ELIMINATION OF A GRADE CROSSING
AT
DOWNERS GROVE, ILLINOIS
BY
S. W. NEWMAN

ARMOUR INSTITUTE OF TECHNOLOGY
1917
AT 463
Newman, S. W.
The elimination of a grade crossing at Downers Grove,
THE ELIMINATION OF A GRADE CROSSING AT DOWNERS GROVE, ILL.

A THESIS

PRESENTED BY

STANLEY W. NEWMAN

TO THE

PRESIDENT AND FACULTY

OF

ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE OF

BACHELOR OF SCIENCE

IN

CIVIL ENGINEERING

MAY 31, 1917
-Object-

As the population of this country increases, elimination of grade crossings, along with many other problems, require more and more thought and serious attention by railroads.

At present in our big cities, track elevation on different scales is being accomplished. Such work is gradually being extended to smaller towns, where grade separation is essential on main lines.

The writer has in mind a recent inspection trip through Iowa, over the Chicago, Milwaukee and St. Paul new double track line. In many places subways were in evidence, where previously grade crossings might have been used.

The problem in hand, was worked out from the railroad end, and the object sought, was to arrive at a fair estimate of the cost of the work. Detail designs were not entered into.
The writer is indebted to the Civil Engineering Department and the Engineering Department of the Chicago, Burlington, and Quincy Railroad, for their kind cooperation and help.

May 31, 1917.

Stanley W. Newman.
little not at least anti at all the

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-how I do what and something quite. We

-kid are hurt on

-III, etc. etc.
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Vieu of Location

Cross-section in Three Places

Position Plut on the Calook
Discussion.

Taking up type of bridge to be used.

Data.
Discussion

Taking the case of...
Discussion.

Owing to the flat angle of the highway with the bridge the question of suitability of different types of structures arises.

A 40'-0" roadway with 13'-6" clearance will be provided for. Columns will be placed along the center of the roadway. C. B. & Q. specifications will be used.

The following two types of bridges suggest themselves as being most suited to the problem.

(a) Through plate girder bridge with steel floor and columns.

(b) Combination of through plate girder and concrete floor and columns.

Type (a) is at once eliminated due to the present high price of steel.

Type (b) is as shown in Fig. 1. The four outer girders take the longer span of 48'-10"; supporting the triangular concrete slabs 1, 3, 4 and 6. Slabs 2 and 5 have clear
Discussion.

spans of 20'0".
**Loading.**

Live and dead loads found; assumptions with regard to same.
ADAM

Lives and grows forever

Somehow, somehow

After waiting so long

One would have to assume...
Loading.

Owing to the skew of the bridge, the standard engine loading as given in Fig. 2, cannot be directly used in obtaining the maximum moment in the span. In obtaining this moment 50' - 0" was taken as the length of span.

According to specifications Page 17, the standard live load is assumed as spread over 14' - 0" laterally. Hence considering a strip 1' - 0" wide and 50' - 0" long, the maximum moment is obtained by considering one fourteenth of the live load. The equivalent live loading or uniform load giving this maximum moment, is then found by substituting in the common moment formula

\[ M = \frac{w l^2}{8} \text{ or } w = \frac{8M}{l^2} \]

Maximum Moment.

The criterion for maximum moment is that the average load in advance of a panel
<table>
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<th>LOADS ARE FOR EACH RAIL. IMPACT FOR ONE RAIL ONLY.</th>
</tr>
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</tr>
<tr>
<td>0</td>
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<tr>
<td>10</td>
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<tr>
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<td>30</td>
</tr>
<tr>
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<tr>
<td>50</td>
</tr>
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**STANDARD LOAD OF NOV. 1, 1906**

C.B. & Q. RY.

**FIG. 2**
Loading.

point should be equal to or just greater than average in the truss. In this case the section of maximum moment will occur at the center of span. Hence this section will be considered.

Placing wheel D at center

Average in advance of D

\[
\frac{7 + 14 + 14}{1} = 35 \text{ kips}
\]

Average in truss

\[
\frac{7 + 4\times14 + 10 + 10}{2} = 41.5 \text{ kips}
\]

Wheels advance

Average in advance of center

\[
\frac{3.5 + 14}{1} = 49 \text{ kips}
\]

Average in truss = 41.5 kips

Therefore the above position of wheel loading satisfies the criterion. Wheel H is not considered in moment, due to its infinitesimal lever arm when the loads advance.
Loading.

