910.009

STRUCTURAL CALCULATIONS

PROJECT:

51ST AVENUE & SALT RIVER BRIDGE

MARICOPA COUNTY, ARIZONA

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lood Control District of MC Library
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Phoenix, AZ 85009

CLIENT:

MARICOPA COUNTY HIGHWAY DEPARTMENT

3325 WEST DURANGO

PHOENIX, ARIZONA 85009

262-3611

JUNE, 1980

E. M. PLUMMER
CONSULTING ENGINEERS
3666 NORTH MILLER RD.
SCOTTSDALE, ARIZONA 85251
941-2061

Registered Professional Engineer (Structural)
CERTIFICATE NO. 5153
ERNEST MALCOLM PLUMMER
Date Signed 6-8-80
ARIZONA, U.S.A.

ERNEST M. PLUMMER, P.E.

E.M. PLUMMER CONSULTING ENGINEERS
STRUCTURAL . CIVIL ENGINEERS
3666 NORTH MILLER ROAD, SUITE 105 · SCOTTSDALE, ARIZONA 85251 · 602-941-2061

May 28, 1980

Mr. Francis Lathrop, P.E.
Assistant County Engineer
3325 West Durango
Phoenix, Arizona 85009

RE: 51st Avenue Bridge
Maricopa County, Arizona

Dear Mr. Lathrop:

This is in reference to subject project for your approval and use.

The scour depth for the original 1000 foot bridge as determined by Southwest Computing was elevation 980 for a 130,000 cfs flood. Since no additional hydraulic analysis was made for a 200,000 cfs flood, the scour depth was dropped to elevation 975. The high water elevation was set at top of deck of the original 51st Avenue Bridge based on photographs taken in March, 1980 at flood peak flow. Using this high water elevation, a minimum of 5'(±) freeboard remains at high water elevation and bottom of exterior girder.

Based on Soil Report by Nicholas-Cowie, Inc. dated February 5, 1980 with borings made on December 12, 1979, all pile caps are above the water table except hole No. 3 which is elevation 980. As minor dewatering, if any, will be necessary no tremie concrete was included in this design. In the event water is encountered above pile caps additional costs will be necessary unless the Contractor can dewater the excavations by means other than tremie concrete.

If you have any questions relative to the above please call.

Sincerely,

E. M. PLUMMER CONSULTING ENGINEERS, INC.

E. M. Plummer, P.E.

EMP:lc

cc: Nicholas-Cowie, Inc.

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SUBJECT 51st Ave & Salt River Bridge Maricopa Cty
SHEET NO 1 OF
BY EMP DATE 8/8/2
JOB NO

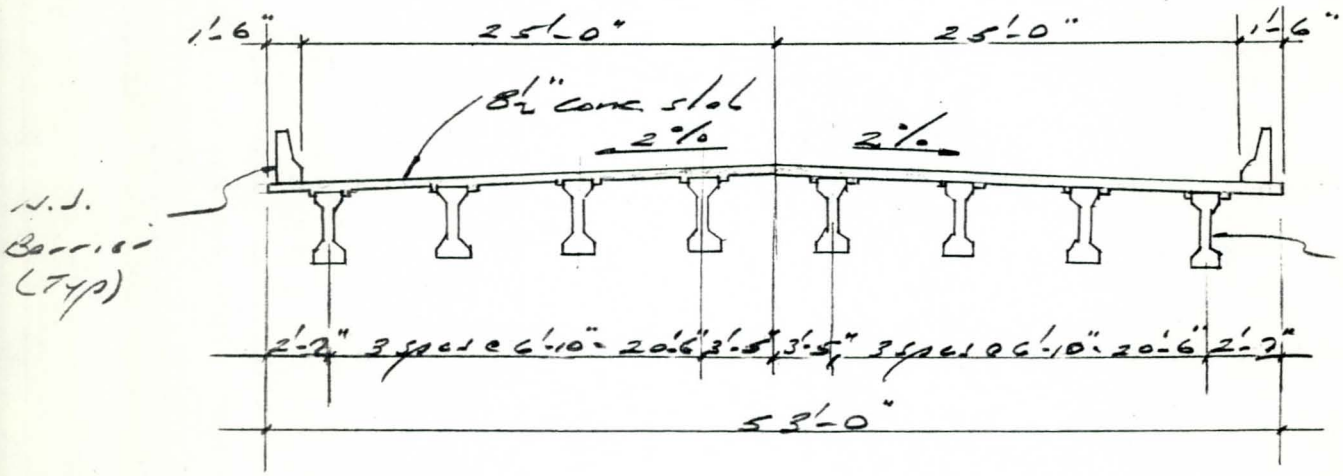
Superstructure Design

A. Design Criteria

cast in place concrete Deck on PCI standard AASHTO Type IV-I Girder

Gird. span 100'
Loading HS20-44
Concrete Deck Type S (f'_c = 4500 psi)
Concrete Piers & Abut. Type S (f'_c = 3500 psi)
Reinf. Stl. (Deck & Piers) f_y = 60,000 psi

B. Typical Section



ENGINEERING DIVISION
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SUBJECT 51st Ave & Salt River

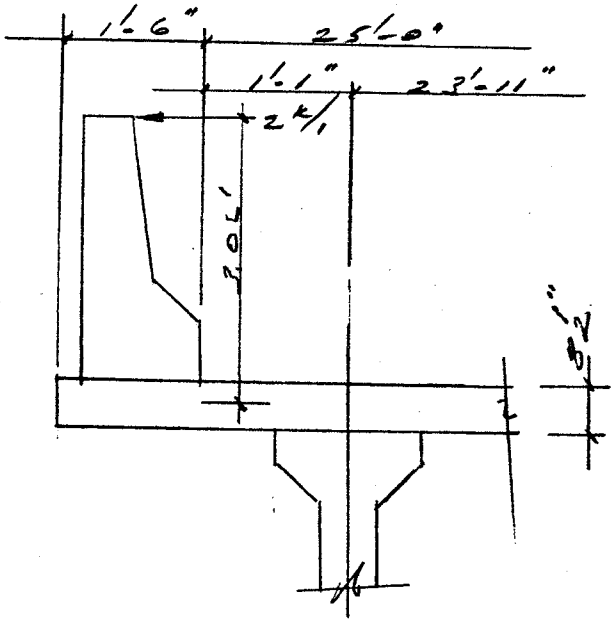
SHEET NO 2 OF

BY EMP DATE 8/9/79

JOB NO

CLIENT:

Deck Design



Horiz F = 10k/5' = 2k/'

Horiz. Barrier Mom = 2k × 3.02' = 6.040'k
DL Barrier = 360#/' × 2.13 = 0.766
Slab = 106#/' × 2.58²/2 = 0.352
7.158'

Barrier only - React. to Ext. Girder

Barrier Mom = 360#/' × 2.13' = 766'#/'

	A		B		C	
	0	1.0	0.5	0.5	0.5	0.5
	-766	0				
		+766				
			+383			
			-192	-192		
					-96	+96
					0	0
		-96				
		+96				
		766	+48			
			-24	-24		
			216			
Mom	-766	+766	-216	+216	-96	+96
✓	360	0	0	0	0	0
ΔM/L	360	143	143	46	+46	46
R	503#/'		-189#/'		92#/'	

(Deck Design cont.)

DL - 8½" slab { 8" Design
½ wearing surface

$w_{DL} = \frac{8.5}{12} \times 150 = 106$ #/'

FEM = 106 #/' × $\overline{6.83}^2/12$ = 412'#

Cant Mom = 7158'#/' (see Pg. #1)

	A		B		C		D	
	0	1.0	0.5	0.5	0.5	0.5	0.5	0.5
	+7158	-412	+412	-412	+412	-412	+412	-412
		-6746	0	0	0	0	0	0
			-3373					
			+1686	+1686				
		+843			+843			
		-843			-421	-421		
	+7158	-7158	-422	-211			-211	0
			+317	+317			+106	+106
			-1380	+1380	+159	+53	+306	-306
					-106	-106		
					+887	-887		
V	626	363	363	363	363	363	363	363
ΔM/L		1250	-1250	-33	332	-85	-85	0
ΣV		1613	-1613	31	695	278	448	363
R		2239 #/'		(-)1582 #/'		973		811

Cant V = 360 #/' + $\frac{8.5}{12} \times 150 \times 2.5'$ = 626 #/'

Int V = $\frac{8.5}{12} \times 150 \times \frac{6.83'}{2}$ = 363 #/'

Pos. Mom = 106 #/'² × $\overline{6.83}^2/8$ − $\left[\frac{-1582 + 973}{2}\right]$ = 31 '#

618

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SUBJECT 51st Ave Br.
SHEET NO 4 OF
BY EMP DATE 1/23/80
JOB NO.
CLIENT:

(Deck Design Con't.)

FEM (slab DL) = 106 #/ft² × 6.88²/12 = 418'#/'

0	1.0	0.5	0.5	0.5	0.5
-1118	+418	-418	+418	-418	+418
	+700	0	0	0	0
		+350			
		-175	-175		
	-88			-88	
	+88			+44	+44
-1118	+1118	+44	+22	-462	+462
		-33	-33		
		-232	+232		

LL

Int.

$M_{LL} = \left(\frac{S+2}{32}\right) \times P_{20} \times 0.8 \times I$

$M_{LL} = \left(\frac{6+2}{32}\right) \times 16.0 \times 0.8 \times 1.3 = 4.16'^{k}$

$P_{20} = 16^{k}$
$I = 1.3$
$S = 6.83 - 1.67 + \frac{1.6}{2}$
$S = 6.00'$

Cant Mom:

$E = 0.8x + 3.75 = 3.75$ $x = 0$

$M = \frac{Px}{E} = M = 0$

Slab Design:

I. DL + LL = 0.23 + 4.16'^k = 4.39'^k

II. Slab DL + Barrier LL = 7.16'^k — Max

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SUBJECT 51st Ave Br. SHEET NO. 5 OF
BY EMP DATE 1/23/8
JOB NO.

(Deck Design Cont.)

