have been worked out on the next page one can safely conclude that the B.M. won't increase for 50% hence design against \( "P" \) is O.K.

Use 20" (17" eff) round column

- \( 5 - \frac{3}{4}"\) bar. reinforcement
- \( \frac{1}{2}" \) - lateral ties 12" apart.
Second Story Interior Column

Description:
Same as for third story int col.

Loading

Load from top

Top floor load $21 \times 21 \times 328$ 108,000#

D.W. (of col + col head)$P = \frac{6,500}{259,000}$

Design

Fig. 23” dia (20” eff.) $p = 2\%$, 1% spiral

$M = \frac{0.022 \times 200 \times 21 \times 1767^2}{12 \times 328} = 28800\# = 345,000\#$

Assume 3rd & 2nd story col. to take the moment in the ratio of 2:3 respectively

$\therefore \frac{2}{5} \times 345 = 207,000\#$

Investigate stresses caused by B.M. by formula $f = \frac{My}{I\delta}$

$I_{xx} = \frac{\pi d^4}{64} = \frac{19 \times 20^2}{64} = 7850$
Assuming $14 - \frac{3}{4}" Y$

$$I_{hors} = (15 - 1)^{4} \times 44 \times (3.32^{2} + 3.12^{2} + 3.50^{2}) = 176 \times 14 \times 2.75 = 3380$$

$$\therefore I_{total} = 11240"^4$$

$$f = \frac{P}{A} + \frac{My}{I} = \frac{259000}{\frac{10}{3}} + \frac{207000 \times 10}{6.28 \times 14}$$

$$= \frac{259000}{\frac{10}{3}} + \frac{207000}{1124} = 645 + 184 = 829 < 700 + 50\% 700$$

Hence O.K against B.M.

Use $23'' (20'' eff)$ round column

$14 - \frac{3}{4}" Y$ lought reinforce

$\frac{3}{8}" Y$ pitch $= 2"$ 1% Spiral hooping
First Story Interior Column.

Description

Same as for 3rd story interior columns.

Loading

Load from top

2nd story floor load \( 21 \times 21 \times 328 \)

D. W. (of col + col. load)

\[ P = 412000 \# \]

Design.

Try 27" (24" eff) \[ p = 2\% \]

1% spiral hoopings

\[ M_{\text{eff}} = 345000" \# \]

B.M carried by col = say 207000" #

Since the B.M of 207000"# didn’t increase the stress intensity in the concrete 50% for second story col.

First story col. is safe against B.M. and design for \( P \) is O.K

Use 27" (24" eff) round col.

14 - 1" p

Longt. reinf.

\[ \frac{1}{2} " \text{ pitch } 2-2\frac{1}{2} " \]

1% Spiral hoopings.
Basement Interior Column

Description

Same as for 3rd story int. col.

Loading

Load from top: 412 000

1st story floor load: 21 x 21 x 328 144 500

D.W. (of col + col load) P = 567 000#

Design

Try 3\(\frac{3}{8}\)" dia (28" eff.) \(P = 25\% \text{(approx)}\) 1% spiral hoops

\[ A_s = \frac{567 000}{700 \times 14} - \frac{23 \times \pi}{4 \times 14} = 58.0 - 43.5 = 14.5" \]

B.M. (as explained above) doesn't influence design

Design for P O.K

Use 31" (28" eff.) round col

8 - 1\(\frac{1}{4}\)" f
4 - 1" f
\(\frac{1}{2}\)" f pitch = 2" 1% spiral hoops
Footings for Interior Columns

Description

The footings shall be square - with reinforcement only at bottom & consisting of two sets of bars placed at right angles to each other & parallel with the sides of the footing

Loading

Assume allowable safe bearing capacity of soil is 3 tons per sq ft

As basement floor is placed directly on soil the footing load equals say 600,000 ft

Design

Required $A$ of footing $= \frac{600,000}{6000} = 100$ ft² Use 10 x 10

Load producing punching shear $= 100 - \frac{75 \times 12^2}{2 \times 4} - 600,000 = 568,000$ ft

