EDDY

Design of Reinforced Concrete Engine House

Civil Engineering
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DESIGN OF REINFORCED CONCRETE ENGINE HOUSE

BY

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THESIS

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I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

CLARENCE LEROY EDDY

ENTITLED Design of Reinforced Concrete Engine House

BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Civil Engineer

In Charge of Major Work

Ira O. Baker
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Recommendation concurred in:

Committee
on
Final Examination
INTRODUCTION

Most railway engine houses are of the circular type, having radial stalls, access to which is obtained by means of a centrally located turntable. The usual materials for construction are wood, brick and stone. The cheapest class of house is built entirely of wood, while the more permanent structures are built of brick or stone. In most every case, however, the roof and columns are made of wood.

The requirements for an engine house are as follows:

1. that it be large enough to accommodate the largest engine used on the system,
2. that it have a low first cost,
3. that the cost of maintenance be low,
4. that it be easily heated,
5. that it be well lighted, and
6. that it be well ventilated.

One of the large items of maintenance expense is fire insurance, which could be eliminated entirely if fireproof materials were used. This has been accomplished by using a steel roof on brick or stone walls, but the escaping gases and steam from the engines are very injurious to steel, making this material unfit for engine house construction.

Reinforced concrete is well adapted for use in this class of work, and it is proposed here to design an engine house of the general circular type, using reinforced concrete for the roof and columns. On account of appearances and a slight saving in expense, brick will be used for the outside walls. Concrete is not suitable
for the front post or column, so this will be made of cast iron. The doors and ventilators will be made of wood.

The subject is divided into two parts.

Part I is a presentation of the theories upon which the design of the beams is based, together with the formulas used, the assumptions as to working stresses etc.

Part II is a description of the building, the design, the specifications and an estimated cost per stall.
PART I
THEORIES AND FORMULAS

The roof of the engine house is to be of reinforced concrete slabs carried by reinforced cross beams or purlins to main or radial reinforced beams which are supported by reinforced concrete columns.

The design of the slabs and beams is based upon the straight line theory of distribution of stress, with the concrete taking no tension. In this theory the following assumptions are made:

1 - A plane section before bending remains a plane section after bending,*

2 - Compression is taken entirely by the concrete,
3 - Tension is taken entirely by the steel,
4 - Initial tension or compression is absent in the steel,
5 - Adhesion of concrete to steel is perfect,
6 - Modulus of elasticity of concrete within the usual limits of stress is a constant.

The concrete is to be in proportions of 1 : 2 : 4 by weight and mixed to wet consistency.

Modulus of elasticity of concrete assumed to be 3,000,000 and the safe working compressive stress 700 lbs. per sq. in.

Mild steel reinforcement is to be used and Modulus of elasticity is assumed as 30,000,000. The yield point is taken as 30,000 lbs. per sq. in. and the safe working stress as 14,000 lbs. per sq. in.

* See article by Prof. A. N. Talbot in Proc. Amer. Soc. for Testing Materials - 1904.
The roof slabs are continuous over the cross beams but expansion is provided for at the radial beams. The maximum bending moment allowed for the slabs is taken as \( \frac{1}{10} w l^2 \) for uniform load. Expressed in inch pounds, then, the bending moment, \( M = \frac{6}{5} w l^2 \).

The cross beams will be considered as supported at the ends and the maximum bending moment is taken as \( \frac{1}{8} w l^2 \) for uniform load. Expressed in inch pounds, \( M = \frac{3}{2} w l^2 \).

For the radial beams which are continuous over supports, the maximum resisting moment is taken as \( \frac{1}{10} w l^2 \).

The formulas used are those derived by Taylor & Thompson and given in "Concrete, Plain and Reinforced", pp. 295 - 298.

For any loading of beam, the dimensions are obtained from the formula given below.

\[
d^2 = \frac{M}{Kb}
\]

\( M \) = maximum bending moment, or since the resisting moment \( (M_r) \) must be equal to or greater than the bending moment, \( M = M_r \).

\( d \) = distance from outside compressive fiber to center of gravity of steel in inches,

\( b \) = breadth of beam in inches,

\( K \) = a constant depending upon the values of working stresses in the concrete and steel.

\[
K = \frac{1}{\left(\frac{1}{S} \right)} \left( \frac{1}{1 + \frac{1}{Cr}} \right) \left( \frac{1}{3(1+\frac{1}{Cr})} \right)
\]

\( C \) = working stress in concrete \( = 700 \)

\( S \) = working stress in steel \( = 14 \ 000 \)
r = ratio of moduli of elasticity of steel to concrete
   = 10

Substituting these values in the formula and solving for K we get a value of 104

$$ K = 104, \text{ then } d^2 = \frac{M}{104b} $$

When $M = \frac{1}{8} wl^2$ then

$$ d^2 = 12 \frac{1.5 w}{104 b} $$

and when $M = \frac{1}{10} wl^2$

$$ d^2 = 12 \frac{1.2 w}{104 b} $$

If $h$ = height of beam, and

$e$ = extra depth of concrete below center of gravity of steel

then $h = d + e$.

