A PROPOSED HIGHWAY UNDERPASS FOR THE MICHIGAN AVENUE RAILROAD GRADE CROSSING IN JACKSON, MICHIGAN

Thesis for the Degree of B. S.

MICHIGAN STATE COLLEGE

John Ed. Ryan

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A Proposed Highway Underpass for the Michigan Avenue Railroad Grade Crossing in Jackson, Michigan

A Thesis Submitted to

The Faculty of

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AGRICULTURE AND APPLIED SCIENCE

by

John Ed. Ryan

Candidate for the Degree of

Bachelor of Science

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To

My Wife

Without whose encouragement and understanding I would never be in the position to write this.

ACKOWLEDGEMENT

The author wishes to express his thanks and appreciation to the following faculty members for their advise and cooperation in making available textbooks and material used in the design of this underpass.

Mr. Nothstine - ass't-prof., Civil Engineering, MS.C.

Mr. Miller - prof., Civil Engineering, MS.C.

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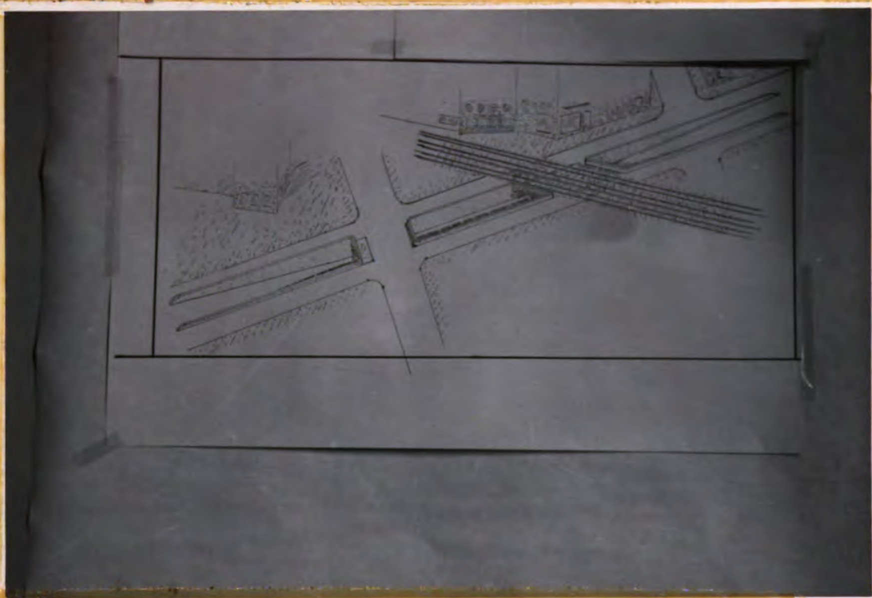
He also wishes to thank the following men for making available the maps from which this thesis was planned.

Mr. Fry - City Engineer, Jackson, Michigan.

Mr. Brisbin - Div. Engineer, New York Central Railroad.

June, 1949 John Ed. Ryan



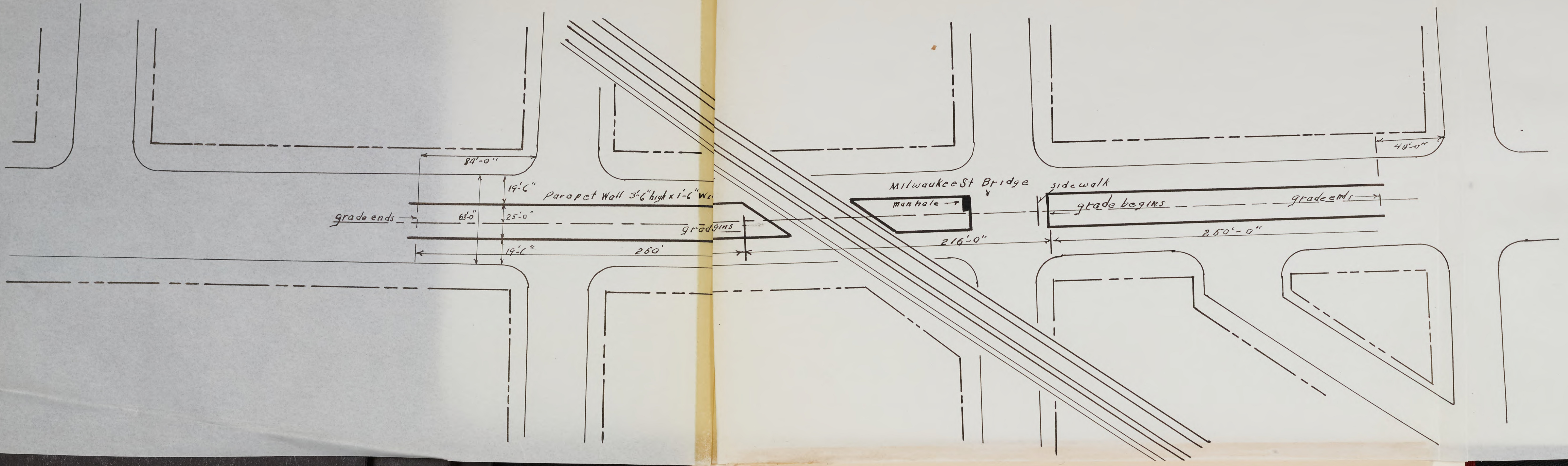
INTRODUCTION

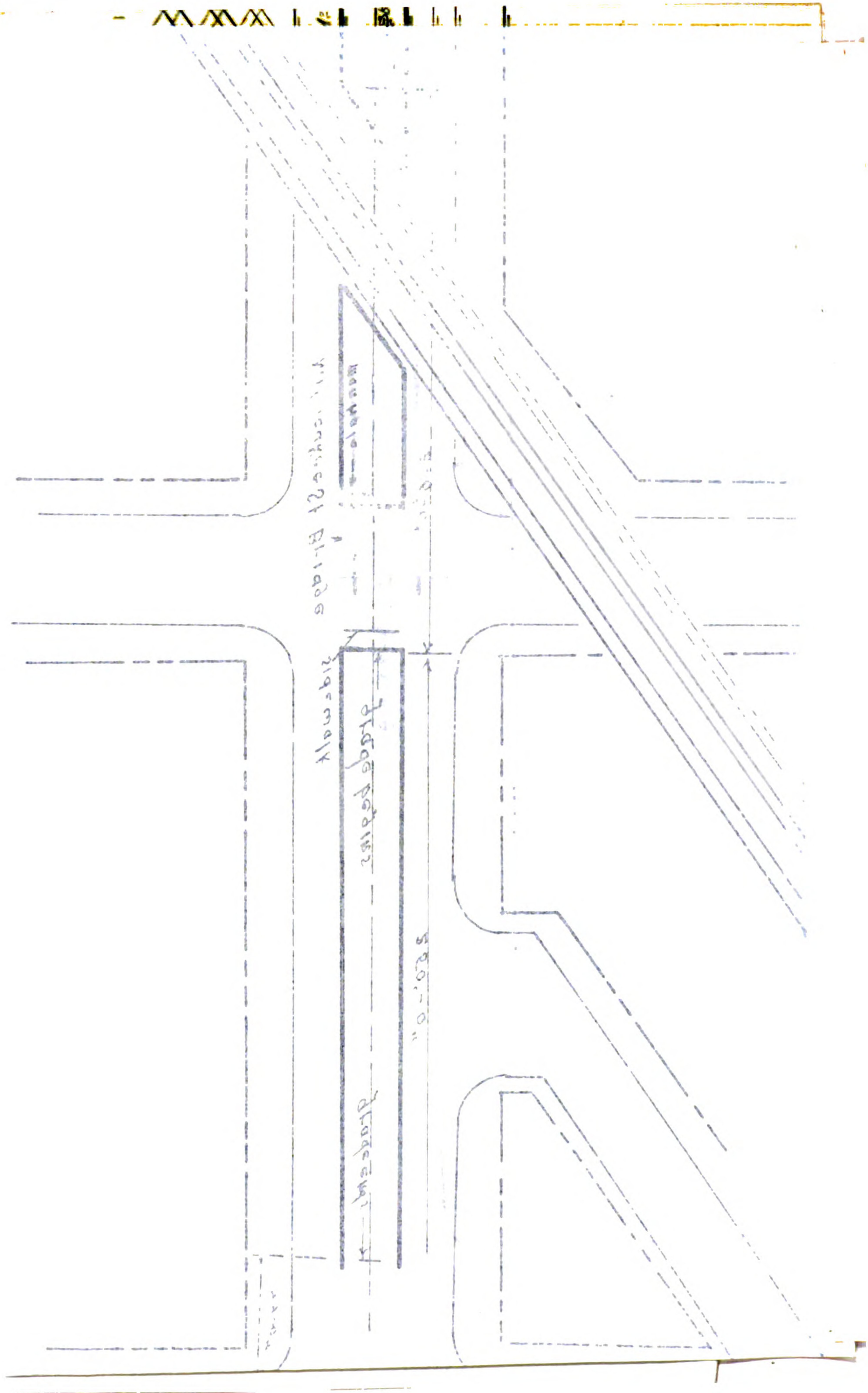
Due to the vast amount of railroad traffic and also the even larger volume of automobile traffic that must have a rightaway between Milwaukee and Columbus street in The Middle of Jackson Michigan and due to the economical impossibility of raising the tracks above their present grade an under-pass for the street is the only solution. The possibility of such a pass has been discussed for many years. Nothing has ever been done about the sitution however. The most impottant reason for this is the fact that too much valuable property would be ruined should the whole street be dropped below the present grade. As far as the author knows the design offered as a compromise to the situation is original. It is believed that such a project would not only relieve the traffic situation but also do very little damage to the value of the abuting property.

The under-pass suggested here-in consists of dropping the two middle lanes of the street and leaving the two outside lanes at the present level thus leaving aceess roads to the abuting property. The entire length of the project would be seven-hundred and sixteen feet long. Such a length would allow a grade of less than 8% at both ends of the project. This grade is relatively steeper than is recommended in most designs but is well within the maximum range as specified by the Michigan State Highway Dept. It is also less than several grades already existing in the city. The design will of necessity include suggestions for rerouting a main sewer

which now exists in the area, design of a bridge to carry the railroad and one to carry Milwaukee Street over the depressed road. Due to the fact that very few persons ever use that section of Columbus Street between Michigan Avenue and Pearl Street it is not thought necessary to provide a a crossing at this location. If such crossing was provided it would be necessary to carry the underpass for a distance of two-hundred and fifty feet beyond the intersection and into the already congested area between Cooper and Francis Streets which would also bring it into higher-valued sections.

A plan view of the proposed project is shown on the following page.


84'-0"
19'-6"
Parapet Wall 3'-6" high x 1'-6" w
grade ends
63'-0"
25'-0"
grade begins
19'-6"
250'
Milwaukee St Bridge
manhole
sidewalk
grade begins
grade ends
216'-0"
250'-0"
48'-0"



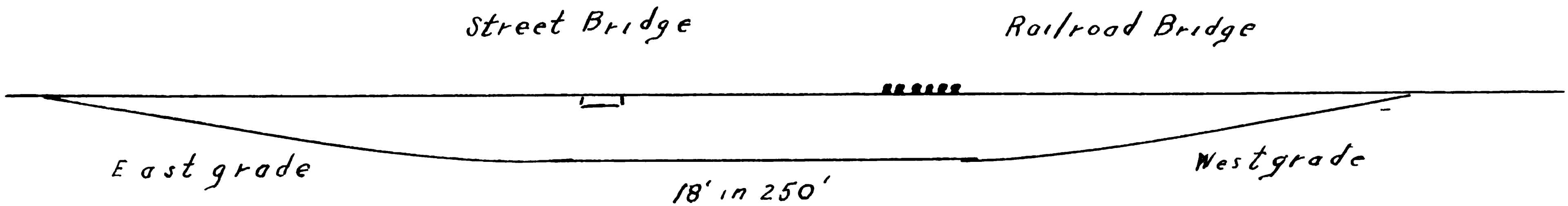
SEWER RELOCATION

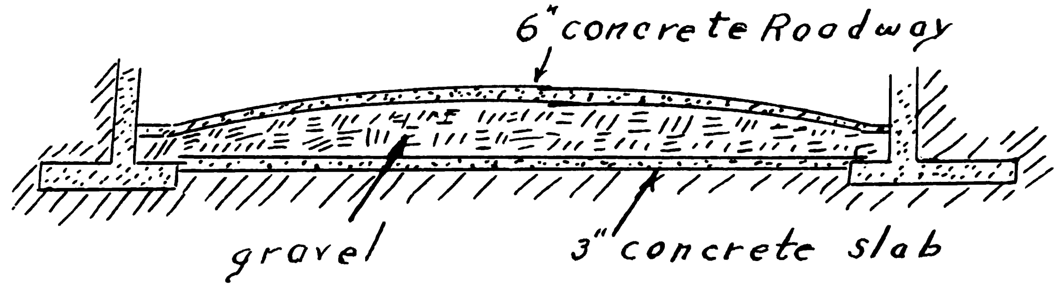
Due to the fact that there are no natural grades to relocate the sewer around there are many possibilities to consider in changing the sewer system to make way for the underpass. It is thought that the relocation as suggested in red on the sewer map is the best. (See map in back)

#2 manhole is moved to the north to the center of Van Dorn Street and the sewer (24" V.P.) is swung to it from "1. A new manhole is located on the south side of the main street and a 12" V.P. sewer is connected directly to the #4 manhloe. No other change in this run is then necessary as the present sewer will take the flow. From the relocated #2 a 36" concrete sewer is run to Pearl Street and thus to #9 . #4 manhole will be moved west about twenty feet . The present sewer crossing Michigan Avenue at Columbus St. is ten feet below the surface grade. This is sufficient as the elevation of the underpass will be only six feet lower than present grade at this point giving enough frost protection. Two new manholes will have to be constructed to join the two 12" V.P. secondary sewers and they will both then flow into #8 and thus to #9. The present large sewer between Milwaukee and Columbus Streets will be needed to carry the drainage pumped to it from the underpass.