$\therefore \quad d = \frac{568,000}{31.4 \times 120} = 48.7$ say 49''

No stumps are needed as (dia of col + 2 x depth of footing at col) > width of footing — It also follows that the reinforcing bars at the bottom of footing can be evenly spaced
\[ A_s = \frac{M}{fs} = \frac{600000 \times 6.2}{16000 \times \frac{2}{3} \times 49} = 5.45 \]

B.M acting on each set of rods = 600000 \times 6.2  
From Hook's diagram

Use 13- \( \frac{3}{4} \)" deep 9.5" c to c Baro should be hooked at the ends

Use 40\times40" Base plate as A of B.P must equal twice the A of column
Design of Parapet Wall.

Description

Height of parapet wall shall be at least 3' - 6" above roofing.

Width of parapet wall as girders say 10".

Loading

Roof load coming onto girders = $\frac{1}{6} \times 22 \times 232 = 851 \text{ lb.}$

Width of girders $6 \times \frac{10}{12} \times 150$

Design

$M = \frac{1850}{1600} \text{ (foot-lb)}$

$M = \frac{1600 \times 2^2 \times x}{9} = 84200 \text{ lb}$

$A_s = \frac{84200}{3 \times 1600 \times \frac{3}{4}} = 2.0 \text{ in.}$ Use $5 - \frac{3}{4}''$ $y$

Assume effective $d = 0.3''$

Vertical reinforcement say $\frac{1}{2}'' y$ $12$ c to c at support $24$ c to c at Midspan.

Temperature & other reinforcement as shown in fig.
Design of Wall Girder

Description

Let the girder be 30" approx. extending from col to col.

Loading

Floor load coming onto girder \( \frac{1}{2} \times 313.22 = 156.61 \)

Wh of fenestra window \( 8\% \times (6 \times 10) \)

D.W of girder

Design

\[
M = \frac{wL^2}{12} = \frac{1700 \times 21^2}{12} = 748000
\]

\[
bd^2 = \frac{M}{R} = \frac{748000}{107.5} = 6950 \quad b = 10 \quad d = 26.5
\]

\[
A_s = \rho bd = 0.077 \times 10 \times 26.5 = 2.04" \quad \text{Use } 5 - \frac{3}{4}" \text{Y}
\]

Use 5 - \( \frac{3}{4}" \text{Y} \) at top at columns by bending up 3 - \( \frac{3}{4}" \text{Y} \)

* by additional 2 - \( \frac{3}{4}" \text{Y} \) 3 - 0" long

Shrinkage - use \( \frac{3}{4}" \text{Y} \)

\[
S = 1700 \times 10 \times 10 = 17000\text{f}
\]

\[
x = 11 \left(1 - \frac{40}{73}\right) = 5.90 \quad y = \frac{17000}{10 \times 26.5^2} = 73.4
\]

\[
s = \frac{2 \times 39 \times 6000 - 7 \times 26.5}{17000} = 12.9 \text{ at } 12"
\]

Space shrinkage at each end and others 6" - 12" - 12" - 18" - 18"
Third Story Wall Column

Description

Wall columns shall be square or rectangular in shape.

A bracket 20" x width of w. col shall be provided for each wall column.

Loading

Total roof load on col  \(22 \times \frac{1}{2} \times 21 \times 232\) = 53,500

Wt. of the adjoining girders  \(750 \times 11 \times 2\) = 16,500

D. W. of col  \(P = \frac{10,000}{80,000}\)

Design  \(B.M. = .04 \times 232 \times 21 \times 17.5 \times 12 = 732,000\) #

But considering we have wall girders B.M. must be reduced by

\(\frac{1}{6} \times \frac{1}{6} = \frac{1}{3}\) on design ag. \(732,000 \times .667 = 489,000\) #

Supposing we use Fenestra windows 18'-6\(\frac{1}{8}\)' long

\(\therefore 21" (18' - 6\frac{1}{8}) = \text{ say } 30"