Service Ld:

$M_{max} = 7.16^{'k}$

$d = 8.5 - 2.5 - \frac{0.62}{2} = 5.625''$

For $\left.\begin{matrix} \#5 @ 10'' \\ \#6 @ 10'' \end{matrix}\right\}$ Alt @ 5½" $A_s = 0.90$

$\rho = \frac{0.90}{12 \times 5.625} = .013$

$n\rho = 0.013 \times 7 = 0.091 \left\{\begin{matrix} k = 0.345 \\ j = 0.885 \end{matrix}\right.$

$f'_c = 4500$ $f_c = 180$

$E = w^{1.5} 1.33 f_c^{\frac{1}{2}} = 4067$

$n = \frac{2900}{4067} = 7.13$

$n = 7.0$

$f_s = \frac{7160 \times 12}{0.90 \times 0.885 \times 5.625} = 19{,}120$

$f_c = \frac{19{,}120}{7} \times \frac{0.345}{0.655} = 1442^{\#/\square''} \sim 1400^{\#/\square''}$ ok!

Dist. Stl. $= \frac{220}{\sqrt{6.0}} = 89\%$ use 67%

Dist. Stl. $= 0.67 \times 0.90'' = 0.60''$ use #5 @ 6"

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SUBJECT 51st Ave Bridge @ Salt River
SHEET NO. 6 OF
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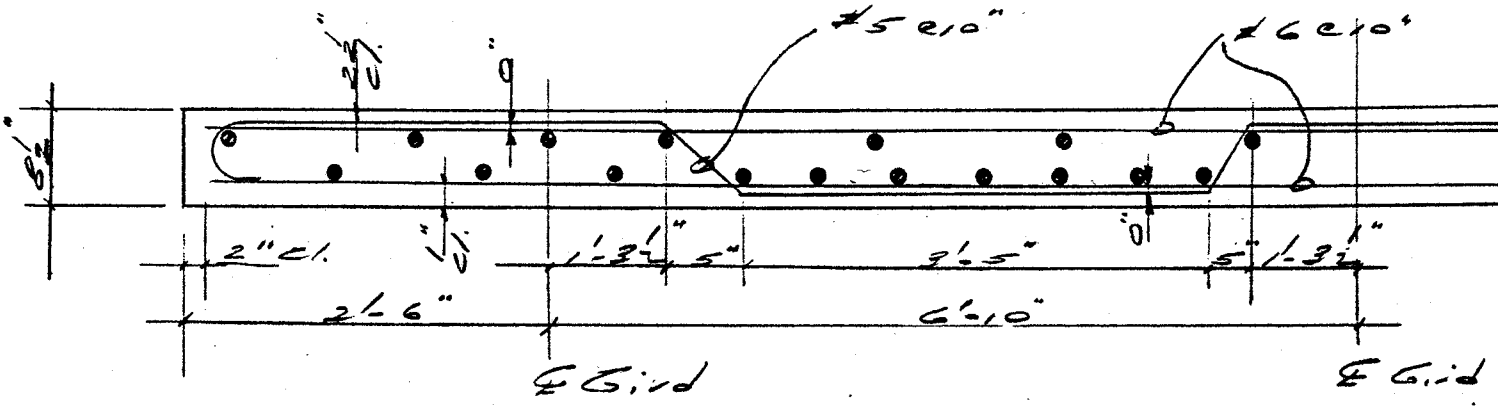
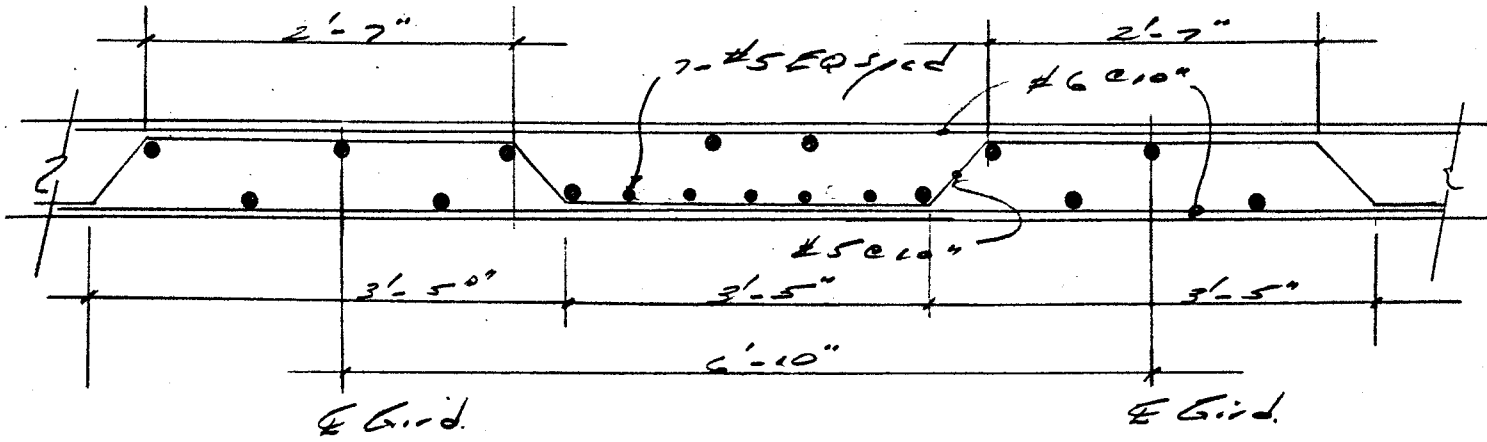
JOB NO.

(Deck Design Cont.)

@ Cant. End



Typ. Int.



Dist. Stl.

For Stl. ⊥ to Traffic % = $\frac{220}{(S)^{1/2}}$ $\frac{220}{(5.83)^{1/2}}$ = 91%
Max 67%

Max A_s = 0.90 □"
Dist. Stl. = 0.90 □" × 0.67 = 0.60 □"
use #5 @ 6"

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SUBJECT 51st Ave Bridge @ Salt River
SHEET NO 7 OF
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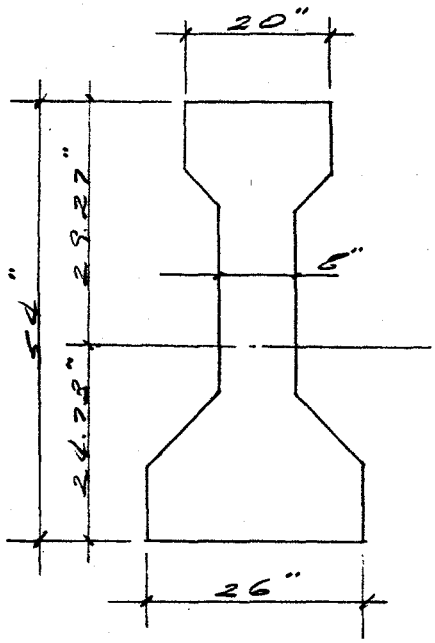
Girder Design



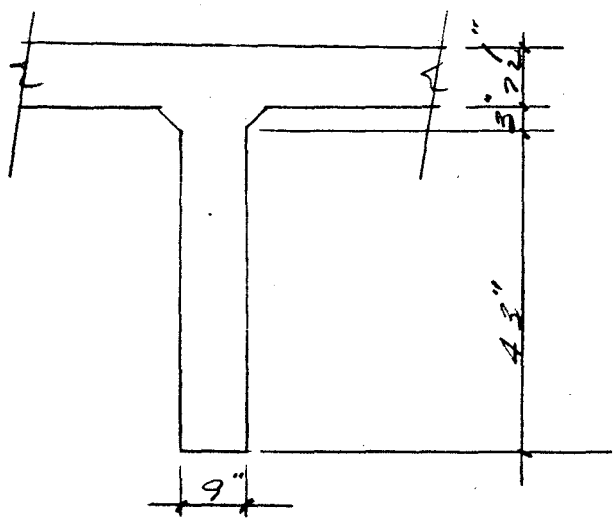
1. Girder Sec. Properties:

wt = 822 #/'
A = 789 □"
I_x = 260,730 in^4
Y_b = 24.73 in
S_b = 10543 in^3
S_t = 8908 in^3

2. Girder Design

f'_c = 5000 psi
f_s = 270,000 psi
f_{si} = 0.7 × 270,000 = 189,000 psi
L = 100'
use Std. PCI Std. Type IV AASHTO Precast Prestressed Girder.

3. Int Diaphragm



Diaph. wt.
0.75 × 3.83' = 2.87
2 × .25²/2 = .06
2.93 □' × 150 #/ft³
wt = 431 #/'

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SUBJECT 51st Ave Bridge SHEET NO. 8 OF
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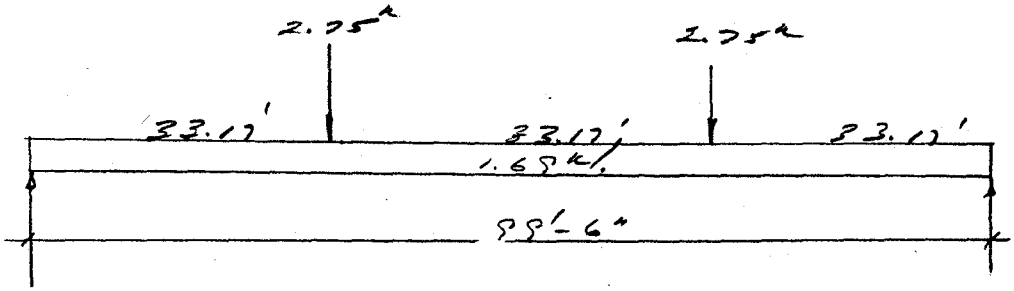
4. DL

Int.



8½" slab = $\frac{8.5}{12} \times 6.83' \times 150\,\#/ft^3$ = 726 #/'

Build up @ Girders = 50

Type IV Girders = 822

Barrier React = $\frac{92}{1690}$ #/'

Diaph wt = $421\,\#/' \left(\frac{6.83 - 0.67'}{\cos 15^\circ}\right)$ = 2,748 #

.9659

R = 1.69 k/' × 99.5'/2 + 2.75k = 86.8 k

Ext.