DESIGN OF THE ROADWAY

Theroad way of the underpass shall be constructed as shown on the following page. Except where necessary for construction purposes the grade will not be excavated below the bottom of the waterproofing slab and will then be backfilled with gravel and compacted. A three inch slab of concrete will then be poured two inches below and over the top of the wall footing. This slab will then be waterproofed by the best methods available preferably with cement grout. Eight inches of gravel will then be placed over this slab and the roadway shaped with a crown of three inches at center. The wearing surface shall be of placed 3000# concrete at least six inches thick and designed to take the full H-20 plus impact loading. The grades leaving the underpass shall begin clear of the bridges and extend for two-hundred and fifty feet to the present road level. The lowest elevation of the grade will be just west of the Milwuakee Street bridge where adrain will carry the drainage water to a dry well outside the wall. Electrically driven sump pumps will carry the sewage from the well to the newly relocated number four manhole. The moters of the pumps will be elevated above the water table and housed in a special manhole. Open tile drains at least four inches in diameter will criss-cross under the middle third of the under pass to carry any seepage through the water proofing to the dry well. Gutters at least six inches wide will be provided on both sides of the roadway. The two lanes will be separated by raised buttons along the middle line and the center line will be painted


Street Bridge
Railroad Bridge
East grade
West grade
18' in 250'


6" concrete Roadway
gravel
3" concrete slab

DESIGN OF MILWUAKEE STREET BRIDGE

The Milwuakee Street bridge was design according to the specifications set forth by the American Association of State Highway Officials. The existing street is forty-three feet in width. The width of the bridge was determined from the specification that states that all new bridges shall be at least four feet wider than the approaching road-way. The length of the bridge was set by the width of the underpass. This in turn was determined by the specifications making the minimum width of lane eleven feet and by the fact that it was thought twelve foot clear lanes should be used for the underpass.The standard H-20 loading was used to compute all bending moments and shear stresses in the bridge. This loading is shown diagrammetically in the sketch. All welds were designed according to the specifications of the American Welding Society.

In computing the bending moment and shear in the girders it was assumed that the loads from one wheel were resting directly on the girder and the reaction due to the load on the other wheel was added to this load. (See moment diagram)

The seats for all floor beams and stringers should be fabricated to the girders and floor beams at the shop before delivery to the job.

The two exterior girders are placed higher than the interior girders and a cement curb placed over the flanges. Expansion joints should be provided every five feet to allow for the differance in the expansion of concrete and steel.

The wearing surface of the bridge should be of the bituminous type placed over steel plates. It should be sloped from the center to the edges and also toward the ends. This will prevent water from settling in the center of the bridge. Angles are provided to support the mat plates at the exterior girders.

The West girder will be placed behind a concrete guard wall. This wall shall be at least one foot and a half wide to agree with the retaining wall extensions. It shall have a slightly arched under surface, the center of which shall be at least three inches below the bottom of the lowest girder. Besides performing an archetectural duty of covering the steel work, it wil act as a hinderance to prevent any extra high vehicles from disturbing the bridge. The same type of guard shall be constructed on the East side but it shall be part of the concrete sidewalk bridge. A space of at least six inches should be left between the guard or the sidewalk to facilitate painting the girders.

SYMBOLS AND FORMULAS USED

L.L.	=	Live load
D.L.	=	Dead load
fs	=	Allowable unit stress in steel = 18,000 #/"^{2}
T	=	Tension in member
C	=	Compression in member
h	=	Height of member
P	=	Stress in pounds per square inch
t	=	Thickness
Z	=	Section modulus

Value of fillet welds.

From specifications

Length of weld required.

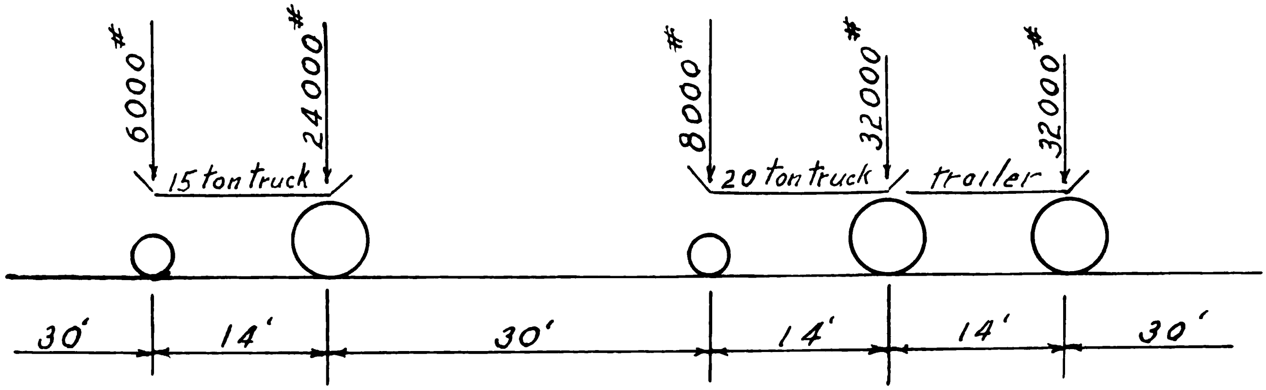
Pull in pounds / value of weld used.

Section modulus

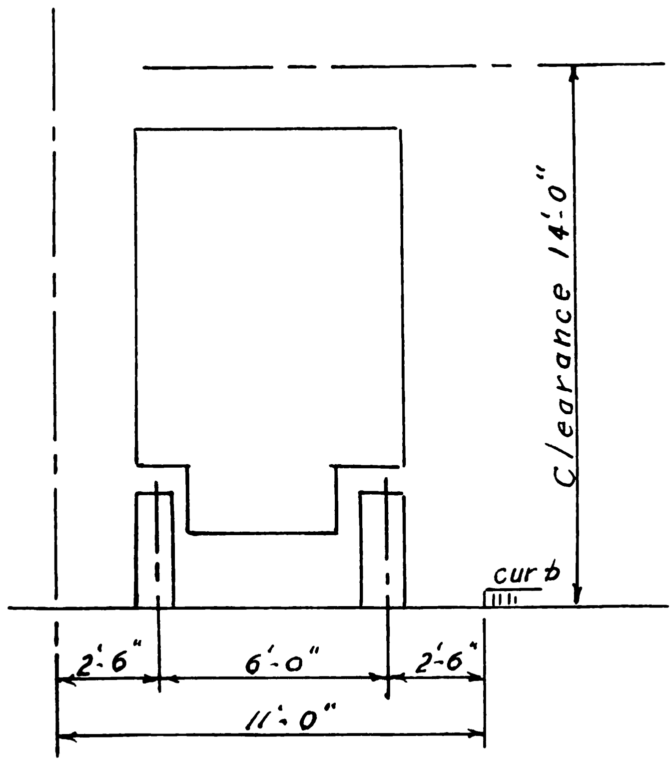
Moment / allowable stress/square inch.

Resisting moment = T = C.

Moment / 2 x height



H - 20 LOADING



SPECIFICATIONS

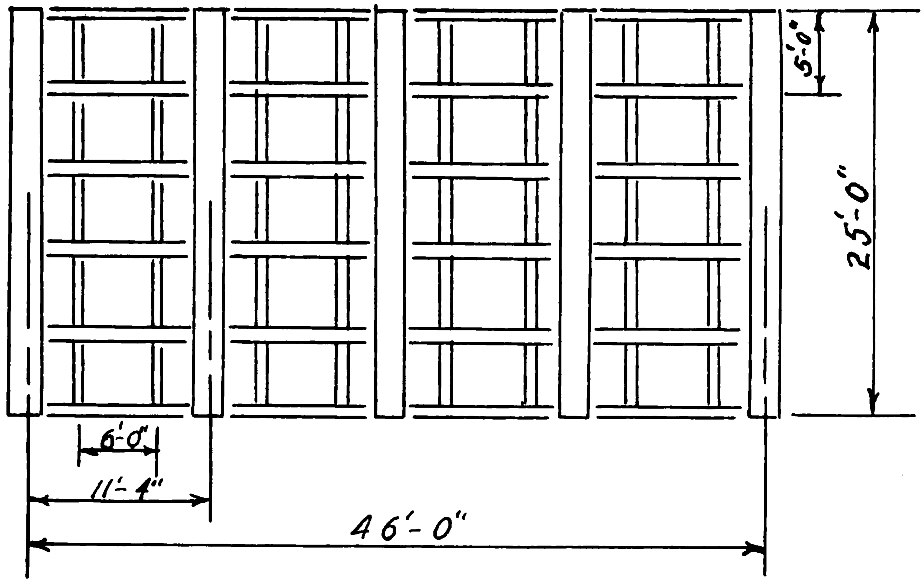
Impact = Live load x $\frac{50}{L + 125}$

Longitudinal forces = 10% live load

Members shall be as deep as is economical with a minimum web thickness of rolled sections of 0.231 in.

Tension fs = 18000 #/"^{2}

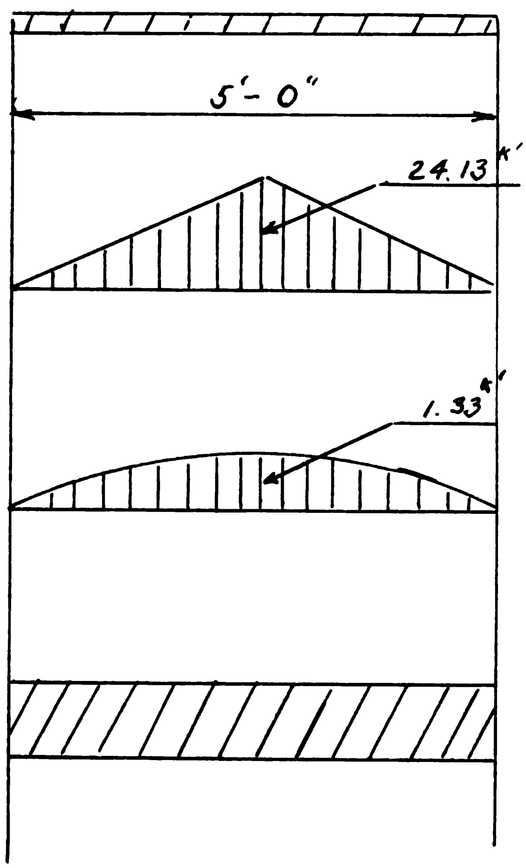
No distribution of loads are to be made in computing the bending moment in any member.



GENERAL LAYOUT OF MILWAUKEE STREET BRIDGE

GIRDERS FLOOR BEAMS STRINGERS

STRINGERS



Maximum bending moment with load at center.

Live load	16,000 #
Impact	1,260
Longitudinal	1,600
Dead load	2,125
Total load	20,355 #

Maximum moment

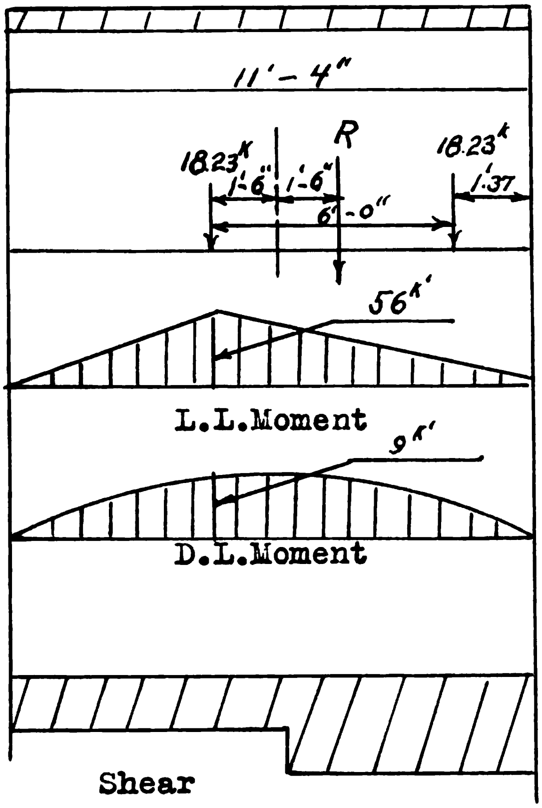
Live load	24,130'#
Dead load	1,330
Total	290,000"#

Section modulus req'd. = 16.1

Use 8"WF20# rolled beam

Z = 17.0 "^{3}

FLOOR BEAM



Live load 18230#/wheel

Dead load 585#/ft.