Try: 30 x 20" col, \(p_0 = 1\%\) \(t = 17"\) \(d' = .10\)

\(X_0 = \frac{489,000}{80,000} = 6.1"\)

\(\frac{X_0}{t} = \frac{6.1}{17} = .36\)

From Zook's diagrams: \(K = .65\)

\(L = .129\)

\(\therefore f_c = \frac{M}{L B + \tau} = \frac{489,000}{.129 \times 27 \times 17 \times 17} = 485\text{ psi} - 0\text{ K.}\)
\[ f'_s = n f_c \left( \frac{d}{K_t - 1} \right) = 15 \times 485 \left( \frac{15}{15\cdot17} - 1 \right) = 7280 \times 0.36 = 2620 / 12'' \]

\[ f'_s = \text{also O.K.} \]

Use 30 x 20'' column

14 - 3/4'' \( f \) - Const. reinfor.

\( \frac{1}{2} ''f \) - Lateral ties 12'' apart
Second Story Wall Column

Description
Same as for third story wall column

Loading
Load from tap
Third story floor load \( 22 \times \frac{1}{2} \times 21 \times 328 \) = 75 600
Wh. of fenestra window & wall girder 20(30 x 120) 6 000
D. W of col \( \frac{9 400}{P = 171 000} \)

Design

\( M = 0.04 \times 328 \times (22 - \frac{3}{3})^2 = 148 000 \) #

\( B.M.\ at\ end = 0.667 \times 148 000 = 967 000 \) #

design as \( 967 000 \times \frac{3}{3} = 580 000 \) # assume \( \frac{3}{3} \) taken by 2nd story col.

Try 30 x 20  \( P = 1.5 \% \) \( t = 17 \) \( d' = .10 \)

\( x_0 = \frac{580 000}{171 000} = 3.4 '' \) \( \frac{x_0}{t} = \frac{3.4}{17} = .20 \)

From Hooks diagrams \( K = 0.99 \)

\( L = 1.20 \)

\( f_c = \frac{M}{L b t^2} = \frac{580 000}{120 \times 27 \times 17 \times 17} = 625 \frac{\%}{\%} < 450 + 50 \% 450 \)

hence O.K.

\( f_s = 105 \) O.K. from companion with third story wall column.

Use 30 x 20 column 14 - 1'' p - for long span \( \frac{1}{2} \) nos. 12'' apart.
First Story Wall Column

Description

Same as for Third story wall column.

Loading

Load from top 171 000
2\textsuperscript{nd} story floor load 75 600

Wt of window & wall girder 8 000

D.W of col

\[
P = \frac{10 400}{26 3 000} = 0.04
\]

Design

As first & second story col's are about equal in stiffness

design against \[967 000 \times \frac{4}{7} = 552 000\] B.M.

Try \[30 \times 20\]" col \[p = 15\%\] \[t = 17\] \[d' = .10t\]

\[N = 15\] \[1\%\] spiral hooping

\[
X_0 = \frac{552 000}{263 000} = 2.1" \quad \frac{X_0}{L} = \frac{2.1}{17} = .124
\]

From Knobbs diagrams \[K = 1.34\]

\[
f_c = \frac{PK}{b't} = \frac{1.34 \times 263 000}{17 \times 27} = 770 ksi
\]

\[770 < 700 + 50\% 700\] hence O.K.

Use \[30 \times 20\]" col \[14 - 1" rebar min\]. \[1/2" pitch 23'" radius]
**Basement Wall Column**

**Description**

The basement wall columns are much wider than the story wall columns and really act like a bearing wall.

**Loading**

Load from top

First story floor load + wall girders

D.W. of col on bearing wall

\[ P = \frac{20,400}{365,000} \]

**Design**

We need not consider B.M. as basement col will carry approx. same B.M as other wall cols but will be 2" as wide.