8½" slab = $\frac{8.5}{12} \times \left(\frac{6.83}{2} + 2.5\right) \times 150$ = 629 #/'

Build up @ Girders = 50

Type IV Girders = 822

Barrier React = $\frac{503}{2004}$ #/'

Diaph wt = $421\,\#/' \left(\frac{\frac{6.83'}{2} - 0.67}{\cos 15^\circ}\right)$ = 1,225 #

R = 2.0 k/' × $\frac{99.5'}{2}$ + 1.23k = 100.73 k

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SUBJECT 51st Ave Bridge SHEET NO 9 OF
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5. Dead Ld. Moments

(a) Int:

M_{Diaph} = 2.75k × 49.75' − 2.75k × 16.58' = 91.2'k

M_{slab} = 726 #/' × 99.5²/8 ——— = 898.5

M_{Grid} = 822 #/' × — ——— = 1017.3

$M_{Grid\ Bump}$ = 50 #/' × — ——— = 61.8

$M_{Barrier\ React}$ = 92 #/' × — ——— = 113.8

2182.6'k

(b) Ext.:

M_{Diaph} = 1.22k × 49.75 − 1.22k × 16.58' = 40.47'k

M_{slab} = 629k × 99.5²/8 ——— = 778.41

M_{Grid} = 822 × — ——— = 1017.30

$M_{Grid\ Bump}$ = 50 #/' × — ——— = 61.80

$M_{Barrier\ React}$ = 503 #/' × — ——— = 622.50

2520.5'k

6. Live Load: $I = \frac{50}{100+125} = 0.22\%$

(a) Int

Truck Ldg = 16k × $\frac{6.83}{5.5}$ × 1.22 = 24.2

Lane Ldg = 0.64 k/' × $\frac{6.83}{5.5 \times 2}$ × 1.22 = 0.48 k/'

— Conc. M = 18k × $\frac{6.83}{5.5 \times 2}$ × 1.22 = 13.64k

— Conc V = 26k × $\frac{6.83}{5.5 \times 2}$ × 1.22 = 19.7k

Live Load + I

(6) Ext Girder.

Truck Ldg: $16^k \times \frac{6.83}{4 + 6.83/2} \times 1.22 = 23.35^k$

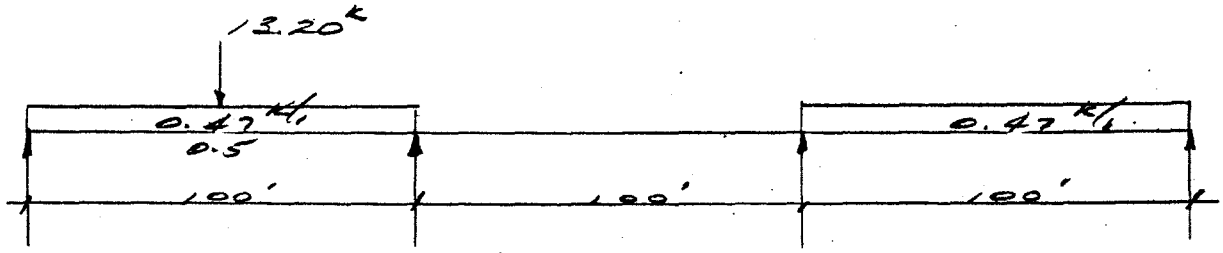
Lane Ldg: $0.640^{k/'} \times \left[\frac{6.83}{2(4+0.25\times6.83)}\right] 1.22 = 0.47^{k/'}$

" " Conc. M: $18^{k'}$ " × " = 13.2^k

" " Conc. V: 26^k " × " = 19.0^k

Max Pos. Mom. (3 span condition - use Ext. Gir.

Span #1 (Lane)

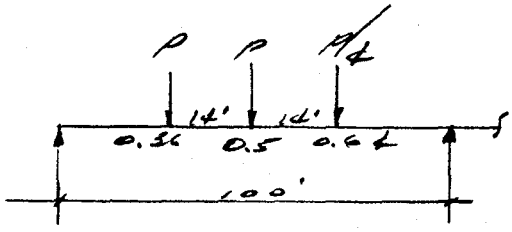


Pos. Mom @ 0.5 pt:

Span #1: 0.0917
Span #3: 0.0083
0.1000 × $0.47^{k/'} \times 100^2$ = 470'

Conc. Pe 0.5 = 0.20 × $13.20^k \times 100'$ = 264
734

Span #1 (Truck)



Mom @ 0.5 pt.

Pe 0.5 = 0.2000
Pe 0.36 = 0.1385
$\frac{.1302}{4}$ P/4 e 0.64 = 0.0326
0.3711

Max. LL+I (+)M = 0.3711 × $23.35^k \times 100'$ = 866.5'^k

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SUBJECT 51st Ave Bridge @ Salt River SHEET NO 11 OF
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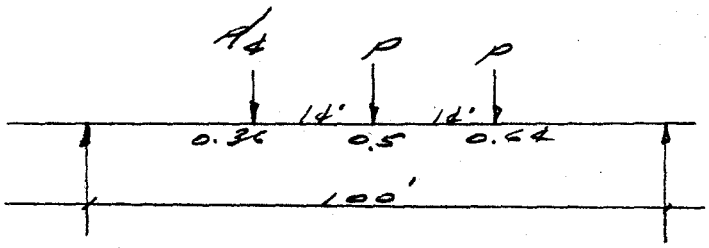
(Pos. Mom. Con't.)

Span #2 (Truck)



Mom @ 0.5 Pt.

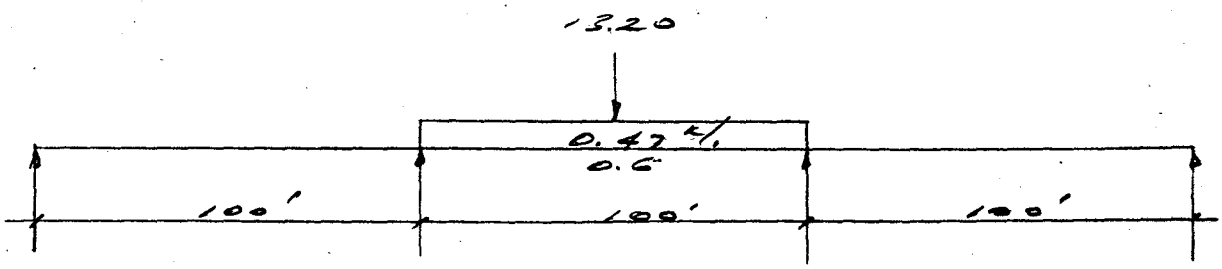
P @ 0.5 = 0.1750

P @ 0.64 = 0.1116

$\frac{0.1116}{4}$ P/4 @ 0.36 = 0.0279

0.3145 × 23.35^k × 100' = 7344 ^'k

Span #2 (Lane)



Pos M @ 0.6 Pt:

P = 0.1664 × 13.20^k × 100' = 219.6

w = .07 × 0.47^k/' × $\overline{100}^2$ = 329.0

548.6 ^'k

Max LL Pos Mom @ Span #1 (Truck) = 866.5 ^'k

(For 3 span condition

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SUBJECT 51st Ave Br. @ Salt River
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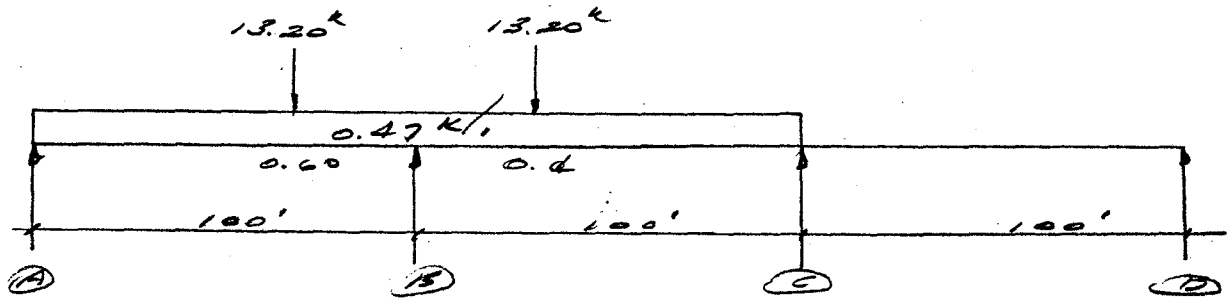
JOB NO

(3 Span Cond. Cont.)

Max LL. Neg. Mom.



Max Neg. Mom. @ B:

w/ span #1 Loaded = 0.0667
span #2 Loaded = 0.0500
0.1167 × 0.47 k/' × 100² = 548.5

Conc. P @ 0.6 = 0.102k
Conc P @ 0.6 = 0.0800
0.182k × 13.20k × 100' = 240.4
789.3

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SUBJECT 51st Ave Bridge @ Salt River SHEET NO. 13 OF
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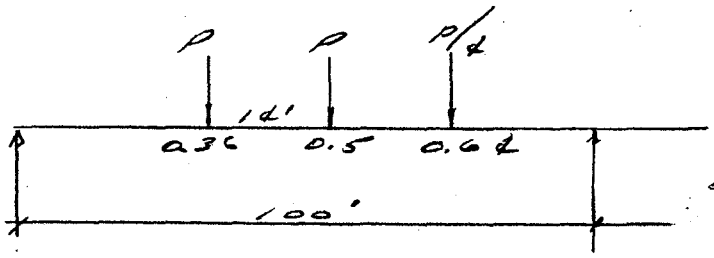
Four Span Continuity

Span #1 Truck Ldg.

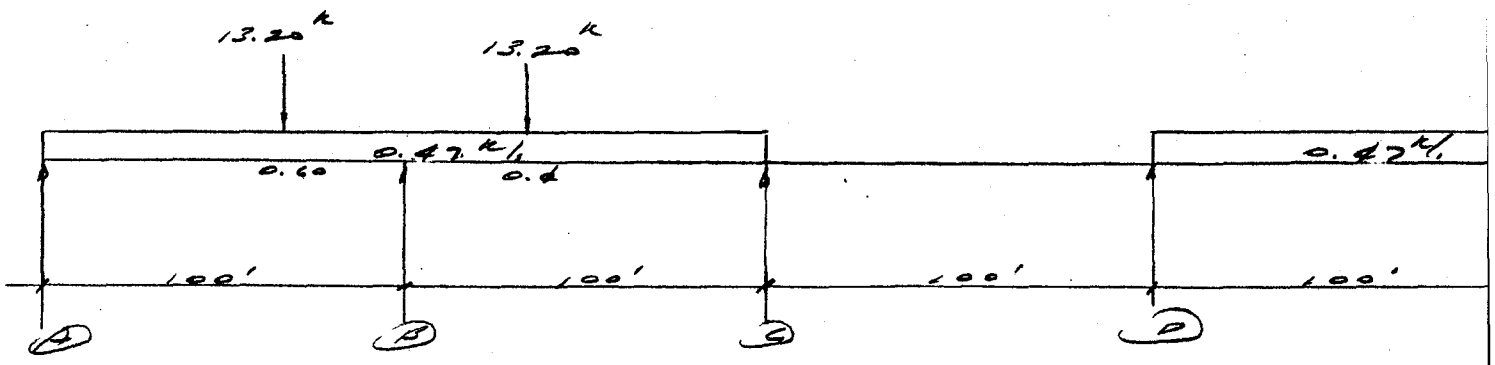


Mom. @ 0.5 pt.