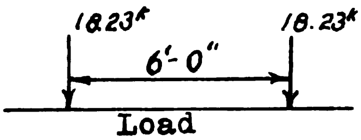
Maximum Moments

Live load	56000'#
Dead load	9000'#
Total	65000'#
	780000"#

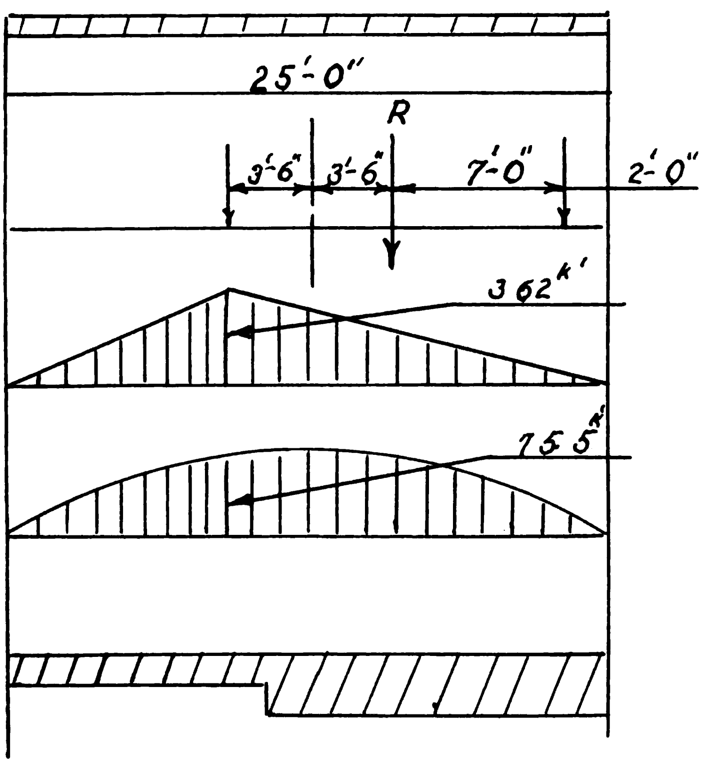
Section modulus req'd.
$43.4"^3$

Use--12"WF36# rolled beam

$Z = 45.9"^3$



GIRDER



Live load $= (18.23^k\ 9.65^k x2)$
$= 55800$ #

Dead load = 1000#/ft.

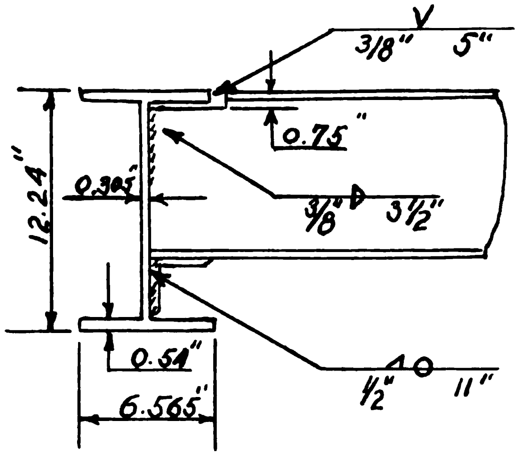
Maximum moments

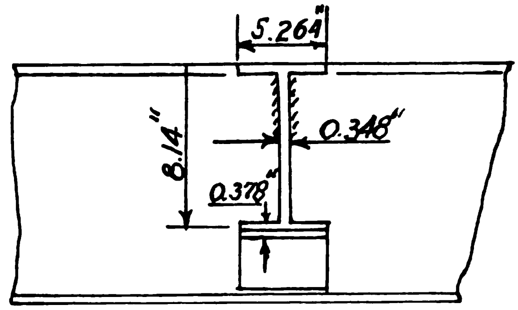
Live load	362000'#
Dead load	75500'#
Total	437500'#
	5240000 "#

Section modulus req'd.
$292\ "^3$

Use-- 24"WF120# rolled beam

$Z = 299.1\ "^3$





STRINGER CONNECTION

Shear

live load	32000 #	Value of 1/2" fillet weld	
dead load	1260 #		4000 #/"^{2}
impact	1060 #	Length req'd.	$\frac{34320}{4000}$ = 8.58"
Total	34320 #		

Use a 3 1/2" x 3 1/2" x 1/2" angle 5" long.
Weld all around with 1/2" fillet weld.

Fabricate seat before placing floor beam.

Moment

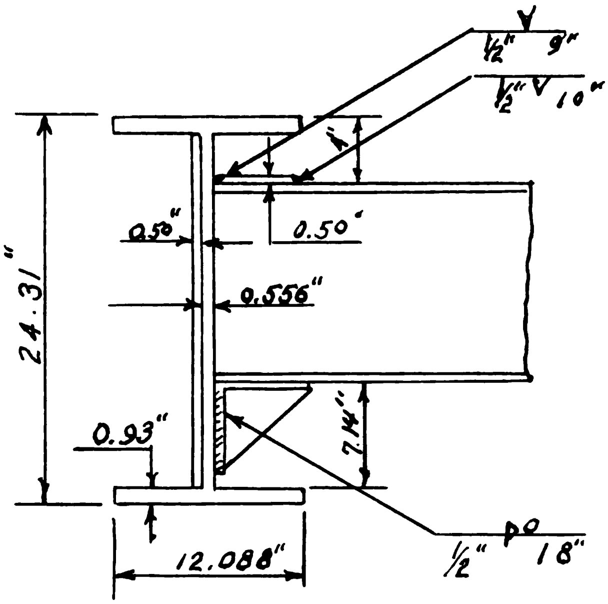
Value of stringer to resist moment = 17 x 18000
= 306000 "#

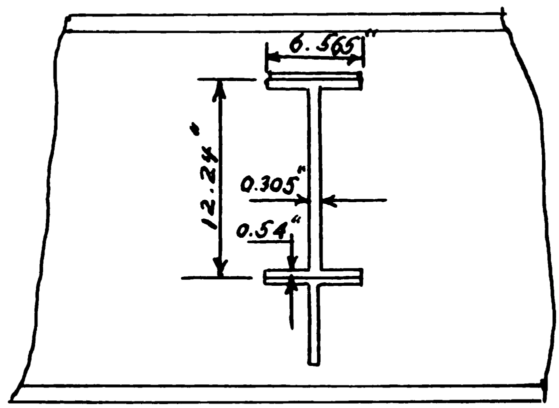
$$T = C = \frac{306000}{2 \times 8.14} = 18,850 \#$$

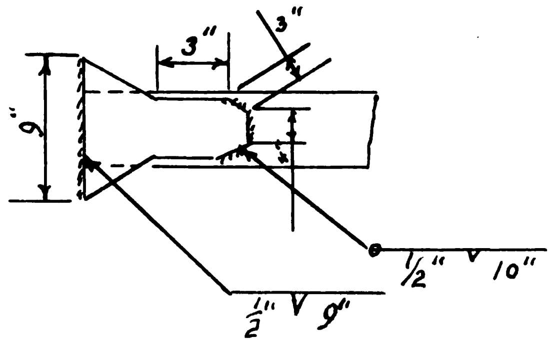
Value of 3/8" fillet weld = 3000 #

Length req'd. $= \frac{18,850}{3,000} = 6\ 1/2"$

Use 3/8" fillet weld 3 1/2" both sides of top of web.
Butt-weld flange to flange of floor beam.







Exterior floor beam connection

Shear

Live load & Impact	55800 #	Value of 1/2" fillet weld
Dead load	6600 #	4000 #/"2
Total	62400 #	Length req'd. $\frac{62400}{4000} = 15.6"$

Use a 12"WF36# split beam connection seat fabricated before placeing on both exterioe and interior beams.
Weld all around with 1/2" fillet weld as shown.

Moment

Resisting moment of beam = 45.9 x 18000 = 830,000 "#

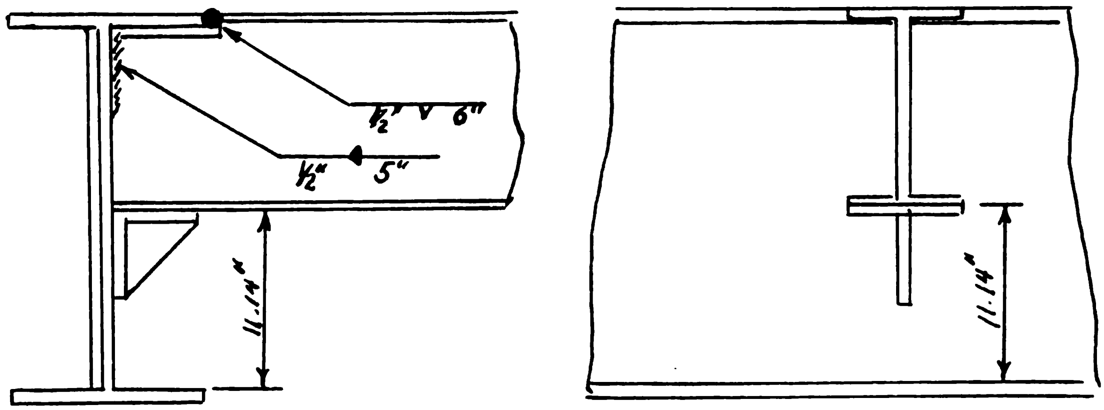
$$T = C = \frac{830,000}{2 \times 12.24} = 34200 \#$$

Lengthl/2" weld req'd.

$$\frac{34200}{4000} = 8.55 \text{ in.}$$

Use a 1/2" plate connection as shown, welded with 1/2" weld.

NOTE - Use 1/2" x 6" plate stiffeners on outside of girder opposite the floor beams. Tack stiffeners with 1/2" welds 3" long on 6" c.c.



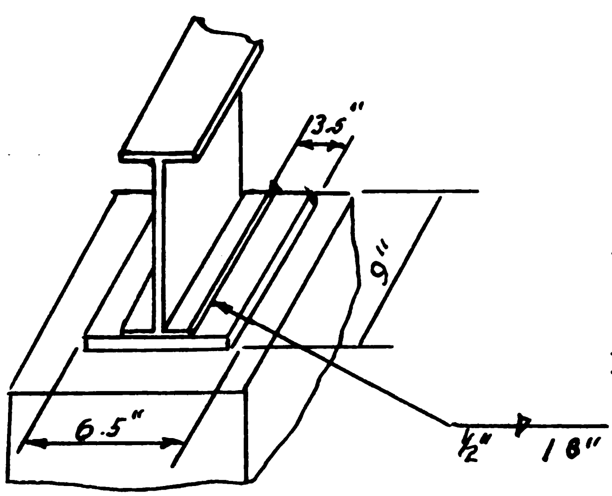
INTERIOR FLOOR BEAM CONNECTION

Use same seat as on the exterior connections.

Length of weld needed same as exterior.

Use 1/2" fillet weld both sides and at top of web as shown. Butt-weld flanges of floor beam and girder.

Design of bearing plate



Reaction

L.L.& I	55800 #
D.L.	15000 #
Total	70800 #

Area req'd. 70800/600 = 118 sq.in.

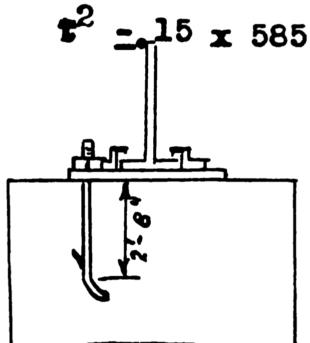
Use a plate 9" x 13 1/2"
Area = 121.5 sq.in.

P = 70800/121.5 = 585 #/sq.in

Moment = $\frac{585}{9}$ x 3.5 x 1.75
= 400 "#

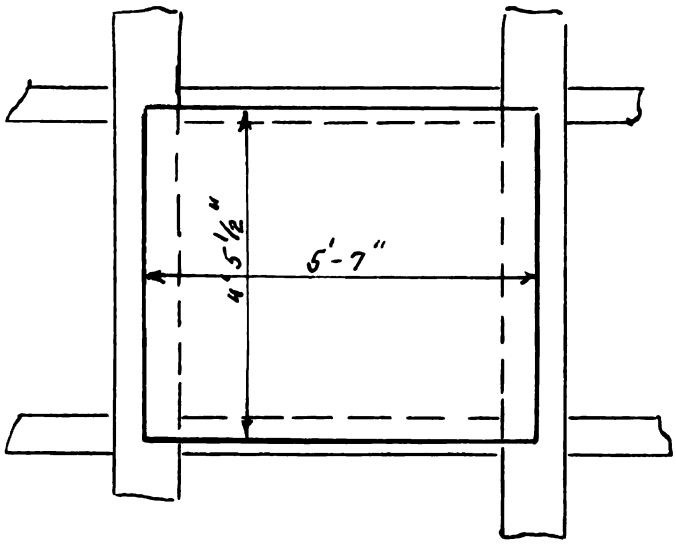
$t^2 = .15 \times 585 \times 3.5^2 = 1.08$ sq. in. $\quad t = 1.04$ in.