Using the standard load diagram and taking moments about wheel I

\[ R(\text{Left}) \times 50 - 1991 = 0 \]

Or \( R(\text{Left}) = \frac{1991}{50} \)

Taking moments about wheel D,

\[ \frac{1991}{50} \times 25 - 336 = 659.5 \text{ kips per rail} \]

Or \( 659.6 \times 2 \times 2000 = 2,638,000 \text{ kips ft. \# per track} \)

Therefore the equivalent live load

\[ \frac{8 M}{L^2} = \frac{8 \times 2,638,000}{50^2} = 8,440 \text{ \# per ft. of track.} \]
Loading.

Impact.

J. A. I. Waddell from numerous tests assumes the following formula

\[ I = \frac{165}{nL + 150} \]

where

\[ n = \text{Number of tracks} \]
\[ L = \text{Length of loaded span} \]

Therefore

\[ I = \frac{165}{3 \times 50 + 150} = .55 \]

Hence the total equivalent live load

\[ 8,440 + .55 \times 8,440 = 13,080 \text{ # per ft of track.} \]

\[ \frac{13,080}{14} = 935 \text{ # per sq. ft. of bridge.} \]
\[ \Delta \left( \frac{1}{\tau^2} \right) \]

correlate to move \( \xi \)

and 3 to 5

\[ \frac{\Delta}{\xi} \]

the only function here is due to 

\[ \frac{1}{\tau^2} \cdot \frac{1}{\xi} \cdot \frac{1}{\Delta} \]

result 10
Subway.

Sections for slabs, girders, columns and etc. found. Wts. and volume obtained.
Loading

Dead Load per foot of track

1 Tie 8 x 8 x 8  43 B.M. @4½  193#
Ballast @ 100# per cu. ft.

Loaded lft. deep  1400
Waterproofing @ 3# per sq. ft  42
Track And Fastenings @ 150  150

Total Per Ft. Of Track  1785

Per foot of width or square foot

\[
\frac{1785}{14} = 128\# \text{ per sq. ft.}
\]

Estimate slab weighs 350# per sq. ft.
Therefore total dead load per sq. ft.

\[
350 + 128 = 480\#
\]

Design Of Girder.

In the following figure, the girder is taken as 48'-10" center to center of end bearings. Although the loading was figured for a 50'-0" span, there is no serious error in assuming the shorter span.
Subway.

The triangle in black represents the area of dead load and the triangle in red the live load. Moments are taken about "a" and "c" and dead load and live load reactions computed.

D. L. Reactions.

R(Left) Moments about "c"

\[
\frac{9.4 \times 44.2}{2} \cdot (4.6 + 14.7) = 4,010
\]

\[
\frac{4.6 \times 9.4}{2} \cdot (1.53) = 66
\]

Total M = 4076

R(Left)

\[
\frac{4076 \times 480}{48.8} = 40,100
\]

R(Right) Moments about "a"

\[
\frac{9.4 \times 44.2}{2} \cdot (29.4) = 6,101
\]

\[
\frac{4.6 \times 9.4}{2} \cdot (44.2 + 1.53) = 988
\]

Total M = 7,089
Subway.

R(Right)

\[
\frac{7089 \times 480}{48.8} = 69,700
\]

Total R = 109,800

Check:

Total Dead Load \[
\frac{48.8 \times 9.4 \times 480}{2} = 110,000
\]

L. L. Reactions.

R(Left) Moments about "c"

\[
\frac{32.5 \times 7.0}{2} \times 22.9 = 2605
\]

\[
7.7 \times 7.0 \times 8.25 = 445
\]

\[
\frac{7.0 \times 3.4}{2} \times 3.26 = 39
\]

Total M = 3089

R(Left)

\[
\frac{3089 \times .935}{48.8} = 59,100
\]

R(Right) Moments about "a"

\[
\frac{32.5 \times 7.0}{2} \times 25.2 = 2940
\]
Subway.

R(Right) Con.

\[ 7.0 \times 7.7 \times 40.05 = 2100 \]

\[ 3.4 \times 7.0 \times 45.5 = 543 \]

\[ \frac{2}{2} \text{ Total } M = 5643 \]

R(Right) \[ \frac{5643 \times 935}{48.8} = \frac{107,900}{167,000} \]

Check:

Total load \[ \frac{7.0 \times 32.5 + 7.7 + 7.0 \times 1.7}{2} \times 935 = 166,900 \]

As this is not a uniformly varying load, the shear curve will not be a straight line, but a curve. Hence the following criterion which is proven in standard works on "Strength of Materials" is used.