Use 24' x 60" col 14'-1" Y long, 1'-6" half 12" apart, 10 - 4" dia.
Basement Exterior Wall

Description

The basement ext. wall will be 24" thick (same as adjoining columns) - it will start approx 3' below level of first floor. This wall will be monolithic with basement columns - but will have its own (separate) foundation and thus partly act as a bearing wall; retaining wall & slab between basement columns

Design

1. As a bearing wall it is evidently safe as it only has to carry the basement window; its own weight & part of the col. load at parts adjoining those cols.

2. As a retaining wall we can make a rough design

The depth of the wall (till the level of basement floor) equals approx 8'

Assume for soil \( \theta = 0^\circ \)  Assume a 7' surcharge to take care of concentrated loads

\[
M \text{ per ft of length at basement floor} = 3 \times 366 \times 8 \times 12 = 105,500" \#
\]

average \( p = 366 \)
Moment arm = 3' above
\[ bd^2 = \frac{M}{R} \quad 12\times24\times24 > \frac{105,500}{107.5} \quad \text{hence O.K.} \]

\[ A_3 = \frac{105,500}{16,000 \times \frac{3}{2} \times 22} = 0.34 \text{ in}^2 / \text{ft}^3 \]

Use \( \frac{3}{4} \) " C.C. 12" c to c

Temperature steel (transverse) \( \frac{1}{2} " \) 12" c to c inside

" longitudinal \( \frac{1}{2} " \) 24" c to c outside

3. As a slab between col-c the basement wall is alright

as being safe as a retaining wall it has no tendency
be overstressed in bending as a slab subject to
load (in this case transverse pressure of earth)
Basement Floor

The basement floor is to consist of a concrete slab laid directly on the soil. There will be only temperature reinforcing. Care must be taken to make the floor water and damp-proof.

Use 6" slab with 1/2" granolithic finish

3/8" of 2'-0" concrete throughout the area of the floor.
Footings for Wall Columns

Description
The footings shall be square with reinforcement only at bottom consisting of two sets of bars placed at right angles to each other parallel with the sides of the footing—as we are not limited in land space, the footings can overhang from the wall.

Loading

Footing load = oay 385,000 #

Design

Req A of footing \( \frac{385,000}{6000} = 64.17 \) Use 8x8

Load producing punching shear = \( \frac{64 - 25.5}{64} \times 385,000 = 325000 \)

\[ d = \frac{325000}{120 \times 14 \times 12} = 16.1" \text{ use } 18." \]

The intensity of vert. shear for measuring diag. tension is determined \( [48 - (12 + 18)] = 18" \) from edge of footing

\[ \frac{\sqrt{18}}{d} = \frac{18}{12 \times 14 \times 12} = 48 \% \text{ if we use } d = 19" \text{ no shanks will be needed.} \]
\[ A_s = \frac{M}{f_s \cdot d} = \frac{2600000}{16000 \cdot \frac{2}{3} \cdot 19} = 9.1 \text{ in} \quad \text{1 to wall} \]

Approx. Max. B.M. = \( 8 \, (6000 \times 3 \times 1.5 \times 12) = 2600000'' \#

Use \( 21 - \frac{3}{4}'' \) " in center section 5'-wide hence 10'' c.to.c.

Use \( 2 - \frac{3}{4}'' \) " 1 in each outer section.

\[ A_s = \frac{M}{f_s \cdot d} = \frac{650000}{16000 \times \frac{2}{3} \times 19} = 2.4 \text{ in} \quad \parallel \text{ to wall} \]

Approx. B.M. = \( 8 \, (6000 \times 1.5 \times 1.75 \times 12) = 650000'' \#

Use \( 6 - \frac{3}{4}'' \) " in center section 5'-wide hence 10'' c.to.c.

Use \( 2 - \frac{3}{4}'' \) " 1 in each outer section.
Typical Outer Panel.
Stairway

Description

Stairway shall consist of an inclined slab with steps formed upon its upper surface. There shall be 2 flights to a floor with a platform half way up.

Width 4 ft.

Rise 6½ in.