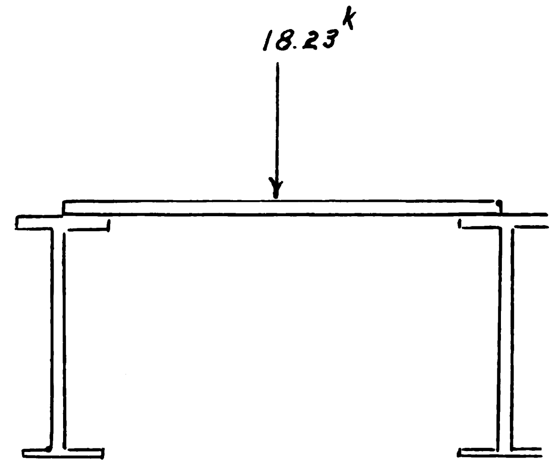
Use a bearing plate 1 1/4"x 9"x 13 1/2"



Anchor plate to abutement with four 1/2" bolts.

Weld girder to plate at one end and secure free end with connestions similiar to those shown in such a way as to allow for expansion but to take side trust.





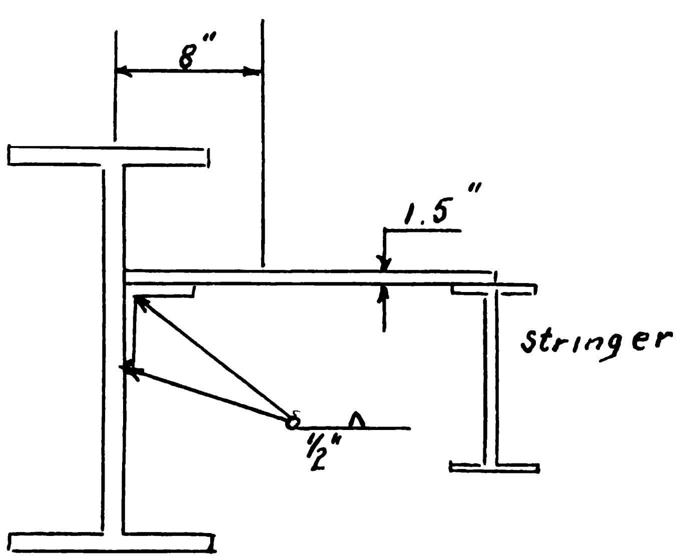
FLOOR PLATE

Max. moment $=$ 9.12 x 3 $=$ 27360 '# $=$ 328320 "#

Section modulus req'd. $=$ 18.25 "^{3}

$$h^2 = \frac{18.25 \times 6}{53.5} = 2.04 \text{ sq.in.} \qquad h = 1.43 \text{ in.}$$

Use plates 6'-0" x 5'-0" x 1 1/2".



Provide angles alogg the web of the exterior girders.

$$\text{Shear} = \frac{18.23 \times 18}{28} = 11800\text{'\#}$$

Length ofl/2" weld needed

$$\frac{141600}{4000} = 37 \text{ in.}$$

Use 1/2" fillet weld 12" long on 24" c.c.

Curb is to be placed concrete over upper flange of exterior girder. Provide expansion joints every five feet.

SIDEWALK BRIDGE

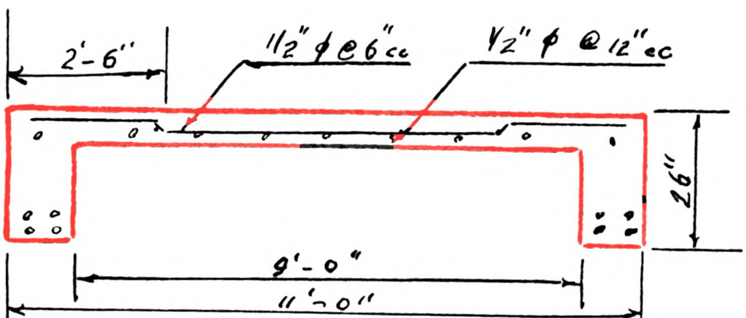
The sidewalk bridge crossing the underpass at the intersection of Milwuakee Street was designed as a one-way slab supported on two simple concrete beams. The beam were extended upward on the east side to provide a guard rail.

Width between curb and guard = 10'- 0"

Span length = 25 '- 0"

Loading = 200"/ "^{2}

fc	--	3000 #/"^{2}
fs	--	18000
fc'	--	1000
v	--	90
u	~~66~~	150
R	--	157



Slab Design

Assumed a 12" width for the beams, clear span = 9'* 0"

Moment -- $1/8\ wl^2$ $\quad 1/8 \times 200 \times 9^2 = 2025$ '#/'

$$d = \sqrt{\frac{M}{R\ b}} = \sqrt{\frac{2025 \times 8}{157 \times 1}} = 3.7" \quad \text{Used } 4"$$

$$As = \frac{M}{fs\ j\ d} = \frac{2025 \times 8}{18000 \times 7 \times 4} = 0.0322\ "^2/"$$

Use 1/2" Ø --- 6" c.c. = 0.0334 "^{2}/"

Longitudinal steel --- use 9 1/2" Ø -- 12" c.c.

DESIGN OF BEAMS

Load = 200 x 4.5 150 = 1050 #/' = 26250 #

Moment = $1050 \times 9^2 \times 1/8$ = 82000 '#

d = $\sqrt{\frac{82000}{157 \times 1}}$ = 23" Add 2" for insulation

$v = \frac{V}{b\,j\,d} = \frac{26250 \times 8}{12 \times 7 \times 23}$ = 109 #/"^{2}

Use an effective depth of 24"

$A_s = \frac{82000 \times 8 \times 12}{18000 \times 7 \times 24}$ = 2.72 "^{2}

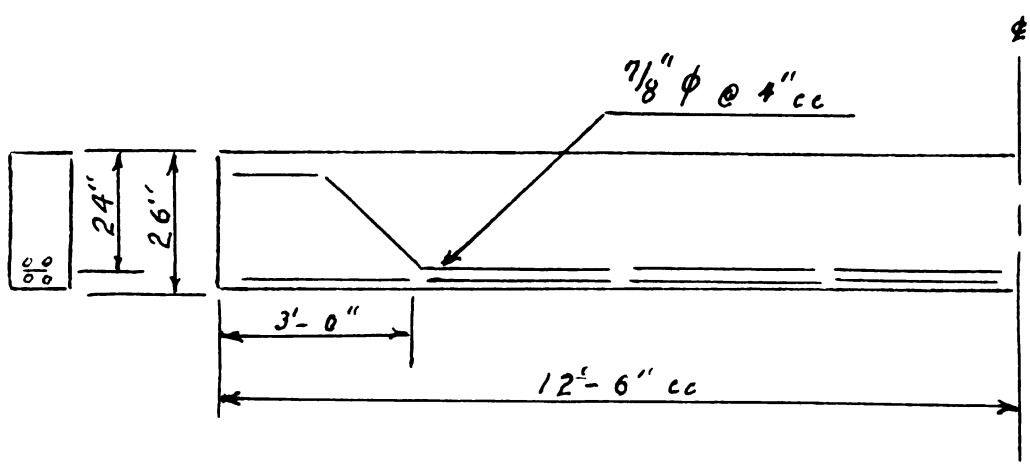
Use 4 7/8" ∅ in two rows at 4" c.c.

$u = \frac{V}{\Sigma o\, j\, d} = \frac{26250 \times 8}{3.141 \times \frac{12}{4} \times 7 \times 24}$ = 13.8 #/"^{2}

Design of Bearing Seat

Area req'd = $\frac{1050 \times 25}{2 \times 600}$ = 22"^{2}

Set beams on wall with a length of 19" resting on wall.

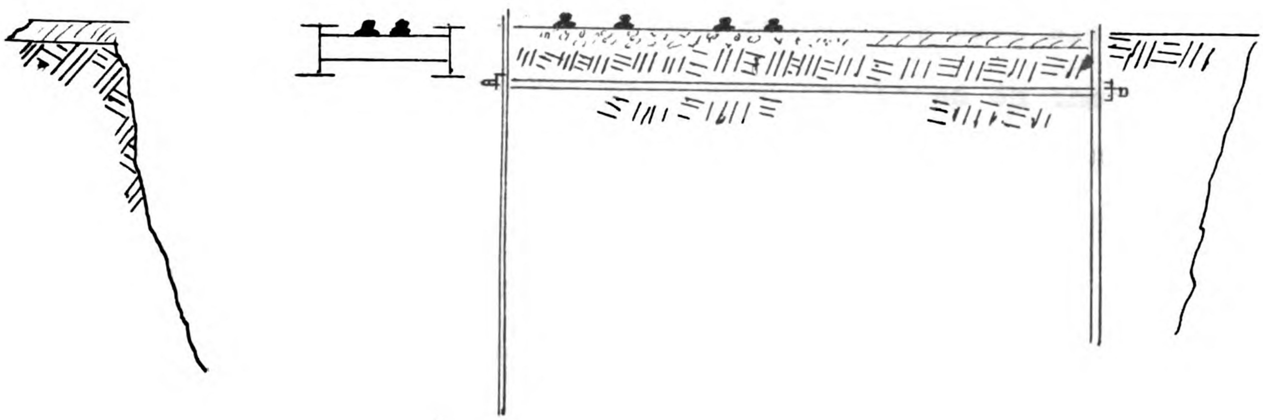


DESIGN OF THE RAILROAD BRIDGE

The railroad bridge was designed according to the specifications set forth by the American railroad Engineering Association. (See sketch). The present grade and line will be held for all three tracks. An increase in stress equal to twenty percent was used to provide for the lurching effect of the engines and cars.Vertical impact was taken at eighty percent although this was less than the percent found from the formula for impact.This was to keep the increase in stress within the hundred percent maximum specified.

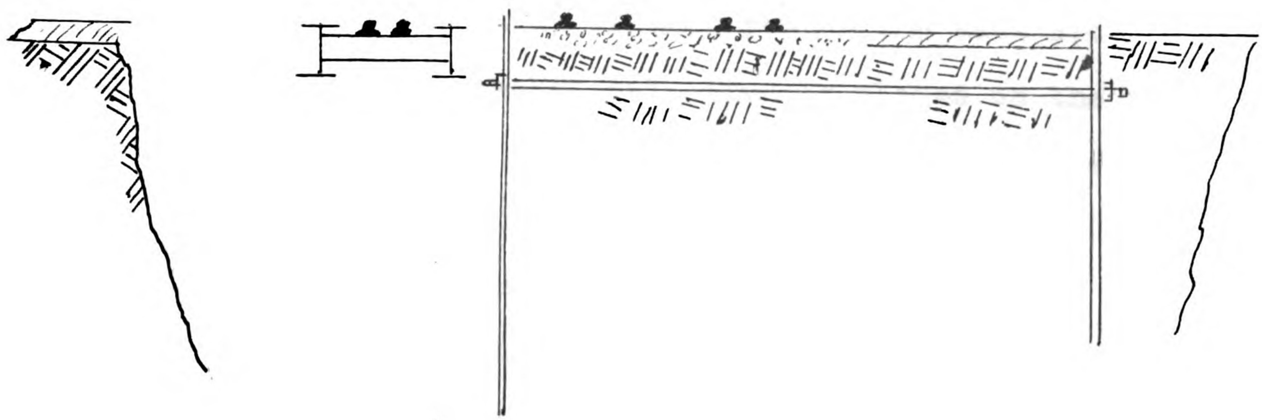
The bridge shall be of the open-floor rolled beam type. There shall be a separate span for each set of tracks and it shall be prefabricated either in the shop or at the job before erection. This is to facilitate better welding methods. The rails shall be supported 8" x 8" ties resting on the stringers and clamped to them with suitable holding-down bolts. They shall be spaced with not more than six inch openings. The ties should be capable of carrying the maximum wheel load plus one-hundred percent impact assumed to be distributed over three ties. They should extend the full width of the span. Wooden wheel guards shall be attached to the ties flush with the inside flange of the girders. They shall be secured with bolts thru every third tie.

The bearing plate for the girders shall be anchored to the abutements with anchor bolts sunk at least two feet into the concrete and hooked. The free end of the girders shall be secured as was the street bridge and the other welded.



Due to the impossibility of delaying the railroad traffic even for a half day some method of construction must be devised for supporting the tracks during the construction period. The following method is suggested. The bridge for #1 track will be constructed first. All switching for which this track is used will be done from the other two tracks.

First a row of MZ-32 piling will be driven between the #1 and #2 tracks and at a distance of eight feet from the center line of the #2 track. This will give the required clearance for the trains. (See sketch above) A row of similair piling will be driven fifteen feet east of the center line of the #3 track. #1 track will then be removed and the earth excavated to a depth of six feet. One and three-quarter inch tie rods will be driven under the two tracks. As each ten-foot length is driven another section will be attached with a suitable sleeve. Eight rods on five-foot



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The remaining excavation under track #1 can then be excavated and the bridge and abutements constructed without danger of the other two tracks failing under load.