P @ 0.50 = 0.1998
P @ 0.36 = 0.1583
0.150/4 P/4 @ 0.64 = 0.0325
0.3706 PL

Max (LL + I) (+) M = 0.3706 × 23.25 × 100' = 865.4'k ←

Max LL Neg. Mom



w ~ Span #1 Loaded = 0.0670
Span #2 Loaded = 0.0491
Span #4 Loaded = 0.0045
0.1206 × 0.47k/' × 100' = 56

Conc. P @ 0.6 = 0.1029
Conc. P @ 0.4 = 0.0789
0.1818 × 13.20k × 100' = 239
806.

Max

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SUBJECT 51st Ave Bridge @ Salt River
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6. Live Load Moments (Simple Span)

$L = 99'\text{-}6''$

$I = 1 + \frac{50}{99.5 + 125} = 1.22$

From AASHTO Appendix

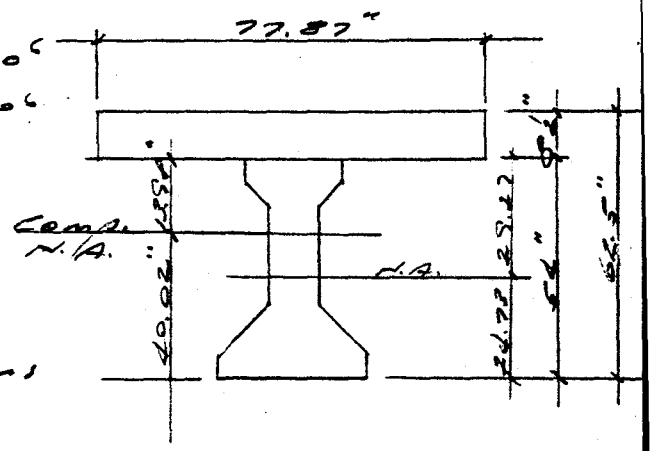
$M_{LL} = 1515.0'^k \times \frac{6.83'}{5.5} \times \frac{1}{2} = \underline{940.68'^k}$

$M_{LL+I} = 940.68'^k \times 1.22 = \underline{1147.63'^k}$

End Shear $V = 65.26^k \times 1.22 \times \frac{6.83}{5.5 \times 2} = \underline{49.44^k}$

7. Properties of Composite Section (Int.)

Slab - $f'_c = 4500$ #/□" $E = 4.066 \times 10^6$
Gird - $f'_c = 5000$ #/□" $E = 4.28 \times 10^6$



$\frac{E_G}{E_S} = \frac{4.28}{4.06} = 1.053$

$12t = 12 \times 8.5 = 102''$
c to $c = 6'\text{-}10'' = 82''$ ← Governs
$\frac{1}{4}L = \frac{99.5' \times 12}{4} = 298$

Equiv. width $= 82'' \times \frac{1}{1.053} = 77.87''$

	A	Y	AY	AY^2	I_o
Slab	661.9	33.52	22186.9	743,704	3,985
Gird	789.0	-	-	-	260,730
	1450.9				264,715
					+ 743,704
					1,008,419

$e = \frac{22186.9}{1450.9} = 15.29'' \times 22186.9 = (-)\ 339,237$

669,182 in⁴

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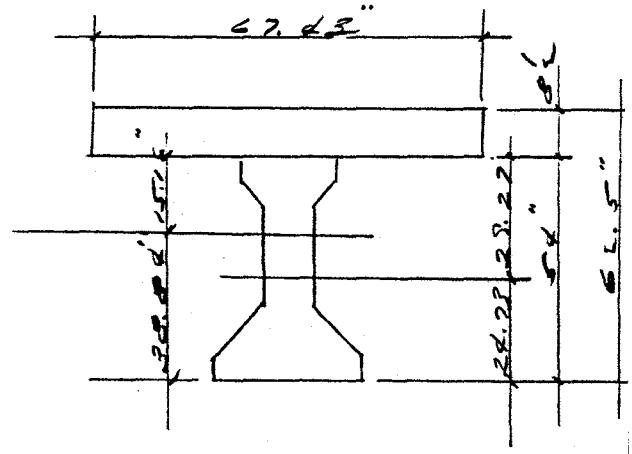
SUBJECT 51st Ave Bridge @ Salt River
SHEET NO. 15 OF
BY EMP DATE 8/16/7
JOB NO.

Properties of Composite Grid (Ext.)

slab $f'_c = 4500$ #/□" $E = 4.066 \times 10^6$
Grid $f'_c = 5000$ $E = 4.28 \times 10^6$



$\frac{E_G}{E_s} = \frac{4.28}{4.06} = 1.053$

12 t = 12 × 8.5 = 102

5'-11" = 71"

$\frac{1}{4}L = \frac{99.5' \times 12}{4} = 298$

Equiv. width = 71 × 1/1.053 = 67.43

	A	Y	AY	AY^2	I_o
slab	573	33.52	19212	643,992	3450
Grid	789				260,730
	1362				264,180
					643,992
					908,172

TV

$e = \frac{19212}{1362} = 14.11 \times 19212$ —— (−) 270,999
637,173 in⁴

slab $Y_t = 23.16$ $S_t = 27,511$ in³
Grid $Y_t = 15.16$ $S_t = 42,029$
Grid $Y_b = 38.84$ $S_b = 16,405$

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(Properties of composite section con't.)

Slab Y_t = 22.48" S_T = 29,768 in³
Gird Y_t = 13.98 S_T = 47,867
Gird Y_b = 40.02 S_B = 16,721

8. Homogeneous Section Stresses (Ext Girder)

		Top	Bott
Slab DL_T	778.41'k × 12000/8909 =	1048	-
Slab DL_B	- - /10543 =	-	887
Diaph DL_T	40.47'k × 12000/8909 =	55	-
Diaph DL_B	- - /10543 =	-	46
Gird DL_T	1079.1 × 12000/8909 =	1454	-
Gird DL_B	- /10543 =	-	1228
~~[illegible]~~	~~[illegible]~~	~~[illegible]~~	-
~~[illegible]~~	~~[illegible]~~	~~[illegible]~~	~~[illegible]~~
Conc. Barr. DL_T	622.5 × 12000/42029 =	177	-
Conc. Barr DL_B	- /16405 =	-	455
$(LL + I)_T$	866.50 × 12000/42021 =	247	-
$LL + I)_B$	- /16405 =		633
		2981	3249
	Allow. Tens.	212	212
		2769 #/□"	3037 #/□"

9. Determination of Prestress Force Req'd.

$$P_F = \frac{f_b A}{\frac{e y_b}{r^2} + 1} \qquad e = 24.73 - 5.5 = 19.23"$$

$$P_F = \frac{3037 \times 789}{\left(\frac{19.23 \times 24.73 \times 789}{260,730}\right) + 1} = 985.5^k$$

say 986^k

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(9. Det. of P.F. Con't.)

CR on P.F.

$$P.F. = \frac{M_{DL} + m_b M_{LL} - f_t' K_t A}{e + K_t}$$

$$m_b = \frac{I/c_b}{I'/c_b'} = \frac{260{,}730}{24.73} \Big/ \frac{632{,}173}{38.84} = 0.64$$

$\Sigma M_{DL} = 1897.9$ $\qquad K_t = I/Ay_t = \frac{260{,}730}{789 \times 29.27} = 11$

$M_{LL} + \text{comp DL} = 866.5^{'k} + 622.5 = 1489$

$$PF = \frac{(1897.9^{'k} + 0.64 \times 1489^{'k})12000 - 200 \times 11.29 \times 789}{19.23'' + 11.29}$$

$PF = 1056 - 986^k$

10. Calculation of Working Stress

$f_s = 270^k$

$f_c' = 5000\ \#/\square''$

Total Losses $\Delta f_s = SH + ES + CRc + CRs$ (friction loss excluded

11. Approx. Design Before Ckg. Losses

$u = 1.3D + 2.86(LL + I)$

$= 1.3 \times 2520.0^{'k} + 2.86 \times 866.5^{'k}$

$= 3276 + 2478$

$= 5754^{'k}$

$d = 54 - 5.5 - 5.5/2 = 45.75''$

$F_u = 5754^{'k} \times 12 / 45.75 = 1509.3^k$

$A_s = \frac{1509.3^{'k}}{270 \times 0.9} = 6.21^{\square''}$

No. of $\frac{1}{2}''\phi$ strands $= \frac{6.21^{\square''}}{0.153} = 40.6$ say $46 - \frac{1}{2}''\phi$

11. Prestress Loss

(a) SH = 17000 − 150 RH (RH = 40% for PHX)

= 17000 − 150 × 40

= 11,000 #/□"

For shrinkage after 28 days

SH = 11000 #/□" × .4 = 4400 #/□"

(b) Elastic Shortening

$E_s = \frac{E_s}{E_{ci}} f_{cir}$

$= \frac{28 \times 10^6}{3.83 \times 10^6} f_{cir} = 7.303 f_{cir}$

(c) Creep of Concrete

$CR_c = 12 f_{cir} - 7 f_{cds}$

(d) Relaxation of Prestressing Steel

$CR_c = 20{,}000 - 0.4 E_s - 0.2(SH + CR_c)$

$= 20{,}000 - 0.4 \times 7.303 f_{cir} - 0.2(4400 + 12 f_{cir} - 7 f_{cds})$

$= 19120 - 2.92 f_{cir} - 880 - 2.4 f_{cir} + 1.4 f_{cds}$

$= 19120 - 5.32 f_{cir} + 1.4 f_{cds}$

$\therefore \Delta f_s = 4400 + 7.303 f_{cir} + 12 f_{cir} - 7 f_{cds} + 19120 - 5.32 f_{cir} + 1.4 f_{cds}$

$= 23520 + 13.98 f_{cir} - 5.6 f_{cds}$

compute f_{cir} (using Trial strands = 48 − ½"φ)

$f_{cir} = \frac{F}{A} + \frac{Fe^2}{I} - \frac{M_n^{dl} e}{I}$

$M_n^{dl} = 822 \text{ #/'} \times 99.5^2/8 = 1017.3'^k$

$F = 48 \times 0.153 \times \underset{\text{assumed}}{0.63} \times 270 = 1249^k$

$f_{cir} = \frac{1249}{789} + \frac{1249 \times 19.23^2}{260{,}730} - \frac{1017.3'^k \times 12 \times 19.23}{260{,}730}$

$f_{cir} = 1583 + 1771 - 900 = 2454 \text{ #/□"}$

(Prestress Loss Con't.)

