W. S. Kingsbury, Jr.

THESIS.

# Report on the Design of a RAPID TRANSIT VIADUCT For the SIXTH & MAIN TERMINAL EXTENSION. OF THE PACIFIC ELECTRIC RAILWAY in LOS ANGELES.

Civil Engineering. June 11, 1925.

California Institute of Technology.
Pasadena , California.

This report was originally undertaken as a separate and distinct problem and as such, it has been carried on. During this time a report covering the same situation, as a part of a more elaborate scheme of rapid transit has been completed and published.

The above-mentioned report is that of the Kelk-De Leauw Company, Consulting Engineers, Chicago, who have made a comprehensive study of the entire utility transportation problem of the city and county of Los Angeles, and who have devised means and made reccommendations for the construction of a suitable transit system.

There is nothing original in the idea of the construction of the Transit Viaduct herein referred to. For several years the Pacific Electric Railway has made plans for a similar extension of the present short viaduct running easterly from the Sixth and Main Station to the banks of the Los Angeles River in order that the heavy interurban trains from easterly and southerly points might be taken from the streets of the industrial and business districts which they at present traverse.

The plan outlined herewith is designed to provide for the same situation, but with a further consideration.

It will be realized that in the future such a unit as a four-track viaduct so placed cannot bear the enormous burden of traffic which will travel to and from the points of the Pasadena Lines, the eastern Huntington Drive Lines, the Pomona and San Bernardino Divisions, or those of the Southern Division, of of the Southern Beach points and Long Beach and San Pedro.

It was believed that at the time such a viaduct would be crowded to capacity a large subway "loop" would be in order, and this would tap off the "local" traffic--frequent schedule traffic, such as that from near points as Pasadena, etc. Thus the great bulk of traffic would not be thrown upon one corner, Sixth and Main Streets. The trains from the long, more infrequent runs, which, of course, would be much more numerous in the future, would continue to operate via the elevated structure into Main Street Station.

Such was the arrangement which this problem embodied. Exactly what the Kelk-De Leauw solution is, this author is unaware. The ideas, while independent, are essentially the same. Here the purpose of the investigation is to determine the practicability of constructing such a line---high-speed viaduct--- of plain reinforced concrete. It may be that such a material would prove quite uneconomical; however, with certain exceptions, after design-investigations, omly a small part of which are included herein, the author still believed that concrete construction is desirable.

There are several types of structure possible, the difference depending upon the material to be used. Wooden construction is, of course, barred. Fill, either free or confined is not considered due to the congested area traversed. A wider range of structures is possible because of the fact that the viaduct will not traverse the streets, but will stand on a private right-of-way lying between Sixth and Seventh Streets. Therefore, span length and arrangement of column supports is a question of economy and not a matter of keeping the area below the tracks clear.

As to the types of structure possible there may be---the reinforced-concrete structure herein designed; an all-steel, closed deck, type; concrete-and-steel construction; steel with concrete casing.

Open-deck is out of the question for city use. Slab deck---smooth embedment----or cushion ballast are the two more desirable forms of decking.

The short length of viaduct now in operation is of concrete-steel construction. A steel framecarries a shallow concrete trough holding the ballast and track. Such type has been used in the East, with variations.

Steel frame with metal flooring is another variation.

Steel frame encased in concrete is highly desirable from a standpoint of good appearance, adurability and noiselessness, but the cost is almost prohibitive.

The single metal standard carrying a two-track concrete deck, as is used in the Philadelphia system, is very good, although here two sych units would be necessary. The form is good where ground clearance is desired ans such a system is reccommended for outlying boulevard installations where the massive bent or trestle type is undesirable.

After much investigation and subsequent preliminary design, the following type was selected for the unit:

A four-track solid deck, cushion-ballasted, structure built monolithically in a transverse section, and continuous in longitudinal direction, said continuity to not exceed three panels, the standard panel being thirty feet, center-to-center, with end conditions assumed as supported. Three columns will support the crossvbeam. The construction will be T-beam girder. Footings will be continuous.

For street crossings advantage will be taken of the present curb line column location. For street crossings under 40 ft., curb-to-curb, no piers will be placed in the roadway; for over 40ft. piers may be placed. For single span crossing the design shall be for simply-supported reinforced-concrete T-girder. Span of street shall be monolithic with supports.

