

AN ANALYSIS OF A ROLLED BEAM,
DECK TYPE HIGHWAY BRIDGE

Thesis for the Degree of B. S.

MICHIGAN STATE COLLEGE

T. S. Katalenich

1948

**SUPPLEMENTARY
MATERIAL
IN BACK OF BOOK**

An Analysis of a Rolled Beam,
Deck Type Highway Bridge

A Thesis Submitted to

The Faculty of
MICHIGAN STATE COLLEGE

of

AGRICULTURE AND APPLIED SCIENCE

by

T. S. Katalenich

Candidate for the Degree of
Bachelor of Science

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INTRODUCTION

The bridge selected for analysis is located 1.8 miles northwest of Reed City, Michigan, on U.S.10. This structure is a single span, rolled beam, deck type highway bridge. It was designed for H-20 loading and width of roadway to be of sufficient width to accommodate three lanes of traffic, although a two lane pavement exists at the present time.

The design of this structure was governed by, "Specifications for the Design of Highway Bridges" adopted by Michigan State Highway Department November, 1936. As in the design of most structures, there are a few instances where experience and practical application of construction methods has permitted a deviation from strict application of the specifications. Such instances will be made a note of in the analysis.

The bridge provides a crossing of Johnson Creek, a stream which drains a basin of approximately 12 sq. miles. The basin top soil is composed of a very sandy loam with a low runoff coefficient.

SYMBOLS and NOTATION

A_s	area of tensile reinforcement
b	width of rectangular beam
d'	distance from extreme fiber to compressive resultant
d	effective depth of flexural members
e	eccentricity
e'	eccentricity measured from gravity axis.
f_c	compressive stress in extreme fiber
f'_c	ultimate compressive strength of concrete
f_s	stress in tensile reinforcement
I	moment of inertia
j	ratio of distance (jd)
k	ratio of distance between extreme fiber & N.A. to eff. d
K	$\frac{1}{2}f_c$ jk (Reinforced Concrete--Sutherland & Reese, p. 520)
L	length of span; length of anchorage of reinforcement bars
M	external moment
n	ratio of modulus of elasticity of steel to concrete
N.A.	neutral axis
	sum of perimeters of bars
P	external concentrated load
s	spacing of reinforcement bars
u	bond stress
v	shearing stress
V	total shear
w	permissible soil pressure; uniformly distributed load
y	distance of moment arm of a horizontal force resultant
x	distance of moment arm of a vertical force resultant

ANALYSIS of CHANNEL OPENING

Specifications:

- Art. 11: In general, the waterway provided shall be sufficient to insure the discharge of flood waters without undue backwater head and at a velocity which will not increase the erosive action of the stream to such an extent as to endanger the structure, or cause damages to upstream property.
- Art. 13: Bridges proposed over streams where future drain projects are a probability shall have footings at a sufficient depth estimated to prevent instability or undermining when the drain project is carried out.
- Art. 14: Natural obstructions, such as islands, rocks, trees and brush which retard or deflect the stream in the vicinity of a bridge shall be removed and such portions of the channel shall be cleaned out as are necessary to straighten out the stream at the bridge and prevent eddies or scour.
- Art. 15: The clear width of all openings and the clear vertical distance between the superstructure and the flood water elevation shall be sufficient for the passage, without damage to the structure, of ice floes and of the largest drift or debris which may be expected. Ordinarily a minimum of one foot vertical clearance shall be provided above extreme high water.

A. Computation of the Cross-Section needed:

Area of basin = 12 sq. mi.

Coefficient taken from Highway Map .25

Talberts Formula:

$$a = 127 C \sqrt{A_m^3} \quad \text{where;}$$

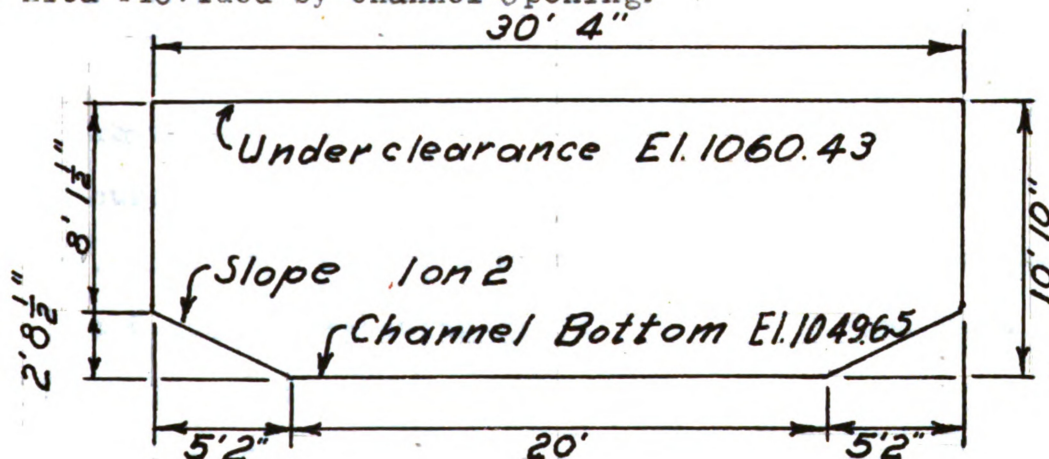
a = area in sq. ft.

C = Coefficient taken from weather map.

A_m = Drainage Basin in square miles.

$$a = 127 (.25) \sqrt{12^3} = 203 \text{ sq.ft. needed}$$

B. Area Provided by Channel Opening:



1. To find x: Fig. 1

$$x = \tan. 26.30' (5.17') = .498 (5.17') = 2.67'$$

2. Area provided:

$$A = \frac{(20 + 30.33)(2.67)}{2} + 30.33 (7.11) = 283.2 \text{ sq.Ft.}$$

It is obvious that sufficient channel area has been provided as flood areas and other drainage facilities in the area have not been discounted from the 203 sq.ft. needed. The clear width of 30' 4'' provides sufficient width for passage of largest drift or debris to be expected. Abutment footing is 4.2' below channel bottom which is sufficient.

Spec

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SLAB ANALYSIS

Specifications:

Art. 18: In no case shall the roadway on a bridge be made less in width than that provided for traffic on the bridge approaches and preferably the width of roadway should be not less than the following:

Two lane highway (pavement)	24 ft.
Three lane highway	33 ft.

Art. 20: Substantial curbs shall be built on each side of the roadway and they shall have a width not less than 6 in. and a height of not less than 9 in. measured above the wearing surface at a point adjacent to the curb.

Art. 22: Approach grades shall preferably not exceed 4 % and intersecting grades shall be joined by a parabolic vertical curve.

Art. 24: The roadway shall be crowned to fit the approach pavement and sloped to provide effective drainage of the roadway surface.

Suitable gutters or provisions for drainage shall be constructed at the ends of the approaches adjacent to the bridge so as to prevent erosion of approach shoulders and fills by water draining off the ends of the structure.

Bridge roadway surfaces of 40 ft. width or less shall be constructed with transverse parabolic crown of height not less than given by the following formula:

$$C = 0.00187 R^2 \quad \text{where:}$$

C = Crown of roadway in inches.

R = Width of roadway in feet.

The minimum crown shall be three-fourths ($\frac{3}{4}$) inch.

Art. 25: Substantial railings shall be provided along each side of the bridge for the protection of traffic. The top of railing shall be not less than 3' -0'' above the top of the curb, and when on a sidewalk, not less than 3' -0'' above the top of the sidewalk. Railings shall contain no opening of greater width than eight (8) inches. Ample provision shall be made for inequality in the ratio of movement of the railing and the supporting superstructure, due to temperature or erection conditions.

Art. 26: Where no separate wearing surface is provided on concrete floor slabs, an additional slab thickness of one-half inch shall be provided. This one-half inch thickness on the top of the slab shall be disregarded in computing strength of floor slabs.

Art. 29: The dead load shall consist of the actual weight of all materials and construction comprising the completed design.

The following weights of materials may be used in estimating dead load:

Steel	490 lb./cu. ft.
Concrete, plain or reinforced	150 lb./cu. ft.
Loose sand and earth	100 lb./cu. ft.

Art. 30: For structures with concrete slab floors without separate wearing surface, a minimum allowance of 20 pounds per square foot of roadway shall be made, in addition to the weight of any monolithically placed concrete wearing surface, to provide for future wearing surface.

Art. 31: The live load on roadways shall consist of a train of standard motor trucks, in each traffic lane, as pictured in Figure 2.

The truck trains shall be assumed to occupy traffic lanes, each having a width of 9 feet corresponding to the standard truck clearance width. Within the curb to curb width of the roadway, the traffic lanes shall be assumed to occupy any position which will produce the maximum stress, but which will not involve overlapping of adjacent lanes, nor place the center of the lane nearer than 4 feet 6 inches to the roadway face of the curb.

All trucks in the same, or adjacent, traffic lanes shall be assumed headed in the same direction.

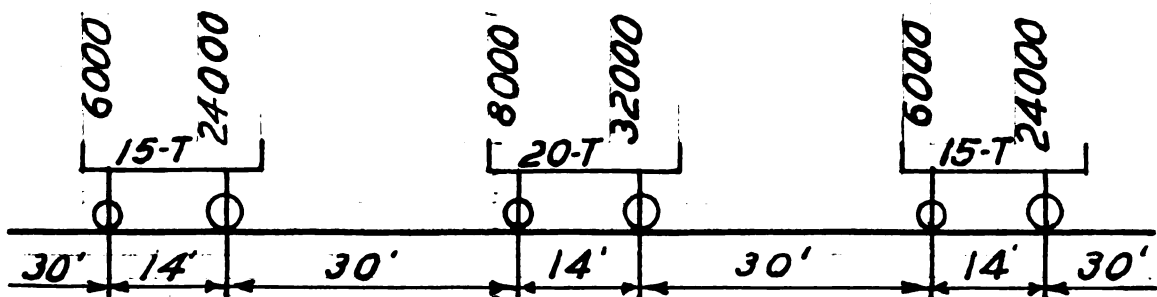


Fig. 2 Roadway Loads

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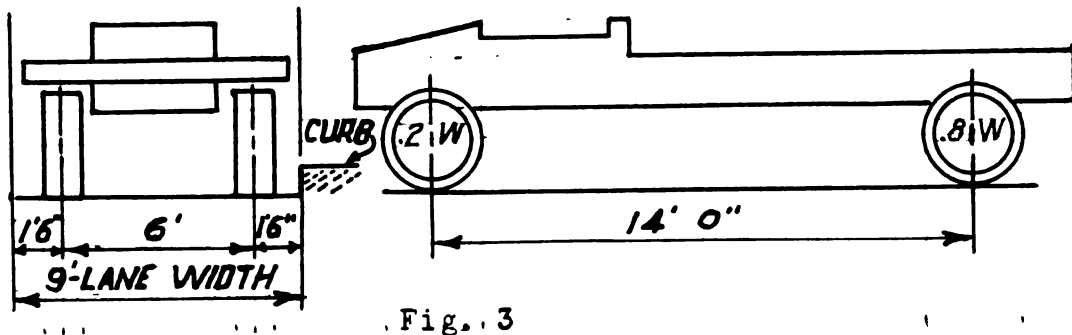
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Art. 32: The Standard Motor Truck, as specified above, is a motor truck with dimensions and weight distribution as shown in Fig. 3.



Art. 33. When roadway provides for two lanes of traffic or less, the design shall provide for the maximum load that can be placed simultaneously in all traffic lanes.

When provision is made for three lanes of traffic, the design shall provide for 90% of the simultaneous maximum loading of all lanes.

Art. 35. Railings shall be designed to resist a horizontal force of not less than 150 pounds per lineal foot, applied at the top of the railing, and a vertical force of not less than 100 pounds per lineal foot. For railings adjacent to the roadway, the bottom rail shall be designed for a horizontal force of 500 pounds per lineal foot of rail.

Art. 36. Curbs shall be designed to resist a force of not less than 500 pounds per lineal foot of curb applied at the top of the curb.

Art. 37: All live load stresses, shall be increased by an allowance to provide for dynamic effect. The impact

allowance shall be determined by multiplying the maximum live load stress by the coefficient determined by the following formula:

$$I = \frac{L+20}{6L+20} \quad \text{where}$$

I = Impact Coefficient

L = Span Length

Art. 54 General Assumptions in concrete Structure Design:

- a. Calculations are made with reference to unit working stresses and safe loads, as elsewhere specified herein, rather than with reference to ultimate strength and ultimate loads.
- b. A section plane before bending remains plane after bending.
- c. The modulus of elasticity of concrete in compressions is constant within the limits of working stresses; distribution of compressive stress in flexure is therefore rectilinear.
- d. The ratio "n" of the modulus of elasticity of the steel to that of the concrete shall be taken as follows (applies also to compression members)

$$n = \frac{E_s}{1000 f'_c} = \frac{30,000}{f'_c}$$

- e. Concrete shall be assumed as offering no tensile resistance.
- f. The bond between concrete and metal reinforcement is assumed to remain unbroken throughout the range of working stresses.

the first of these is the fact that the system is not in a steady state. The second is the fact that the system is not in a steady state.

The third is the fact that the system is not in a steady state.

$$\frac{d}{dt} \left(\frac{1}{r} \right) = -\frac{1}{r^2} \frac{dr}{dt}$$

where r is the radius of the sphere.

The fourth is the fact that the system is not in a steady state.

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The twenty-second is the fact that the system is not in a steady state.

- g. Initial stress in the reinforcement due to contraction or expansion of the concrete is neglected.
- h. Nomenclature and formulae for design shall be those common usage as given in the Standard Specifications for Concrete and Reinforced Concrete of the Joint Committee.

Art. 58. The maximum spacing of principal reinforcement in walls and slabs shall not exceed two times the thickness of the slab or wall, nor more than 24 inches.

Art. 59. For slabs the distance from the surface of the concrete either top or bottom, to the center of the nearest bar shall be not less than one and one-half times the diameter of the bar nor less than one and one-half inches.

Art. 61. The length of bar added for anchorage may be either straight or bent. The inside radius of bend shall not be less than four diameters of the bar. A standard hook as referred to in these specifications shall consist of a semi-circular bend, whose inside radius is four bar diameters, and a final tangent length of four bar diameters.