Ck for Assumed relaxation factor of 0.63. Assume strands released 18 Hours after stressing.

$f_{si} = 70\%$

Relax Loss = 3.5%

$.035 \times 0.70 \times 270{,}000 = 6615$ #/□"

$E_s = 7.303 f_{ci} = 7.303 \times 2315 = 16906$ #/□"

$f_s = 0.70 \times 270{,}000 - 6615 - 16906 = 165479$

$\frac{f_s}{f_s'} = \frac{165479}{270{,}000} = 0.61$ ok!

Compute f_{cds}:

$$f_{cds} = \frac{M_{DL}^s e}{I} + M_c^d\left[e + \frac{(y' - \bar{y})}{I'}\right]$$

$$= \frac{778.4^{'k} \times 12 \times 19.23}{260{,}730} + 724.8^{'k} \times 12\left[\frac{19.23 + (38.84 - 24.73)}{632{,}173}\right]$$

$= 0.6594$

Total P.S. Loss $= 23520 + 13.98 \times 2454 - 5.6 \times 1142$

$= 23{,}520 + 34306 - 6392$

$= \underline{51454}$ #/□"

$\therefore f_s = 0.70 \times 270{,}000 - 51454 = 137546$

$P_T = 986^k$

$A_s = \frac{986^k}{137.5^k/□"} = 7.17$ □"

No. of ½"φ strands $= \frac{7.17}{0.153} = 46.8$

use 48-½"φ strands.

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(Girder Design Con't.)

$K_b = \frac{260,730}{789 \times 24.73} = 13.36$

$P_f = 986^k$ $\quad P_i = 986^k \times \frac{0.7 \times 270}{137.5} = 1335.8^k$

$f_t = \frac{F_o}{A} - \left(\frac{F_o e - MG}{AK_b}\right) = (+)\frac{1336}{789} - \left(\frac{1336 \times 19.23 - 1078.1 \times 12}{789 \times 13.36}\right)$

$= (+)\,1693 - 1210 = 483^{\#/\square''}$

$f_b = \frac{1336}{789} + \left(\frac{1336 \times 19.23 - 1078.1 \times 12}{789 \times 13.36}\right)$

$= 1693 + 1210 = (+)\,2903^{\#/\square''}$

Properties of I-Beam Transformed:

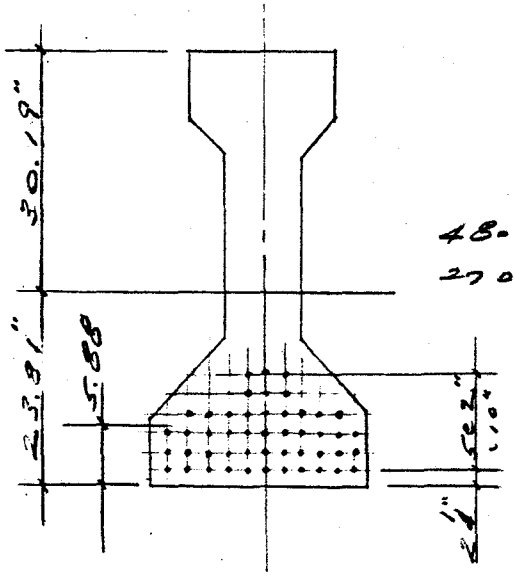
Steel Centroid -

$\bar{x} =$

11 × 2.25" =	24.75
11 × 4.25" =	46.75
11 × 6.25 =	68.75
9 × 8.25 =	74.25
3 × 10.25 =	30.75
3 × 12.25 =	36.75
	282.5 / 48 = 5.88

$A_s = 48 \times 0.153^{\square''} = 7.34^{\square''}$

$A = 7.34^{\#}(6.53 - 1) = 40.61^{\square''}$



48 - ½"φ
270k strand

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(Transformed Bm. Sec. Properties con't.)

	A	Y	AY	$A\bar{Y}^2$	I_o
Grid	789.0	-	-	-	260,730
Steel	40.6	18.85	765	14,426	-
	829.6				260,730
					14,426
					275,152

$e = \frac{765}{829.6} = 0.92 \times 765$ (-) 703

274,453 — I_o

$Y_b = 24.73 - 0.0.92 = 23.81$ $S_b = 274,453/23.81 = 11,526$ in

$Y_t = 29.27'' + 0.92 = 30.19$ $S_t = 274,453/30.19 = 9090$

$K_t = I/AY = 274,453/829.6 \times 30.19 = 10.96''$

$K_b = I/AY = 274,453/829.6 \times 23.81 = 13.89''$

Properties of composite section w/I-Bm Transformed

	A	Y	AY	$A\bar{Y}^2$	I_o
Grid T	829.6	-	-	-	274,453
Slab	573.0	33.52	19,206	643,817	3,450
	1402.6				277,903
					643,817
					921,720

$e = \frac{19206}{1402.6} = 13.69'' \times 19206$ (-) 262,990

658,730

Slab $Y_T = 24.08''$ $S_T = \frac{658,730}{24.08} = 27,355$ in^3

Grid $Y_T = 15.58''$ $S_T = \frac{658,730}{15.58} = 42,280$

Grid $Y_b = 38.42$ $S_b = \frac{658,730}{38.42} = 17,145$

$m_b = \frac{I/c_b}{I'/c_b'} = \frac{274,453}{23.81} / \frac{658,730}{38.42} = 0.67$ $m_t = \frac{274,453}{30.19} / \frac{658,730}{15.58} = 0.2$

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CK Homogenous Section Stresses

		Top	Bott.
Slab DL T	778.4'k x 12000/9090	1027	-
Slab DL B	- x 12000/11526	-	810
Diaph DL T	40.47 x 12000/9090	53	-
Diaph DL B	- x 12000/11526	-	42
Grid DL T	1079.1 x 12000/9090	1424	-
Grid DL B	- x 12000/11526	-	1123
~~[illegible]~~	~~[illegible] x 12000/[illegible]~~	~~[illegible]~~	-
~~[illegible]~~	~~[illegible]~~	~~[illegible]~~	~~[illegible]~~
Conc Barr. DL T	622.5 x 12000/42,280	176	-
Conc Barr DL B	- x 12000/17,145	-	435
(LL+I)T	866.50 x 12000/42,280	245	-
(LL+I)B	- x 12000/17,145	-	606
		2925 #/□"	3016 #/□"

Assumed f_{ci} = 4000 #/□"
Allow f_{ci} = $3(4000)^{1/2}$ = 189.74 #/□"

e = 23.84" - 5.88 = 17.93"

$$P_F = \left[\frac{(\overset{DL}{1897.9} + \overset{LL+I+Comp\,DL}{0.67 \times 1489})12000 - 189.74 \times 13.89 \times 829.6}{17.93 + 13.89}\right]$$

P_F = 1023^k

$A_s = \frac{1023^k}{137.4^k/□"} = 7.45^{□"}$

No. of Strands = $\frac{7.45^{□"}}{0.153}$ = 48.6 (48 - 1/2"φ strands - OK!

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Check Initial Stresses

$P_i = 1023^k \times \frac{189.74}{139.} = 1391^k$ ←

$f_t = \frac{P_i}{A} - \frac{P_i e}{S_t} + \frac{M_G}{S_t}$

$f_b = \frac{P_i}{A} + \frac{P_i e}{S_b} - \frac{M_G}{S_b}$

$f_t = \frac{1391}{829.6} - \frac{1391^k \times 17.93}{9090} + \frac{1079.1^{'k} \times 12}{9090}$

$f_t = 1677^{k/\square''} - 2744^{k/\square''} + 1425 = (+)\ 358^{\#/\square''}$ ok!

$f_b = \frac{1391}{829.6} + \frac{1391 \times 17.93}{11,526} - \frac{1079.1 \times 12}{11526}$

$f_b = 1677 + 2164 - 1123 = (+)\ 2718^{\#/\square''}$ ok!

Check Final Stresses (In Position)

Prestress Force:

$f_t = \frac{P_f}{A} - \frac{P_f e}{S_t} = \frac{1023}{829.6} - \frac{1023 \times 17.93}{9090} = 1233 - 2018 = (-)\ 785$

$f_b = \frac{P_f}{A} + \frac{P_f e}{S_b} = \frac{1023}{829.6} + \frac{1023 \times 17.93}{11526} = 1233 + 1591 = (+)\ 2824$

	Top	Bottom
Slab	(+) 1027	(-) 810
Diaph	(+) 53	(-) 42
Girder	(+) 1424	(-) 1123
~~Fut. Asphalt~~	~~(+)~~	~~(-)~~
Conc. Barriers	(+) 176	(-) 435
LLL I	(+) 245	(-) 606
Prestress	(-) 785	(+) 2824
	(+) 2140 #/□"	(-) 192 #/□"

Max Allow Tens. in precompressed zone:
$f_t = 6\sqrt{5000} = 424^{\#/\square''} > 192^{\#/\square''}$ ok!
Max $f_c = 0.4 f'_c$: Req'd $f'_c = \frac{2140}{0.4} = 5350^{\#/\square''}$
Transfer = 2718 = 4530 #/□" ≈ 4000 [illegible]

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CK Girder Design for ultimate Capacity

Assume Group IA: $u = \frac{1.3}{\phi}[D + 2.2(L + I)]$ $\phi = 1.0$ Flex. $\phi = 0.9$ shear

$M_u = A_s f_{su} d\left(1 - 0.6\frac{\rho f_{su}}{f'_c}\right)$

Eff. d

$d = 54'' + 8.0'' - 5.88'' = 56.12''$

$\rho = \frac{A_s}{bd} = \frac{48 \times 0.153}{80 \times 56.12} = 0.00164$

$f_{su} = f'_s\left(1 - 0.5\frac{\rho f'_s}{f'_c}\right)$

$= 270\left(1 - 0.5 \times \frac{0.00164 \times 270}{5.35}\right) = 258.82^{k/\square''}$

N.A. is outside Flg. if:

$t < \frac{1.4 d \rho f_{su}}{f'_c} = \frac{1.4 \times 56.12 \times 0.00164 \times 258.82}{5.35}$

$= 6.23 < 8.0''$ Avail.