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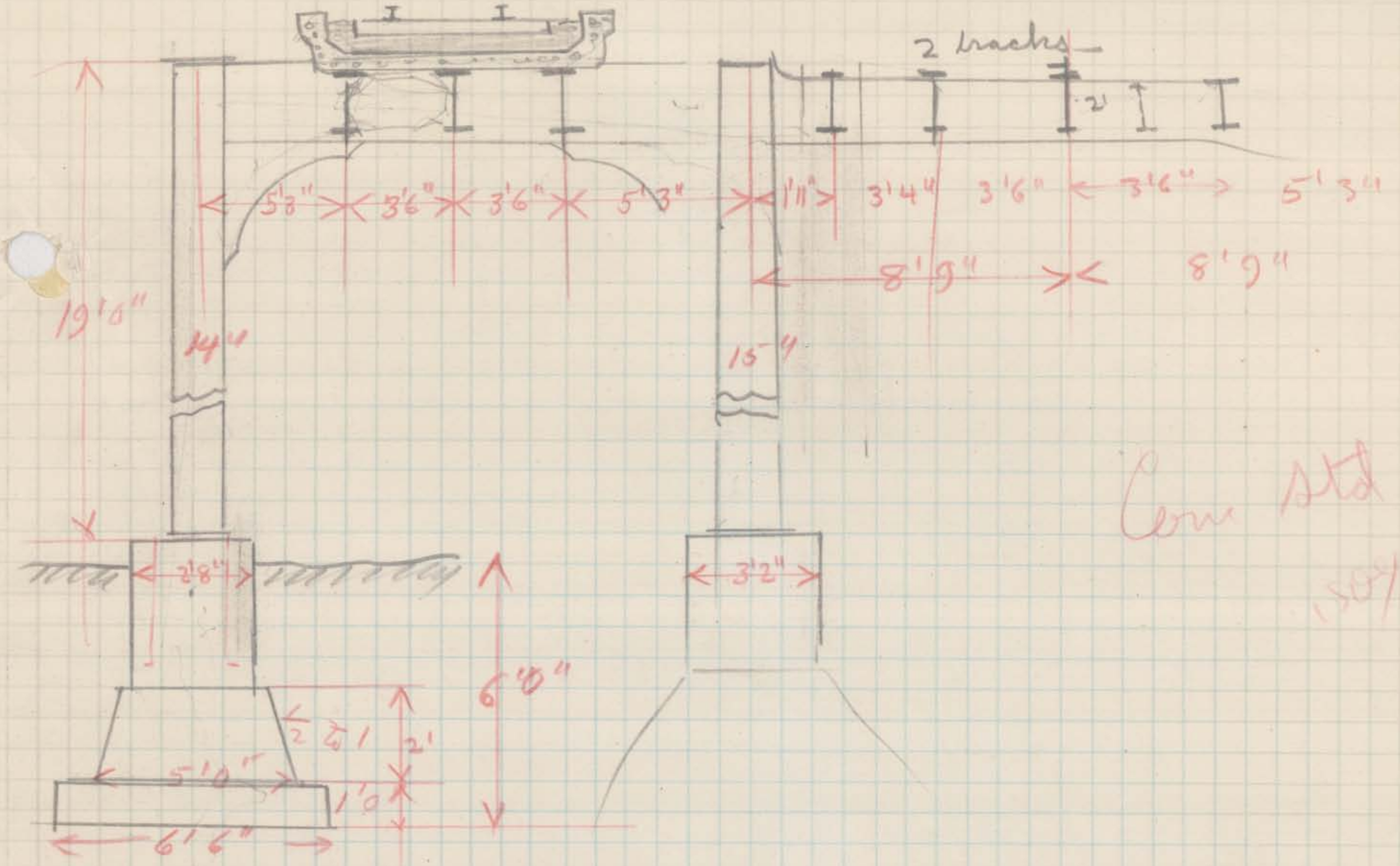
Sketch copies of Bents 13 and 32 of existing structure.