Art. 64. Where reinforcement is used to resist tensile stresses developed by beam action, the bond stress shall be taken not less than that computed by the following formula:

$$u = \frac{8 V}{7 \sum p d}$$

Art. 66. Horizontal reinforcement for shrinkage and temperature stresses normal to the principal reinforcement shall be provided where the principal reinforcement extends in one direction only. Such reinforcement shall be placed at exposed surfaces and shall provide not less than one eighth square inch of reinforcement per foot of width of surface.

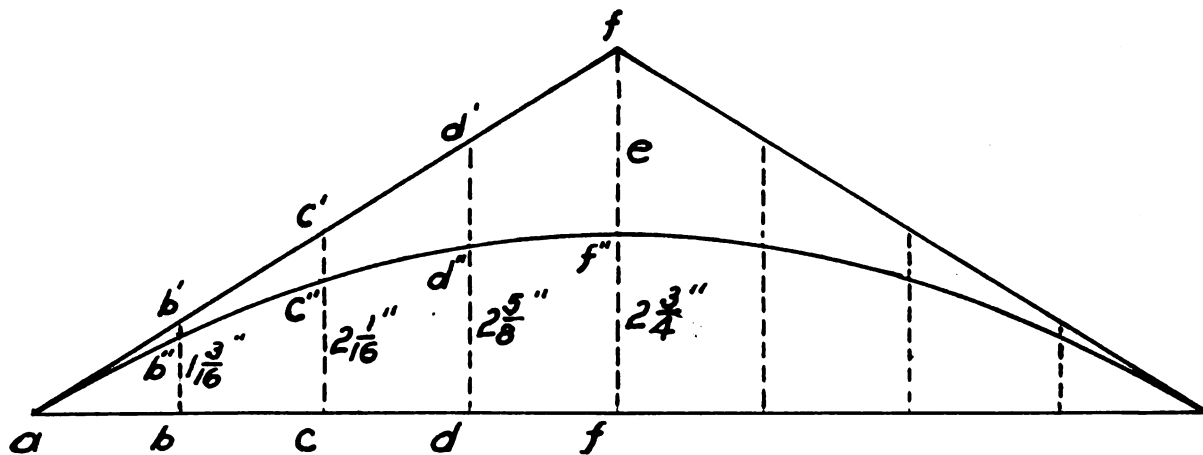
Crown Analysis: (Spec. Art. 24.)

Width of roadway 38 Ft.

$$C = 0.00187 R^2$$

$$C = 0.00187 (38)^2 = 2.7 \text{ in.}$$

$$C = 2 \frac{3}{4}'' = e \quad (\text{Parabolic Curve})$$



Crosssection of Road Crown

Fig. 4

Computations: (quarter-sections of a right triangle)

$$ff' = 2 e$$

$$f'f'' = e$$

$$dd' = \left(\frac{3}{4}\right) 2e = \frac{3e}{2}$$

$$d'd'' = \left(\frac{3}{4}\right)^2 e = \frac{9e}{16}$$

$$cc' = \left(\frac{1}{2}\right) 2e = e$$

$$c'c'' = \left(\frac{1}{2}\right)^2 e = \frac{e}{4}$$

$$bb' = \left(\frac{1}{4}\right) 2e = \frac{e}{2}$$

$$b'b'' = \left(\frac{1}{4}\right)^2 e = \frac{e}{16}$$

Crown Dimensions:

$$bb'' = \frac{e}{2} - \frac{e}{16} = \frac{7e}{16} = \frac{(2.75)7}{16} = \frac{13}{16}''$$

$$cc'' = e - \frac{e}{4} = \frac{3e}{4} = \frac{(2.75)3}{4} = 2 \frac{1}{16}''$$

$$dd'' = \frac{3e}{2} - \frac{9e}{16} = \frac{15e}{16} = \frac{(2.75)15}{16} = 2 \frac{5}{8}''$$

View Showing Roadway Width and Slab Support:

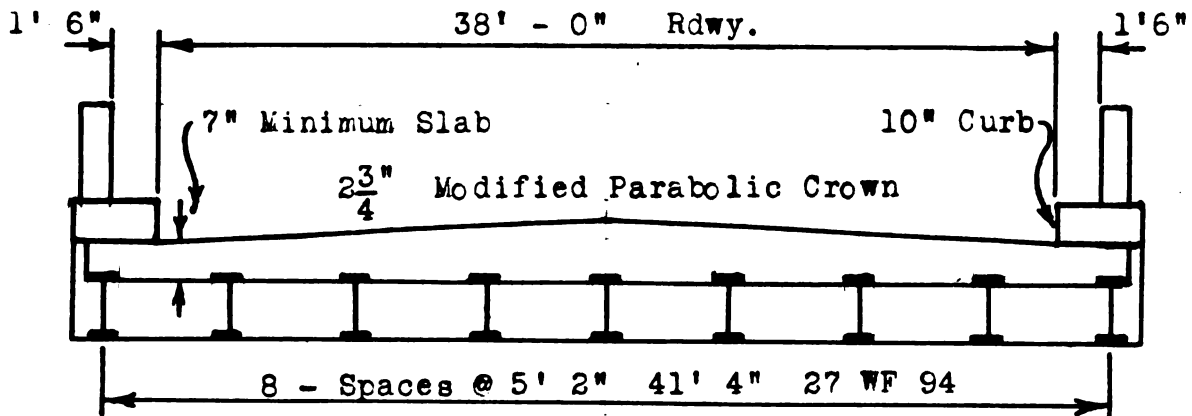


Fig. 5

Maximum Loading on Slab occurs when rear wheel is over point midway between stringers:

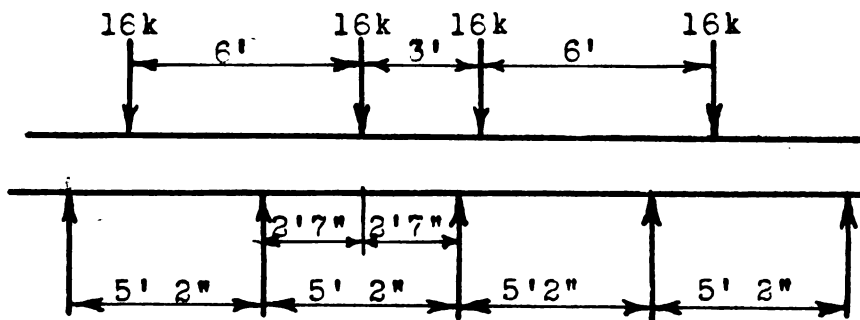


Fig. 6

A. Effective width: Spec. 41: Wheel concentration shall be assumed as uniformly distributed on a line perpendicular to the main reinforcement over an effective width not more than the value given by the formula:

$$B = 0.7S + 2 \quad \text{where:}$$

B Effective width of slab in feet.

S Span of slab, center to center of supports.

$$B = 0.7 (5.17') + 2 = 5.6'$$

B. Maximum Dead Load Moment:

1. Dead Load per foot of slab:

Depth of slab

design depth 7.00''

crown 2.75

camber .19

wearing surface .50

total depth 10.44''

$$D.L. = \frac{10.44}{12} (1) (1) (150) = 131.0 \text{ lb. per ln. ft.}$$

Extra allowance 20.0

Total D.L. 151.0 lb. per ln. ft.

2. Maximum D. L. Moment:

$$\text{Max. Mo.} = \frac{1}{12} w l^2 = \frac{1}{12} (151) (5.17) (12) = 4000 \text{ lb. in.}$$

C. Maximum Live Load Moment:

H-20 loading used in analysis. The beam is regarded as a continuous loaded beam and maximum positive and negative moments are computed using formulae in Kirkham's "Highway Bridges" page 74.

11. *Chrysomelidae* (10 spp.)

1. *Chlorophyll a* (Chl *a*)

11. *Chrysomelidae* (10 spp.)

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1. *Journal of the American Medical Association*, 1997; 277: 1033-1036.

1. *Journal of the American Medical Association*, 1990; 263: 1027-1031.

• **Prevalence** – the proportion of the population with a disease at a particular point in time

1. Max. positive moment:

$$M = \frac{1}{5} Pl = \frac{1}{5} (16000) (5.17) (12) = 198,000 \text{ lb. in.}$$

2. Max. negative moment:

$$M = \frac{1}{6} Pl = \frac{1}{6} (16,000) (5.17) (12) = 165,000 \text{ lb. in.}$$

Maximum is due to positive moment. Inasmuch as the steel in the slab is the same in top and bottom, we will consider analysis for positive moment only.

3. Max. L.L. moment for 1' width of slab:

$$\text{Max. Mo.} = \frac{198,000}{5.6'} = 35,400 \text{ lb. in.}$$

4. Impact:

$$I = \frac{L + 20}{6L + 20} = \frac{32.58 + 20}{6(32.58) + 20} = .24$$

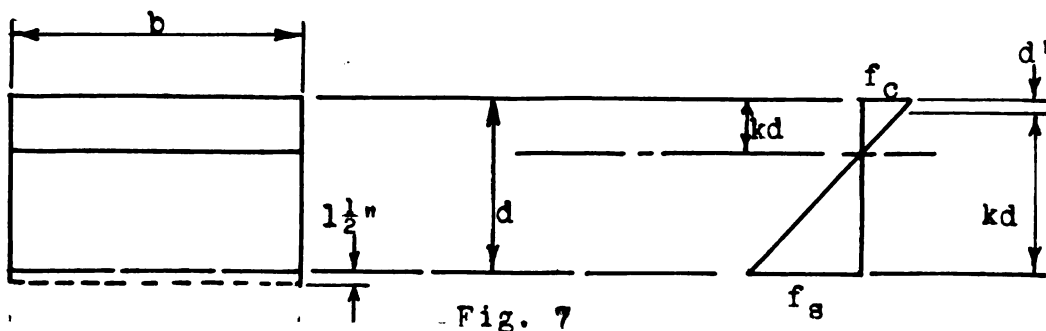
$$\text{Impact} = 35,400 (0.24) = 8600 \text{ lb.in.}$$

5. Total Moment:

Live Load	35,400 lb. in.
Impact	8,600
Dead Load	<u>4,000</u>
Total Moment	48,000 lb. in.

D. Steel needed:

$$d = 7 - 1.5 = 5.5''$$



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1. To find jd :

$$x = \frac{1200 (5.5)}{3000} = 2.2''$$

$$z = \frac{2.2}{3} = .73''$$

$$jd = d - z = 5.5 - .73 = 4.77''$$

2. To find A_s :

$$A_s = \frac{M}{f_s (jd)} = \frac{48,000}{18,000 (4.77)} = .56 \text{ sq. in. per ft.}$$

E. Steel provided: (per foot of concrete)

$\frac{5}{8}''$ round bars spaced at 6''.

$$A_s = .307 \text{ sq. in. (2)} = .62 \text{ sq. in.}$$

F. Check stress:

$$f_c = \frac{2M}{(b) (jd) (kd)} = \frac{(2) 48,000}{12 (4.77) (2.2)} = 775 \text{ lb. per sq. in. less than 1200 p.s.i.}$$

$$f_s = \frac{M}{A_s (jd)} = \frac{48,000}{.62 (4.77)} = 16,500 \text{ lb. per sq. in. less than 18,000 p.s.i.}$$

G. Check Shear:

Formula for maximum shear from Steel Construction Manual of AISC 5th edition 1947 page 376.

$$V = \frac{5}{8} w L + \frac{11}{16} P = \frac{5}{8} (151) (5.17) + \frac{11}{16} \frac{(16,000)}{5.17}$$

$$V = 487.5 + 2130.0 = 2617.5 \text{ lbs.}$$

$$v = \frac{V}{b (jd)} = \frac{2618}{12 (4.77)} = 46.2 \text{ p.s.i. less than 60 p.s.i.}$$

$$u = \frac{8 V}{7 \Sigma o d} = \frac{8 (2618)}{7 (2) (5.77) (5.5)} = 133 \text{ p.s.i. less than 150 p.s.i.}$$

H. Temperature steel provided normal to principal reinforcement:

$\frac{1}{2}$ in. circular bars equally spaced at $\frac{(5.17')}{3}$

$$A_s = \frac{1.963}{1.72} = .114 \text{ sq. in. per ln. ft. (top)}$$

$$A_s = \frac{1.963}{1.29} = .157 \text{ Sq. in. per ln. ft. (bottom)}$$

A_s required Spec. art. 66;

.125 sq. in. per ln. ft.

Temperature steel in top of slab is .011 sq. in. less than required. Since it is desired to maintain one bar directly over a stringer, it was necessary to space the bars as they are. This deficiency is so small that it is negligible. Temperature steel in bottom of slab is more than sufficient. Maximum spacing is 20 in. which is within specifications.

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STRINGER ANALYSIS

Specifications:

Art. 43. The bending moment carried by each interior beam or stringer shall be taken not less than that determined by the following formulae:

M = Bending moment for one traffic lane.

$N = \frac{\text{Width of Traffic Lane (not to exceed 10')}}{\text{Spacing of stringers or beams}}$

C = Coefficient based on type of floor.

M' = Bending moment on one beam or stringer.

$$M' = C \left(\frac{M}{N} \right)$$

Value of C is one for reinforced concrete slab.

In determining the end shear on longitudinal beams or stringers, the floor slab or flooring shall be assumed to act as a simply supported beam.

Art. 47. Structural steel:

Axial tension (net section) 18,000 p.s.i. . .

Tension on extreme fibre in flexure 18,000 ''

Shear on power-driven rivets and pins 13,500 ''

Shear on gross area of webs of beams & girders, $\frac{V}{A}$, where the clear distance between flanges is not more than 60

times the thickness of the web 12,000 ''

Art. 79. Depth ratio of rolled beams not more than $1/25$ of the span.

Art. 80. Rolled beams shall be proportioned by the moments of inertia of their net sections.

Journal of Management Education 30(6)

• *Journal of the American Medical Association*, 2000; 283: 2669-2674

• • • • •

1. *Journal of Management Studies*, 1997, 34, 1, 1-14.

Art. 88. The minimum thickness of structural steel shall be $5/16$ in. except for gusset plates, fillers and railings. Gusset plates shall in no case be less than $3/8$ in. in thickness.