$\therefore$ N.A. is inside Flange

$M_u = 1.3(2520 + 2.2 \times 866.50) = 5754.2^{'k}$

Allow. $M_u = 48 \times 0.153 \times 258.82 \times 56.12\left(1 - 0.6 \times \frac{0.00164 \times 258.82}{5.35}\right) \times 0.9$

$M_u = 91434.1^{''k}$ or $7619^{'k} > 5754.2^{'k}$ ok!

CK Stl. %

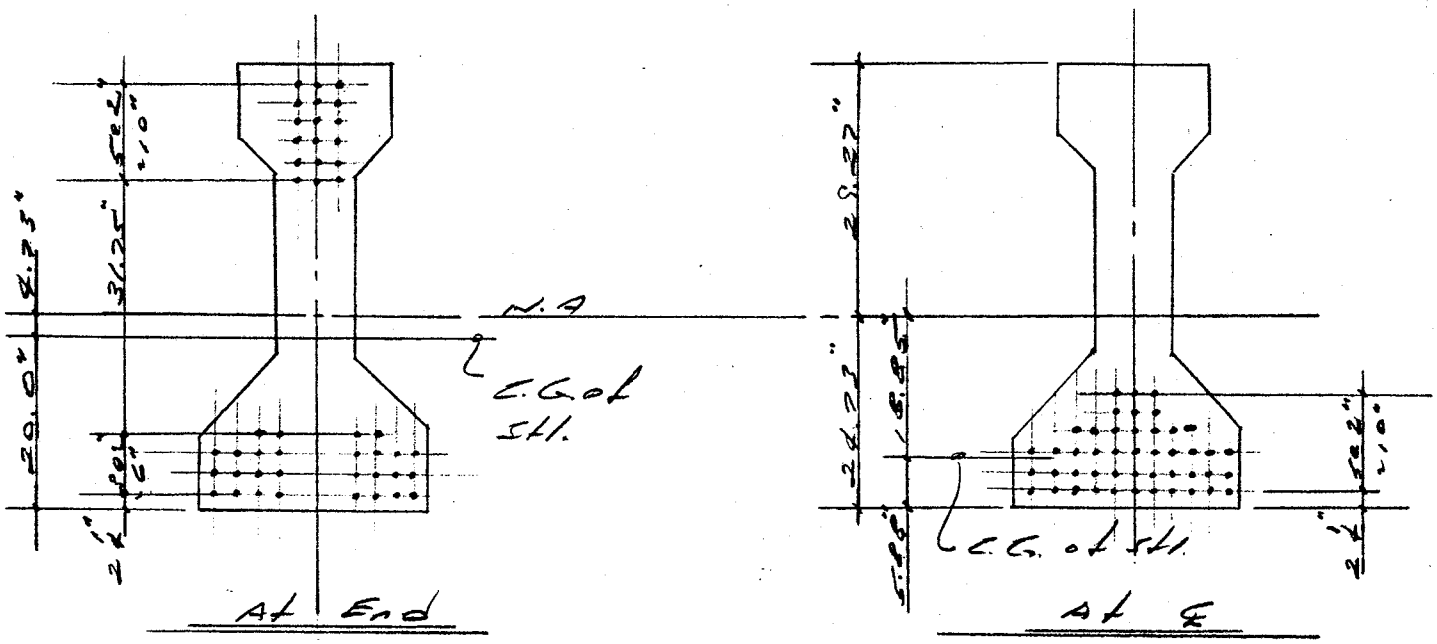
$\rho \frac{f_{su}}{f'_c} \leq 0.30$; $\rho \frac{f_{su}}{f'_c} = 0.00164 \times \frac{258.8}{5.35} = .079 < 0$ ok!

Req'd $A_s \geq 0.003 A_c$ @ Time of Transfer

$0.003 \times 789^{\square''} = 2.37^{\square''} < 48 \times 0.153 = 7.34^{\square''}$ ok!

(Girder Design Cont.)

Path of Prestressing Stl.



8 @ 2.25"	18.00"
8 @ 4.25	34.00
8 @ 6.25	50.00
6 @ 8.25	49.50
3 @ 50	150.00
3 @ 48	144.00
3 @ 46	138.00
3 @ 44	132.00
3 @ 42	126.00
3 @ 40	120.00
	961.00 / 48 = 20.0"

11 @ 2.25"	24.75
11 @ 4.25	46.75
11 @ 6.25	68.75
9 @ 8.25	74.25
3 @ 10.25	30.75
3 @ 12.25	36.75
	282.0

$\bar{x} = \frac{282.0}{48} = 5.88"$

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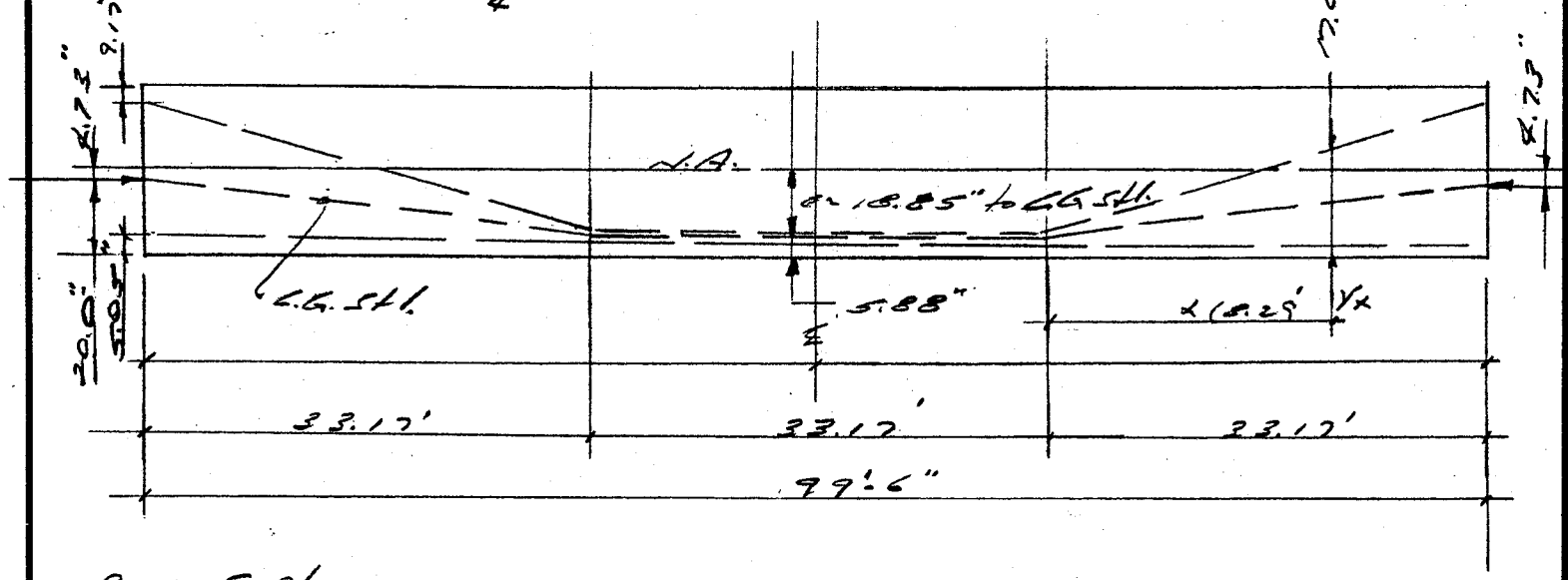
(Path of Prestressing Stl. con't.)

C.K. Girder @ 1/4 Pt.



@ .25 pt

$x = 33.17' - 24.88' = 8.29'$

$Y_x = 44.83" \times \frac{8.29'}{33.17} + 5.88 = 17.08"$

$x_o = \frac{1}{48 \times 0.153^{\square"}} \left[18 \times 0.153^{\square"} \times 16.97 + 30 \times 0.153^{\square"} \times 5.05" \right]$

$x_o = \frac{1}{7.34^{\square"}} \left[47.04 + 23.18 \right] = 9.57"$

$e_{1/4} = 24.73" - 9.57" = 15.16"$

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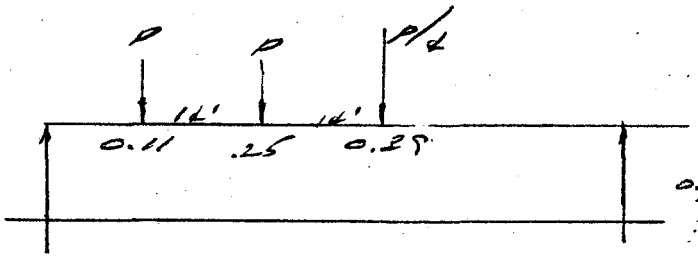
CLIENT:

CK. Design @ 1/4 Pt

LL @ 1/4 Pt.:



Mom. @ 0.25 Pt.

P @ 0.25 = 0.1469
P @ 0.11 = 0.0690
0.1251/4 P/4 @ 0.39 = 0.0313
0.2472

M @ 0.25 Pt = 0.2472 × 23.35^k × 100' = 577.2'^k

Homogeneous Section Stresses @ 1/4 Pt.