After track #1 is completed and ready for use all the through traffic can be routed over this bridge by means of existing switches while the other bridges are constructed.

The construction on the Milwaukee street bridge and the rest of the project can be carried on at the same time .

Counterforts will be provided at that section of abutment where the bridge girders rest on the wall. An extra pile will be driven directly under each girder to take the excess load due to the bridge.

SYMBOLS AND FORMULAS USED

L.L. = Live load

D.L. = Dead load

Z = Section modulus

fs = Allowable stress in steel

fc = Allowable stress in concrete

t = Thickness

h = Height

T = Tension

C = Compression

Value of welds.

Specifications

Length of welds required.

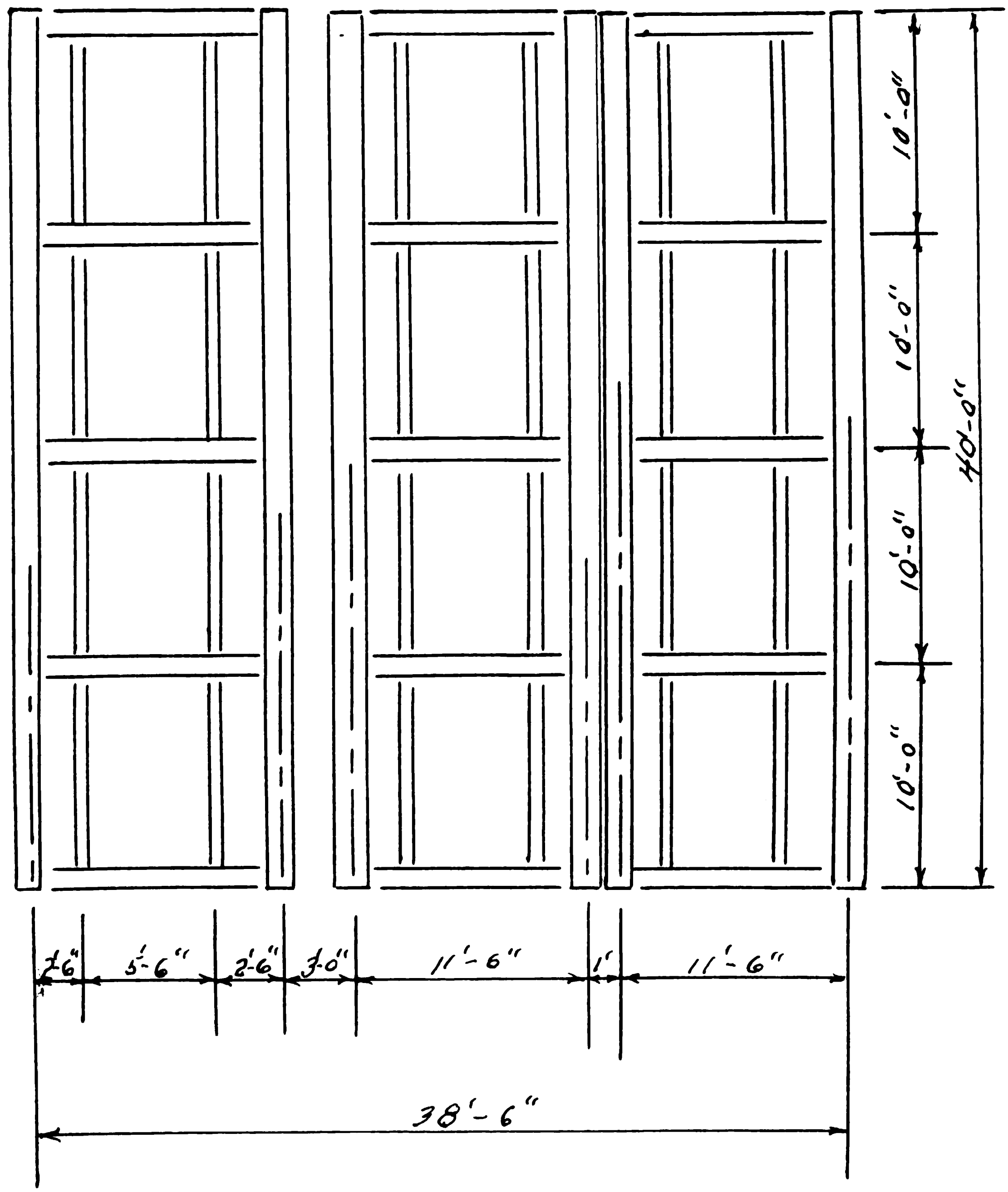
Stress in pounds / value of welds used

Resisting moment = T = C .

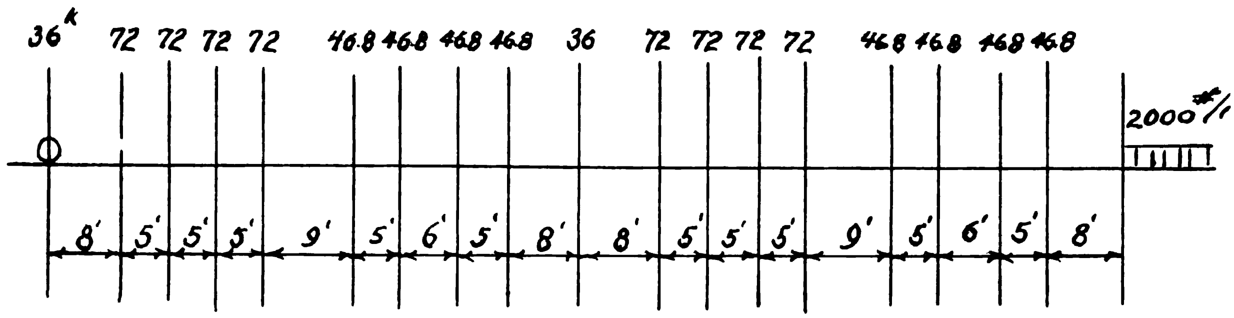
Moment / 2 x h

Safe area for bearing

Load / safe bearing pressure.

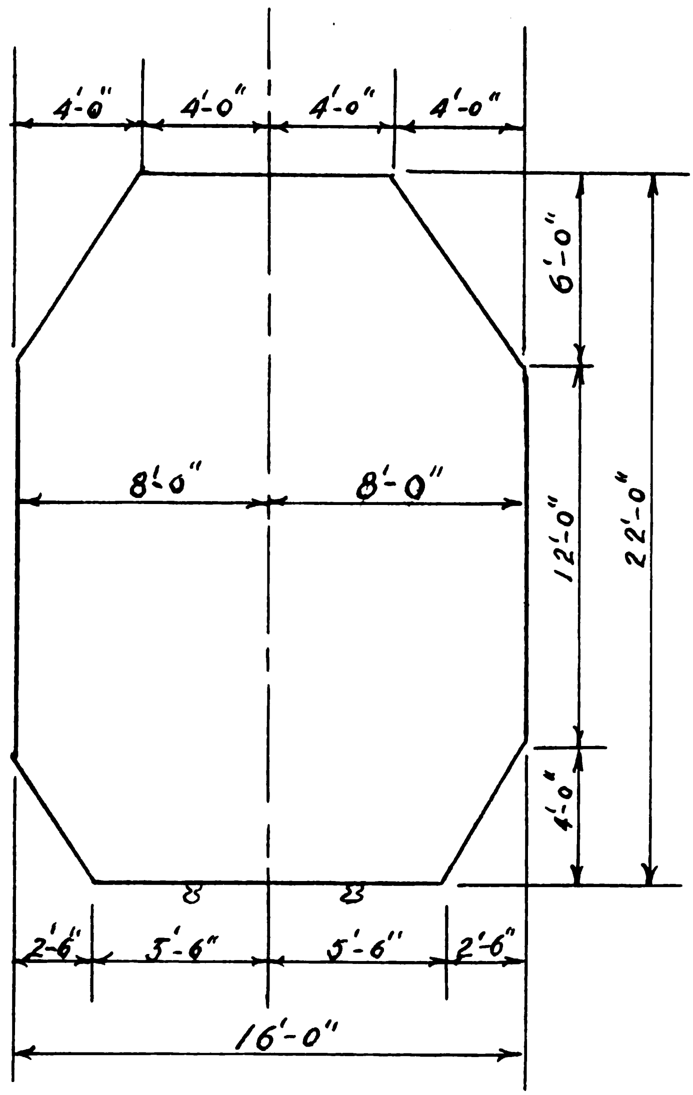


GENERAL LAYOUT OF RAILROAD BRIDGE GIRDERS, FLOOR BEAMS AND STRINGERS



H-72 LOADING

SPECIFICATIONS



Min. spacing
1/15 of span

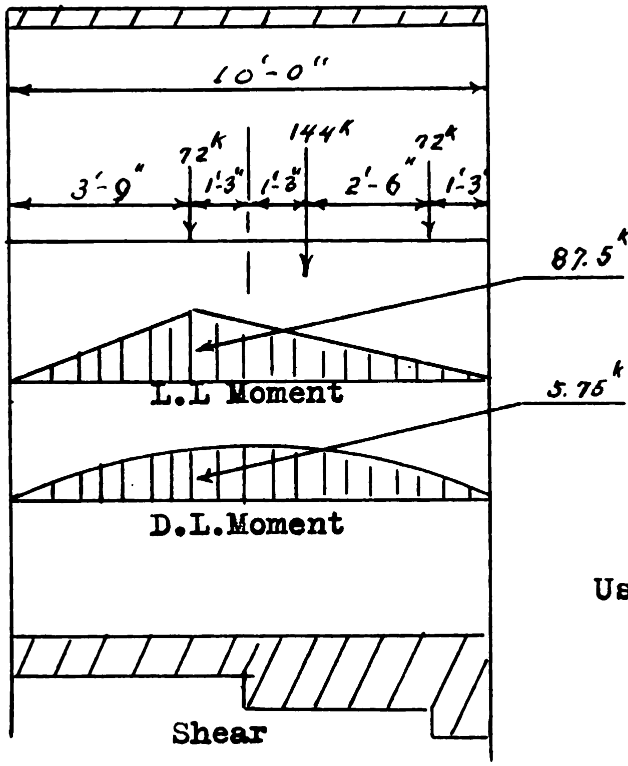
Min. depth beam
1/15 of span

Loading	#/ftcu
Dead-steel	480
bit.	150
track	200#/ft

Live load E-72
Impact
lurch 20 %
vertical
100-0.60L

Axial Tension
18,000 #/sq.ft.

STRINGER



Dead load	325#/ft
Live load	E-72

Maximum Moment

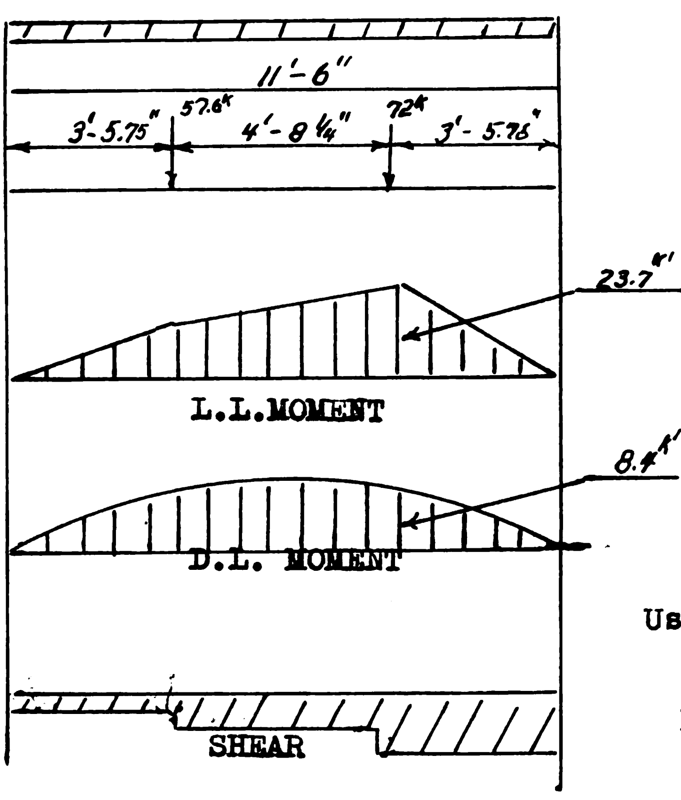
Live load	87750 '#
Lurch (20%)	17550 "
Impact(80%)	70200 "
Dead load	5750 "
Total	181250 '#
	2175000 "#

Section modulus req'd. 120.8 cu.in.