The ratio of area of steel to area of beam above the center of gravity of the steel ($p$) may be found by the following formula,

$$ p = \frac{1}{S} \frac{S}{2(-) \left(1 + \frac{S}{C} \frac{S}{Cr}\right)} $$

Substituting values of $C = 700$ and $S = 14,000$ and $r = 10$ in this formula, $p = 0.0083 = 83\%$ of steel, which will be used.
PART II

GENERAL DESCRIPTION

The house is circular in plan with radial engine stalls, entrance to which is made by means of a centrally located turntable. The distance from the center of the turntable to the outside face of the front post is 87 feet, and the depth of the house is 84 feet out to out. The angle subtended at the center by each stall is \(6^\circ 34'\ 17''\) and the width of stall is 13 feet at the front and 25 feet 6-5/8 inches at the back. (See Sheet No. 1)

The roof is of reinforced concrete slabs, continuous the length of the stall and carried by cross beams to the main beams which are radial and located between stalls. Over those radial beams, expansion is provided for in the roof slabs. The roof slabs are to be covered with a composition roofing fastened to nailing strips laid in the roof slab.

The radial beams are supported by columns, all of which are of reinforced concrete except the front column which is cast iron on account of having to carry the swinging doors.

A vertical offset is made in the roof at the second column from the front of the house in order to provide window space. The roof slopes both ways from this offset, the water from the roof being carried down on the outside of the house at the back and down on the inside at the front.

Each stall is provided with an engine pit and these pits are connected with a cross pit at the front of the house. The engine pits are to afford means of repairing engines, washing out etc., and are to carry the steam pipes for heating the house and the washout pipes. The cross pits collect the water from the engine pits, carry
the steam and washout pipes etc.

Smoke Jack and ventilator is provided for each stall. The ventilator is to provide additional means of ventilation other than that afforded by the smoke jack.

The floor is cement on a concrete base and slopes in each stall towards the engine pit where provision in made for drainage under the rails into the pit.

The outside walls are made of brick and are 17" thick. Two window openings each 5' x 13' are made in this wall for each stall.

For the details of construction, refer to the drawings.

Sheet No.1 shows a part plan and longitudinal section of the house and a rear elevation of one stall.

Sheet No.2 shows beam details.

Sheet No.3 shows column and foundation details.

Sheet No.4 shows pit and ventilator details, and

Sheet No.5 shows details of doors and smoke jack ring.
DESIGN

ROOF SLABS

Assumed Loading

Composition Roofing -------------- 5 lbs. per sq. ft.
Snow ----------------------------- 20 "  "  "  "
Roof Slab (2-1/2" thick) ---------- 32 "  "  "  "
Total ------ 57 "  "  "  "

On account of the roof being so flat the normal wind load is neglected.

The maximum span for a slab 2-1/2" thick to carry a load of 57 lbs. per sq. ft. is 7'-5". The span used varies from 6' to the maximum of 7'-5". The area of steel required per foot in width of slab is 0.168 square inches.

Use Expanded metal, 3 inch mesh, No. 10 gauge. Actual area of steel reinforcement used per foot in width is 0.185 square inches. Make the distance from the steel to the bottom of the slab 3/4".

CROSS BEAMS

For convenient reference, the beams are numbered beginning at the back of the house consecutively towards the front. The length of these beams vary from 25'-5" at the back of the house to 13' at the front, and in order to maintain a more uniform depth without an excessive variation in the breadth, the spacing is varied.

From beam 1 to 4 --- 3 spaces @ 6'-0"
"  " 4 to 7 --- 3 " @ 6'-8"
"  " 7 to 10 -- 3 " @ 7'-4"
"  " 11 to 13 -- 3 " @ 7'-5"

Beam 11 is in the same vertical plane as beam 10 but under the windows at the vertical offset of the roof.
BEAM NO. 1

It is considered that this beam carries the roof independent of the outside wall.

Length of beam = 25.4 feet.
Span of roof carried = 5 feet.

\[ W = \text{uniform load of beam exclusive of weight of beam} \]
\[ = 57 \times 5 = 285 \text{ lbs.} \]

Assume \( d = 22" \) then the safe load \( (W') \) for beam 1" wide and 25.4 feet long is 28 lbs. This is exclusive of the weight of the beam.