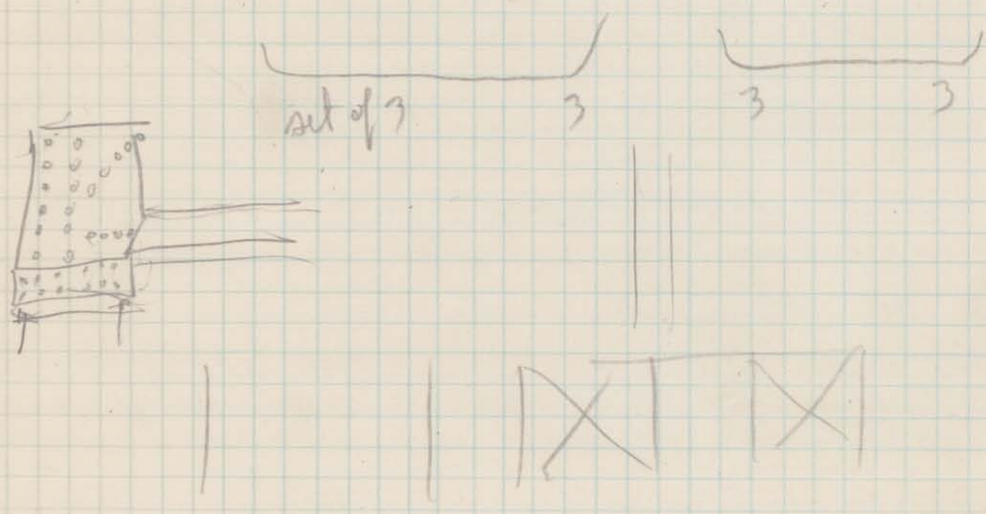



Bent 32

Conc Std

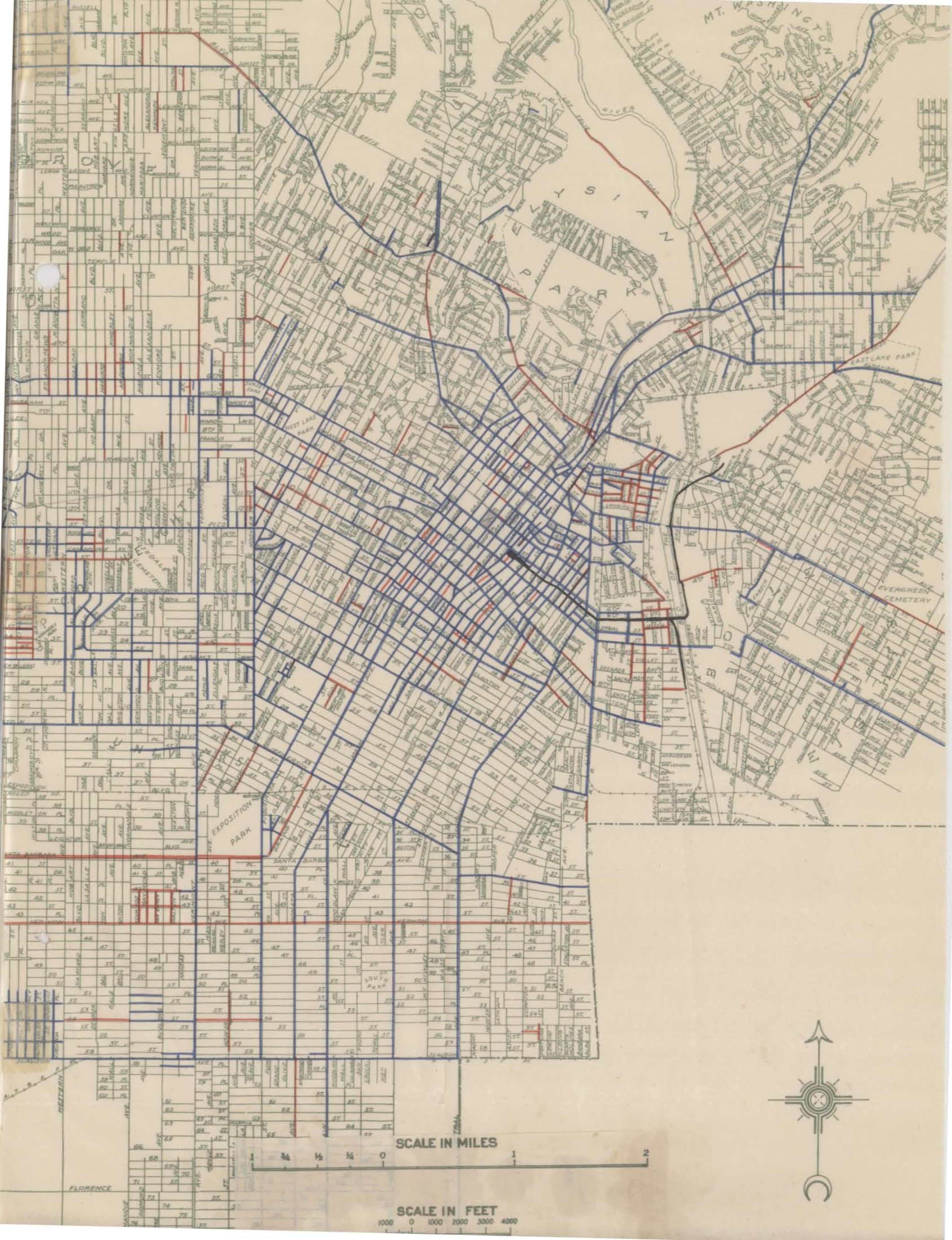
1909

30" Pl. Girders across Maple Ave




40' spans at ats.

Sketch Plats of Positions to determine characteristic bays and street spans. NOTE distances are from property line to property line.