Run 12 in. (Tread 12½")

Transverse reinforcement shall consist of 1-½' ¥ under each step.

Method of support & dimensions shown in fig.

Loading

L.L. 100 #/hor. ft.

Wh of stairs Proposed slab:

$$\tan x = \frac{6.5}{12} \Rightarrow x = 28^\circ 25'$$

$$\cos x = 0.88 \Rightarrow Wh = \left(\frac{6.5 \times 12 + 12 \times 7}{2} \right) \times 0.88 = 150 \#$$

$$L.L. \quad 100$$

$$D \, W \quad 140$$

Total W = 240 #/
Design of Main Slab
\[ M = \frac{wL^2}{8} \]
\[ w = 240 \quad L = \text{clear span} = 11'0" \]
M = \frac{240 \times 11^2 \times 12}{8} = 43,600" \#
\[ d = \sqrt{\frac{43,600}{12 \times 1075}} = \sqrt{33.7} = 5.8 \quad \text{say} \quad 5\frac{3}{4}" \]
\[ A_s = 4 \times 0.077 \times 5.8 \times 12 = 2.14" \]
Use \( 7 - \frac{5}{8}" @ 8" c to c \)

Design of Platform Slab
\[ M = \frac{wL^2}{8} \quad \text{assum.} \quad w = 160" \#
\[ M = \frac{160 \times 4.2^2 \times 12}{8} = 4220" \#
\[ d = \sqrt{\frac{4220}{12 \times 1075}} \approx 1.8" \]
\[ A_s = 8 \times 0.077 \times 1.8 \times 12 = 1.33" \]
Use \( 12 - \frac{3}{4}" @ 8\frac{3}{4}" c to c \)

Design of Stairway Cross Beam (at floors)
\[ M = \frac{wL^2}{10} \quad w = 240 \times 6 + 160 \times 2 = 1760 \quad L = 8' \]
\[ \text{D.W. of beam} \quad \frac{140}{176} = 1900 "/" \]
\[ M = \frac{1900 \times 8^2 \times 12}{10} = 146,000" \#
\[ S = 1900 \times 4 = 76,000" \#
\[ bd^2 = \frac{146,000}{1075} = 1350 \quad b = 8" \quad d = 13" \]
\[ A_s = \rho \ bd = 0.077 \times 8 \times 13 = .81" \]
Use \( 4 - \frac{1}{2}" @ \) top at ends by bending up \( 2\frac{1}{2}" @ \) placing two additional \( \frac{1}{2}" @ 2'0" long. \]
\[ x_1 = \frac{c}{2} \left(1 - \frac{v}{u}\right) = 4 \left(1 - \frac{40}{40}\right) = 2.08 \] 

\[ v = \frac{76,000}{\frac{7}{8} \times 13 \times 8} = 84.067 \] 

Use \( \frac{3}{8} " \) stirrups \( V \) 

\[ S = \frac{3}{2} \times \frac{22 \times 16,000}{76,000} \times \frac{7}{8} \times 13 = 8" \]

Space stirrups at each end thus \( 3" - 6" - 6" - 9" - 9" \)

**Design of Stairway Cross Beam**

\[ M = \frac{wL^2}{8} \quad w = 1900 \# \quad L = 8' \]

\[ M = 1900 \times \frac{8^2}{8} = 182,000 \# \quad S = 76,000 \# \]

\[ b d^2 = \frac{182,000}{107.5} = 1700 \quad b = 10" \quad d = 13" \]

\[ A_s = \pi b d = 0.0777 \times 10 \times 13 = 1.000 " \quad \text{Use } 2 - \frac{5}{8} " \]

Use \( 2 - \frac{5}{8} " \) at top at end by bending up \( 2 - \frac{5}{8} " \)

\[ x_1 = 208' \quad v = 84 \quad L_{at\ end} = 8' \]

Space stirrups at each end thus \( 3" - 6" - 6" - 9" - 9" \)