The breadth of beam required to carry the load of 285 lbs.

\[ \frac{W}{W'} = \frac{285}{28} = 10-1/4" \]

Make beam 10-1/4" x 24" \( (e = 2") \)

Area of steel required = 1.87 sq. in.

Twisted bars of the Ransome system will be used except where otherwise specified.

Use 4 - 5/8" bars \( \text{--- Area = 1.56 sq. in.} \)

\[ 2 - 1/2" \text{ " --- " = 0.50 " "} \]

Total \( \text{--- 2.06 " "} \)

Place the 4 - 5/8" bars at the bottom of the beam and space 1-7/8" center to center. Place the 2 - 1/2" bars above the outside bars of the bottom row. (See Sheet No. 2)

In order to prevent diagonal cracks, use 1/2" round stirrups spaced 6" - 12" - 18" - 24" - 30" - 36" etc.

Weight of beam = 6530 lbs.
BEAM NO. 2

Length of beam = 24.5 feet
Span of roof carried = 6 feet.

\[ W = 57 \times 6 = 342 \text{ lbs.} \]

Assume \( b = 1" \) and \( d = 22" \)

\[ W' = 29.6 \text{ lbs.} \]

\[ \frac{W}{W'} = \frac{342}{29.6} = 11-1/2" \]

Make beam 11-1/2" x 24"

Area of steel required = 2.05 sq. in.

Use 4 - 5/8" bars --- Area = 1.56 sq.in.

\[ 2 - 1/2" \quad " \quad " \quad - 0.50 \quad " \quad " \]

Total --- 2.06 " "

Bars are to be spaced as in Beam No. 1 and same stirrups used to prevent diagonal cracks.

Weight of beam = 7240 lbs.

BEAM NO. 3

Length of beam = 23.6 feet
Span of roof carried = 6 feet.

\[ W = 57 \times 6 = 342 \text{ lbs.} \]

Assume \( b = 1" \) and \( d = 22" \)

\[ W' = 23.6 \text{ lbs.} \]

\[ \frac{W}{W'} = \frac{342}{23.6} = 10" \]

Make beam 10" x 24"

Area of steel required = 1.82 sq. in.
Use 4 - 5/8" bars --- Area = 1.56 sq. in.

2 - 1/2"  " --- "  = 0.50 " "

Total ---- 2.06 " "

Spacing of the rods and stirrups to be the same as in Beam No. 1

Weight of beam = 6070 lbs.

**BEAM NO. 4**

Length of beam = 22.7 feet

Span of roof carried = 6 - 1/3 feet.

Besides the uniform load carried by this beam, there is to be carried a concentrated load at the center of 420 lbs. due to the smoke jack and ring weighing 600 lbs. This concentrated load at the center is equivalent to a uniform load per lineal foot of 37 lbs.

\[ W = 57 \times 6 - 1/3 + 37 = 398 \text{ lbs.} \]

Assume \( b = 1" \) and \( d = 22" \)

\[ W' = 39 \text{ lbs.} \]

\[ \frac{398}{39} = 10 1/4" \]

Make beam 10 1/4" x 24"

Area of steel required = 1.87 sq. in.

Use same reinforcement and spaced the same as for Beam No. 1.

Area of steel used = 2.06 sq. in.

Weight of beam = 5980 lbs.

**BEAM NO. 5**

Length of beam = 21.7 feet.

Span of roof carried = 6 - 2/3 feet.

Besides the uniform load carried by this beam, there is to
be carried a concentrated load at the center of 180 lbs, due to the smoke jack and ring weighing 600 lbs. This load at the center of 180 lbs, is equivalent to a uniform load of 17 lbs.

\[ W = 57 \times 6 \ 2/3 + 17 = 397 \text{ lbs.} \]

Assume \( b = 1'' \) and \( d = 22'' \)

\[ W' = 45 \text{ lbs.} \]

\[ \frac{397}{45} = 8.82\text{''} \]

Make beam 9'' x 24''

Area of steel required = 1.64 sq.in.

Use 3 - 5/8'' bars --- Area = 1.17 sq. in.

\[ 2 - 1/2'' \quad " \quad " \quad = 0.50 \quad " \quad " \]

Total --- 1.67 " "

Place the 3 - 5/8'' bars at the bottom of the beam and space 1 - 7/8'' center to center. Place the 2 - 1/2'' bars above the two outside bars in the bottom row. Use same reinforcement for diagonal cracks as in Beam No. 1.

Weight of beam = 5020 lbs.

BEAM NO. 6

Length of beam = 20.7 feet.

Span of roof carried = 6 2/3 feet.

\[ W = 57 \times 6 \ 2/3 = 380 \text{ lbs.} \]

Assume \( b = 1'' \) and \( d = 22'' \)

\[ W' = 52 \text{ lbs.} \]

\[ \frac{380}{52} = 7.308\text{''} \]

Make beam 8'' x 24''
Area of steel required = 1.46 sq.in.