Art. 92. The diameter of rivets in angles carrying calculated stress shall not exceed one-fourth of the width of the leg in which they are driven.

The minimum distance between centers of $3/4$ in. rivets shall be not less than $2\frac{1}{2}$ in.

The minimum edge distance for $3/4$ in. rivets shall be $1\frac{1}{4}$ in.

Art. 97. All connections shall be proportioned to develop not less than the full strength of the members connected provided that the full strength does not exceed the maximum computed stress by more than 50%, in which case the latter shall govern.

No connection, except for lacing bars and handrails, shall contain less than three rivets. Connections shall be made symmetrical about the axes of the members in so far as practicable.

Art. 110. Provision shall be made for expansion and contraction, to the extent of $1/8$ in. for each 10 feet of span. Expansion ends shall be firmly secured against lifting or lateral movement.

Art. 111. Spans of less than 70 feet may be arranged to slide upon metal plates with smooth surfaces.

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Art. 117. Superstructure steelwork shall be securely anchored to the substructure. Anchor Bolts shall be not less than one inch in diameter embedded not less than ten inches in the masonry and shall be swedged or threaded to secure a satisfactory grip in the masonry or otherwise suitably anchored.

Art. 124. Diaphragms shall be provided at the third points of all I-Beam spans of forty feet or more.

Art. 127 (1). Sole plates shall each be not less than $3/4$ in. thick and not less than the thickness of the flange angles plus $1/8$ in. Preferably, they shall not be longer than 18 in.

A. Maximum Dead Load Moment:

1. Dead Load per ln. ft. of stringer

(distance between stringers - 5' 2'')

151 lb. (5.17') 780

wt. per ft. of 27 WF 94 Beam 94

Total dead load 874 lbs. per ft. of stringer

$$2. M = \frac{1}{8} w l^2 = \frac{1}{8} (874) (32.67)^2 = 117,000 \text{ ft. lb.}$$

B. Maximum Live Loading. (H-20 loading)

1. Maximum loading on stringer (A) will occur when two trucks are side by side with the wheel of one truck directly on the stringer and the respective wheel of the other truck 3' to the side of the first wheel.

(shown below)

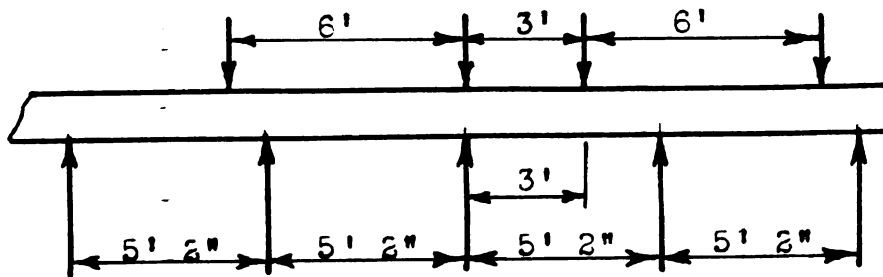


Fig. 7

Maximum load rear axle:

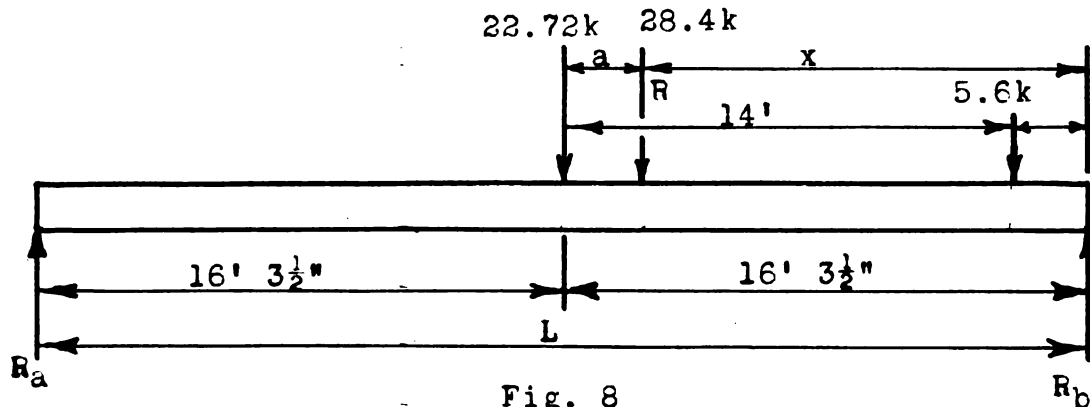
$$R_a = 16,000 + \frac{3 (16,000)}{5.17} = 16,000 + 6,720 = 22,720 \text{ lbs.}$$

Maximum load front axle:

$$R_a = 4,000 + \frac{3 (4,000)}{5.17} = 4,000 + 1,680 = 5,680 \text{ lbs.}$$

C. Maximum Live Load Moment:

Loading to produce maximum live load moment on stringer will occur when rear wheels of the two trucks will simultaneously reach a point the distance $(\frac{a}{2})$ passed the center of the span. (absolute moment)



1. To find R_a and R_b :

$$R_a = \frac{22,720 (16.29') + 5,680 (2.29')}{32.58'} = 11,750 \text{ lbs.}$$

$$R_b = 28,400 - 11,750 = 16,650 \text{ lbs.}$$

2. To find x :

$$x = \frac{11,750 (32.58')}{28,400} = 13.5'$$

3. To find a :

$$a = 16.29' - 13.5' = 2.79'$$

4. To find Absolute Maximum Moment: (Formula from "Structural Theory" Sutherland & Bowman, 3rd. edition 1944, page 116)

$$M = \frac{R_1}{L} \left[\left(\frac{L}{2} \right)^2 - \frac{L(a)}{2} + \left(\frac{a}{2} \right)^2 \right] - R_L b$$

$$M = \frac{28,400}{32.58'} \left[\left(\frac{32.58'}{2} \right)^2 - \frac{32.58' (2.79')}{2} + \left(\frac{2.79'}{2} \right)^2 \right] - 0$$

$$M = 196,000 \text{ lb. ft.}$$

[illegible]

5. Spec. Art. 43:

$$M' = C \left(\frac{M}{N} \right) = \frac{1}{9} \frac{(135,000 \text{ lb.ft.})}{5.17} = 156,000 \text{ lb.ft.}$$

M' above is much less than the moment computed in 4 above. Therefore I will use the larger moment in this analysis.

D. Beam size:

1. Total moment on stringer:

Dead Load moment	117,000 lb.ft.
Live Load moment	196,000 "
Impact (196,000 x .24)	<u>47,000 "</u>
Total moment	360,000 lb.ft.

2. To find $\frac{I}{C}$ (section modulus)

$$\frac{I}{C} = \frac{M}{s} = \frac{360,000 (12)}{18,000 \text{ psi}} = 240 \text{ in.}^3$$

27 WF 94 beam has $\frac{I}{C}$ of 242.8 in.³ Therefore the beam is suitable to carry the maximum loading on the bridge.

3. Depth Ratio: Spec. Art. 79.

$$\text{Ratio} = \frac{1}{32.58 (12) \div 27} = \frac{1}{14}$$

The ratio is greater than specifications call for ($\frac{1}{25}$). Therefore the beam is satisfactory for depth.

4. Check Shear: Spec. Art. 47.

$$27 \div .49 = 58 \text{ (less than 60 times web thickness)}$$

$$V = 16,650 (1.24) + \frac{874}{2} (32.58) = 34,900 \text{ lbs.}$$

$$s = \frac{V}{A} = \frac{34,900}{.49 (26.9)} = 2,650 \text{ p.s.i. (less than 12,000 therefore O.K.)}$$

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10. The tenth is the fact that the
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which are not yet fully understood.

E. Diaphragms: Provided at 1/3 distance of span.

Spec. Art. 124

Connection angles 4 x 4 x 3/8

Horizontal angles 3 x 3 x 3/8

Diaphragm plate 18 x 3/8

Force resisted by Diaphragms: Spec. Art. 38

$$\text{Area of substructure} = \frac{9(27)(30.33)}{2(12)} = 307 \text{ sq.ft.}$$

$$\text{Area of side elevation} = 5(30.33)(1.5) = \underline{228} \text{ "}$$

$$\text{Total area} \quad \quad \quad 535 \text{ sq.ft.}$$

$$\text{Lateral force, wind on structure} = 535(30) = 16,050\#$$

$$\text{Lateral force, wind on Live Load} = 150(30.33) = \underline{4,600\#}$$

$$\text{Total force} \quad \quad \quad 20,650\#$$

Area steel required:

$$A_s = \frac{20,650}{18,000} = 1.15 \text{ sq. in.}$$

Area steel provided: (2 plates)

$$A_s = 2(18) \left(\frac{3}{8} \right) = 13.5 \text{ sq.in.}$$

This is much more steel area than is necessary.

Stress in rivets:

$$s = \frac{20,650}{2(5)(.442)} = 4,700 \text{ p.s.i. (allowed is 13,500)}$$

F. Bearing Plates:

Plate size: 12" x 1/2" x 19 1/2"

Bearing on concrete:

$$f_c = \frac{34,900 \text{ lb.}}{12(19.5)} = 149 \text{ p.s.i. (this is very low)}$$

G. The ends of the stringers are not connected but are embedded in concrete a depth of one foot, with two steel bars passing through the web of the stringers. This gives the necessary stability.

ABUTMENT ANALYSIS

Specifications:

Art: 39. Retaining walls, abutments and structures built to retain fills shall be designed to resist pressures determined in accordance with the "Rankine" theory of pressure distribution in non-cohesive granular material, provided that no structure shall be designed for an equivalent fluid pressure of less than 30 pounds per square foot.

To provide for live load an equivalent earth surcharge of four feet shall be applied over all surfaces subject to highway traffic.

Art: 59. In footings and other principal structural members where the concrete is in direct contact with soil, the reinforcement shall have a minimum covering of 3 in. of concrete measured to the center of bar.

Art. 63. (b) In cantilever footings all bars shall be anchored by means of standard hooks at the outer ends of the bar.

In analysis of the Abutment, four types of loadings will be considered as follows:

Case 1: Abutment before stringers are placed and only pressure is due to retained soil without allowance for live loading over fill.

Case 2: Pressure due to retained soil With allowance for live loading over fill and stabilizing moment due to dead load of bridge.

Case 3: Pressure due to retained soil not allowing for live loading surcharge and stabilizing moment due to dead and live loading of bridge.

Case 4: Pressure due to retained soil with allowance for live loading surcharge and stabilizing moment due to dead and live loading of bridge.

Total Height of Fill:

Surcharge live load	4' 0"	
Surcharge (12" pavement)	1' 6"	
Distance, pavement & abutment	2' 6 $\frac{5}{8}$ "	
Total surcharge	8' 5 $\frac{5}{8}$ "	(Call it 8') 8' 0"
Height retaining		15' 17 $\frac{5}{8}$ "
Total height of fill		23' 17 $\frac{5}{8}$ "

Weight of reinforced concrete	150 lb. per cu.ft.
Weight of fill	100 lb. per cu.ft.
Angle of repose of fill	30 degrees

The first part of the document discusses the importance of maintaining accurate records of all transactions. It emphasizes that every entry must be clearly documented, including the date, amount, and purpose of the transaction. This ensures transparency and allows for easy verification of the data.

The second part of the document outlines the procedures for handling discrepancies. It states that any difference between the recorded amounts and the actual amounts must be investigated immediately. The responsible parties are required to provide a detailed explanation of the discrepancy and take steps to correct it.

The third part of the document describes the process for reconciling accounts. It requires that all accounts be reconciled at the end of each month. This involves comparing the recorded transactions with the actual bank statements and ensuring that they match. Any differences must be identified and resolved.

The fourth part of the document discusses the importance of regular audits. It states that an independent audit should be conducted annually to verify the accuracy of the records. The audit should cover all transactions and ensure that they are properly documented and reconciled.

The fifth part of the document outlines the responsibilities of the accounting staff. It requires that all staff members be trained in the proper use of accounting software and procedures. They must also be held accountable for maintaining accurate records and identifying any potential issues.

The sixth part of the document discusses the importance of maintaining proper documentation. It states that all records must be stored in a secure and accessible location. This includes keeping copies of all transactions, receipts, and supporting documents. The documentation should be organized in a way that makes it easy to find and review.

The seventh part of the document outlines the process for handling changes to the accounting system. It states that any changes to the system must be approved by the management team. This includes changes to the accounting software, procedures, or staff. The changes should be implemented in a controlled and documented manner.

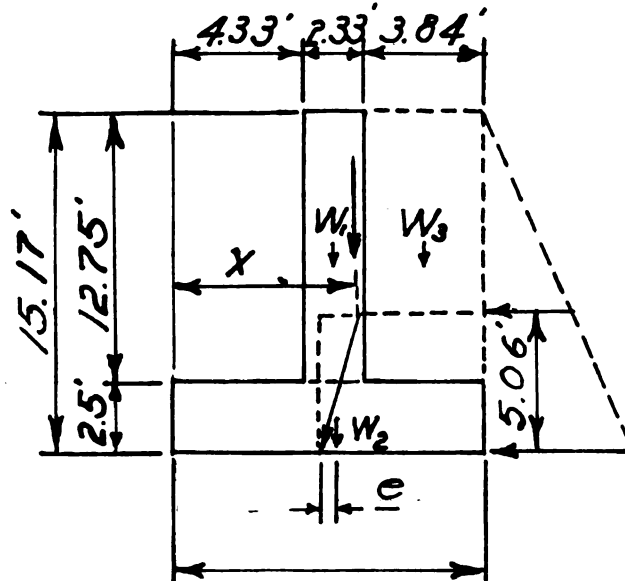
The eighth part of the document discusses the importance of regular communication. It states that the accounting staff should maintain open communication with the management team. This includes providing regular reports on the status of the accounts and any potential issues.

The ninth part of the document outlines the process for handling errors. It states that any errors in the records must be identified and corrected as soon as possible. The responsible parties are required to provide a detailed explanation of the error and take steps to prevent it from happening again.

The tenth part of the document discusses the importance of maintaining accurate records for legal purposes. It states that all records must be kept for a minimum of seven years. This ensures that the company has a complete and accurate record of all transactions for legal and tax purposes.