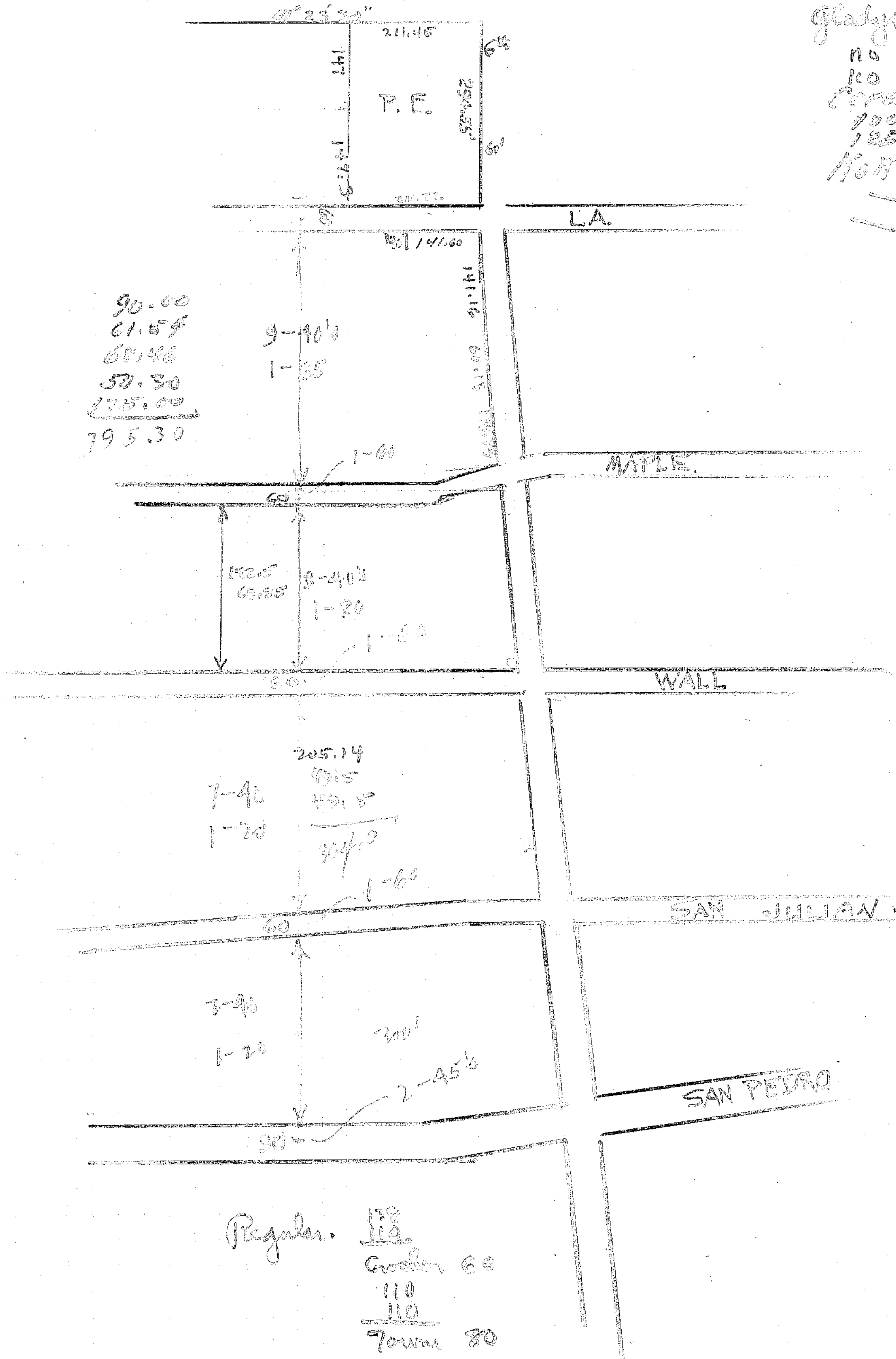


MT. WASHINGTON
ELYSIAN PARK
RIVER
EASTLAKE PARK
WEST LAKE PARK
EVERGREEN CEMETERY
EXPOSITION PARK
SOUTH PARK
SANTA BARBARA
VERNON
FLORENCE
SCALE IN MILES
1 ¾ ½ ¼ 0 1 2
SCALE IN FEET
1000 0 1000 2000 3000 4000