Use- 14"WF84# rolled beam
Z = 130.9

Maximum shear 144600 #

FLOOR BEAM



Dead load	600 #/ft.
Live load	E-72

Use 20% for lurch effect added to one side and subtracted from the other

Maximum Moment

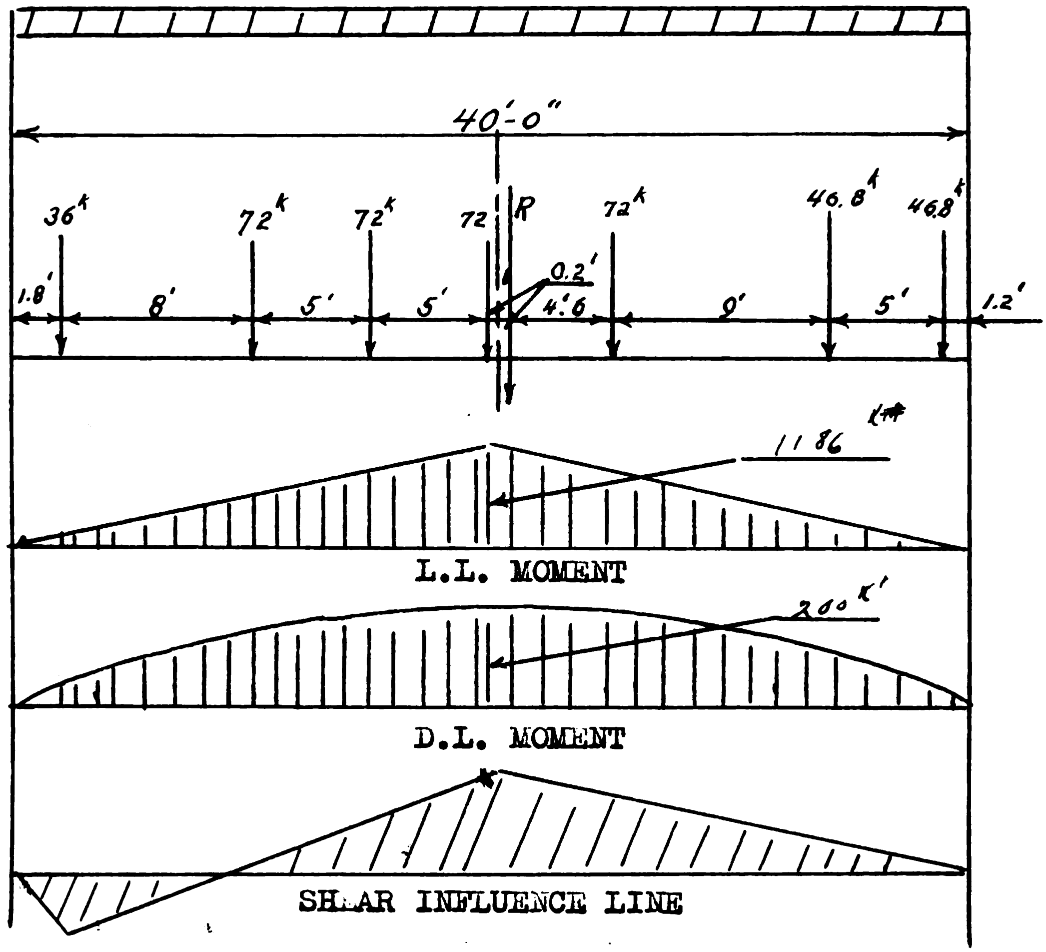
Live load	237000 '#
Dead load	8400 "
Total	245400 '#
	2944800 "#

Section Modulus req'd. 163.5 cu.in.

Use 21"WF96# rolled beam
Z = 168 cu.in.

Maximum shear 144600 #

GIRDER



Dead load	1000 #/'
Live load	E-72

Maximum Moment

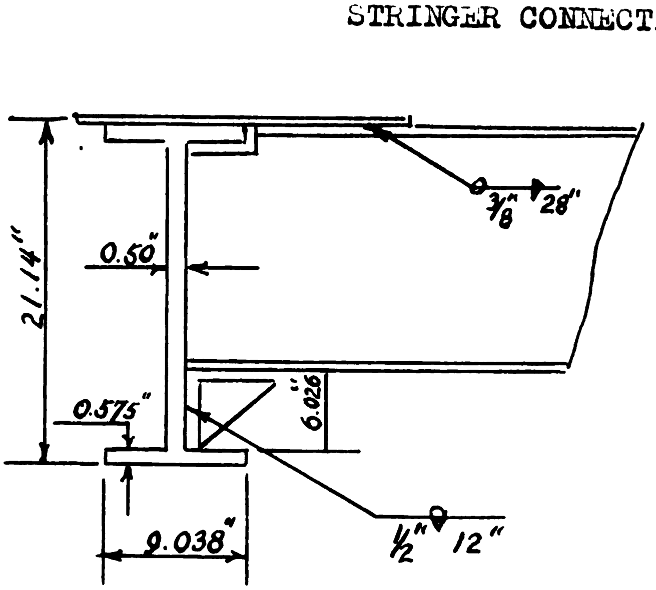
Live load	1186000 '#
Lurch	237200 "
Impact	948800 "
Dead load	200000 "
Total	2572000 '# = 30,864,000 "#

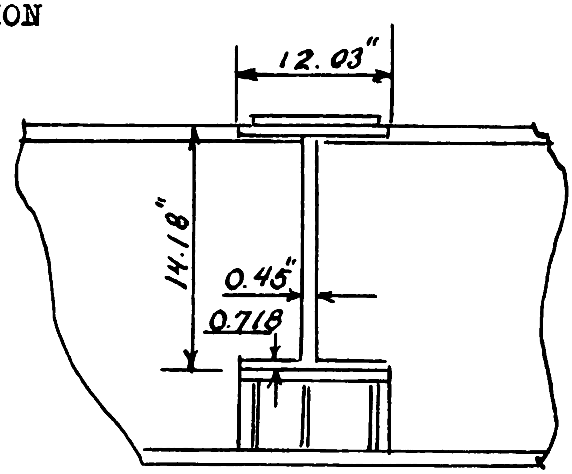
Section modulus req'd. = 1045 cu.in.

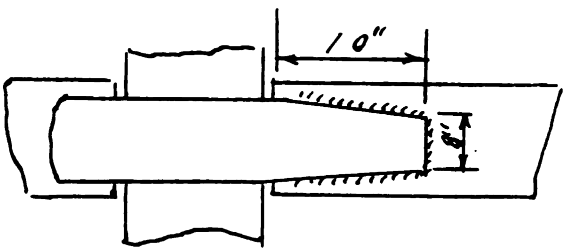
Use 36"WF300# rolled beam
Z = 1105.1 cu.in.

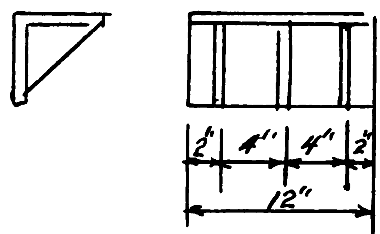
Maximum shear = 244000 #

STRINGER CONNECTION









Shear = 144600 #
Value of 3/8" fillet weld 5000 #/sq.in
Value of 1/2" fillet weld 4000 #/sq.in
Length 1/2" weld req'd. = 36.15 in.

Use a 6"x6"x1/2"x12" angle for seat reinforced as shown with 1/2" plate. Weld all around.

Moment = 2175000 '#

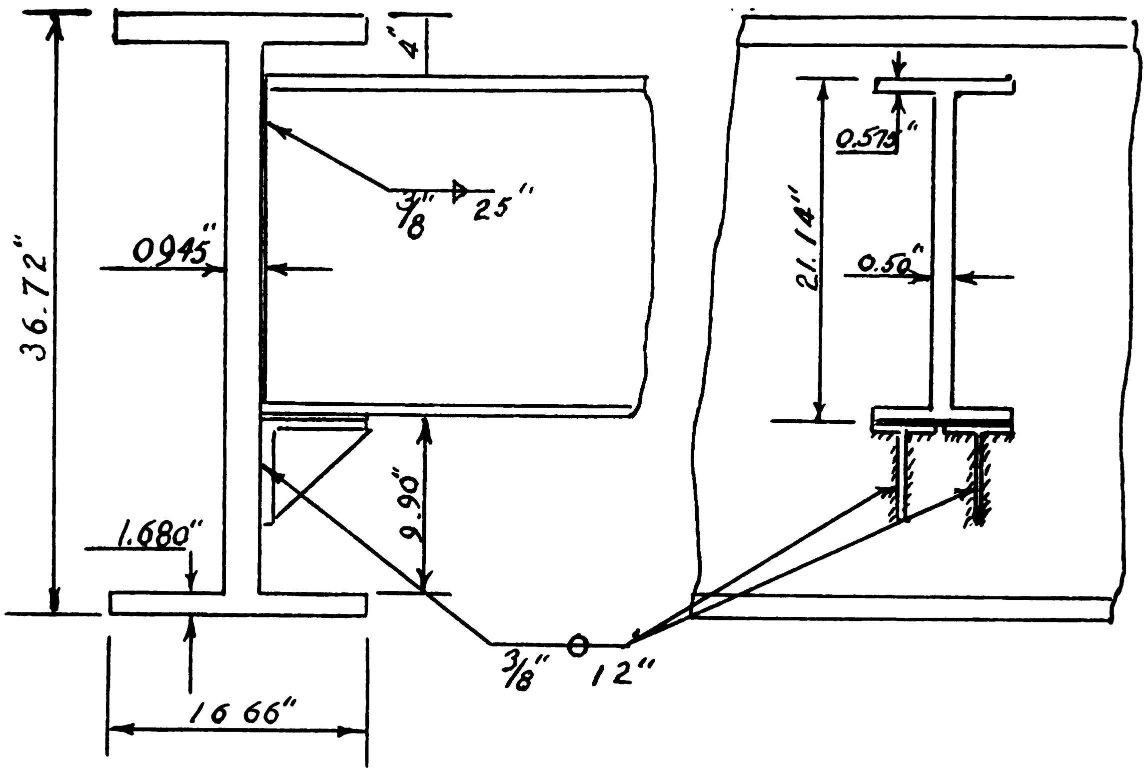
$$T = C = \frac{2175000}{2 \times 14.18} = 155000\#$$

Length of 3/8" weld req'd. $= \frac{155000}{3000 \times 2} =$ 26"

Value of 3/8" plate 9"long = 60800 #
Value of 1" plate 9" wide = 162000 #

Use a 1" thick plate cut as shown and welded with 3/8" fillet weld as shown.

FLOOR BEAM CONNECTION



SHEAR = 144600 #
Value of 1/2" fillet weld = 4000 #/ sq.in.

Length of weld req'd. = $\frac{144600}{4000}$ = 36.15 in.

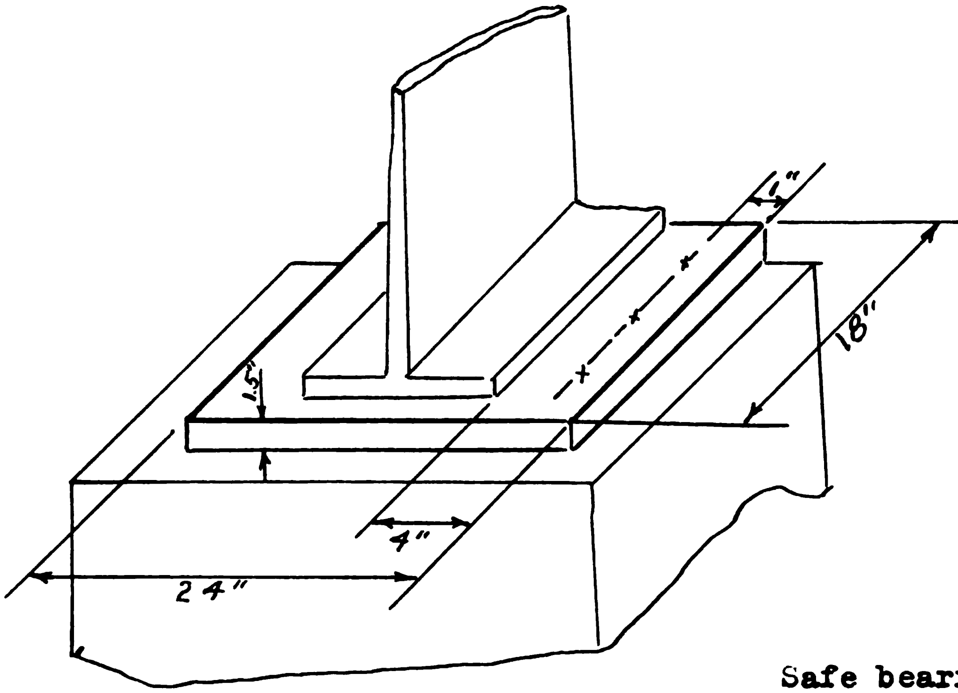
Use 2 ST 7WF split beam tees with a 1/2 " plate seat. Cut flanges of tees to 10". Weld all around as shown with 1/2" fillet weld.

Moment = 2944800"#
T = C = $\frac{2944800}{2x\ 21.14}$ ≤ 70,000 #

Length of 3/8" weld req'd. $\frac{70,000}{3,000}$ = 23.3 in.

Weld both sides of web for a distance of 8" from top and butt weld flange to web of girder.