Case 1

Abutment before stringers are placed and only pressure is due to retained soil without live load surcharge:



$$P' = Cwh = .33 (100) 15.17 = 504 \text{ lb.}$$

$$P = \frac{504}{2} (15.17) = 3820 \text{ lb.}$$

$$W_1 = 150 (2.33) (12.75') = 4460 \text{ lbs.} \quad \frac{\text{arm}}{5.5} = \frac{\text{moment}}{24,800 \text{ lb.ft.}}$$

$$W_2 = 150 (2.50) (10.5) = 3940 \quad 5.25 = 20,660 \text{ "}$$

$$W_3 = 100 (3.84) (12.75) = 4900 \quad 8.58 = 42,000 \text{ "}$$

$$\text{Total wt.} \quad 13300 \text{ lbs.} \quad \text{Total Mo.} \quad 87,460 \text{ lb.ft.}$$

To find "x":

$$x = \frac{87,460}{13,300} = 6.57'$$

To find "e"

$$e' = \frac{5.06 (3820)}{13,300} = 1.46' \quad 6.57 - 1.46 = 5.11'$$

$$e = 5.25 - 5.11 = .14'$$

Earth Pressure:

$$P = \frac{13,300}{10.5'} \left[1 \pm \frac{6(.14)}{10.5} \right] = 1270 (1 \pm .08) = 1370 \#/\text{sq.ft.} \quad 1170 \#/\text{sq.ft.}$$

Overturning Factor:

$$\text{Ratio} = \frac{87,460 \text{ lb.ft.}}{3,820(5.06)} = 4.4 \quad (\text{very safe})$$

Sliding Factor:

$$\text{Ratio} = \frac{13,300(.50)}{3,820} = 1.74 \quad (\text{Just on the borderline of being safe})$$

It is obvious that the resultant intersects the base within the middle third since "e" is only .14'.

Stem Moment:

$$p = C^wh = .33 (12.75)(100) = 421 \text{ lbs.}$$

$$M = \frac{(421)}{2} (12.75) \left(\frac{12.75}{3} \right) = 11,400 \text{ lb. ft.}$$

Toe Moment:

$$p = \frac{6.17 (355)}{10.5} + 1090 = 1299 \text{ lbs.} \quad (\text{earth pressure at edge of stem})$$

Moment upward due to earth pressure:

$$1299 (4.33) \left(\frac{4.33}{2} \right) = 12,050 \text{ ft. lb.}$$

$$\frac{146}{2} (4.33) \left(\frac{2}{3} \right) (4.33) = \underline{896} \quad "$$

$$\text{Total Moment} = 12,946 \text{ ft. lb.}$$

Moment downward due to concrete in toe:

$$M = 150 (4.33)(2.5) \left(\frac{4.33}{2} \right) = 3,470 \text{ ft. lb.}$$

$$\text{Toe Moment} = 12,946 - 3,470 = 9,476 \text{ ft. lb.}$$

Heel Moment:

$$p = \frac{3.84 (355)}{10.5} = 130 \text{ lb./sq.ft.} \quad (\text{earth pressure at edge of stem.})$$

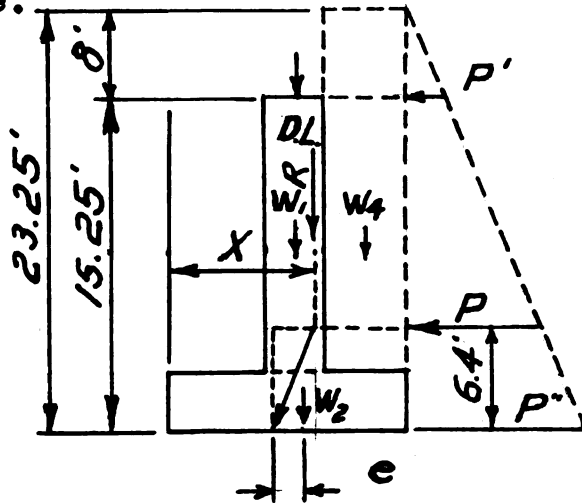
$$\text{Upward } M = 1090(3.84) \left(\frac{3.84}{2} \right) + \frac{130(3.84) \left(\frac{3.84}{3} \right)^2}{2} = 8369 \text{ ft.lb.}$$

$$\text{Downward } M = 3.84(2.5)(150) + 4900 \times \frac{3.84}{2} = 12,180 \text{ ft.lb.}$$

$$\text{Heel Moment} = 12,180 - 8,369 = 3,811 \text{ ft. lb.}$$

Case 2

Pressure due to retained soil with allowance for live load surcharge and stabilizing moment due to dead load of bridge.



To find horizontal force:

$$P' = Cwh = .33(100)(8) = 264 \text{ lb.}$$

$$P'' = Cwh = .33(100)23.25 = 768 \text{ lb.}$$

$$264 (15.25) \frac{(15.25)}{2} = 30,700 \text{ ft.lb.}$$

$$\left(\frac{768 - 264}{2} \right) (15.25) \frac{(15.25)}{3} = 19,550 \text{ ft.lb.}$$

$$\text{Total Moment} = 50,250 \text{ ft.lb.}$$

$$P = 264 (15.25) + \frac{(768 - 264)(15.25)}{2} = 7870 \text{ lb.}$$

$$y = \frac{50,250 \text{ ft.lb.}}{7870 \text{ lb.}} = 6.4'$$

Dead Load of deck per foot of Abutment:

$$\text{D.L.} = \frac{874 \text{ lb.} (33.87')}{2 (5.17')} = 2860 \text{ lbs.}$$

1. The first part of the paper is devoted to the study of the properties of the function $f(x)$ defined by the equation

$$f(x) = \int_0^x \frac{1}{1+t^2} dt.$$

It is shown that the function $f(x)$ is increasing and concave down on the interval $(-\infty, \infty)$.

2. In the second part of the paper, we consider the function $g(x)$ defined by the equation

$$g(x) = \int_0^x \frac{1}{1+t^2} dt + \int_0^x \frac{1}{1+t^4} dt.$$

It is shown that the function $g(x)$ is increasing and concave down on the interval $(-\infty, \infty)$.

3. In the third part of the paper, we consider the function $h(x)$ defined by the equation

$$h(x) = \int_0^x \frac{1}{1+t^2} dt + \int_0^x \frac{1}{1+t^4} dt + \int_0^x \frac{1}{1+t^6} dt.$$

It is shown that the function $h(x)$ is increasing and concave down on the interval $(-\infty, \infty)$.

4. In the fourth part of the paper, we consider the function $k(x)$ defined by the equation

$$k(x) = \int_0^x \frac{1}{1+t^2} dt + \int_0^x \frac{1}{1+t^4} dt + \int_0^x \frac{1}{1+t^6} dt + \int_0^x \frac{1}{1+t^8} dt.$$

It is shown that the function $k(x)$ is increasing and concave down on the interval $(-\infty, \infty)$.

5. In the fifth part of the paper, we consider the function $l(x)$ defined by the equation

$$l(x) = \int_0^x \frac{1}{1+t^2} dt + \int_0^x \frac{1}{1+t^4} dt + \int_0^x \frac{1}{1+t^6} dt + \int_0^x \frac{1}{1+t^8} dt + \int_0^x \frac{1}{1+t^{10}} dt.$$

It is shown that the function $l(x)$ is increasing and concave down on the interval $(-\infty, \infty)$.

To find Resultant Vertical Force:

$$D.L. = 2860 \text{ lbs. } 5.46' = 15,600 \text{ lb.ft.}$$

$$W_1 \quad 150 (2.33)(12.75) = 4460 \quad " \quad 5.5' = 24,800 \quad "$$

$$W_2 = 3940 \quad " \quad 5.25' = 20,660 \quad "$$

$$W_4 \quad 20.75 (3.83)(100) = \underline{7950} \quad " \quad 8.58' = \underline{68,250} \quad "$$

$$\text{Total weight } 19210 \text{ lbs: Total M } 129,310 \text{ lb.ft.}$$

$$x = \frac{129,310 \text{ lb.ft.}}{19,210 \text{ lbs.}} = 6.72'$$

$$e' = \frac{6.4' (7870)}{19,210} = 2.62' : 6.72' - 2.62' = 4.10'$$

$$e = 5.25' - 4.10' = 1.15'$$

Earth Pressure: Pressure greater at toe.

$$P = \frac{19,210}{10.5'} (1 \pm .66) = \begin{matrix} 3020 \text{ lb.per sq.ft.} \\ 620 \text{ lb.per sq.ft.} \end{matrix}$$

Overturning Factor:

$$\text{Ratio} = \frac{129,310 \text{ lb.ft.}}{7870 \text{ lb.}(6.4)} = 2.6 \text{ (this is satisfactory)}$$

Sliding Factor:

$$\text{Ratio} = \frac{19,210 \text{ lb.} (.50)}{7870 \text{ lb.}} = 1.2 \text{ (this is unsatisfactory)}$$

Check if Resultant intersects base within middle third:

$$\frac{10.5}{3} = 3.5' : \frac{3.5}{2} = 1.7' \text{ (greater than 1.15' therefore within middle third)}$$

Stem Moment: (tending to overturn)

$$P = CWh = 20.75(100)(.33) = 685 \text{ lb.}$$

$$264 (12.75) = 3370 \text{ lb. } \frac{12.75'}{2} = 21,500 \text{ lb.ft.}$$

$$\frac{(685-264)(12.75)}{2} = \underline{2680 \text{ lb.}} \quad \frac{12.75'}{3} = \underline{11,400 \text{ lb. ft.}}$$

$$\text{Total wt.} = 6050 \text{ lb. } \text{Total Mo.} = 32,900 \text{ lb. ft.}$$

Stem Moment: (tending to stabilize)

$$2860 (1.125') = 3210 \text{ lb.ft.}$$

$$4460 (1.165') = \underline{5200} \text{ lb.ft.}$$

$$\text{Total Mo.} = 8410 \text{ lb.ft.}$$

Total Stem Moment:

$$M = 32,900 \text{ lb.ft.} - 8410 \text{ lb.ft.} = 24,490 \text{ lb.ft.}$$

Total Toe Moment:

$$p = \frac{6.17 (2400)}{10.5} + 620 = 2040 \text{ lb.per sq.ft. (earth pressure at edge of stem)}$$

Moment due to Earth Pressure:

$$2040 (4.33) = 8780 \text{ lbs.} \quad \frac{\text{arm}}{4.33} = 18,900 \text{ ft.lb.}$$

$$\frac{(2400 - 2040)}{2} (4.33) = \underline{795} \text{ lbs.} \quad \frac{2(4.33)}{3} = \underline{2,260} \text{ "}$$

$$\text{Total weight} = 9575 \text{ lbs: Total Mo.} = 21,160 \text{ ft.lb.}$$

Moment due to toe concrete:

$$150 (2.5) (4.33) = 1615 \text{ lbs.} \quad \frac{4.33}{2} = 3,470 \text{ ft.lb.}$$

$$\text{Total Moment} = 21,160 - 3,470 = 17,690 \text{ ft.lb.}$$

$$\text{Total Shear} = 9,575 - 1615 = 7,960 \text{ lbs.}$$

Total Peel Moment:

$$P = \frac{3.83 (2400)}{10.5} + 620 = 1500 \text{ lbs.per sq. ft. (earth pressure at edge of stem)}$$

Earth Pressure Moment upward:

$$620 (3.83) = 2370 \text{ lb.} \quad \frac{3.83}{2} = 4,550 \text{ ft.lb.}$$

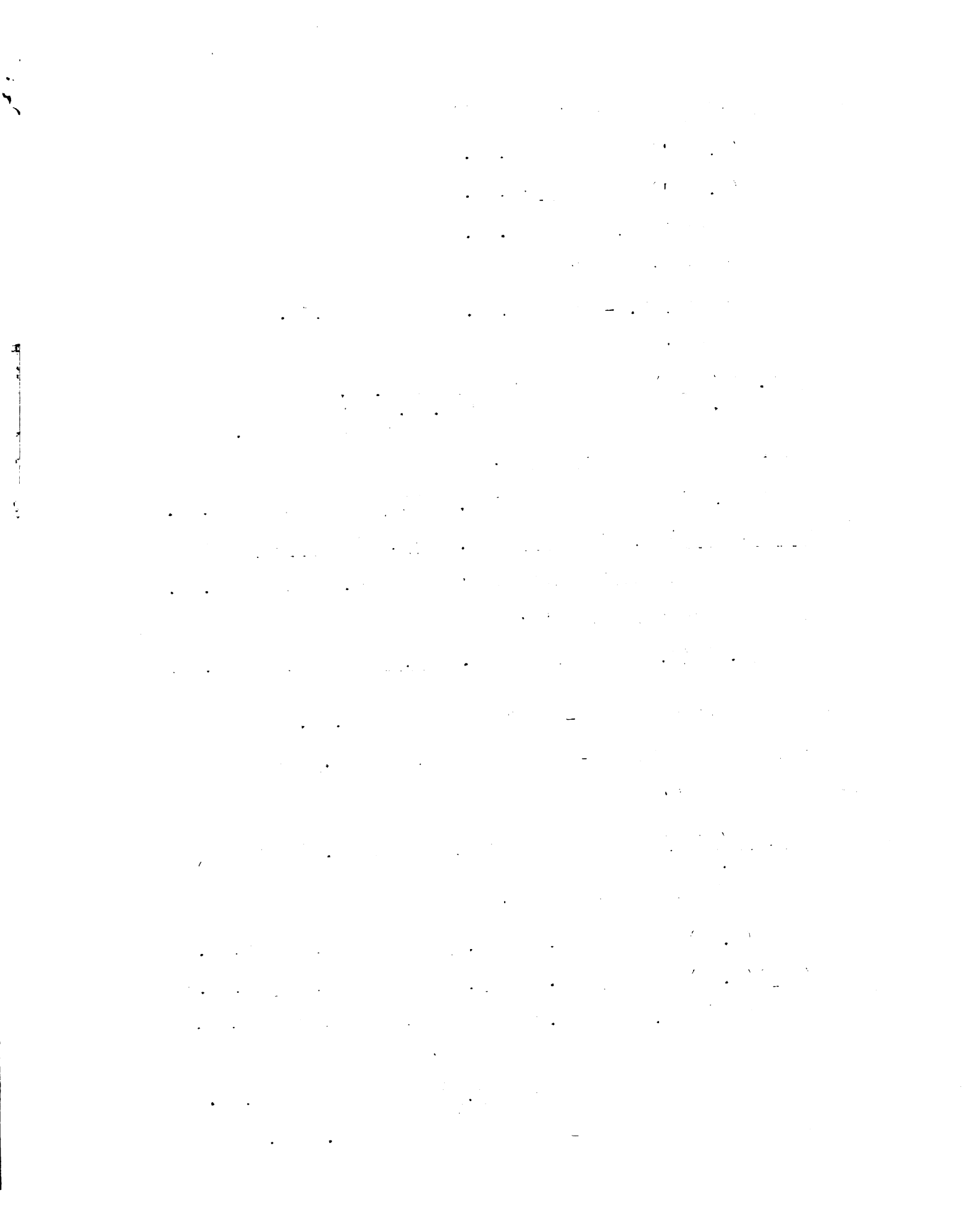
$$\frac{(880)}{2} (3.83) = \underline{1685} \text{ lb.} \quad \frac{3.83}{3} = \underline{2,150} \text{ ft.lb.}$$

$$\text{Total wt} = 4055 \text{ lb.: Total Mo.} = 6,700 \text{ ft.lb.}$$

Earth and Concrete Moment Downward:

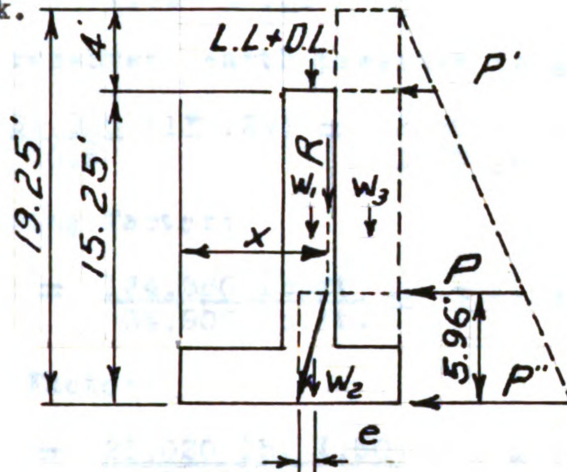
$$7950 + 1435 = 9,385 \text{ lbs.} \quad \frac{3.83}{2} = 18,000 \text{ ft.lb.}$$

$$\text{Total Moment} = 18,000 - 6,700 = 11,300 \text{ ft. lbs.}$$



Case 3

Pressure to retained soil without allowance for live load surcharge. Stabilizing moment due to dead and live loading of deck.



$$P' = .33 (4)(100) = 132 \text{ lb.}$$

$$P'' = .33 (19.25)(100) = 636 \text{ lb.}$$

To find "P": horizontal force due to earth pressure.

$$132 (15.25) = 2,015 \text{ lb.} \quad \frac{15.25}{2} = 15,400 \text{ lb.ft.}$$

$$\frac{(636 - 132)}{2} (15.25) = 3,840 \text{ lb.} \quad \frac{15.25}{3} = 19,500 \text{ "}$$

$$\text{Total P} = 5,855 \text{ lb.} \quad \text{Total Mo.} = 34,900 \text{ lb.ft.}$$

$$y = \frac{34,900 \text{ lb.ft.}}{5,855 \text{ lb.}} = 5.96'$$

To find Resultant of vertical forces:

$$\text{D.L. + L.L. of Deck} = \left[16,650 + \frac{874(33.58)}{2} \right] \div 5.17 = 6200 \text{ \#/ft.}$$

$$\text{D.L. L.L. of Deck} = 6200 \text{ lb.} \quad \frac{\text{arm}}{5.46'} = \frac{\text{moment}}{33,900 \text{ lb.ft.}}$$

$$W_1 = 4460 \text{ "} \quad 5.5 = 24,800 \text{ "}$$

$$W_3 = 100(3.83)(16.75) = 6420 \text{ "} \quad 8.58 = 55,000 \text{ "}$$

$$W_2 = 3940 \text{ "} \quad 5.25 = 20,660 \text{ "}$$

$$\text{Total wt.} = 21020 \text{ lbs.} \quad \text{Total Mo.} = 134,360 \text{ lb.ft.}$$

$$x = \frac{134,360 \text{ lb.ft.}}{21,020 \text{ lbs.}} = 6.4'$$

$$e' = \frac{5.96 (5,855)}{21,020} = 1.66' : \quad 6.4 - 1.66 = 4.74'$$

$$e = 5.25 - 4.74 = .51'$$

Earth Pressure: earth pressure is greater at toe

$$P = \frac{21,020 (1 \pm .29)}{10.5} = \begin{array}{l} 2580 \text{ lb.per sq.ft.} \\ 1420 \text{ lb. per sq.ft.} \end{array}$$

Overturning Factor:

$$\text{Ratio} = \frac{134,360 \text{ lb.ft.}}{34,900 \text{ lb.ft.}} = 3.8 \text{ (satisfactory)}$$

Sliding Factor:

$$\text{Ratio} = \frac{21,020 \text{ lb.} (.50)}{5,855 \text{ lb.}} = 1.8 \text{ (Satisfactory)}$$

It is obvious that the Resultant intersects the base within the middle third as "e" is very small.

Stem Moment:

$$p = .33 (100)(16.75) = 552 \text{ lb.}$$

Overturn Moment: (Due to earth pressure)

$$132 (12.75) = 1,685 \text{ lb.} \quad \frac{12.75}{2} = 10,700 \text{ ft.lb.}$$

$$\frac{420}{2} (12.75) = \frac{2,680}{3} \text{ lb.} \quad \frac{12.75}{3} = \frac{11,400}{3} "$$

$$\text{Total wt.} = 4,365 \text{ lb.} \quad \text{Total Mo.} = 22,100 \text{ ft.lb.}$$

Stablizing Moment: (Due to loaded deck and wt. of stem)

$$6200 (1.125) = 7,000 \text{ ft.lb.}$$

$$4460 (1.165) = \underline{5,200} "$$

$$\text{Total Mo.} = 12,200 \text{ ft.lb.}$$

$$\text{Stem Moment} = 22,100 - 12,200 = 9,900 \text{ ft.lb.}$$

Toe Moment:

$$p = \frac{6.17 (1160)}{10.5} + 1420 = 2100 \text{ lb.per sq.ft. (earth pres-}$$

sure next to stem edge)

Moment Upward:

$$2100 (4.33) = 9,100 \text{ lb. } \frac{4.33}{2} = 19,700 \text{ ft.lb.}$$

$$\frac{480}{2} (4.33) = \frac{1,030}{3} \text{ " } \frac{(4.33)^2}{3} = \frac{2,980}{3} \text{ "}$$

$$\text{Total wt.} = 10,130 \text{ lb. } \text{Total Mo.} = 22,680 \text{ ft.lb.}$$

Total Toe Moment:

$$M = 22,680 - 3,470 = 19,210 \text{ ft.lb.}$$

Heel Moment:

$$P = \frac{3.83(1160)}{10.5} + 1420 = 1843 \text{ lb./sq.ft. (pressure next to stem edge)}$$

Moment Upward:

$$1420 (3.83) = 5440 \text{ lb. } \frac{3.83}{2} = 10,400 \text{ ft.lb.}$$

$$\frac{423}{2} (3.83) = \frac{811}{3} \text{ " } \frac{3.83}{3} = \frac{1,035}{3} \text{ "}$$

$$\text{Total wt.} = 6251 \text{ lb. } \text{Total Mo.} = 11,435 \text{ ft.lb.}$$

Moment Downward:

$$M = 6420 + 1435 = 7855 \text{ lb. } \frac{(3.83)}{2} = 15,030 \text{ ft.lb.}$$

$$\text{Total Moment} = 15,030 - 11,435 = 3,595 \text{ ft.lb.}$$

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• The second of these is the fact that the

• of the system is not a simple one.

• The third of these is the fact that the

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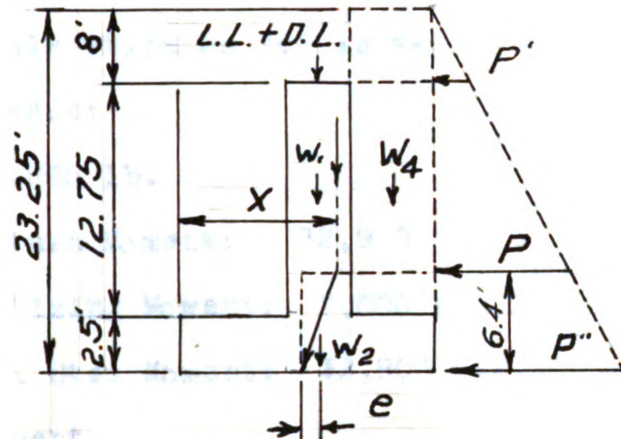
• The seventh of these is the fact that the

• of the system is not a simple one.

• The eighth of these is the fact that the

Case 4

Pressure due to retained soil with live load surcharge and stabilizing moment due to dead and live load on deck.



Resultant Horizontal Force = 7870 lb. : $y = 6.4'$

To find Resultant Vertical Force:

		<u>arm</u>	<u>moment</u>
D. & L. load on deck--	6200	5.46'	33,900 ft.lb.
W_1	= 4460	5.5	24,800 "
W_2	= 3940	5.25	20,660 "
W_4	= <u>7950</u>	8.58	<u>68,250</u> "

Total weight = 22550#. Total Mo. = 147,610 ft. lb.

$$x = \frac{147,610 \text{ ft. lb.}}{22,550 \text{ lb.}} = 6.55'$$

$$e' = \frac{6.4 (7870)}{22,550} = 2.23' : 6.55' - 2.23' = 4.32'$$

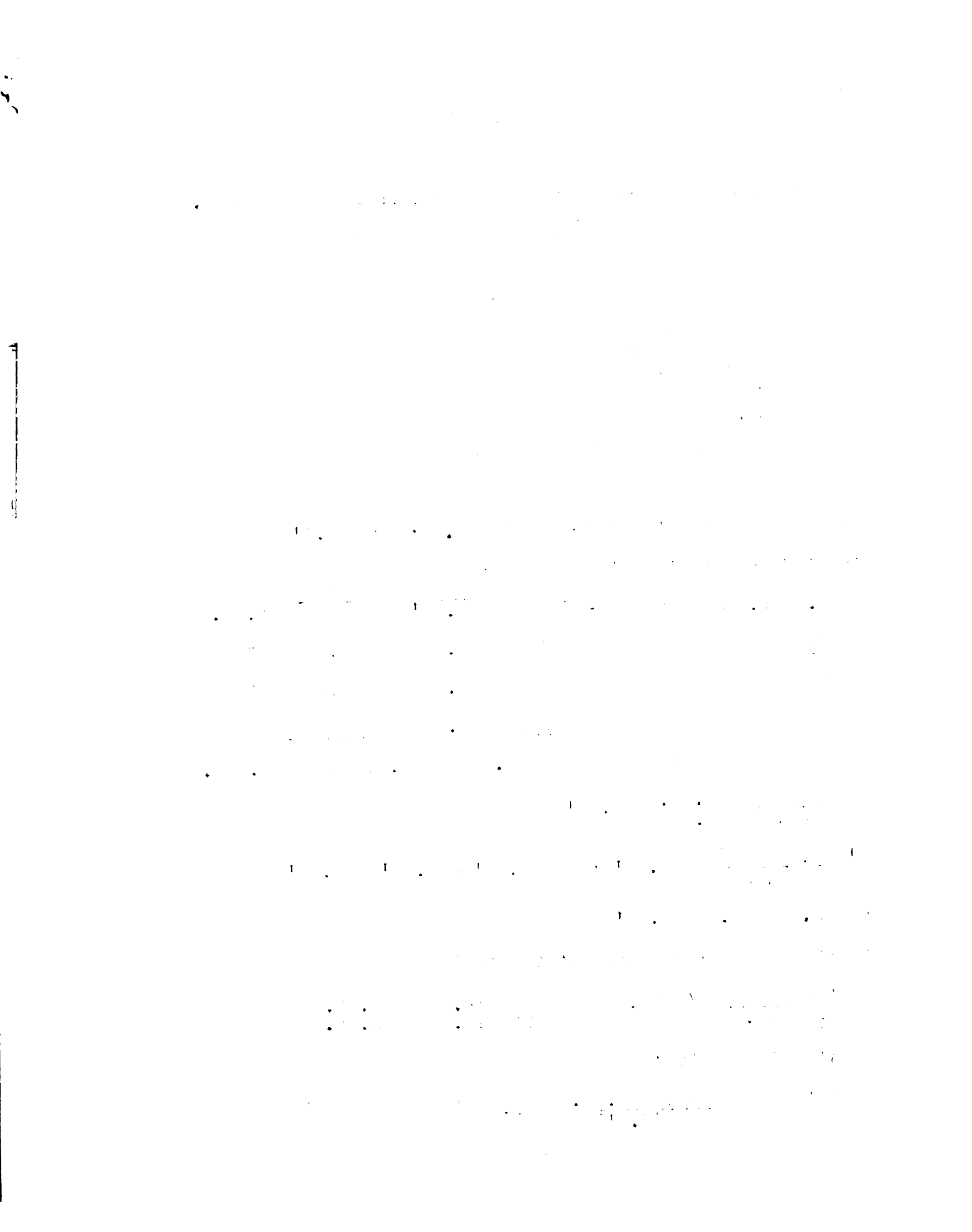
$$e = 5.25 - 4.32 = .93'$$

Earth Pressure: (greater at the toe)

$$P = \frac{22,550}{10.5} (1 \pm .55) = \begin{matrix} 3320 \text{ lb. per sq.ft.} \\ 965 \text{ lb. per sq.ft.} \end{matrix}$$

Overturning Factor:

$$\text{Ratio} = \frac{147,610 \text{ ft. lb.}}{7870 (6.4')} = 2.9 \text{ (satisfactory)}$$



Sliding Factor:

$$\text{Ratio} = \frac{22,550 \text{ lb. } (.50)}{7870 \text{ lb.}} = 1.4 \text{ (this is unsatisfactory)}$$

It is obvious that the Resultant intersects the base within the middle third as "e" is very small.