Use 6 - 1/2" bars --- Area = 1.50 sq.in.

Place 4 bars at the bottom of the beam and space 1 1/2" center to center. Place 2 bars above the two outside bars of the bottom row. Use same stirrups and space the same as in Beam No.1.

Weight of beam = 4260 lbs.

BEAM NO. 7

Length of beam = 19.7 feet.

Span of roof carried = 7 feet.

\[ W = 57 \times 7 = 399 \text{ lbs.} \]

Assume \( b = 1" \) and \( d = 20" \)

\[ W' = 48 \text{ lbs.} \]

\[
\frac{W}{W'} = \frac{399}{48} = 8 1/2" 
\]

Make beam 9" x 22"

Area of steel required = 1.49 sq. in.

Use same reinforcement as in Beam No. 6 and space bars same.

Weight of beam = 4190 lbs.

BEAM NO. 8

Length of beam = 18.6 feet.

Span of roof carried = 7 1/3 feet.

\[ W = 57 \times 7 \frac{1}{3} = 418 \text{ lbs.} \]

Assume \( b = 1" \) and \( d = 20" \)

\[ W' = 56 \text{ lbs.} \]

\[
\frac{W}{W'} = \frac{418}{56} = 7 1/2" 
\]

Make beam 8" x 22"
Area of steel required = 1.33 sq. in.
Use same reinforcement and space bars as in Beam No. 6

Weight of beam = 3510 lbs.

BEAM NO. 9

Length of beam = 17.5 feet
Span of roof carried = 7 1/3 feet.

\[ W = 57 \times 7\frac{1}{3} = 418 \text{ lbs.} \]

Assume \( b = 1" \) and \( d = 20" \)

\[ W' = 66 \text{ lbs.} \]

\[ \frac{W}{W'} = \frac{418}{66} = 6 \frac{1}{2}" \]

Make beam 7" x 22"

Area of steel required = 1.16 sq. in.
Use 5 - 1/2" bars --- Area = 1.25 sq. in.
Place 3 bars at the bottom of the beam and space 1 1/2"
center to center. Place two bars above the two outside bars of the
bottom row. Use 1/2" round stirrups spaced as in Beam No. 1.

Weight of beam = 2890 lbs.

BEAM NO. 10

Length of beam = 16.4 feet.
Span of roof carried = 5 feet.

\[ W = 57 \times 5 = 285 \text{ lbs.} \]

Assume \( b = 1" \) and \( d = 13 \frac{1}{2}" \)

\[ W' = 30 \text{ lbs.} \]

\[ \frac{W}{W'} = \frac{285}{30} = 9 \frac{1}{2}" \]

Make beam 9 1/2" x 15" (\( e = 1.5" \))
Area of steel required = 1.06 sq. in.
Use same reinforcement and space bars same as in Beam No.9.
To prevent diagonal cracks, use 3/8" round stirrups spaced as follows: 4" - 8" - 12" - 16" - 20" - 24" - 28" - 32" etc.

Weight of beam = 2500 lbs.

BEAM NO. 11

Length of beam = 16.4 feet.
Span of roof carried = 3.7 feet.
Besides the roof load carried by this beam, there is to be carried the weight of the windows in the vertical offset which is estimated as 30 lbs. per lineal foot.

\[ W = 57 \times 3.7 \times 30 = 240 \text{ lbs.} \]
Assume \( b = 1" \) and \( d = 13 \frac{1}{2}" \)
\[ W' = 30 \text{ lbs.} \]
\[ \frac{W}{W'} = \frac{240}{30} = 8" \]

Make beam 8" x 16"

Area of steel required = 0.90 sq. in.
Use 4 - 1/2" bars --- Area = 1.00 sq. in.
Place the four bars at the bottom of the beam and space 1 1/2" center to center.
Use same diagonal reinforcement as in Beam No. 10.

Weight of beam = 2100 lbs.

BEAM NO. 12

Length of beam = 15.3 feet
Span of roof carried = 7.4 feet.

\[ W = 57 \times 7.4 = 422 \text{ lbs.} \]
Assume $b = 1"$ and $d = 13\frac{1}{2}"$

$W' = 38$ lbs.

$W = \frac{422}{38} = 11\frac{1}{4}"

Make beam $11\frac{1}{4}" \times 15"$

Area of steel required = 1.25 sq. in.

Use 5 - 1/2" bars --- Area = 1.25 sq.in.

Place all bars at the bottom of the beam and space 1 1/2" center to center. Use 3/8" round stirrups spaced as in Beam No. 10 to prevent diagonal cracks.