GIRDERSEAT AND CONNECTION



Safe bearing of concrete
600#/sq.in.

Maximum shear = 244000 #

Bearing area req'd. $= \frac{244000}{600} =$ 407 sq.in.

A plate 24" x 18" furnishes 430 sq.in.

Moment in plate = 4" x 18" x 567#/"^{2} x 2" = 82.000"#

Section modulus req'd. = 4.59 "^{3}

$t^2 = \frac{4.59 \times 6}{18} = 1.54$

t = 1.24 in. Use 1 1/2" x 18" x 24" plate

Secure as for Milwuakee Street bridge.

DESIGN OF RETAINING WALLS AND ABUTEMENT

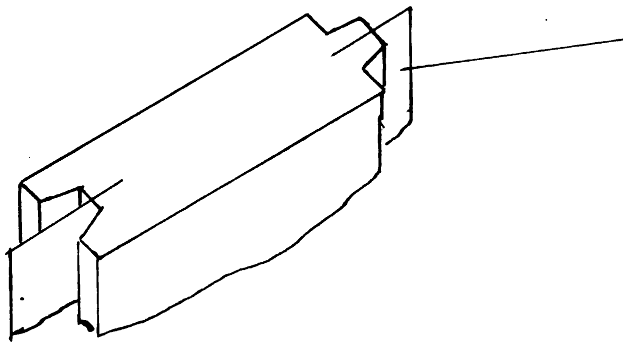
The retaining walls and abutements were designed as counterforts wall due to the height that is necessary for proper clearance under the bridges. The loads acting on the walls were computed graphically by the Culmann's method. See following pages for computations. The resultant of all the forces falls well within the middle third of the base.

The vertical slab was designed as a simple slab supported by the counterforts. The thickness of the slab was governed by the fact that the water table is high. It was designed in one foot strips taken at different hieghts. Maximum bending moment was computed assuming the load to act on the clear distance between counterforts. The load was assumed to be acting as hydrostatic pressure.

The rear portion of the base slab was designed as a simple beam supported by the counterforts. The load on the slab is equal to the differance between the upward earth presure and the downward load from the earth and surcharge above it.

The toe slab was designed as a simple counterfort with only the upward earth pressure acting. To satisfy requirements of bond and to provide traverse reinforcement in the heel every fourth bar was continued into the heel.

Moment in the counterfort was assumed to be due to the pressure of the earth on the vertical slab over a length of wall equal to the distance between counterforts. Effective depth is the perpendicular distance from the front of



of the vertical slab joint to the steel allowing three inch insulation at the surface.

The walls are to built in sections and each section will be constructed so as to provide joints similair to that shown above. This will provide a more water-tight joint than could be obtained by ordinary construction. Before back-filling the walls will be given two three-eigth inch coats of cement grout plaster and cover with burlap soaked in bituminous material. An additional coat of the same material will be placed over this. All back fill will be good quality gravel and sand. These walls must well water-proofed because of the fact that the water table is only seven feet from the surface. The Grand River flows almost parrallel with the walls and is only two-hundred and eighty feet from the center of Michigan Avenue at its closest position.

Concrete piles will support the toe of the wall base and should be capable of supporting eight ton. They will be placed in line with each counterfort which will be on eleven foot centers except under the bridges where they will be under each girder. Additional piles will be provided directly under the vertical section supporting the girders. These piles should be capable of supporting at least ten ton. All of the piles will be imbedded at least six into the base slab. The steel in the slab will be at a distance of three inches from the pile where the effective depth of the slab was assumed in the design.

Both the vertical slab and the rear portion of the base slab will be tied to the counterforts as shown in the steel arrangement diagram.

The concrete used in the walls should be capable of developing a compressive stress of at least twenty-five hundred pounds per square inch at the end of twenty-eight days. It should be placed in as high and as long a section as is economically possible.

The wall will extent past the upper road level for three and one-half feet to act as a guard rail. This extention will be reinforced with five-eigth inch round bars on six inch centers and placed in a horizontal position. This extention will tie into the guard rails of the bridges. This joint will be rounded with a radius of curvature of the outside not less two feet.

SYMBOLS AND FORMULAS USED

E = Pressure of earth acting on the wall at the angle of repose assumed to be 34^0.

f = Pressure per square foot acting on the base.

$$f = P/A\ (1 \pm 6e/b)$$

P = Total load acting---- p_1 & p_2 = maximum and mimimum soil pressure.

A = Area.

e = eccentricity.

b = Width.

M = Bending moment. = $1/8\ wl^2$ or P x Distance acting.

w = Load per foot of length.

l = Length.

u = Bond stress.

$$u = V / z_0 \times j \times d .$$

V = Total shearing load.

z_0 = Summation of perimeters.

j = Ratio of the resultants of the compressive and tensile stresses to the effective depth. (Assumed to be 7/8 in all computations.)

d = Effective depth or distance from steel to opposite side.

As = Area of steel required to take tensile stress.

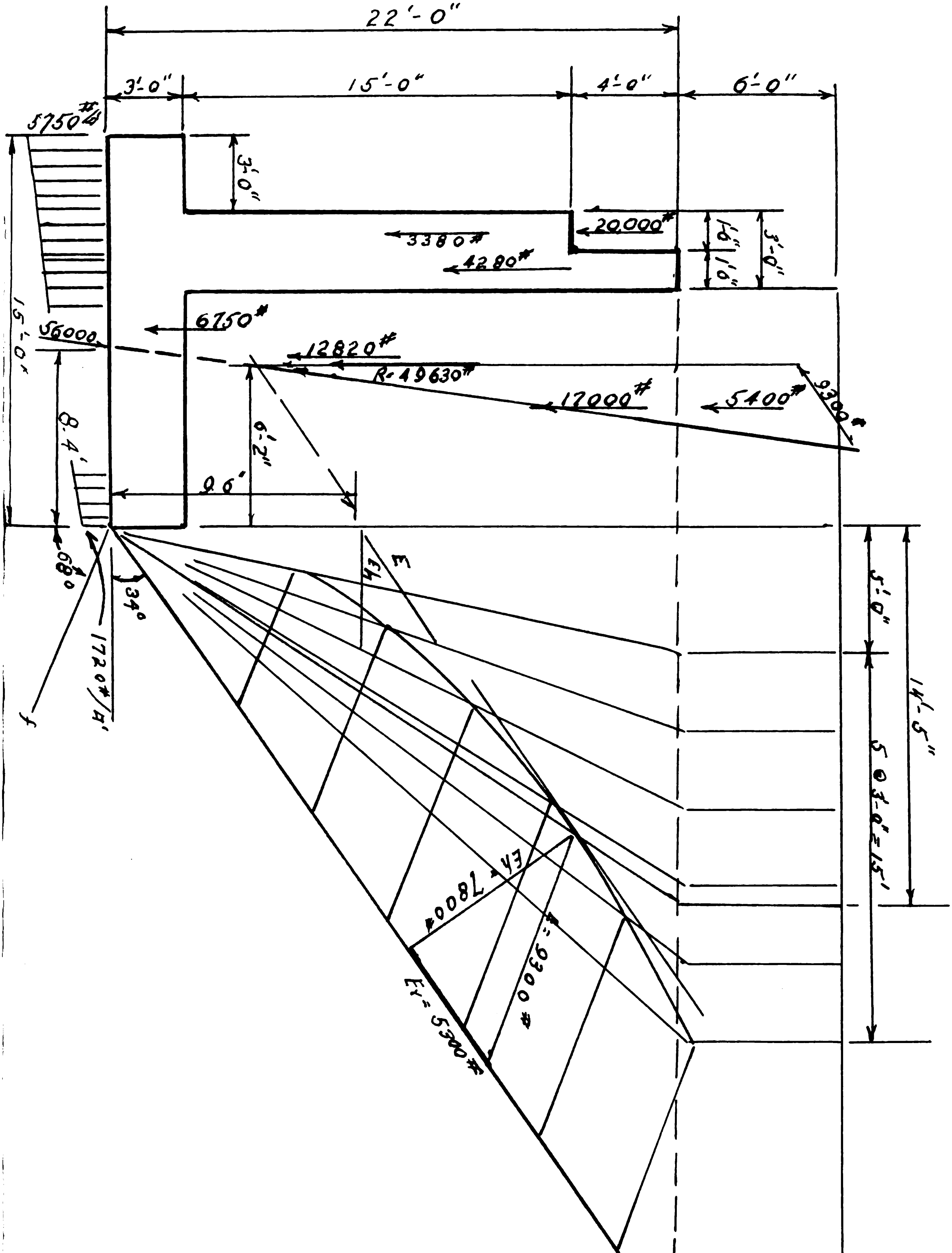
$$As = M / fs \times j \times d$$

fs = Allowable tensile stress in steel (18,000 $\#/''^2$)

ø = Round bars.

= Square bars.

c.c. = Center to center distance.



22'-0"
3'-0"
15'-0"
4'-0"
6'-0"
5750#
3'-0"
20,000#
3380#
4280#
1'-6"
1'-0"
3'-0"
15'-0"
6750#
56000
12820#
R=49630#
17000#
5400#
9300#
8.4'
6'-2"
9.6'
68°
34°
1720#/ft'
f
E
Eh
3'-0"
14'-5"
5 @ 3'-0" = 15'
Eh=7800#
E=9300#
Ev=5300#

ABUTMENTS AND RETAINING WALLS

Earth pressure

1 - 5' x 6' x 1' x 100 = 3000 #
5' x 22' x 1/2 x 1' x 100 5500 #
8500 #

2 - 8500 (3'x 6' x 1'x100) 3'x 11'x 1'x 100) = 13600#

3 - 13600 5100 = 18700#

4-5-6- Add 5100# for each increment to the last weigbt.

E-pressure of the earth on the wall = 9300# acting at an angl e equal to 34^0.

Presure was computed by means of Culman's method. (see scketch)

Weight resisting earth pressure.

Weight of wall -- concrete as sumed at 150 $\#/'^3$

1.5 x 15 x 150	=	3380	x	11.25	38000
1.5 x 19 x 1 x 150	=	4280	x	9.75	41800
0.5 x 19 x 9 x 150	=	12820	x	6.00	76920
3.0 x 15 x 1 x 150	=	6750	x	7.5	50600

Weight of soil

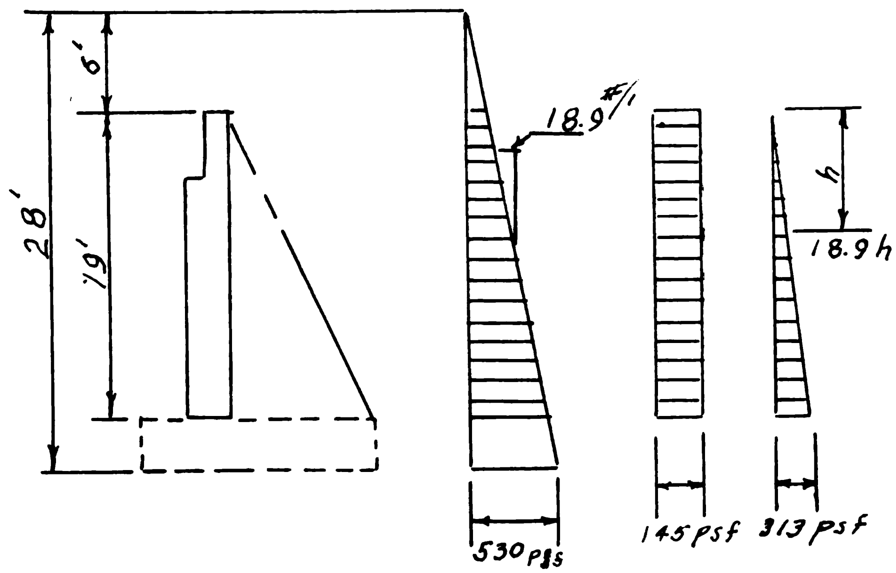
9 x 6 x 1x100	=	5400			
9 x 19 x 1 x 100	=	17000			
		22400	x	4.5	101000
		49630			308320

Resultant of resisting weight acts 6.2' from end of heel.

Resultant of all forces acting on the wall = 56000 #
Acts at a point 8.4 ' from the end of the heel which is well within the middle third of the base.

$$f = \frac{P}{A} \left(1 \pm \frac{6e}{b} \right) = \frac{56000}{15 \times 1} \left(1 \pm \frac{6 \times 0.9}{1}\right)$$

p_1 = 5750 #/sq.ft.
p_2 = 1720 #/sq.ft.



DESIGN OF VERTICAL STEM

$A = 6/28\ B = 0.214\ B$

$Eh = 7800\# = \frac{28}{2}(p\quad 0.214p)$ $\qquad p = 675$ psf

$Ap = 0.214 \times 675 = 145$ psf

$Bp = 22/28 \times 675 = 530$ psf

$Cp = 19/28 \times 675 = 458$ psf

slope = 18.9 #/ft.