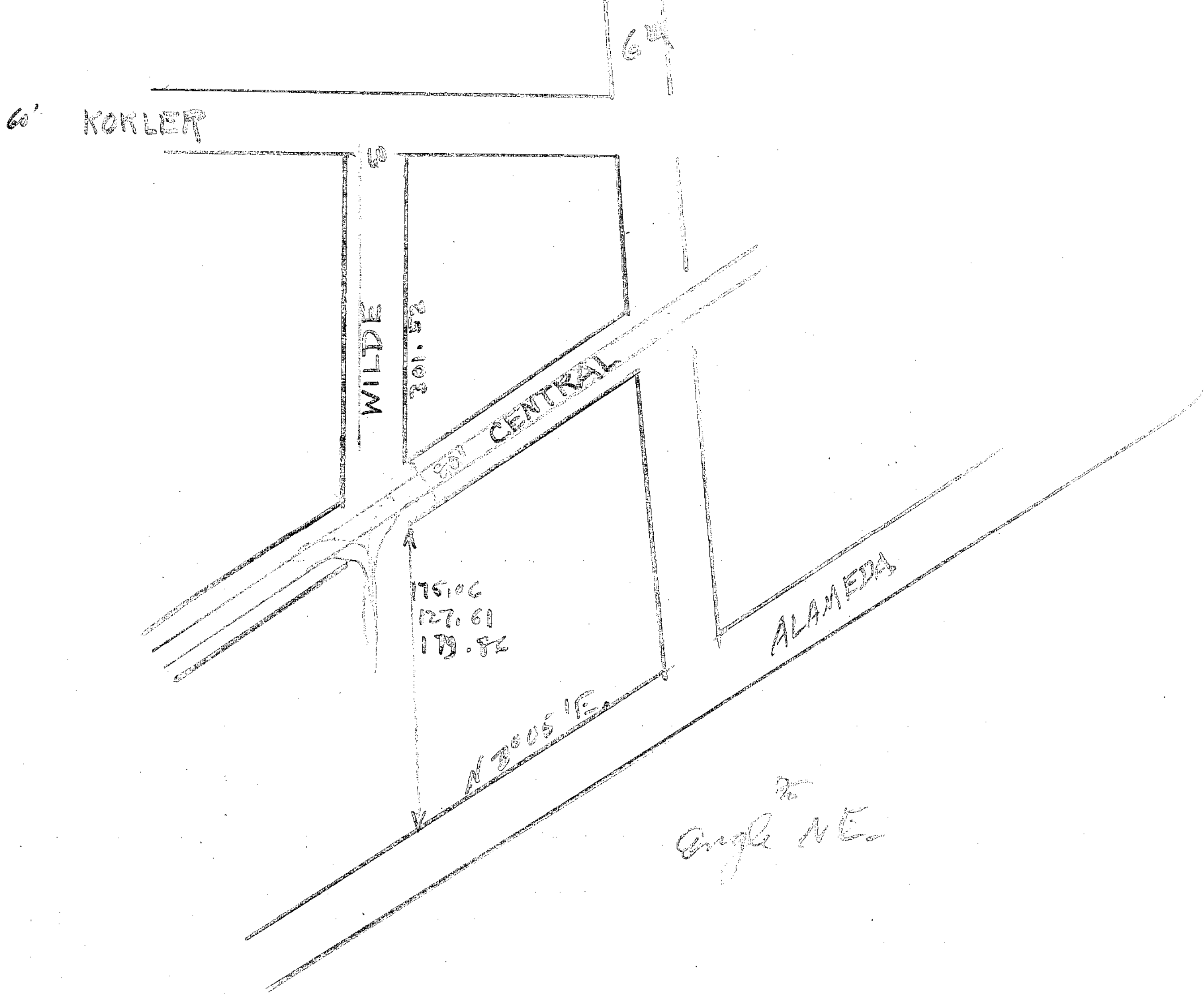
74
Sd. 1

660.30

110
110
Gladys 60
110
110
Ceres 60,
200
185
Kohler 60




Regular 178
118
Gordon 60
110
110
Towne 80
110
110
Stanford 60


60' KOHLER
WILDE
301.52
CENTRAL
127.61
ALAMEDA

Location of Terminal Viaduct.

BLACK line represents viaduct system under this design.

Design Data obtained from Structural Engineer's Office,

Pacific Electric Railway .

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Design Plates---series of
MWC 87e

Old design was for Cooper's E-35; New to be for E-40.
Concrete @ 150 #/cu.ft.
Earth filling @ 100#/cu.ft.
Ballast @ 120 #/cu.ft.
Timber @ 48 #/cu.ft. treated.
Pressure on ground under footings @ 6000 #/sq.ft.
Pressure of columns on pedestals @ 250 #/sq.in.
Compression on columns 800( 1 + min/max ) - 35 l/r.
Wind 300 #/lin.ft.
7.5 ft. above base of rail.
Wind 200 #/lin.ft. at base of rail.
For bending effect on columns due to wind the anchorage is assumed to fix the lower ends of the columns and the anti-resultant of the wind forces will be applied midway between the top of the pedestal and the bottom of the bracket.

Above data adopted for this design.