"The bending moment in a simple span is a maximum, when the shear passes through passes through zero."
Subway.

Several sections are tried in Fig. 3 and the shear obtained on the left of the section. The following result was obtained at a section 29'-0" from the left support.

\[
\begin{align*}
L.I. A. & \quad \frac{24.8 \times 4.20 \times 935}{2} = 48,700 \\
D. L. A & \quad \frac{29.0 \times 7.35 \times 480}{2} = 51,100 \\
\text{Total} & \quad \frac{99,800}{2} = 99,800
\end{align*}
\]

The Shear = 99,200 - 99,800 which is equal to practically zero.

Hence the bending moment on the plate girder is a maximum at 29'-0" from the left support.

Bending moment at this section

\[
(99,200 \times 29 - 48,700 \times 24.8/3 - 51,100 \times 29/3) \times 12
\]

\[= 23,700,000 "] B.M.

In Well's "Steel Bridge Designing" a total weight of 19,000# is given for a through plate girder 48'-6" long. The total bending moment on the girder is 31,478,400 "].
Subway.

The weight of two girders of the same span vary directly as the bending moment. Therefore the weight of the girder in hand is equal to

\[
\frac{23,700,000 \times 19,000}{31,478,000} = 15,000 \text{ lbs}
\]

Wt. of girder.

Floor Slabs.

The same dead loads and live loads as previously determined for the girders, will be used in the design of the slabs. Theoretically these loads may be too heavy; however owing to the complex analysis, the loading as given will be assumed as sufficiently safe.

D. L. (Including Wt. Of Slab) = 490#
L. L. = 935#

Span 22'-0"

Page 22 of the Burlington Spec's. give Allowable Stress in Steel
End View - Looking At Girders

Fig. 4
Subway.

\[ 12,000 \left(1 + \frac{D}{L+D}\right) = 12,000 \left(1 + \frac{480}{1,415}\right) \]

\[ = 16,000\# \]

Allowable Stress In Concrete

\[ \frac{D}{500 \left(1 + \frac{480}{1415}\right)} = \frac{500 \left(1 + \frac{480}{1415}\right)}{1415} = 670\# \]

16000 and 650 will be used respectively.

In determining the required section area the following formula will be used

\[ bd^2 = \frac{M}{Pfj} \]

where

- \( M \) = Bending Moment
- \( p \) = ratio of steel area to area of concrete
- \( j \) = factor multiplied into \( d \) to give effective distance between center of compression and tension areas
- \( f_s \) = tensile strength of steel

\[ M = \frac{w l^2}{8} = \frac{1415 \times (22)^2 \times 12}{8} = 1,030,600\"\# \]
Subway.

From Hool's "Reinforced Concrete Construction" Page 194 Vol 1

\[
d^2 = \frac{M}{K \cdot b}
\]

where \( K = p \cdot f_s \cdot \beta = 107.4 \)

\( b \) is assumed as 12"

Therefore

\[
d^2 = \frac{1,030,000}{12 \times 106.4} = \frac{797}{28.2} \]

Make overall depth of slab 31"

Total length of slab #2 = 95.25 ft.

Volume of #2 and 5

\[
= 2 \times 22 \times 95.25 \times 2.58
\]

\[
= \frac{408.0 \text{ cu. yds}}{27}
\]

The triangular slabs 1, 3, 4 and 6 are made the same thickness as 2 and 5.

Volume of #1

\[
= \frac{51.0 \times 19.0}{2 \times 27} \times 2.58
\]

\[
= 116.4 \text{ cu yds.}
\]
\[
\frac{1}{y} \frac{\partial y}{\partial x}
\]

\[ a - b = a \quad \text{or} \quad b \]

\[ \text{will} \quad \text{be} \quad \text{your} \quad \text{result} \]

\[ a + b = a \quad \text{or} \quad b \]

\[ \text{will} \quad \text{be} \quad \text{your} \quad \text{result} \]

\[ a - b = a \quad \text{or} \quad b \]

\[ \text{will} \quad \text{be} \quad \text{your} \quad \text{result} \]

\[ a + b = a \quad \text{or} \quad b \]

\[ \text{will} \quad \text{be} \quad \text{your} \quad \text{result} \]

\[ a - b = a \quad \text{or} \quad b \]

\[ \text{will} \quad \text{be} \quad \text{your} \quad \text{result} \]
Subway.

Therefore total volume of 1, 3, 4 and 6 is equal to

\[ 4 \times 116.4 = 465.6 \text{ cu. yds.} \]

Slabs to be properly reinforced.