Stem Moment:

$$p = 685 \text{ lb.}$$

$$\text{Overturn Moment: } 32,900 \text{ ft.lb.}$$

$$\text{Stablizing Moment: } 7,000 + 5,200 = 12,200 \text{ ft.lb.}$$

$$\text{Total Stem Moment: } 32,900 - 12,200 = 20,700 \text{ ft.lb.}$$

Toe Moment:

$$p = \frac{2355 (6.17)}{10.5} + 965 = 2345 \text{ lb.per sq.ft.}$$

Upward Moment:

$$2345 (4.33) = 10,150 \text{ lb. } \frac{4.33}{2} = 21,800 \text{ ft.lb.}$$

$$\frac{975}{2} (4.33) = \frac{2,110}{2} \text{ lb. } \frac{(4.33)^2}{3} = \frac{6,100}{3} "$$

$$\text{total wt.} = 12,260 \text{ lb. } \text{Total.M.} = 27,900 \text{ ft.lb.}$$

$$\text{Total Toe Moment: } 27,900 - 3,470 = 24,430 \text{ ft.lb.}$$

Heel Moment:

$$p = \frac{2355 (3.83)}{10.5} + 965 = 1823 \text{ lb.per sq.ft. (earth pressure)}$$

Upward Moment:

$$965 (3.83) = 3700 \text{ lb. } \frac{3.83}{2} = 7,070 \text{ ft.lb.}$$

$$\frac{858}{2} (3.83) = \frac{1645}{2} \text{ lb. } \frac{3.83}{3} = \frac{2,100}{3} \text{ ft.lb.}$$

$$\text{Total wt} = 5345 \text{ lb. } \text{Total Mo.} = 9,170 \text{ ft.lb.}$$

$$\text{Total Moment} = 18,000 - 9,170 = 8,830 \text{ ft. lb.}$$

$$\text{Total Shear} = 9,385 - 5,345 = 4,040 \text{ lbs.}$$

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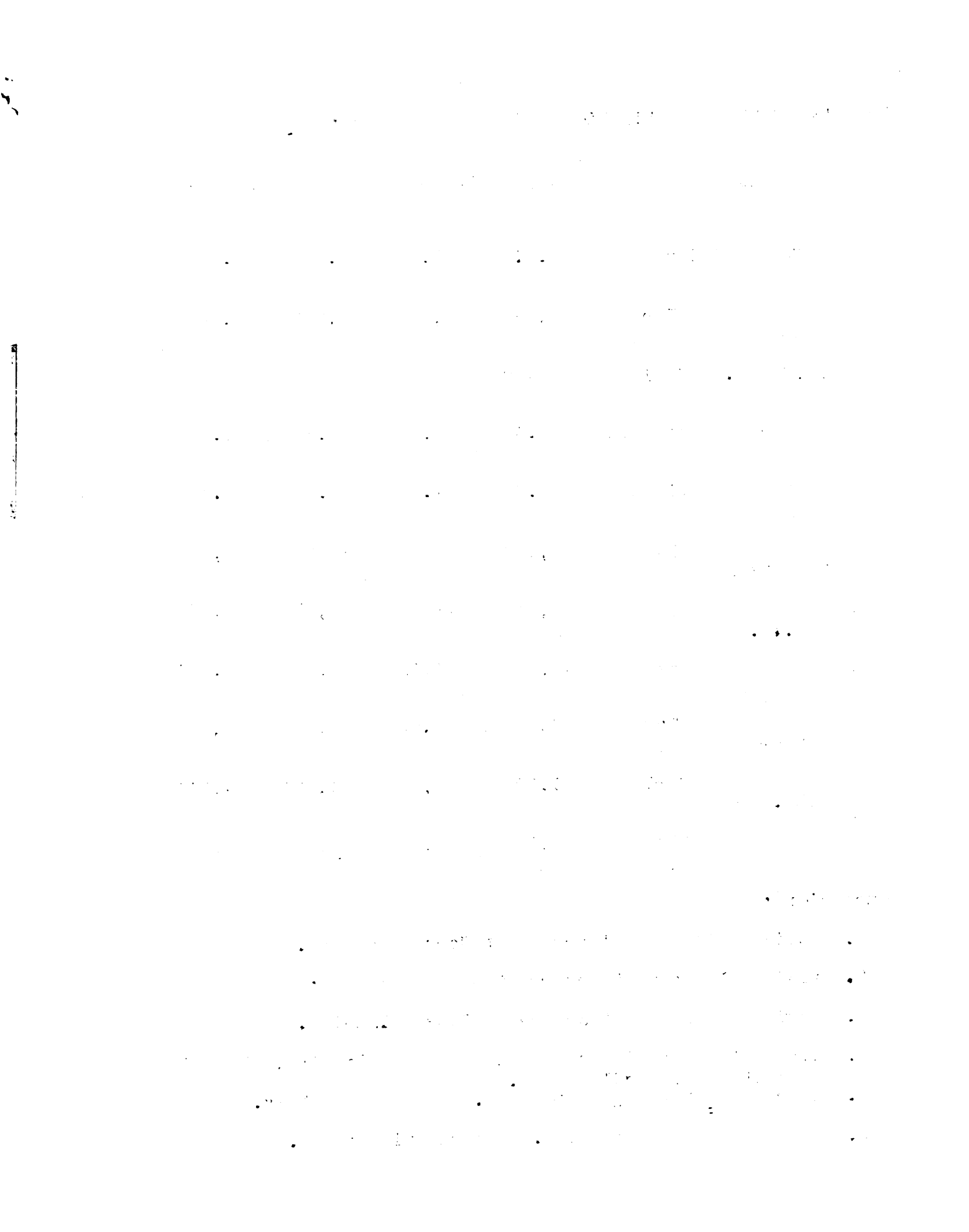
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Results of the Invertigations of the Four Cases:

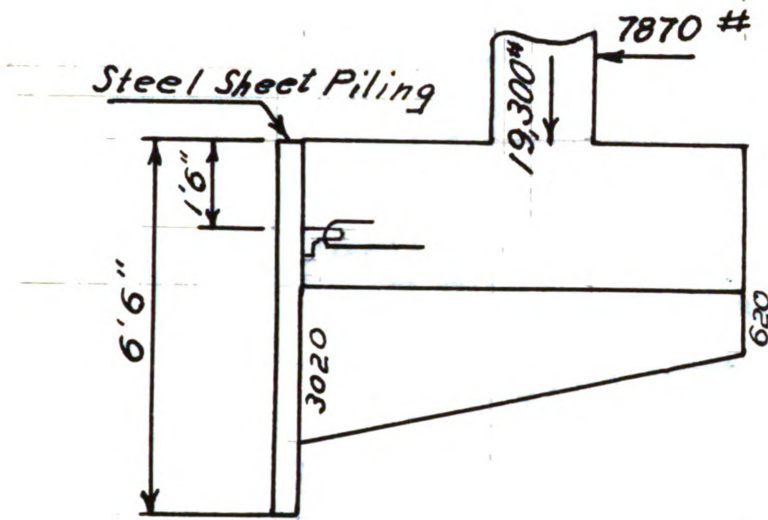
ITEM		CASE 1	CASE 2	CASE 3	CASE 4
Eccentricity		.14	1.15	.51	.93
Earth Pressure lb./sqft.	Toe	1,370	3,020	2,580	3,320
	Heel	1,170	620	1420	965
Safety Factor	Overturning	4.4	2.6	3.8	2.9
	Sliding	1.7	1.2	1.8	1.4
Moments ft.lb.	Toe	9,476	17,690	19,210	24,430
	Heel	3,811	11,300	3,595	8,830
	Stem	11,400	24,490	9,900	20,700
Shear lbs.	Toe	4,291	7,960	8,505	10,635
	Heel	1,892	5,330	1,604	4,040
	Stem	2,690	6,050	4,365	6,050

Conclusions:

1. Maximum Stem moment occurs at Case 2 loading.
2. Maximum Toe moment occurs at Case 4 loading:
3. Maximum Heel moment occurs at Case 2 loading.
4. Greatest Excentricity occurs at Case 2 loading, which is within the middle third.
5. Lowest Overturning Factor , 2.6, is satisfactory.
6. Lowest Sliding Factor, 1.2, is unsatisfactory.



Resistance to Sliding:



Lowest Sliding Factor occurs with case 2 loading:

To secure against sliding there is provided steel sheet piling driven to a depth of 6' 6" and a secure bond between footing and piling (fig. above) exists by means of an angle iron welded to piling and a length of reinforcement bar hooked through angle and embedded in the footing.

$$\text{Sliding Factor} = \frac{19,310 (.50) + 3020(2.5)}{7870} = 2.2$$

This factor is satisfactory.

• The first part of the paper is devoted to a discussion of the various methods of determining the rate of reaction. The second part is devoted to a discussion of the various factors which influence the rate of reaction. The third part is devoted to a discussion of the various factors which influence the equilibrium constant. The fourth part is devoted to a discussion of the various factors which influence the activation energy. The fifth part is devoted to a discussion of the various factors which influence the rate of reaction. The sixth part is devoted to a discussion of the various factors which influence the equilibrium constant. The seventh part is devoted to a discussion of the various factors which influence the activation energy. The eighth part is devoted to a discussion of the various factors which influence the rate of reaction. The ninth part is devoted to a discussion of the various factors which influence the equilibrium constant. The tenth part is devoted to a discussion of the various factors which influence the activation energy.

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STEM ANALYSIS

Forces acting on Stem:

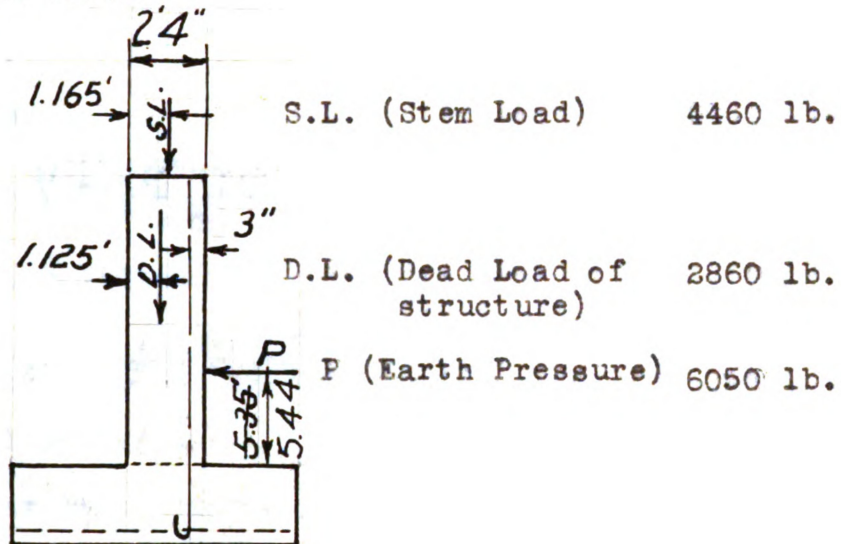


Fig. 9

To find "jd":

$$f_c = 1200 \text{ psi.}$$

$$kd = \frac{1200 (25)}{3000} = 10 \text{ in.}$$

$$f_s = 3000 \text{ psi.}$$

$$d' = \frac{10}{3} = 3.33 \text{ in.}$$

$$n = 10$$

$$jd = 25 - 3.33 = 21.67 \text{ in.}$$

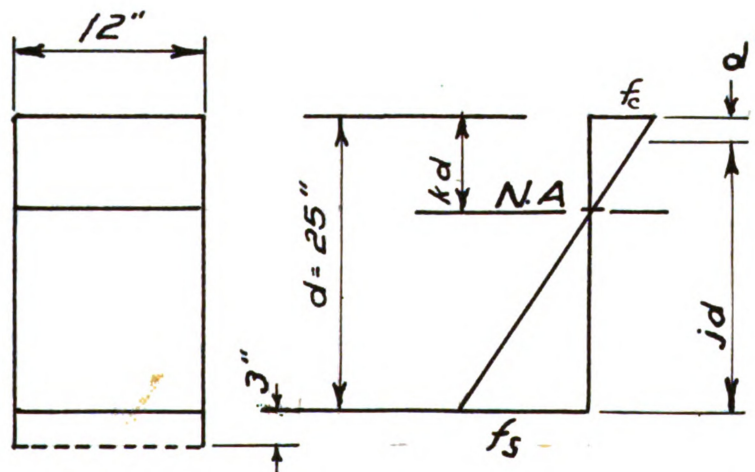


Fig. 10

Stem Analysis: (moment Case "2")

$$M = 24,490 \text{ ft.lb.}$$

$$V = 6,050 \text{ lb.}$$

Depth required:

$$d = \sqrt{\frac{M}{K b}} = \sqrt{\frac{24,490 (12)}{208 (12)}} = 11" : (\text{stem is } 28")$$

Area of steel required:

$$A_s = \frac{M}{f_s (jd)} = \frac{24,490 (12)}{18,000 (21.67)} = .75 \text{ sq. in.}$$

Area of steel provided:

$\frac{3}{4}$ " circular bars, spaced at 8" and 1'4" alternately.

$$A_s = .442 \left(\frac{12}{8} \right) = .663 \text{ sq. in.}$$

Check f_s :

$$f_s = \frac{M}{A_s (jd)} = \frac{24,490 (12)}{.663 (21.67)} = 20,500 \text{ lb./sq.in.}$$

The steel above seems to be overstressed; however Mr. Puffer of Michigan State Highway explained to me that it is their policy of allowing a 30% over design stress because they feel that the bridge will probably never be fully stressed. Also, they feel that the rigidity of the structure resists the force caused by the loading sufficiently to warrant this policy. The problem above is beyond the scope of this paper, therefore I will only mention that the stress above is well within the 30% allowed. This same condition occurs in the steel placed in the toe.