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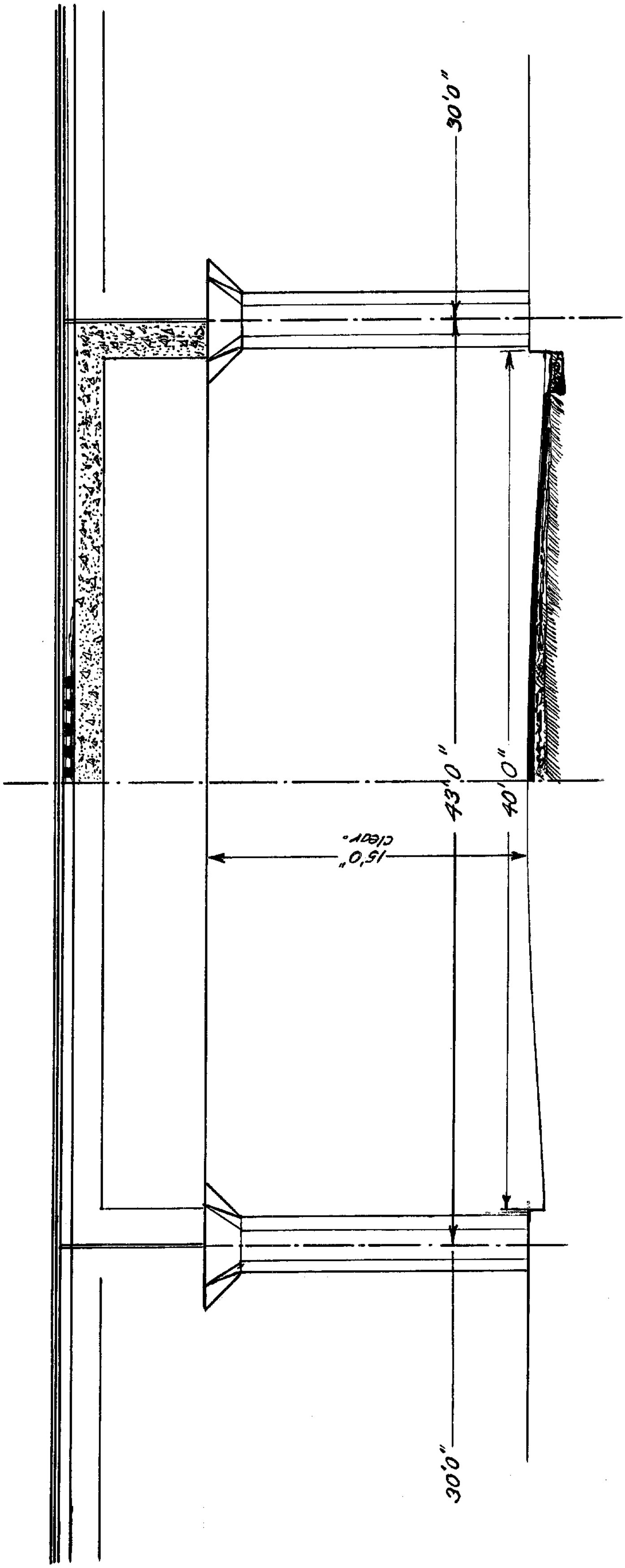