Girders.

Assume columns are spaced 7'-0". Girders are therefore 7'-0" long.

Load on girders per lin. ft. is

Assume wt. of girder at 725 lbs per lin. ft. 725

D. L. of track and slab

\[ 480 \times 22 = 10,550 \]

L. L. of track and slab

\[ 935 \times 22 = 20,580 \]

Total load per ft. 31,855

\[
\text{Bending Moment} = \frac{wL^2}{6} = \frac{31,855 \times 7^2 \times 12}{6} = 2,340,000"#\]
Fig. 5

SECTION OF SUBWAY PROPER

Top Of Tile: 1-1/2 Per Ft.

Top Of Tile: $0.00.

Scale 1/6

13'-6" Clear

2'-0"

2'-8"

10'-0"

10'-0"

1'-6"

1'-6"

0'

1'-6"

2'-0"

2'-0"

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Subway.

\[ \frac{b d^2}{K} = \frac{2,340,000}{107.4} = 21,790 \]

Let \( b = 24'' \) Therefore \( d = 30\frac{1}{2}'' \)

Overall depth = 33\frac{1}{2}'' = 2.79'

Length of girder = 106

Therefore Total Volume is equal to

\[ \frac{106 \times 2 \times 2.79}{27} = 21.9 \text{ cu. yds.} \]

Girders to be properly reinforced.

Columns

Load from girder = 7 x 38,855

\[ = 272,000 \]

The following formula will be used in obtaining the required cross-section area

\[ P = E_c A \left[ 1 + 36.5 \frac{d}{b} \right] \left[ 1 + 14 \frac{d}{b} \right] \]
Subway.

Let \( P_e = 500 \) #

\( P_s = \frac{1}{2} \) %

\( P_v = 5 \% \) (Not to exceed 8%)

Therefore

\[
A = \frac{272,000}{500(1 \times 36.5 \times 0.15)(1 \times 14 \times 0.05)} = 208
\]

Or use columns 2'-0" square. Fifteen columns will be used making a total volume of

\[
\frac{11.25 \times 4}{27} \times 15 = 25.5 \text{ cu yds.}
\]

Abutment Walls.

Specifications give 15" as minimum thickness. 18" will be used.

Length = 106'-0"  Height = 21.5'

Volume is equal to

\[
\frac{2 \times 106 \times 1.5 \times 21.5}{27} = 253 \text{ cu. yds.}
\]
Subway.

Subway Floor.

The floor will be made as indicated in Fig 5. Sufficient piling will be placed under the abutment and the columns, such that the average load on each pile shall be 20 tons. The floor is to be properly reinforced.

Volume of concrete in floor is equal to

\[ \frac{44 \times 106 \times 3.1}{27} = 537 \text{ cu. yds.} \]

Wing Walls.

According to specifications wing walls are to be designed for \( \frac{1}{3} \) of the total earth pressure. Base is to be \( \frac{5}{8} \) of the height of the backfill.

From Fig.5 the total height from top of tie to surface of roadway is equal to

The text on the page is not legible due to the quality of the image. It appears to be a page from a book or a document, but the content is not discernible.
Subway.

18'-2". Adding 3'-0" to put base below frost line, gives a total required height of about 21'-6" to be designed for.

All four wing walls are to resist the above 21'-6" of earth pressure. Hence the cross-sections of all will be alike. Wing walls will run out until a section of 6'-0" in height is reached at which the base will be 6'-0" wide, the thickness of stem and base remaining the same. Theoretically in order to make the wall economically, another section might be designed, for instance when the height of wall dropped to 10 or 12 feet as in Section B in the accompanying figure. However as a basis of estimate, the Section A as outlined, will be investigated and the other sections assumed as correct. In computing the required amount of concrete, the reduced section will be taken into consideration.

Walls to be safe with reference to shear
Subway.

at the junction of the stem and base, pressure on the toe, and position of resultant force on base. The former must be under 200 \# per square inch, while the latter must fall within the middle third in order to have a positive pressure over the entire base. Reinforcing to be provided.