Weight of beam = 2760 lbs.

BEAM NO. 13

Length of beam = 14.1 feet

Span of roof carried = 7.4 feet.

$W = 57 \times 7.4 = 422$ lbs.

Assume $b = 1"$ and $d = 13\frac{1}{2}"$

$W' = 48$ lbs.

$W = \frac{422}{48} = 9"$

$W' = 48$

Make beam $9" \times 15"$

Area of steel required = 1.00 sq. in.

Use 4 - 1/2" bars --- Area = 1.00 sq.in.

Place all bars at the bottom of the beam and space 1 1/2" center to center. Use 3/8" round stirrups as in Beam No. 10.

Weight of beam = 2030 lbs.

BEAM NO. 14

Length of beam = 13 feet
Span of roof carried = 4 1/4 feet.

\[ W = 57 \times 4 \frac{1}{4} = 240 \text{ lbs.} \]

Assume \( b = 1" \) and \( d = 11 \frac{1}{2}" \)

\[ W' = 40 \text{ lbs.} \]

\[ \frac{W}{W'} = \frac{240}{40} = 6" \]

Make beam 6" x 13"

Area of steel required = 0.57 sq. in.

Use 4 - 3/8" bars --- Area = 0.57 sq. in.

Place all the bars at the bottom of the beam and space not less than 1 1/8" center to center. Use 3/8" round stirrups spaced as in Beam No. 10.

Reinforce the 4" offset over the doors with 1/2" bars in both directions. (See Sheet No. 5)

Weight of beam = 1100 lbs.

RADIAL BEAMS

For convenient reference the beams are numbered, beginning at the back of the house, consecutively towards the front. Beams 1 to 3 inclusive will be considered as continuous over supports and will be allowed a resisting moment of \( \frac{1}{10} w l^2 \). Since the span of the cross beams vary from 25'-5" at the back of the house to 13' at the front, the load carried by the radial beams will vary. The distance between the supports has been varied in order to keep the beams the same size.

RADIAL BEAM NO. 1

Length of beam = 18 feet
The loads carried by this beam are from cross beams 1, 2, 3, and 4 but since 1 and 4 are directly over supports, the bending moment is caused by 2 and 3.

\[ M = \text{maximum bending moment} = 1,065,600 \text{ inch pounds}. \] This in effect is equivalent to a uniform load of 2193 lbs. per lin. ft.

Assume weight of beam as 420 lbs. per foot, then the uniform load \( W \) = 2613 lbs.

\[ d^2 = l^2 \frac{1.2 \ W}{104 \ b} \]

Assume \( b = 12" \) and substitute in above formula with values of \( W = 2613 \) and \( l = 18 \)

\[ d = 29" \]

Make beam 12" x 31"

Weight of beam per foot = 420 lbs. as assumed.

Area of steel required = 2.98 sq. in.

Use 4 - 3/4" bars --- Area = 2.25 sq. in.

\[ 2 - 5/8" \ " \ " \ " = 0.78 \ " \ " \]

Total --- 3.03 " "

Place the 4 - 3/4" bars at the bottom of the beam and space 2 1/2" center to center. Place the 2 - 5/8" bars above the two outside bars in the bottom row.

To provide for negative bending moment over the supports, place 4 - 3/4" bars at the top of the beam and extend each way from the support equal to 1/4 the length of the beam.

Use 1/2" round stirrups spaced 8" - 16" - 24" - 32" - 40" etc to prevent diagonal cracks.

Weight of beam = 7400 lbs.
RADIAL BEAM NO. 2

Length of beam = 20 feet.

\[ M = 1,040,000 \text{ inch pounds}. \]

Equivalent uniform load \((W) = 1,733 \text{ lbs.} \)

Assume weight of beam as 480 lbs. per foot.

\[ W = 2,213 \text{ lbs.} \]

\[ d^2 = 
\frac{1.2 W}{104 b} \]

Assume \( b = 12" \) then \( d = 29" \)

Make beam 12" x 31"

Weight of beam per foot = 420 lbs.  Assumed 480 lbs.

Area of steel required = 2.98 sq. in.

Use same reinforcement as in Beam No.1 and space in same way.

Weight of beam = 8200 lbs.

RADIAL BEAM NO. 3

Length of beam = 22 feet.

\[ M = 965,000 \text{ inch pounds}. \]

\[ W = 1,332 \text{ lbs per foot}. \]

Assume weight of beam as 480 lbs. per foot.

\[ W = 1,612 \text{ lbs.} \]

Assume \( b = 12" \) then \( d = 29" \)

Make beam 12" x 31"

Weight of beam = 420 lbs per foot.

Area of steel required = 2.98 sq. in.

Use same reinforcement as in Radial Beam No.1 and space in same way.