**Design of Stairway Girder**

**Loading as shown**

1) \( \frac{1}{5} \) adjoining panel load = 313.2 \( \frac{7}{2} \) = 1320 \# 

2) Fire-proof Terra-cotta masonry \( 580 \# \)

3) Bearing wall (concrete) \( 13 \times \frac{3}{2} \times 30 \) \( \text{assume } 30' \) \( \text{sqft} \)

4) D.W. of Girder \( 450 \)

\[ S = 36,000 \# \text{ approx.} \]
\[ M_{at
debt} = \frac{5}{12} \left( \frac{2350 \times 37 \times 12 + 12 \times 7600 \times (10.5 - 6.5) + 2800 \times (10.5 - 8.5) \times 12}{7} \right) = 0.667 \left( 1550000 + 364000 + 66000 \right) = 1980000 = 1320000''"# \]

\[ bd^2 = \frac{M}{R} = \frac{1320000}{107.5} = 12300 \quad b = 16 \quad d = 30 \]

D. W of Girder \[ 16 \times \frac{34}{144} \times 150 = \frac{550}{100} \]
\[
\text{Additional } M = \frac{100 \times 21}{12} x \frac{X}{12} = 44000''# \]
\[
\frac{1320000}{1364000''#} \]
\[
16 \times 30^2 \times 107.5 > 1364000 \quad \text{Hence design O.K.} \]

\[ A_5 = \varphi \cdot bd = 0.0077 \times 16 \times 30 = 3.7'' \quad \text{Use 6''-3''} \]

\[ \text{Use 8''-3'' at top at ends by bending up 4''-3'' and providing additional 3''-0'' long} \]

\[ x = \frac{L}{2} \left( 1 - \frac{40}{56} \right) = 5.62' \]

\[ v = \frac{36000}{16 \times 30 \times \frac{2}{7}} = 85.7 \]

\[ \text{Use } \frac{1}{2}'' \text{ stirrups} \quad \omega = \frac{3}{2} \times \frac{49 \times 16000 \times \frac{2}{7} \times 30}{36000} = 13.80'' \]

\[ \text{Space stirrups at each end thus 6''-12''-12''-18''-18'' in the middle every 24''} \]
Elevator Shaft.
A complete design of the Elevator Shaft, Pent House, adjoining columns etc... has not been attempted - but an analysis of conditions in the Elevator Stairway panel was made - also a rough design of beams, girders & bearing walls for a typical floor.

Description
The Pent House with the Elevator machinery rests two beams & girders on the adjoining 2 wall & 2 interior columns. The arrangement of beams & girders at the floors is shown on the floor drawing.
Design of Bearing Wall

Description

The bearing wall supports the stairway cross beams (mid floor ones) and rests on the girder (the Stairway girder). The bearing wall is 12" thick.

Loading

At each 1900 x 4 = 7600 # (load from stairway cross beams)
At other end say 300 x 4 = 1200 # (load from outer end of stairway platform)
Dead wt. = 980 #/f

Design

Use $p = 1\%$, $\frac{5}{8}$" $4 \times 5$ c.t.o.c. on each side

Evidently the wall is plenty safe enough to carry the load it being so arranged that there is no B.M.
Design of Elevator Shaft Beam

Description

This beam has to carry the adjoining floor load and also take care of any concentrated loads that might occur in loading or unloading the elevator platform.

Loading

Floor load \( 313 \times 3 \) 940

Equivalent of conc. load \(-200\%\) 200

D. W. of beam below slab \( 60 \) 1200 \(+/-\)

Design

\[ M = \frac{wL^2}{10} = \frac{1200 \times 11^2 \times 12}{10} = 174,000 \text{"} \text{"} \]

\[ bd^2 = \frac{M}{R} = \frac{174,000}{108} = 1610 \text{ assume } b = 10 \]

\[ A_s = pbld = 0.0077 \times 10 \times 13 = 1.00 \text{"} \text{"} \]

Use \( 10 \times 15" \)

Steel at bottom 2 - \( \frac{1}{2}" \)
Steel at ends 2 - \( \frac{3}{8}" \)

Steel at top at ends 2 - \( \frac{1}{2}" \) are bent up at ends
2 - \( \frac{3}{8}" \) are provided at ends 2' - 6" long
Design of Stairway Girder (between stairway & elevator shaft)

Description
This girder carries the partition between the stairway & elevator shaft & also takes the load from the stairway cross-beams & the elevator shaft beam.