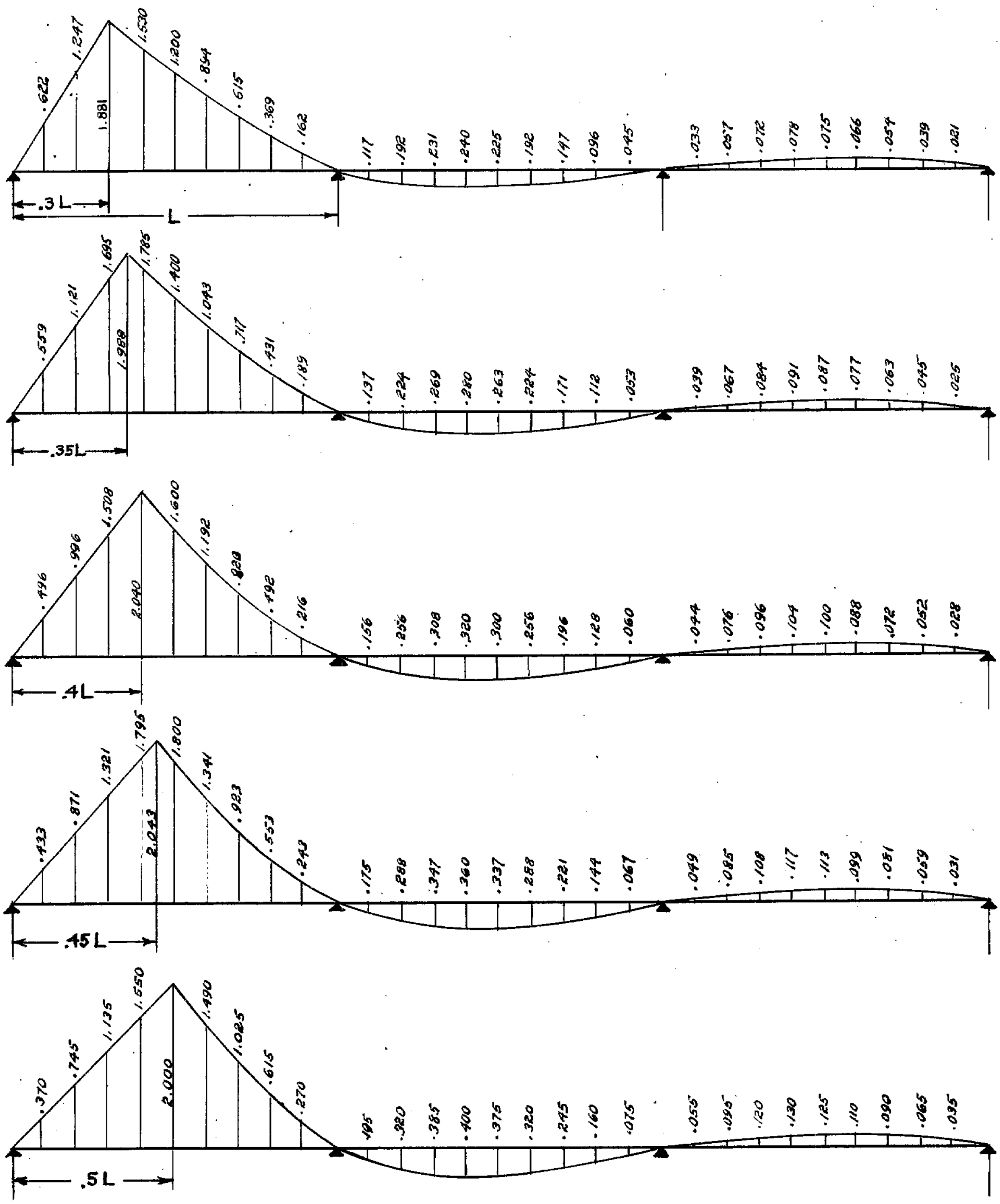
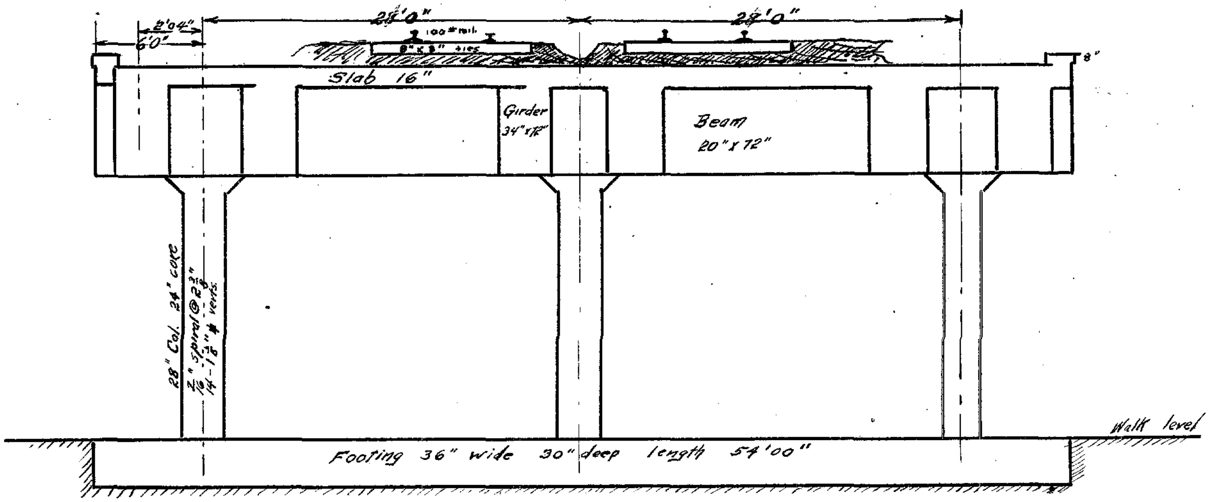