Weight of beam = 9000 lbs.
RADIAL BEAM NO. 4

Length of beam = 22' - 4"

This is the vestibule beam and is considered as supported at the ends, so the maximum resisting moment is taken as \( \frac{1}{8} \) \( wL^2 \) or equal to the bending moment.

\[ M = 785 \, 000 \text{ inch pounds.} \]
\[ W' = 1049 \text{ lbs. per foot} \]

Assume weight of beam as 430 lbs. per foot, then
\[ W = 1479 \text{ lbs.} \]

Assume \( b = 12'' \) then \( d = 30'' \)

\[ d^2 = \frac{L^2 \times 1.5 \times W}{104 \times b} \]

Make beam 12'' x 32''

Weight of beam = 430 lbs. per foot as assumed.

Area of steel required = 3.00 sq. in.

Use same reinforcement as in Radial Beam No.1 except omit the 4 - 3/4'' bars over the supports.

Weight of beam = 9500 lbs.

COLUMNS

The columns are numbered from the back towards the front of the house. No.1 is in the outside wall, but is considered as taking load independent of the wall. Columns 1 to 4 inclusive are reinforced concrete and column 5 is cast iron.

The length and loading of each column is given in the following table.
<table>
<thead>
<tr>
<th>Number</th>
<th>Length</th>
<th>Direct load</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20' 00&quot;</td>
<td>35300</td>
</tr>
<tr>
<td>2</td>
<td>21' 1 1/2&quot;</td>
<td>52300</td>
</tr>
<tr>
<td>3</td>
<td>22' 4 1/2&quot;</td>
<td>47300</td>
</tr>
<tr>
<td>4</td>
<td>23' 9&quot;</td>
<td>44600</td>
</tr>
<tr>
<td>5</td>
<td>16' 7&quot;</td>
<td>20100</td>
</tr>
</tbody>
</table>

Since the wall is independent of column 1, it will be assumed that the wall takes all of the wind load and that none is transferred to the columns. The columns, then, are designed to take the direct load only and no provision is made for flexure due to bending. With the wind on the front of the house this would not be the correct assumption to make, but since the building is circular in form, it is assumed that the wind pressure on the front will not be considerable and will be neglected.

Make columns 1 - 2 - 3 and 4 of 12" x 12" section reinforced with a 3/4" twisted bar in each corner and bound together with 3/8" loops spaced 18" apart.

At the base of the columns place a 10" x 10" x 3/8" plate to prevent the bars from settling before the concrete has set.

The maximum stress comes upon column 2 and amounts to 52300 lbs. Area of section is 144 square inches.

\[
\text{Stress per sq. in.} = \frac{52300}{144} = 363 \text{ lbs.}, \quad \text{but this is including the snow load of 20 lbs. per sq. ft. of roof surface and is not liable to occur until the concrete has set and is not considered excessive.}
\]

Besides the direct load due to the roof and beams, column 5 carries the swinging doors weighing 1350 lbs. These doors are swung by three strap hinges on 1" bolts passing through the cast
iron column. At the points where the bolts pass through column, lugs are cast inside of the column and cored for 1" bolts.

The foundations for the columns are of plain concrete, and are designed to limit the pressure on the earth to 3 tons per square foot. This might be excessive for some soils and footings would have to be extended to reduce the pressure on the earth.

The foundation for the outside walls is also of plain concrete and is to extend down to solid soil and below frost. This depth may vary from four to seven feet according to the location.

The engine and cross pits are of plain concrete with a coat of cement in the bottom 3/4" thick. The track is carried over the cross pit by a 10" @ 25 lbs. I Beam which is coated with concrete to protect it from the drippings from the engines.

The roof is designed to carry the Dickinson Fireproof Wood Smoke Jack which, being light, is especially adapted for light roofs. This jack has a space around the chimney for ventilation which is an additional advantage.

To further provide for ventilation, openings 3' x 5' are left in the roof, one for each stall, over which wooden ventilators are placed. These are light and being small offer little danger from fire. For details see Sheet No. 4.

To provide lighting, two windows are placed in the outside walls for each stall, four sash are placed in each door and three sash in the vertical offset of the roof. The windows in the wall are 2 sash - 35 Lts. 10" x 10" and are to be provided with cord, pulleys and weights for raising and lowering. The vestibule windows are pivoted at the center so as to swing in at the top. These sash have 18 Lts. 8" x 14". The sash in the doors are 4 Lts. 12" x 12"
and are to slide sideways.