Check f_c :

$$f_c = \frac{2 M}{j d (b) (k d)} = \frac{24,490 (12)^2}{21.67 (12) (10)} = 226 \text{ lb./sq.in.} \\ (1200 \text{ psi. allowable})$$

Check shear:

$$v = \frac{V}{b (j d)} = \frac{6050}{12 (21.67)} = 23.2 \text{ psi. (60 psi. allowable)}$$

Check bond:

$$u = \frac{8 V}{\sum \phi_s d} = \frac{8 (6050)}{7 \left(\frac{12}{8} \right) \frac{3}{4} (77) \frac{25}{25}} = 104 \text{ psi. (150 psi. allowable)}$$

Anchorage is sufficient as a standard hook is provided which is hooked over another bar and embedded 27".

Stem analysis $\frac{1}{3} h$:

$$M = 13,780 - 8410 = 5,370 \text{ ft.lb.}$$

Thickness of stem is constant throughout.

Check f_s :

$$f_s = \frac{M}{A_s (j d)} = \frac{5370 (12)}{.331 (21.67)} = 9,000 \text{ psi. (18,000 psi allowable)}$$

The amount of steel used above is just half of the steel provided in bottom of stem. Every other bar is cut off 1'8" above the $\frac{1}{3} h$ point taken above, therefore sufficient steel is present.

• The first part of the document is a list of the names of the persons who have been appointed to the various offices of the Board of Directors of the Corporation.

• The second part of the document is a list of the names of the persons who have been appointed to the various offices of the Board of Directors of the Corporation.

• The third part of the document is a list of the names of the persons who have been appointed to the various offices of the Board of Directors of the Corporation.

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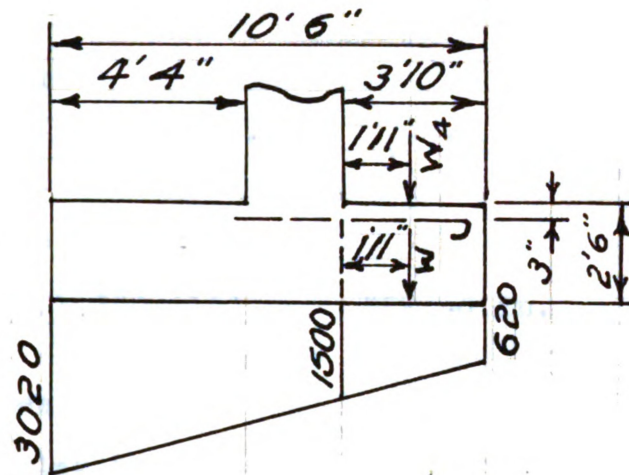
• The seventh part of the document is a list of the names of the persons who have been appointed to the various offices of the Board of Directors of the Corporation.

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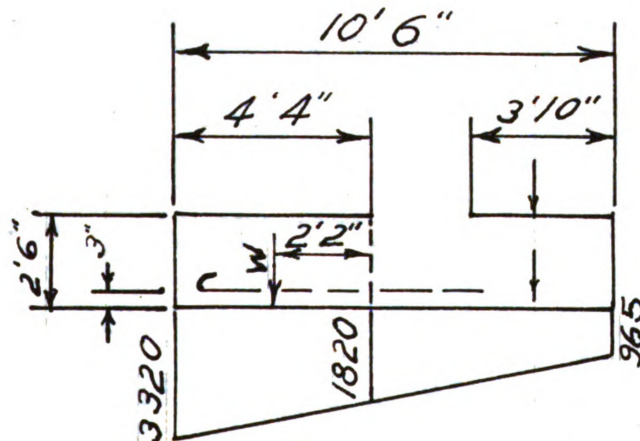
• The ninth part of the document is a list of the names of the persons who have been appointed to the various offices of the Board of Directors of the Corporation.

Forces acting on base of Abutment:

A. Forces acting on Heel (Case 2):

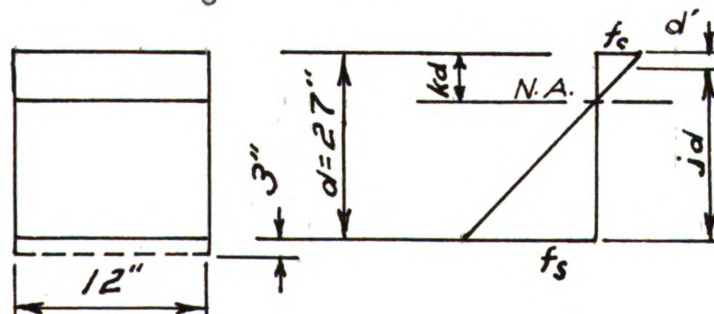


B. Forces acting on Toe (Case 4)



C. To find "jd": $kd = \frac{27(1200)}{3000} = 10.8 \text{ in.}$

$$jd = 27 - \frac{10.8}{3} = 23.4 \text{ in.}$$



Heel analysis: (moment Case "2")

$$M = 11,300 \text{ ft. lb.}$$

$$V = 5,330 \text{ lb.}$$

Depth required:

$$d = \sqrt{\frac{11,300 (12)}{208 (12)}} = 7.4" \quad (30" \text{ is provided})$$

Area of steel required:

$$A_s = \frac{11,300 (12)}{18,000 (23.4)} = .322 \text{ sq.in.}$$

Area of steel provided:

$\frac{3}{4}"$ circular bars, spaced at 1'4"

$$A_s = \frac{.44 (12)}{16} = .33 \text{ sq.in.}$$

Check f_s :

$$f_s = \frac{11,300 (12)}{.33 (23.4)} = 17,500 \text{ psi. (18,000 psi. allowable)}$$

Check f_c :

$$f_c = \frac{11,300 (12)}{23.4 (12)(10.8)} = 45 \text{ psi. (very low)}$$

Check bond:

$$u = \frac{8 (5,330) 16}{7 (9) (17) 25} = 43 \text{ psi. (150 psi. allowable)}$$

Check shear:

$$v = \frac{5,330}{12 (23.4)} = 19 \text{ psi. (very low)}$$

Anchorage:

$$L = \frac{17,500 (3)}{4 (150)} = 22" \text{ required (33" provided)}$$

Toe analysis: (moment Case "4")

$$M = 24,430 \text{ ft.lb.}$$

$$V = 10,635 \text{ lb.}$$

Depth required:

$$d = \sqrt{\frac{24,430 (12)}{208 (12)}} = 10.8" \quad (30" \text{ provided})$$

Area of steel required:

$$A_s = \frac{24,430 (12)}{18,000 (23.4)} = .695 \text{ sq.in.}$$

Area of steel provided:

$\frac{3}{4}$ " circular bars, spaced at 8" and 1'4" alternately

$$A_s = \frac{.442 (12)}{8} = .664 \text{ sq. in.}$$

Check f_s :

$$f_s = \frac{24,430 (12)}{.663 (23.4)} = 18,900 \text{ psi. (18,00 psi. design stress allowable)}$$

The overstress here is almost negligible.

Check f_c :

$$f_c = \frac{2 (24,430) 12}{23.4 (12) 10.8} = 193 \text{ psi. (very low)}$$

Check bond:

$$u = \frac{8 (10,635) 8}{7 (9) (77) 25} = 137 \text{ psi. (150 allowable)}$$

Check shear:

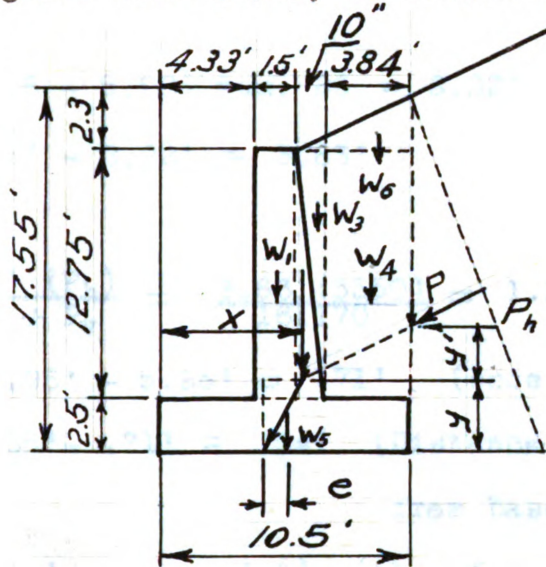
$$v = \frac{10,635}{12 (23.4)} = 37.8 \quad (\text{very low})$$

Anchorage:

$$L = \frac{18,900 (3)}{4 (150) 4} = 24" \quad (34" \text{ provided})$$

WINGWALL ANALYSIS

The wingwall serves only to retain soil with a 26 degree surcharge.



Angle of repose taken as 30 degrees.

$$C = .946 \left[\frac{.946 - (.9 - .755)^{1/2}}{.946 + (.9 - .755)^{1/2}} \right] = .4$$

Soil pressure against footing:

Resultant Vertical Force:

$W_1 = (12.75)(1.5)(150) = 2870$	$\frac{\text{arm}}{5.1'}$	$= \frac{\text{moment}}{14,600 \text{ ft.lb.}}$
$W_2 = (12.75)(.83)(150) = 793$	6.1	= 4,840 "
$W_3 = (12.75)(\frac{.83}{2})(100) = 530$	6.33	= 3,370 "
$W_4 = (12.75)(3.83)(100) = 4880$	8.58	= 42,000 "
$W_5 = (10.5)(2.5)(150) = 3840$	5.25	= 20,700 "
$W_6 = (4.67)(\frac{2.3}{2})(100) = 537$	8.94	= 4,800 "
Total wt = 13450		Total M = 80,310 ft.lb.

$$x = \frac{80,310}{13,450} = 5.96'$$

Resultant Horizontal Force:

$$p = WCh = 100 (.4) (17.55) = 703 \text{ lb.}$$

$$P = \frac{703}{2} (17.55) = 6,170 \text{ lb.}$$

1. *Journal of the American Medical Association*, 1997; 277: 1033-1038.

1. *Chlorophyll a* and *Chlorophyll b* were determined by the method of Arar and Collins (1971) using a Shimadzu 1601 UV-Visible Spectrophotometer.

the 1990s, the number of people in the world who are undernourished has declined from 1.1 billion to 800 million. The number of people who are malnourished has declined from 1.5 billion to 1 billion. The number of people who are obese has increased from 100 million to 300 million. The number of people who are overweight has increased from 100 million to 300 million. The number of people who are obese and overweight has increased from 100 million to 300 million. The number of people who are obese and overweight has increased from 100 million to 300 million.

1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022, 2023, 2024, 2025, 2026, 2027, 2028, 2029, 2030, 2031, 2032, 2033, 2034, 2035, 2036, 2037, 2038, 2039, 2040, 2041, 2042, 2043, 2044, 2045, 2046, 2047, 2048, 2049, 2050, 2051, 2052, 2053, 2054, 2055, 2056, 2057, 2058, 2059, 2060, 2061, 2062, 2063, 2064, 2065, 2066, 2067, 2068, 2069, 2070, 2071, 2072, 2073, 2074, 2075, 2076, 2077, 2078, 2079, 2080, 2081, 2082, 2083, 2084, 2085, 2086, 2087, 2088, 2089, 2090, 2091, 2092, 2093, 2094, 2095, 2096, 2097, 2098, 2099, 2100, 2101, 2102, 2103, 2104, 2105, 2106, 2107, 2108, 2109, 2110, 2111, 2112, 2113, 2114, 2115, 2116, 2117, 2118, 2119, 2120, 2121, 2122, 2123, 2124, 2125, 2126, 2127, 2128, 2129, 2130, 2131, 2132, 2133, 2134, 2135, 2136, 2137, 2138, 2139, 2140, 2141, 2142, 2143, 2144, 2145, 2146, 2147, 2148, 2149, 2150, 2151, 2152, 2153, 2154, 2155, 2156, 2157, 2158, 2159, 2160, 2161, 2162, 2163, 2164, 2165, 2166, 2167, 2168, 2169, 2170, 2171, 2172, 2173, 2174, 2175, 2176, 2177, 2178, 2179, 2180, 2181, 2182, 2183, 2184, 2185, 2186, 2187, 2188, 2189, 2190, 2191, 2192, 2193, 2194, 2195, 2196, 2197, 2198, 2199, 2200, 2201, 2202, 2203, 2204, 2205, 2206, 2207, 2208, 2209, 2210, 2211, 2212, 2213, 2214, 2215, 2216, 2217, 2218, 2219, 2220, 2221, 2222, 2223, 2224, 2225, 2226, 2227, 2228, 2229, 2230, 2231, 2232, 2233, 2234, 2235, 2236, 2237, 2238, 2239, 2240, 2241, 2242, 2243, 2244, 2245, 2246, 2247, 2248, 2249, 2250, 2251, 2252, 2253, 2254, 2255, 2256, 2257, 2258, 2259, 2260, 2261, 2262, 2263, 2264, 2265, 2266, 2267, 2268, 2269, 2270, 2271, 2272, 2273, 2274, 2275, 2276, 2277, 2278, 2279, 2280, 2281, 2282, 2283, 2284, 2285, 2286, 2287, 2288, 2289, 2290, 2291, 2292, 2293, 2294, 2295, 2296, 2297, 2298, 2299, 2300, 2301, 2302, 2303, 2304, 2305, 2306, 2307, 2308, 2309, 2310, 2311, 2312, 2313, 2314, 2315, 2316, 2317, 2318, 2319, 2320, 2321, 2322, 2323, 2324, 2325, 2326, 2327, 2328, 2329, 2330, 2331, 2332, 2333, 2334, 2335, 2336, 2337, 2338, 2339, 2340, 2341, 2342, 2343, 2344, 2345, 2346, 2347, 2348, 2349, 2350, 2351, 2352, 2353, 2354, 2355, 2356, 2357, 2358, 2359, 2360, 2361, 2362, 2363, 2364, 2365, 2366, 2367, 2368, 2369, 2370, 2371, 2372, 2373, 2374, 2375, 2376, 2377, 2378, 2379, 2380, 2381, 2382, 2383, 2384, 2385, 2386, 2387, 2388, 2389, 2390, 2391, 2392, 2393, 2394, 2395, 2396, 2397, 2398, 2399, 2400, 2401, 2402, 2403, 2404, 2405, 2406, 2407, 2408, 2409, 2410, 2411, 2412, 2413, 2414, 2415, 2416, 2417, 2418, 2419, 2420, 2421, 2422, 2423, 2424, 2425, 2426, 2427, 2428, 2429, 2430, 2431, 2432, 2433, 2434, 2435, 2436, 2437, 2438, 2439, 2440, 2441, 2442, 2443, 2444, 2445, 2446, 2447, 2448, 2449, 2450, 2451, 2452, 2453, 2454, 2455, 2456, 2457, 2458, 2459, 2460, 2461, 2462, 2463, 2464, 2465, 2466, 2467, 2468, 2469, 2470, 2471, 2472, 2473, 2474, 2475, 2476, 2477, 2478, 2479, 2480, 2481, 2482, 2483, 2484, 2485, 2486, 2487, 2488, 2489, 2490, 2491, 2492, 2493, 2494, 2495, 2496, 2497, 2498, 2499, 2500, 2501, 2502, 2503, 2504, 2505, 2506, 2507, 2508, 2509, 2510, 2511, 2512, 2513, 2514, 2515, 2516, 2517, 2518, 2519, 2520, 2521, 2522, 2523, 2524, 2525, 2526, 2527, 2528, 2529, 2530, 2531, 2532, 2533, 2534, 2535, 2536, 2537, 2538, 2539, 2540, 2541, 2542, 2543, 2544, 2545, 2546, 2547, 2548, 2549, 2550, 2551, 2552, 2553, 2554, 2555, 2556, 2557, 2558, 2559, 2560, 2561, 2562, 2563, 2564, 2565, 2566, 2567, 2568, 2569, 2570, 2571, 2572, 2573, 2574, 2575, 2576, 2577, 2578, 2579, 2580, 2581, 2582, 2583, 2584, 2585, 2586, 2587, 2588, 2589, 2590, 2591, 2592, 2593, 2594, 2595, 2596, 2597, 2598, 2599, 2600, 2601, 2602, 2603, 2604, 2605, 2606, 2607, 2608, 2609, 2610, 2611, 2612, 2613, 2614, 2615, 2616, 2617, 2618, 2619, 2620, 2621, 2622, 2623, 2624, 2625, 2626, 2627, 2628, 2629, 2630, 2631, 2632, 2633, 2634, 2635, 2636, 2637, 2638, 2639, 2640, 2641, 2642, 2643, 2644, 2645, 2646, 2647, 2648, 2649, 2650, 2651, 2652, 2653, 2654, 2655, 2656, 2657, 2658, 2659, 2660, 2661, 2662, 2663, 2664, 2665, 2666, 2667, 2668, 2669, 2670, 2671, 2672, 2673, 2674, 2675, 2676, 2677, 2678, 2679, 26