Shear at any section of stem

$vx = 145h \qquad 9.50h^2$

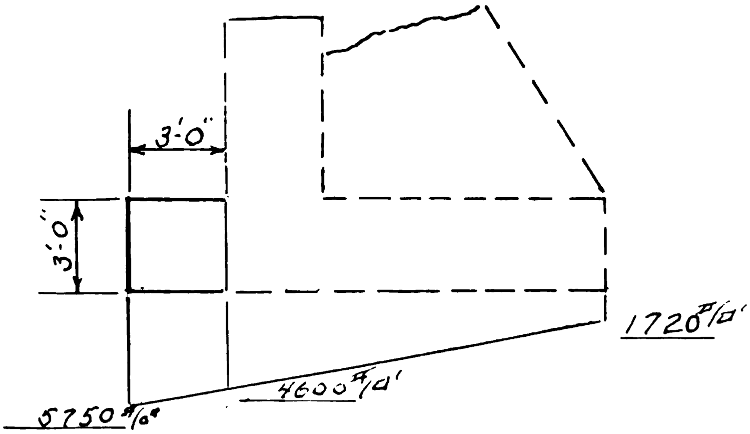
Moment at any section of stem

$Mx = 1/8 \times vx \times l^2 = 13.8\ v$

STEM SCHEDULE

H	V	v	M	As	
4'	732#	1.62	1010"#	$0.0234''^2$	1" Ø--24"c.c.
8'	1767	3.92	24400	0.5200	1" --15"c.c.
12'	3120	6.92	43000	0.9950	1" --10"c.c.
19'	5190	11.50	71500	1.6500	1" -- 5"c.c.

DESIGN OF TOE SLAB



$5750 - 1720 = 4030$

$x = \frac{12' \times 4030}{15'}$

$= 3230$

$P = \frac{3230\ 1720\ 5750}{2}$

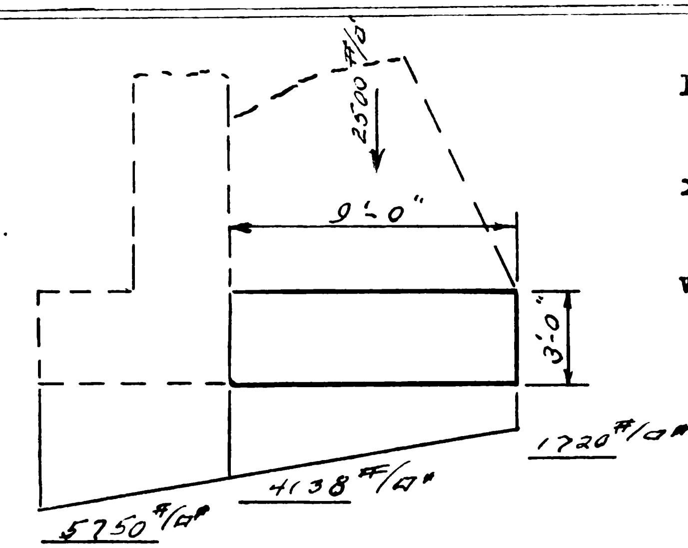
$= 5350$

$P' = 5350 \times 3 = 15150\#$ Mom. $= 15150 \times 2.25' = 34000'\#$

$u = \frac{15050 \times 8}{2.356 \times 27 \times 7 \times \frac{12}{4.5}} = 100$ As $= \frac{34000 \times 12 \times 8}{18000 \times 27 \times 7} = 0.96''^2/'$

Use 3/4" Ø to satisfy bond. Place on 41/2" c.c.

Design of Heel Slab



$x = \frac{9 \times 4030}{15} = 2418$

$wu = \frac{(2418\ 1720)\ 5750}{2}$

$= 2929\ \#/'$

$wd = \frac{22400}{9} = 2500\#/'$

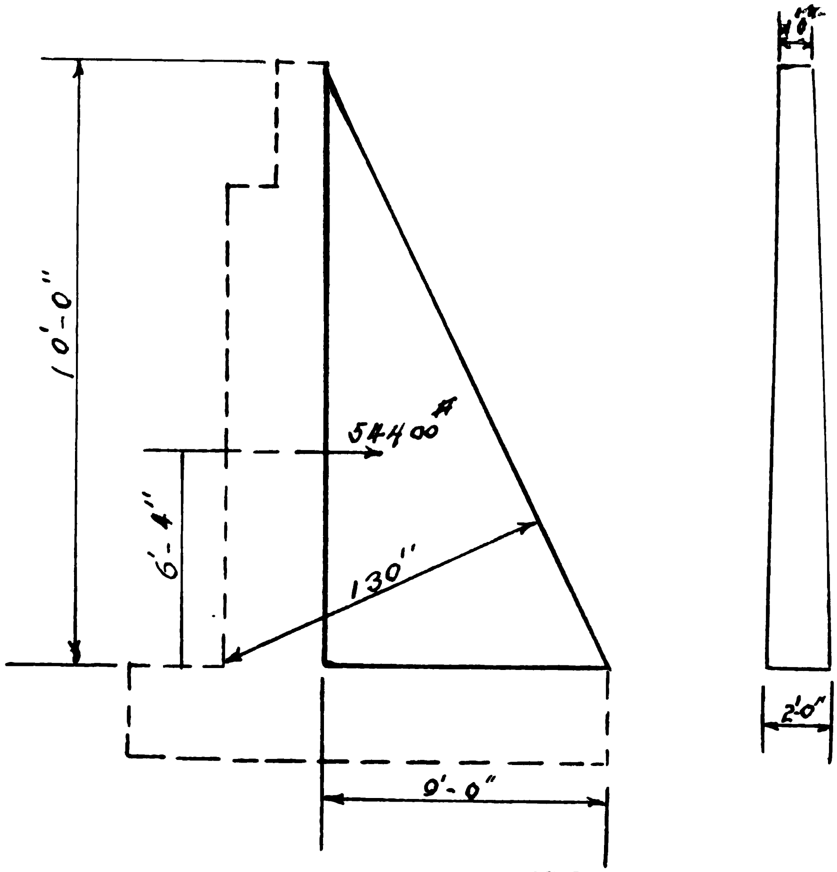
Mom. $= 1/8 \times (2920-2500)2 \times 12 \times \overline{10.5}^2 = 142000\ ''\#$

As. $= \frac{142000 \times 8}{2 \times 18000 \times 7 \times 27} = 0.168\ ''^2$

Shear $= \frac{858 \times 10.5}{2} = 4500\ \#$

$u = \frac{4500 \times 8}{2.356 \times 1 \times 7 \times 27} = 81\ \#/sq.ft.$

Use 3/4# Ø at 12" c.c.



COUNTERFORT DESIGN

$d = 12' \times \frac{19'}{\overline{19^2 \quad 9^2}} \times 12'' - 3'' = 127''$

$P = 0.143 \times 100 \times 19^2 \times 10.5 = 544000\#$

$y = 1/3 \times 19 = 6.33'$

$Mom. = 54400 \times 6.33 \times 12 = 413000''\#$

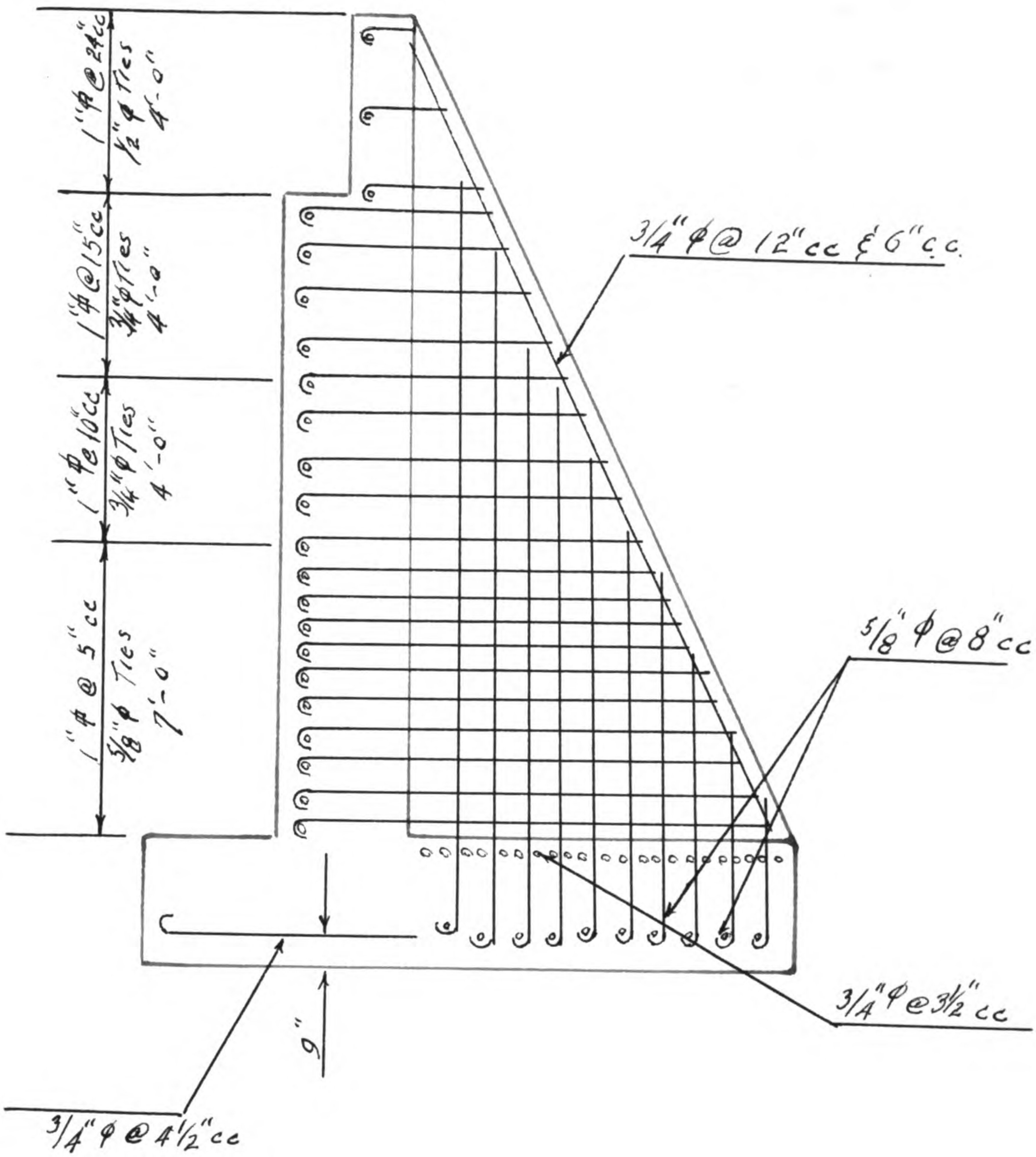
$As = \frac{413000 \times 8}{18000 \times 7 \times 127} = 0.207$ sq. in.

$u = \frac{54400 \times 8}{2.356 \times 1 \times 7 \times 127} = 200$ #/sq.in.

$As = \frac{413000 \times 8}{18000 \times 7 \times 127}$ _* 0.207 sq.in.

$u = \frac{544000 \times 8}{2.356 \times \frac{12}{6} \times 7 \times 127} = 100$#/sq.ft.

Use 3/4" ø at 6" C.C.


1"Φ@24"cc
1/2"Φ Ties
4'-0"
1"Φ@15"cc
3/4"Φ Ties
4'-0"
1"Φ@10"cc
3/4"Φ Ties
4'-0"
1"Φ@5"cc
5/8"Φ Ties
7'-0"
3/4"Φ@12"cc & 6"c.c.
5/8"Φ@8"cc
3/4"Φ@3½"cc
9"
3/4"Φ@4½"cc

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2- Highway Engineers Handbook -- Harger and Bonney

3- Reinforced Concrete Design Handbook
American Concrete Institute

4- Reinforced Concrete -- O'Rourke

5- Reinforced Concrete Design -- Sutherland

6- Modern Steel Structures -- Grinter

7- Steel Construction Handbook -- A.S.C.I.

SEWER MAP - JACKSON, MICH

COAL YARD
GARAGE
ELEC SHOP
I.O.F.F.
COAL BINS & YARD
COAL BINS
CAFE
BARBER
CLOTHS
JEWELER
FLORIST
SEC.HAND
SHOE REPAIR
CAFE
COAL OFFICE
TAILOR
STORE
ARMOURS
STORES
MILWUAKEE ST
238'-12" VP @ 0.248%
W'H'SE TOBACCO
HOTEL
GARAGE
TIRES
DRUGS
43'-0"
NEW YORK CENTRAL RAILROAD
338'-12" VP @ 0.222%
391'-12" VP @ 0.226%
921.59
921.38
MICHIGAN AVE
63'-0"
167'-27" & 28" Br @ 0.006%
144'-27" & 30" BR @ 1.48%
922.75
922.87
922.77
TOWER
PARK
PASSENGER STATION
CLOTHIER
STORE
BARBER
CLOTHIER
STORE
INTERNAT'L HARVESTER
COLUMBUS ST.
CAFE
BAR
STORE BLDG
HOTEL
NEWS
DRUGS
STORE
FURNITURE
W'H'SE GROCER
292'-30" Br. @ 0.19%
CABS