The floor is to be a 3/4" wearing coat of 1 : 2 cement on a 4 1/4" concrete base. To drain, slope the floors in each stall from the line of the columns towards the pits and leave opening at intervals under the rails so water can drain into the pits.
Brick Wall

4 - 3/4 Rods

3 - 3/4 Rods

3 - 3/8 Loops

Plate 10x10 x 3/8

To Solid Foundation

Floor Line

Main Concrete

12 x 12 Columns Reinforced with 3/4" Bar in each corner bound with 3/8" loops spaced 18" centers

36" 24" 24" 18" 18" 12" 12" 12" 12"

SECTION "AB"

Details of Column 5

Cast Iron

COLUMN 5

COLUMN 4

COLUMN 2 & 3

COLUMN 1 & WALL

PLAN OF PIER

SHEET NO 3
SPECIFICATIONS

BRICK WORK

The outside walls shall be laid with first class common hard
burned brick, and all those used on the exposed face shall be care-
fully selected to obtain an even color.

Seventeen inch walls shall be laid to a line on both sides
and every sixth course shall be a header course.

All mortar joints shall be struck and no mortar joint shall
be more than 1/2" thick.

All brick shall be well wet before laying and shall be
shoved into place.

MORTAR

All mortar shall be mixed in the following proportions :-
One part Portland cement and one part Lime to six parts clean, sharp
sand. The lime mortar shall be mixed at least twenty-four hours
before the cement is added and then used at once. Any cement mortar
left over night shall be treated as so much lime mortar and addition-
al cement added.

LIME

All lime shall be freshly burned quick lime. No air slacked
lime shall be used.

CEMENT

Cement to be as specified for reinforced concrete.
SAND

Sand shall be clean, sharp lake or bank sand.

TIES

Brick work shall be carefully bonded to the concrete frame by means of wire ties placed by the concrete contractor for this purpose.

STONE

The cut stone watertable shall be limestone of uniform color and hardness. It shall be cut to lay in its natural bed and be carefully bonded or tied to the other work, using metal ties when necessary. Where sizes are not given, follow scale drawings or secure details from the Engineer.

NAILING STRIPS

The 1" x 3" nailing strips shall be of Norway Pine and shall be placed as soon as possible after the concrete roof slabs are poured so that they may be spiked to the concrete. Nailing strips shall be placed every three feet in the roof and across the stalls. Strips shall also be placed around the ventilator openings.

SASH

All sash shall be first grade clear white pine 1 3/4" thick. The sash in the rear wall shall be provided with pulleys, weights and cords and be fitted so as to move easily. The vestibule sash shall be provided with spring catch and cord and shall be so balanced on pivots that they will automatically close when released. All sash shall be fitted with double strength AA glass.
All window frames shall be No.1 white pine of stock pattern and shall be set as the work is carried up.

DOORS

All doors shall be made of two thicknesses of 1" x 4" beaded pine ceiling, the inside layer placed diagonal and the outside layer placed vertical. Cross braces of 1" x 8" Pine S4S shall be placed on the outside as per plan.

REINFORCED CONCRETE

The work covered by these specifications includes all concrete work of every description about the building and all excavation

FORMS

All forms shall be built from dressed lumber, which for the columns and beams shall not be less than 1 5/8" thick.

The decking for the roof slabs may be 7/8" stuff but shall either be tongued and groved or beveled on one edge so as to make a tight joint.

Provision shall be made in the forms so that the corners of all columns and beams will be beveled. This bevel shall not be less than one inch.

All forms shall be properly braced so as to sustain the loads which may come upon then without bulging or deflecting.

The shoring shall be done with 4" x 4" pieces resting on a pair of wooden wedges.

An opening shall be left at the bottom of all column forms the full width of the column and at least three feet high in order to permit of properly adjusting the reinforcement and cleaning out
the column. The opening shall not be closed until all is in readiness for pouring the column.

REMOVING FORMS

The forms shall be removed in the following order:

First - Not less than one week after pouring remove all column forms.

Second - Not less than ten days after pouring remove all centering supporting roof slabs and the sides of the beams.

Third - Not less than three weeks after pouring remove all bottom plates and shores under the beams. If practical these forms shall be left in place for a longer time.

The contractor shall carefully examine the concrete before ordering any forms removed and shall be entirely responsible if any are removed too soon. The time specified here are minimums and in case of cold weather, more time should be allowed.

MATERIALS

For all reinforced work the contractor shall figure on mixing the concrete in the following proportions, by weight

One part cement.

Two parts sand.

Four parts broken stone.

For plain concrete mixture shall be in proportions of one part cement to three parts sand to five parts broken stone.

BROKEN STONE

For all reinforced work the stone shall be screened limestone
free from all dust and of size so as to pass maximum 3/4" ring.

For plain concrete 2" crushed limestone, crusher run may be used.

3AND

Sand shall be clean and sharp and not contain more than 5% of clay or organic matter and must be approved by the Engineer before being used.