1. *Chlorophyll a* and *Chlorophyll b* were determined by the method of Arar and Collins (1971) using a Shimadzu 1010 spectrophotometer. The concentration of chlorophyll was expressed in $\mu\text{g mL}^{-1}$ of the sample.

$$P_h = 6,170 (.9) = 5,550 \text{ lb.}$$

$$P_v = 6,170 (.44) = 2,720 \text{ lb.}$$

To find y'

$$y = (10.5 - 5.96) \tan. 26 = 2.22'$$

$$y' = 5.85' - 2.22' = 3.63'$$

To find e :

$$e' = \frac{y' (P_h)}{R + P_v} = \frac{3.63 (5550)}{16,170} = 1.25'$$

$$5.96' - 5.25' = .71' \quad (\text{eccentricity of } R_h)$$

$$e = 1.25' - .71' = .54' \quad (\text{Distance } R \text{ intersects base from base center.})$$

$$.54' \text{ less than } \frac{3.3'}{2}; (\text{therefore } R \text{ intersects base within middle third})$$

Earth Pressure on Base:

$$P = \frac{16,170}{10.5} (1 \pm .309) = \begin{matrix} 2020 \text{ lb./sq.ft. (at toe)} \\ 1065 \text{ lb./sq.ft. (at hee)} \end{matrix}$$

Moment against overturning:

$$F = \frac{16,170 (5.96)}{5,550 (3.63)} = 4.8 \quad (\text{good safety factor})$$

Moment against sliding:

$$F = \frac{16,170 (.50)}{5,550} = 1.46 \quad (\text{This is a little low})$$

Sliding factor is a little low but there is sufficient fill over toe to provide passive resistance sufficient to keep wall from sliding.

Stem analysis:

$$p = 100 (.4)(15.05) = 602 \text{ lb.}$$

$$P = \frac{602(15.05)}{2} = 4,503 \text{ lb.}$$

$$P_h = 4,503(\tan 26^\circ) = 4070 \text{ lb.}$$

$$\text{Overturn moment: } 4,070 (5') = 20,350 \text{ ft.lb.}$$

Stabilizing moment:

$$M_s = 12.75(1.5)(150)\frac{(1.5)}{2} + \frac{.83}{2}(12.75)(150)(1.92) \\ M = 3,670 \text{ ft.lb.}$$

$$\text{Total Moment: } 20,350 - 3,670 = 16,680 \text{ ft.lb.}$$

$$d = \sqrt{\frac{16,680 (12)}{208 (12)}} = 10" \quad (30" \text{ provided})$$

$$A_s = \frac{16,680 (12)}{18,000(21.67)} = .512 \text{ sq. in. (required)}$$

Steel Area provided:

$$\frac{3"}{4} \text{ circular bars, spaced at } 8"$$

$$A_s = \frac{.442 (12)}{8} = .663 \text{ sq. in. (provided)}$$

Check f_s :

$$f_s = \frac{16,680 (12)}{.663 (21.67)} = 13,900 \text{ psi. (18,000 psi. allowable)}$$

Check f_c :

$$f_c = \frac{2 (16,680)}{10.8 (12) 21.67} = 119 \text{ psi. (very low)}$$

Check shear and bond:

$$v = \frac{4,070}{12 (21.67)} = 15.6 \text{ psi. (60 psi. allowable)}$$

$$u = \frac{8 (4070) 8}{7(9)(77)25} = 52.7 \text{ psi. (150psi. allowable)}$$

Check steel 4' above base:

$$p = 11.05 (100) (.4) = 442 \text{ lb.}$$

$$P = \frac{442}{2} (11.05) = 2,450 \text{ lb.}$$

Overturning Moment:

$$M = 2,450 \frac{(11.05)}{3} = 9,030 \text{ ft.lb.}$$

Total Moment:

$$M = 9,030 - 2150 = 6,880 \text{ ft.lb. (allowing for stabilizing moment)}$$

To find "d":

$$d = \sqrt{\frac{6,880 (12)}{208 (12)}} = 6" \text{ (narrowest portion of stem } 16"; \text{ therefore depth is O.K.)}$$

Steel provided: half of the steel in bottom of stem is cut off 1' 8" above $\frac{1}{3}h$, therefore we will use one-half the steel provided in bottom of stem in determining the steel stress.

Check f_s :

$$f_s = \frac{6,880 (12)}{.331 (.87) (19.1)} = 15,000 \text{ psi. (18,000 psi. allowed)}$$

Sufficient steel is present in the stem.

Heel Analysis:

$$P = \frac{(2020 - 1065)(3.83)}{10.5} + 1065 = 1415 \text{ lb/sq.ft. (pressure next to stem)}$$

Moment upward:

$$1065 (3.83) \left(\frac{3.83}{2} \right) = 7,840 \text{ lb.ft.}$$

$$\frac{350}{2} (3.83) \left(\frac{3.83}{3} \right) = \underline{633} \text{ "}$$

$$\text{Total Moment} = 8,473 \text{ lb.ft.}$$

Moment downward:

$$M = (4880 + 1440) (1.92) = 11,360 \text{ lb.ft.}$$

Total Moment:

$$M = 11,360 - 8,473 = 2,887 \text{ lb.ft.}$$

Total Shear:

$$V = 6320 - 4575 = 1,745 \text{ lb.}$$

Steel Provided:

$\frac{3}{4}$ " circular bars, spaced at 2' 0".

$$A_s = \frac{.442}{24} (12) = .22 \text{ sq.in. (provided)}$$

Check f_s :

$$f_s = \frac{12(2887)}{.22 (23.4)} = 675 \text{ psi. (very low)}$$

Obvious that shear is satisfactory.

Check bond:

$$u = \frac{8 (1745) 6}{7 (3) (\pi) 27} = 62.8 \text{ psi. (150 psi. allowed)}$$

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Toe Analysis:

$$P = \frac{955 (6.17)}{10.5} + 1065 = 1625 \text{ lb./sq.ft. (earth pressure edge of stem)}$$

Moment upward:

$$1625 (4.33) = 7040 \quad \frac{(4.33)}{2} = 15,100 \text{ ft.lb.}$$

$$\frac{560}{2} (4.33) = 1210 \quad 2 \frac{(4.33)}{3} = 3,490 \quad "$$

$$\text{Total wt.} = 8250 \quad \text{Total Mo} = 18,590 \text{ ft.lb.}$$

Total Moment:

$$M. = 18,590 - 3,470 = 15,120 \text{ ft. lb.}$$

Total Shear:

$$V = 8,250 + 1,615 = 6635 \text{ lb.}$$

Depth is obviously satisfactory.

Area Steel Required:

$$A_s = \frac{15,120 (12)}{18,000 (23.4)} = .43 \text{ sq.in.}$$

Area Steel Provided:

$$\frac{3}{4} \text{ circular bars, spaced at } 1' 0".$$

$$A_s = .442 \text{ sq.in.}$$

Check f_s and f_c :

$$f_s = \frac{15,120 (12)}{.442 (23.4)} = 17,500 \text{ psi. (18,000 allowable)}$$

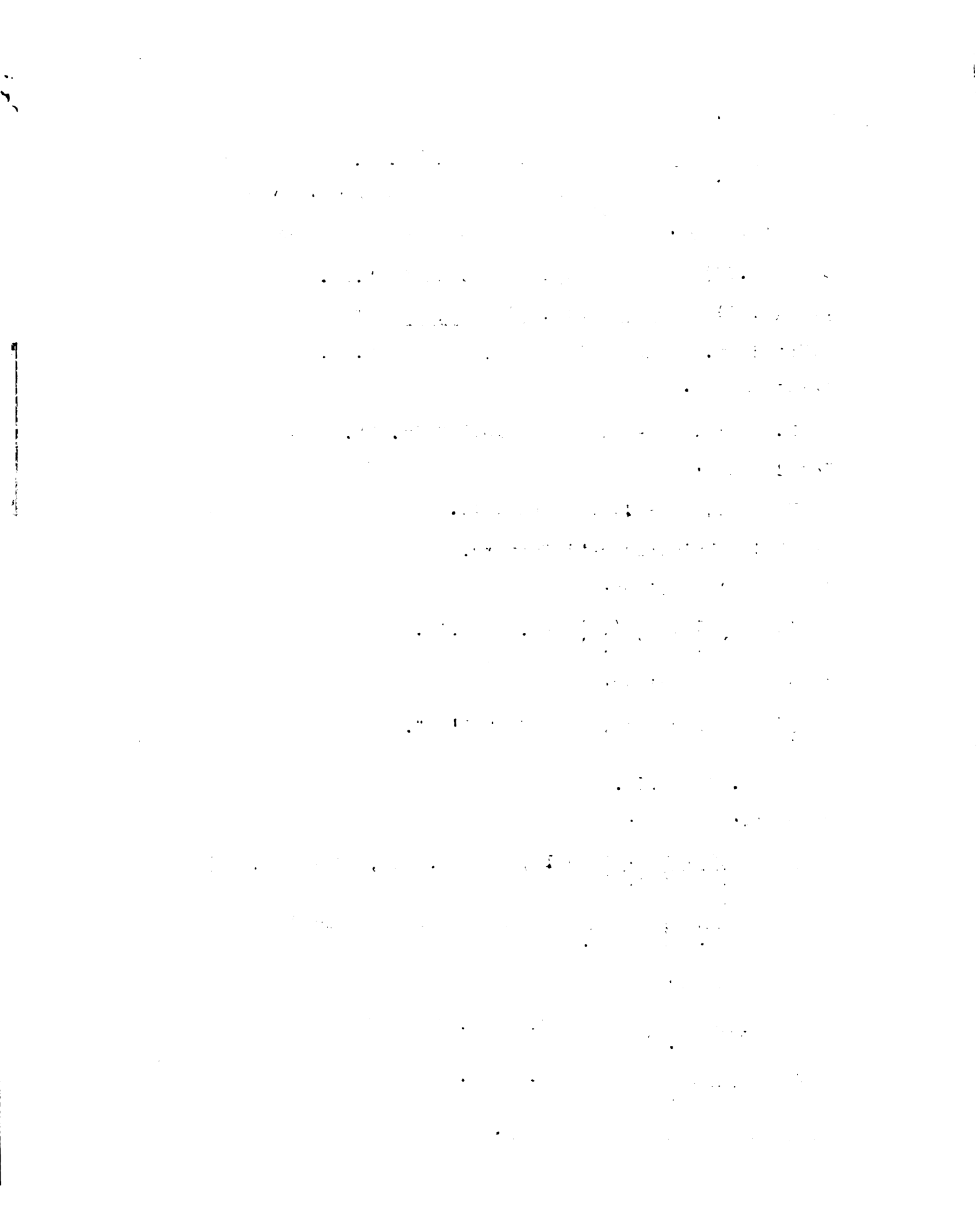
$$f_c = \frac{2 (15,120) (12)}{23.4 (12) 10.8} = 240 \text{ psi. (very low)}$$

Check v and u :

$$v = \frac{6,635}{12 (23.4)} = 23.6 \text{ psi. (very low)}$$

$$u = \frac{8 (6,635) 8}{7 (9) (\pi) 25} = 85.6 \text{ psi. (150 allowable)}$$

Anchorage is sufficient (same as abutment)



CONCLUSION

The analysis of this structure has shown that it is adequately designed and meets all specifications with the exception of the overstressed steel in the stem of the abutment while undergoing maximum bending moment.

The policy of allowing a 30% overstress, if justified, places the stress of the stem steel well within the limit.

Thus the structure can be expected to serve safely and adequately all the traffic that may be passing over it and at the same time provide free passage of all water that may be expected to flow in Johnson Creek.

[REDACTED]

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ROOM ONE ONLY

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