**Design.**

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<th>Description</th>
<th>Dimensions</th>
<th>Weight</th>
</tr>
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<tbody>
<tr>
<td>Wt. of base</td>
<td>2.5 x 13.5 x 150</td>
<td>5060</td>
</tr>
<tr>
<td>&quot; &quot; stem</td>
<td>1.87 x 19 x 150</td>
<td>5350</td>
</tr>
<tr>
<td>&quot; &quot; back fill</td>
<td>19.0 x 6.0 x 100</td>
<td>11400</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>21810</td>
</tr>
</tbody>
</table>

C. of G. Of Vertical Forces.

Moments about c. g. of stem

\[
11400 \times 4.0 + 5060 \times 0 + 5350 \times 0 = 45,600
\]

Resultant therefore acts at

\[
\frac{45,600}{21,810} = 2.25' \text{ from c.g. of stem.}
\]
Subway.

Horizontal Forces.

Pressure at base

\[
\frac{21.5 \times 100}{3} = 7200 \text{ #}
\]

Therefore the total pressure acting at the tc. of g. of the triangle of pressure is equal to

\[
\frac{7200 \times 21.5}{2} = 7,740
\]

which acts at 21.5/3 equal to 7.2' from the base.

Resultant.

By similar triangles

\[
\frac{7740}{21,810} = \frac{x}{7.2}
\]

or \(x\) equals 2.56' where

\(x\) is the distance from the c. of g. of vertical forces.

By looking at the accompanying figure it will be noticed that this falls within the middle third, hence the section is safe.
The text on this page is not legible due to the quality of the image. It appears to be a page from a document or a book, but the content cannot be accurately transcribed.
Subway.

Shear.

Considering total horizontal force acting at junction of stem with base, then the shear is equal to

$$\frac{7550}{4.0 \times 1 \times 144} = 131 \text{ # O.K.}$$

Pressure On Toe.

In as much as the resultant falls very close to the center of the base, there will be no eccentric stresses produced on the toe.

Piles are so spaced, that they carry 20 tons each over the area of the base.

Cu. Yds. of Wing Walls.

North East Wall. 53'-0" long.

$$\text{Volume} = \frac{(73.8 + 21.8) \times 53.0}{2 \times 27} = 47.0$$

North West Wall 18'-6" long

$$\text{Volume} = \frac{(73.8 + 21.8) \times 18.5}{2 \times 27} = 16.4$$
\[
W \times \lambda = \frac{1}{2} \mu^2
\]

To determine the correct solution, let us recall the equation that was mentioned earlier:

\[
W \times \lambda = \frac{1}{2} \mu^2
\]

From this, we can calculate the value of \( \lambda \) by substituting the known values of \( W \) and \( \mu \):

\[
\lambda = \frac{\mu^2}{2W}
\]

Now, let us consider the case where \( \mu = 10 \) and \( W = 20 \):

\[
\lambda = \frac{10^2}{2 \times 20} = \frac{100}{40} = \frac{5}{2}
\]

Therefore, the value of \( \lambda \) is 2.5.
Subway.

South West Wall  43'-0" long.

\[ \text{Volume} = \frac{(73.8 + 21.8) \times 43.0}{2 \times 27} = 38.0 \]

South East Wall  13'-0" long

\[ \text{Volume} = \frac{(73.8 + 21.8) \times 13.0}{2 \times 27} = 11.5 \]

Total Volume Of Wong Walls  112.9 cu. yds.
Excavation and Miscellaneous.

Cross-sections of yardage to be removed. Drainage, side walks, pavement and etc.
Excavation
and
Miscellaneous
Grades of $5\%$, $1\frac{1}{2}:1$ cuts and a 40'-0" roadway were provided. Owing to the change of street grades, provision was made for lowering the sidewalks, in computing the required amount of excavation. As given in the accompanying cross-sections, 15,925 cubic yards of excavation are required.

Drainage.
The curbing along both sides of the subway will drain toward the center catch-basins. Ten inch tile will be used, draining into the sewer along Maple Avenue. The proposed grade is as outlined in the location plat.

In order to take care of drainage from the bridge floor, four inch tile with open joints having loosely packed cinders above them, will be place behind the
null
The image contains engineering sketch and notes. Here is the transcribed text:

**Note:** Sections 0100 - 1445 taken care of by sections on Maple Ave with the exception of a D Prism whose base = 115 x 25/2 and has an average height of 9'0". Volume = 837

Estimated additional excavation for abutment walls, subway floor and wing walls = 1,750

Total to be excavated = 15,925 cu. yds.
Excavation
and
Miscellaneous.
abutment walls. This tile will be so constructed, as to drain into the catch-basins in the subway.

Required
300 ft. of 10" Tile
225 ft. " 4" "
2 Catch-basins

Pavement.
The subway will be paved throughout its length with brick pavement as shown in Fig. 5.