Typical Single-Span Crossing.
scale- 1/8 "

Note- The following set of influence lines is typical of those constructed during the investigation on continuity. They were made on the the assumption of supported ends, with the corrections by Hool. Actual computation was made rather than to adopt outright the conditions given by Hool without applying the conditions to this particular case.

# Influence Lines —Moment
## END SPAN






Section Span —
Scale - $\frac{3}{32}$"

COMPUTATIONS ON A TYPICAL SPAN FOR A 40-FT. (curb-curb) STREET.

Due to Loads :

Moment-------

| | | |
|---|---|---|
| Live---- | 742,666 | ft-# |
| Impact-- | 649,400 | ft-# |
| | 1,392,000 | ft-# |

Shear ---

| | | |
|---|---|---|
| Live --- | 79,200 | # |
| Impact-- | 69,400 | # |
| | 148,600 | # |

*Moment.*

Live Moment = 1,392000 x 12 = 16,700,000 in-#

Wt. ballast = 120x7 = 840 #/lin ft.
" track + ties = 180
1020 #/lin ft.

Moment = $\frac{1}{8}wl^2$ = $\frac{1}{8}$ x 1020 x $43^2$ x 12 = 2,820,000 in-# ~~2,380,000 in-#~~

Slab, at 16"
$\frac{16}{12}$ x 150 = 200 #/ft.
x7
1400 #/linft.

Moment = $\frac{1}{8}$ x1400 x $43^2$ x 12 = 3380000 in-#

Girder, stem (34" x (74"-16")
= 1990 #/linft.

Moment = $\frac{1}{8}wl^2$ = $\frac{1}{8}$ x 1990 x $43^2$ x 12 = 5520000 in-#

Total. —— 28,920,000 in-#

*Shear.*

| | | |
|---|---|---|
| Live + impact | | 148600 # |
| Ballast | 1020 x 21.5 | 21900 # |
| Slab | 1400 x 21.5 | 30100 # |
| Girder stem | 1990 x 21.5 | 42800 # |
| | Total | 243400 # |

$\frac{t}{d} = \frac{16}{68} = .177$
K = .379
Kd = 25.80
$z = \frac{77.4-32}{51.6-16} \times \frac{16}{3}$
= 6.80
jd = d - z = 68 - ~~6.80~~ 6.80
= 61.20"

$\frac{243400}{105}$ = 2310 sq."

If b' = 32" d = 71½"
b' = 33" d = 69.3"
b' = 34" d = 68.0" ✓

*For steel*

$a_s = \frac{M_s}{f_s jd} = \frac{28920000}{16000 \times .874 \times 68.0}$ = 30.40 sq" steel

Bond necessary = (use 1¼" ⌀) Σo = $\frac{243400}{120 \times 61.2}$ = 33.10 sq"

Run thru 7 - 1¼" bars = 35 sq"

∴ u = 113.4 #/in² OK.

d = 68.0"

Place steel in layers

| | | sq." |
|---|---|---|
| Upper — | 6 - 1" ⌑ | 6.00 |
| Middle — | 12 - 1" ⌑ | 12.00 |
| Lower. | 2 - 1" ⌑ 2 } | 12.937 |
| | 7 - 1¼" ⌑ 10.937 } | |
| | Total | 30.937 sq." |

Space layers 1½"
Clearance below = 2"
Total depth = 72"

Stirrups —
Use ⅜"Φ in  6" spac.
Tables — spacing — from center.
6" 8" 8" 20" 24" 34"

Rods bent up.
from center.

10' 4 - 1" ⌑
12' 4 - 1" ⌑
15' 6 - 1" ⌑
18 8 - 1" ⌑

Figured to carry diag. stresses.

Cross-Beam.

Make d = 68.0"
Est. width of 18"
Wt. beam = $\frac{18 \times 72}{144} \times 150 = 1350$ #/lin ft.

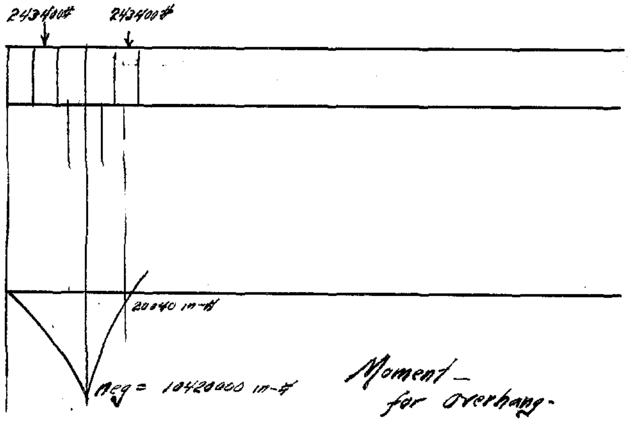
Moments — no difference if restrained. Rectangular
Negative.

$M = \frac{1}{2} \times 1350 \times 6^2 \times 12 = 292000$ in-#
$M = 243400 \times 3.5 \times 12 = 9750000$ in-#
$10042000$ in-#

$bd^2 = \frac{10042000}{.0077 \times .874 \times 16000} = 931000$  $d = 68 \therefore b = 20$

Steel.

$a_s = \frac{10042000}{16000 \times .874 \times 68} = 10.50$ sq"
$\Sigma o$ for bond $= \frac{251520}{120 \times 68 \times .875} = 34.50$




Moment — for Overhang.