CEMENT

All cement used on the work shall be tested as follows:—
All cement shall be of uniform quality, color and weight.

Fineness
Not less than 92% shall pass a standard #100 sieve.

Setting
Initial set shall not take place in less than thirty minutes and final set in not less than three nor more than seven hours. Tests to be made with Gillmore's needles.

Soundness
Pats of neat cement shall show no signs of cracking, checking or warping when tested in hot water, cold water and air. The surface of the air pat shall maintain a uniform color.

Tensile Strength
Standard briquettes shall develop the following tensile strength per square inch.
Neat - 24 hours in water after hard set ---- 175\#
" - 1 day in air - 6 days in water ------------ 450\#
" - 1 day in air - 27 days in water ------- 600\#
1:3 - 1 day in air - 6 days in water ------- 125\#
1:3 - 1 day in air - 27 days in water ------- 200\#

Sand used for making tests shall be standard testing sand.

All cement shall be delivered in suitable packages and protected from injury by dampness or other causes. All cement which fails to pass or is afterwards injured by dampness or other causes shall be immediately removed from the building site.

MIXING AND POURING

All concrete shall be thoroughly mixed in some form of rotary batch mixer.

Sufficient water shall be used so that the concrete will flow readily filling the forms completely.

The concrete in the columns and beams shall be worked or churned with an iron bar or spader.

Before pouring concrete, the forms shall be carefully examined to see that all chips, dirt and other foreign matter has been removed. Forms then shall be wet down with a hose.

The columns shall be poured at least 18 hours before the roof slabs.

Before pouring the roof slabs, the tops of the columns shall be examined and all foreign matter, lattice or soft material removed.

The pouring of the beams and slabs shall be done at the same time and the slabs shall be carried on continuously so far as possible but when it is necessary to stop work in the middle of the
slab, joint shall be made either in the center of the span or directly over a beam.

Before resuming work the joint between the old and new concrete shall be sprinkled with dry cement.

EXPANSION JOINT

Expansion joint shall be provided over each radial beam by cutting through the roof slab a crack 1/2" in width and filling with asphalt. This shall be done before the initial set of the concrete.

STEEL

All plain steel and twisted steel before being twisted shall conform to the specifications for structural steel of the American Society for Testing Materials.

All steel must be free from rust scale but an ordinary thin coating of rust not easily removed will be permitted.

All steel shall be placed exactly as shown on the drawings or as directed by the Engineer. Precautions shall be taken to see that the steel is not moved in pouring the concrete.

In all outside columns and beams, suitable wire ties shall be imbedded in the concrete not more than 12" center to center horizontally and vertically for tying the brickwork in position.

FINISH

As soon after the forms have been removed as practicable all imperfections in the surface of the concrete shall be carefully patched up.

After the building is entirely enclosed all interior surfaces
of brick or concrete shall be painted with white water paint applied
with a spray.

The top of the roof shall be brought to a smooth uniform
surface to receive the composition roofing using a 1 to 3 mortar
finish of whatever thickness may be necessary.

EXCAVATION

The contractor for the concrete work shall do all excavating
called for in the drawings, remove all excess material from the
premises after back filling is done and leave all property adjoining
in first class condition.

In case footings are carried down below the depth shown on
the drawings, the excess depth shall be filled with concrete. No
refilling with dirt will be allowed under the footings.
ESTIMATED COST PER STALL

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost per Unit</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>47 cu. yds. reinforced concrete in place @ 14.00</td>
<td></td>
<td>$658</td>
</tr>
<tr>
<td>70 &quot; &quot; plain concrete in place @ 10.00</td>
<td></td>
<td>700</td>
</tr>
<tr>
<td>1016 sq. ft. floor @ 0.15</td>
<td></td>
<td>152</td>
</tr>
<tr>
<td>11 M of brick in place @ 16.00</td>
<td></td>
<td>176</td>
</tr>
<tr>
<td>17 squares composition roofing in place @ 4.00</td>
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<td>68</td>
</tr>
<tr>
<td>220 sq. ft. windows in place @ 0.25</td>
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<td>55</td>
</tr>
<tr>
<td>Cast iron door post</td>
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<td>30</td>
</tr>
<tr>
<td>1000 ft. B.M. lumber in doors and vent. @ 40.00</td>
<td></td>
<td>40</td>
</tr>
<tr>
<td>Painting</td>
<td></td>
<td>50</td>
</tr>
<tr>
<td>Engineering &amp; Superintendence - 5% of above</td>
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<td>91</td>
</tr>
<tr>
<td>Total Cost</td>
<td></td>
<td>$2020.00</td>
</tr>
</tbody>
</table>

This estimate includes the complete stall with the exception of the track and smoke jack.