	Top	Bott.
Slab DL =	(+) 770	(-) 607
Diaph. DL =	(+) 40	(-) 32
Girder DL =	(+) 1068	(-) 842
Conc. Barriers =	(+) 132	(-) 326
LL + I =	(+) 163	(-) 403
	(+) 2173 #/□"	(-) 2210 #/□"

e = 15.16"

$\frac{eY_b}{r^2} + 1 = \frac{15.16 \times 24.73 \times 789}{260,730} + 1 = 2.13$

$P_f = \frac{f_b A_c}{\left(\frac{eY_b}{r^2} + 1\right)} = \frac{2210 \times 789}{2.13} = 818.6^k$

$P_i = P_f \times \frac{189.7}{139.4} = 1113.2^k$

$A_s = \frac{P_i}{189} = \frac{P_f}{139.4} = 5.89^{\square''}$ ok!

Ck. Stresses @ ¼ Pt.

1. Initial Stresses –

$P_i = 1113.2^k$

$f_t = \frac{P_i}{A} - \frac{P_i e}{S_t} + \frac{M_G}{S_t}$

$f_b = \frac{P_i}{A} + \frac{P_i e}{S_b} - \frac{M_G}{S_t}$

M_G @ ¼ pt:

$M_G = 1079.1^{'k} \times \frac{0.25 \times 0.75}{0.25}$

$M_G = 809.3^{'k}$

$f_t = \frac{1113.2}{789} - \frac{1113.2^k \times 15.16}{9090} + \frac{809.3^{'k} \times 12}{9090} = (+)623$ #/□"

$f_b = \frac{1113.2}{789} + \frac{1113.2^k \times 15.16}{11526} - \frac{809.3^{'k} \times 12}{11526} = (+)2032$ #/□"

< 2408 #/□"

ok.

2. Final Stresses –

$P_f = 816.6^k$

$f_t = \frac{P_f}{A} - \frac{P_f e}{S_t} = \frac{816.6}{789} - \frac{816.6^k \times 15.16}{9090} = (-)327$

$f_b = \frac{P_f}{A} + \frac{P_f e}{S_b} = \frac{816.6}{789} + \frac{816.6^k \times 15.16}{11526} = (+)2015$

		Top	Bott.
Slab	DL	(+) 770	(-) 607
Diaph.	DL	(+) 20	(-) 32
Grid	DL	(+) 1068	(-) 842
Conc. Barriers		(+) 132	(-) 326
LLI I		(+) 163	(-) 403
Prestress		(-) 327	(+) 2015
		(+) 1846 #/□"	(-) 95 #/□"

ok.

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CK. Girder for Shear

1. Dead Load Shears (Ext. Girder)

Max V_{DL} = 100.7^k (See Pg. #8)

DL Shear @ ¼ Pt.:

$V = 100.7^k - 1.69^{k/'} \times 24.90' = 58.6^k$

2. LL Shear for Continuous Section (Ext. Girder)

Truck Ldg. = $16^k \times \frac{6.83}{4 + 6.83/4} \times 1.22 = 23.35^k$

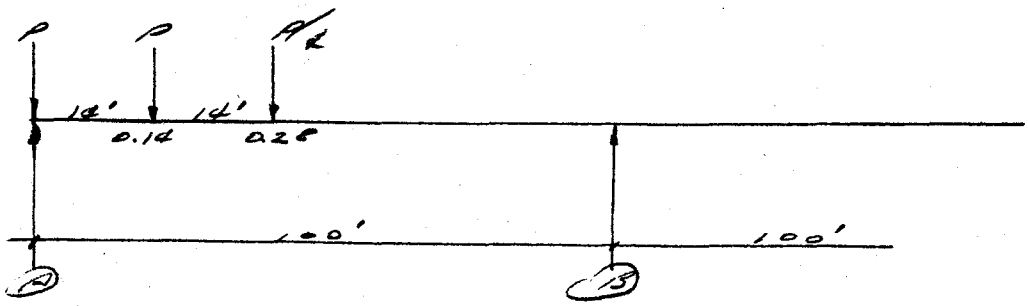
Lane Ldg. = $0.64^{k/'} \times \frac{6.83}{2[4 + 0.25 \times 6.83]} 1.22 = 0.47^{k/'}$

Lane Ldg. = $18^k \times$ — — = 13.2^k

Lane Ldg = 26^k — — = 19.0^k

3. LL Shear @ Expansion End:

@ Truck Ldg.



M @ B –

P @ 0.14 = 0.03546

$\frac{.06876}{4} \cdot P/4$ @ 0.28 = 0.01719

0.05265

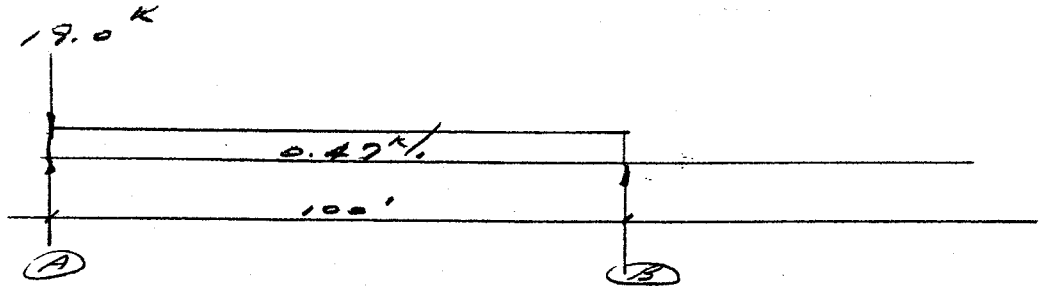
Mom @ B = $0.0526 \times 23.35^k \times 100' = 122.8'^k$

(LL shear con't @ Exp. End. con't.)

LL shear @ Exp. End. — 1.000 P
0.860
0.72 = 0.180
2.040 × 23.25^k = 47.63^k

ΔM/L = 122.8'^k / 100' = (−) 1.23 / 46.40^k

(b) Load LL shear @ Exp. End.



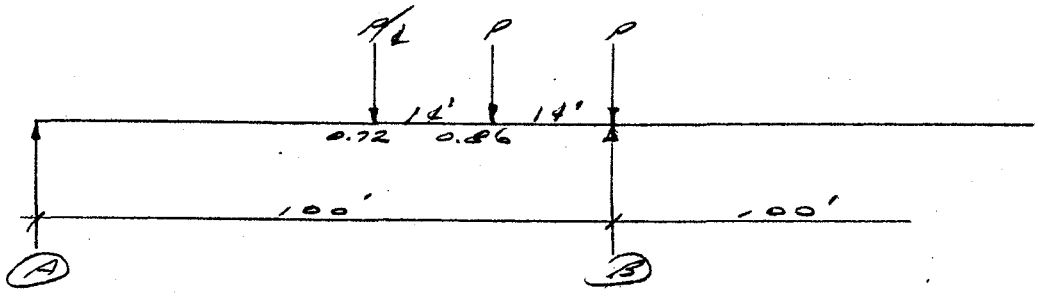
LL Mom @ B: — M = 0.47^k/' × 0.1071 × 100^2 = 503.4'^k

V @ A = 0.47^k/' × 100'/2 = 23.5^k
+ 19.0
42.5^k

(−) ΔM/L = 503.4'^k / 100 = (−) 5.0 / 37.5^k

4. LL shear @ Fixed End.

(a) Truck Ldg.



Mom @ B:

$P @ 0.86 = 0.0574$

$\frac{.0919}{4}$ $P/4 @ 0.72 = \underline{0.0230}$

0.0804

Mom @ B = $.0804 \times 23.35^k \times 100' = 187.7'^k$

LL shear @ Fixed End – $1.000 P$

0.860

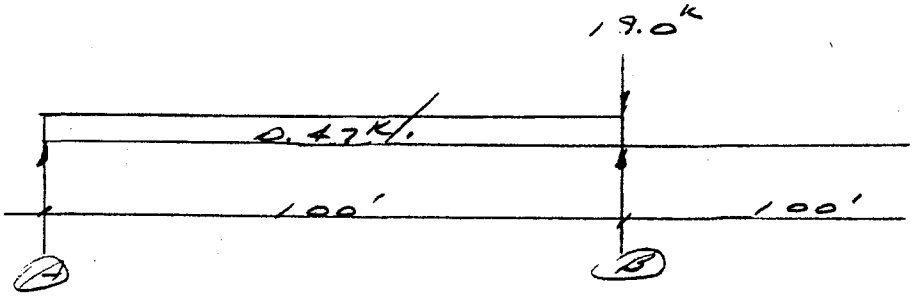
$\frac{0.72}{4}$ — $= \underline{0.180}$

$2.040 \times 23.35 = 47.6$

$\Delta M/L = 187.7'^k/100 = \underline{1.8}$

49.5

(b) Lane Ldg.



LL Mom @ B = $0.47^k/' \times 0.1071 \times 100^2 = 503.4'^k$

V @ B = $0.47^k/' \times 100'/2 = 23.50$

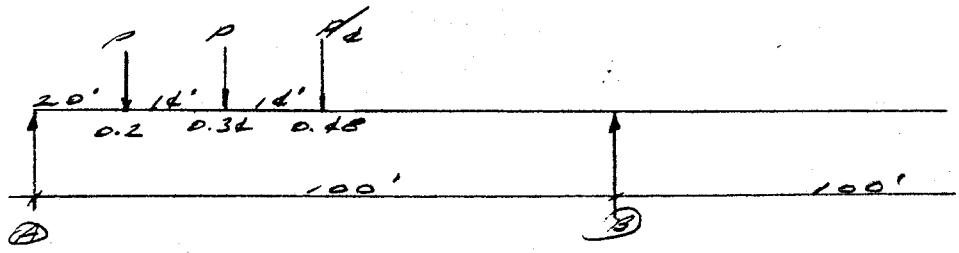
$\Delta M/L = 503.4/100 = 5.03$

$+ 19.00$

47.53^k

Max End LL Shear = 49.50^k
DL shear = 100.70
150.20^k ←

5. LL shears @ pts. + DL
(a) LL V @ 0.20



Mom @ B:

P @ 0.20 = .051^k
P @ 0.34 = .079^k
.09832 / 4, P/4 @ 0.48 = .024^k
0.1558 × 23.35^k × 100' = 363.6$^{'k}$

V @ (A) w/ Loads @ 0.2 pt.