Required
134 sq. yds. of brick paving.

Curbing.
Curbing as shown in Fig. 5, will be used along the walk throughout the subway.
Excavation
and
Miscellaneous.

Required

106 ft. of curbing.

Side walks.

Owing to the change of grade, 85 ft. of sidewalk will have to be torn up and replaced and 238 ft. of new provided, making a total of 323 ft. of sidewalk required.
Cost.

**Steel Girders.**

- 4 Girders @ 15,000# = 60,000#
- Structural Steel @ .06 a lb.
  
  \[ .06 \times 60,000 = 3,600 \]

**Concrete in Subway.**

- Slabs #2 and 5 vol. = 408.0
- " #1, 3, 4, 6 " = 465.0
- Girders vol. = 21.9
- Columns " = 25.5
- Abutm't Walls vol = 253.0
- Subway Floor " = 537.0
- Wing Walls " = 112.9

**Total vol. of Conc.** = 1323.3

**Concrete in place at 12.00 per yd. = 1,323.3 \times 12.00 = 21,880**

**Excavation.**

- 15,925 cu. yds. @ .25 = 3,981

**Tile.**

- 500 ft. of 10" Tile @ .20 = 60
- 225 " " 4" " @ .06 = 15

**Fwd.** = 29,536
Cost.

Forward  29,536

Catch basins.

2 Catch basins @ 15.00  30

Pavement.

134 sq. yds. of brick paving in place @ 1.75  177

Curbing.

106 ft. of curbing @ .60  64

Sidewalks.

323 ft. of 4'-8" sidewalk @ .15 per sq. ft.  218

Engineering at 7%  210

Total Cost.  $30,235
No. 5.

Total cost $8,500.

Freight

2 cases packing & 15.00

Freight per

15% of age of stock leaving

in place of

at

for lot at shipping Q. Co.

Storage

$50.00 at A-24 after May 15.

Invoice

To

20.00

Total cost $8,500.
Specifications.

Extracts from office notes of C. B. & Q.
Abutments

In designing plain concrete abutments the line of thrust, toe and heel pressures and stability against sliding, should be determined, and the piles spaced as required at a loading of twenty tons per pile. The width of the footing to be .525 of the height to base of rail and the thickness of neat work at any point to be .4 of the height to base of rail.

Batter on face of abutments and wings to be 1/2" to the foot.

Old bolts or other scrap should be embedded in the footing and project up into neat
Specifications.

to form bond.

Width of bridge seats to be such that the edge of casting is 1'-0" from face of abutment.

Wings in general, will be thirty degrees, with face of abutment but it is well to investigate the cost of both flare and "U" abutments before deciding on the type. Wings should be designed as retaining walls and the spacing of piles according to the toe pressure found, allowing twenty tons per pile for stress and pile spacing in the same manner as plain concrete abutments. Width of footing to be 5/8 of total height to base of rail.

Face wall, buttresses and bridge seats to be not less than 15" in thickness and properly reinforced to take load on member.

Page 14 Retaining Walls

As a general proposition, retaining walls
Specifications.

will be of the type of wall used on the Chicago Track Elevation. In designing wall, due allowance must be made for the effect of live load on tracks adjacent to wall and stability against sliding.

Piles in footings to be so spaced that the load per pile will not exceed twenty tons.

Batter in face of wall to be $\frac{1}{2}$" to 1'-0". Concrete in retaining walls to be of 1 - 6 gravel concrete or an equivalent crushed stone concrete.

Page 16.

Slabs.

Minimum ballast to be six inches unless otherwise directed.

Slabs to be made of 1 - 4 gravel concrete or 1 - 2 - 4 crushed stone concrete.

Slabs to be designed for standard live load and assumed to spread over 14'-0"
Specifications.

Page 17.

laterally. Load on one rail and total impact to be carried by 7'-0" width.

Allowable stress in steel in slab

\[ D = 1200 \times \left(1 + \frac{L}{L+D}\right) \]

Allowable stress in concrete

\[ D = 500 \times \left(1 + \frac{L}{L+D}\right) \]

Maximum compression in 1-2-4 concrete equals 800# per square inch.

Allowable diagonal tension 30# per square inch.

Allowable shear 200# per square inch.

Allowable bond between steel and concrete 200# per square inch, using "Johnson Corrugated Bars".

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Live load to be standard wheel load-
Specifications.

Structures carrying more than one track, the live load is assumed to spread laterally over a distance equal to center to center of tracks, but not to exceed 14'-0".