Loading as shown

\[ M_{Tc} = \frac{8}{12} \left[ 880 \times \frac{21}{8} + \frac{15}{21} \times (600 \times 10.5 - 600 \times 4.5) + 4 \times 12 \times 600 (10.5 - 8.5) \right] + 364000 \]
\[ = 0.667 \left[ 581000 + 236000 + 66000 + 364000 \right] \]
\[ = 830000 \text{ ft-lb} \]

\[ b = 10 \text{ ft} \]
\[ d = 27.8 \text{ in} \]

\[ A_s = 0.0777 \times 10 \times 27.8 = 2.14 \]
Use \[ 4 - \frac{3}{8}'' \] by bending up \[ 2 - \frac{3}{8}'' \] & providing \[ 2 - \frac{3}{8}'' \] & \[ 2 - \frac{3}{8}'' \] long.
\[ V = 10.5 \times 880 + 690 \times 4 \times \frac{19}{21} + 7600 + \frac{15}{21} \times 6600 = 24000 \text{ ft} \]

\[ v = \frac{24000}{10 \times 27.8 \times \frac{3}{5}} = 98.8 \]

\[ x_1 = \frac{L}{2} \left( 1 - \frac{v}{u} \right) = 10.5 \left( 1 - \frac{40}{98.8} \right) = 6.25' \]

Use \( \frac{1}{2} \) "Pulleys\ W \quad c = \frac{3}{2} \times \frac{79 \times 16000 \times \frac{3}{5} \times 27.8}{24000} = 19" \]

Space rollers at each end thus \( 9'' - 18'' - 18'' - 18'' - 24'' \)

" \quad " \quad in middle every 24" \]
Design of Stairway and Elevator Shaft panel Girder

Description
This girder carries the adjoining floor load & also the Stairway girder (between stairway & elevator shaft); it is supported by the interior adjoining cols.

Loading

\[
\text{Floor load} = \frac{313}{5} \times 21 + 2.5 \times 313 = 1320 + 780 = 2100\text{#}
\]

D.w.h. assume 600\#.

\[
M_{\text{eff}} = \left[ \frac{24\text{,}000 \times 12}{21} + 10.5 \times 2700 \right]9 - \left( 2700 \times 9 \times 4.5 \right) \frac{8}{12} \times 12
\]

\[
= 0.667 \left( 379000 - 109000 \right)12 = 8 \times 270000 = 2160000\#
\]

\[
\sum \beta^2 = 2.550 \times 10.5 + \frac{12}{21} \times 24000 = 28400 + 13800 = 42200\#
\]

\[
b d = \frac{42200}{105} = 402.10\quad b = 15^\circ\quad d = 22.4\text{"}
\]

\[
A_s = \frac{2160 \times 1000}{16000 \times \frac{22.4}{2}} = 6.88\text{"}\quad \text{Use 10" - 1" I}
\]

\[
M_{\text{at supp}} = \frac{8}{18} \times 270000 \times 12 = 1620000\#
\]

Have compression steel at supports so as to keep fc<75%.

Mafe at load is o.k. as the girder acts as T-beam.
The required number of Reinforcing Bars at any section is shown on Drawing.

The arrangement and lengths of Bars is given for two typical hands.

The Point of Inflection is assumed to occur as distance from center of Column equal to one quarter of the span length.

The Bars are bent up as shown on stanch. The Bars are hooked at the ends where unable to develop full strength two band at each place as Wall Sections etc.

Second Floor Plan

FLOOR PLAN of
Reinforced Concrete Ware House

TO ACCOMPANY THESIS BY BEYBOLIAN