∴ RA = 0.800
0.660
P/2 = 0.120
1.590 × 23.35^k = 37.13^k
ΔM/L = 363.6$^{'k}$/100' = (4) 3.63
40.76^k ← LL V

DL = 100.7^k − 2.0^k/' × 20' 60.70 ← DL V
101.46 ← TL V

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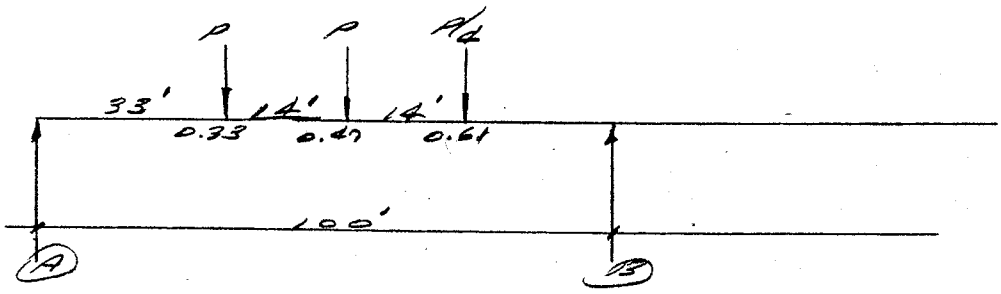
(b) LL V @ 1/3 pt:



Mom @ B:

P @ 0.33 = 0.07817
P @ 0.47 = 0.09728
P/4 @ 0.61 = 0.02560
0.20105 × 23.35^k × 100' = 469.4'

0.1022/4 —

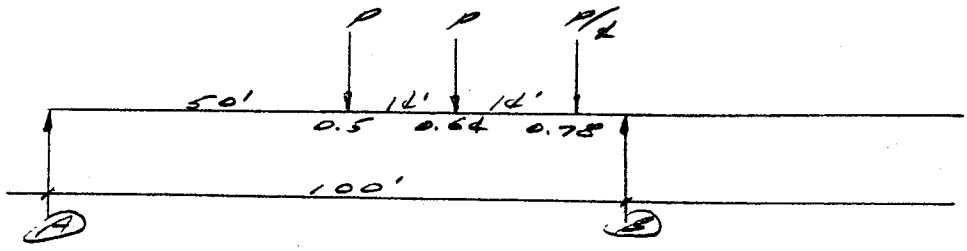
R_A = 0.670
= 0.530

0.61/4 — = 0.153
1.353 × 23.35 = 31.59^k

ΔM/L = 469.4'^k/100 = 4.69
36.90^k ← LL V

DL = 100.7^k − 2.0^k/' × 33' = 34.70 ← DL V
71.60^k ← ΣTL V

(c) LL V @ 1/2 pt:



Mom @ B:

P @ 0.5 = 0.1004
0.64 = 0.1000
P/4 @ 0.78 = 0.0202
0.2206 × 23.35^k × 100' = 515.1'^k

0.0808/4 —

R_A = 0.50
= 0.36
P/4 — = 0.08
0.94 × 23.35^k = 21.95^k

ΔM/L = 515.1'^k/100 = 5.15
26.10^k ← LL V

0 ← DL V
26.10^k ← ΣTL V

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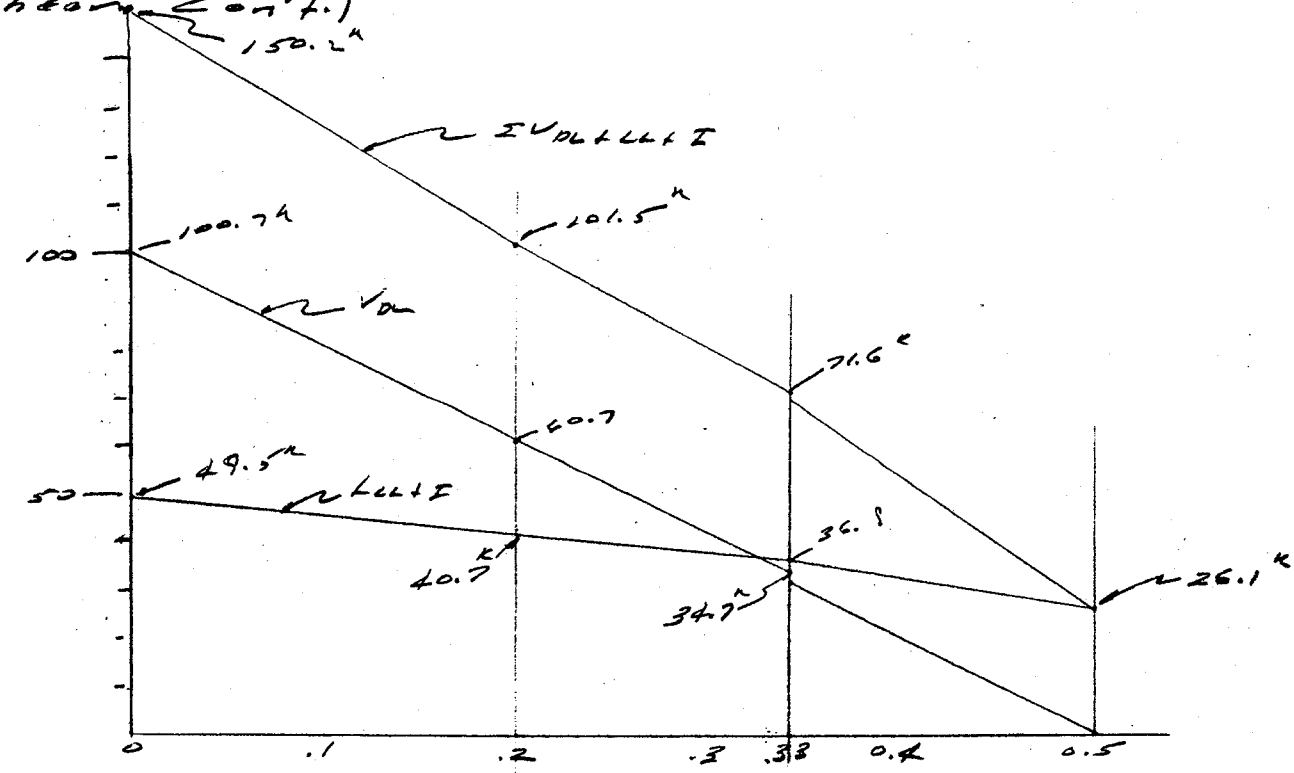
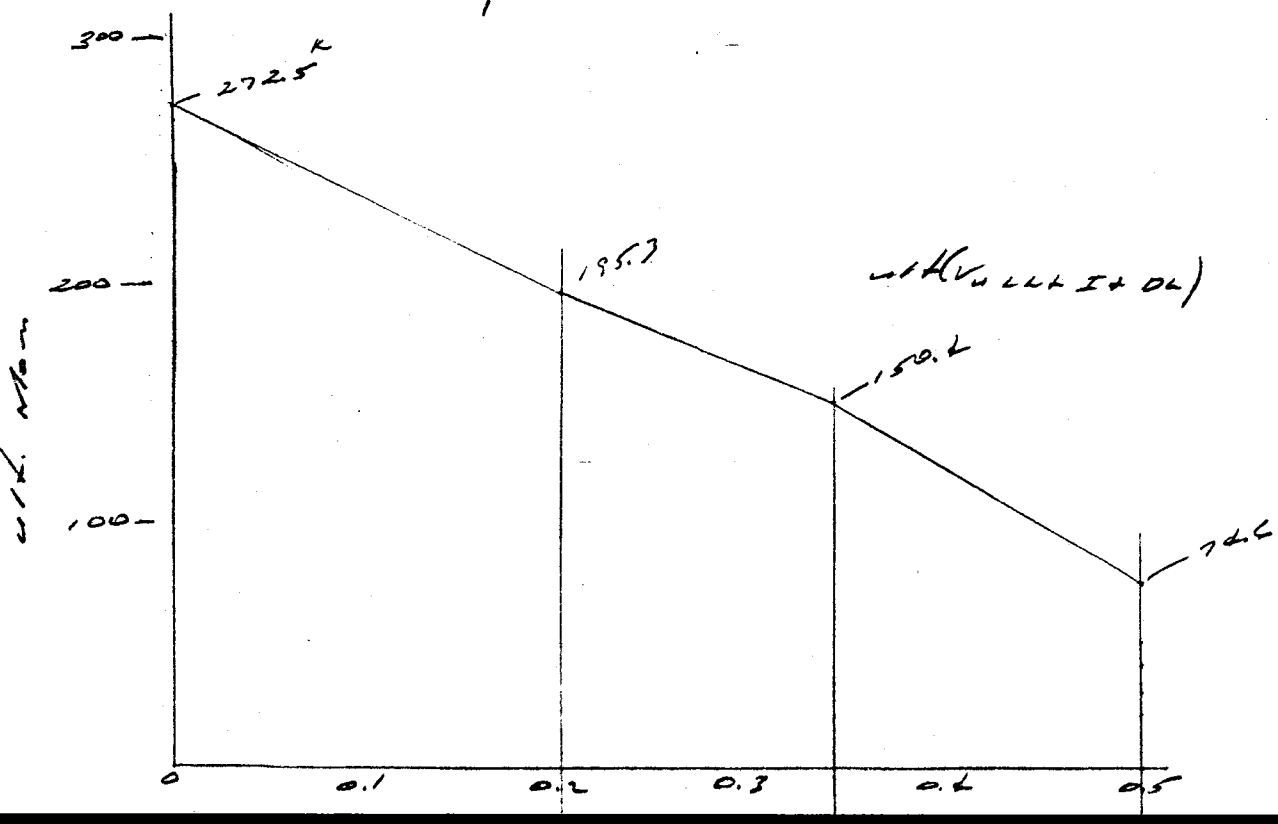
(Shear Con't.)



Shear carried by Conc. @ ℄ = 180#/□" × 8" × 7/8 × (54" − 5.66) = 60

Shear carried by Conc. @ Ends = 180#/□" × 8 × 7/8 × (54 − 19.1) = 43.9

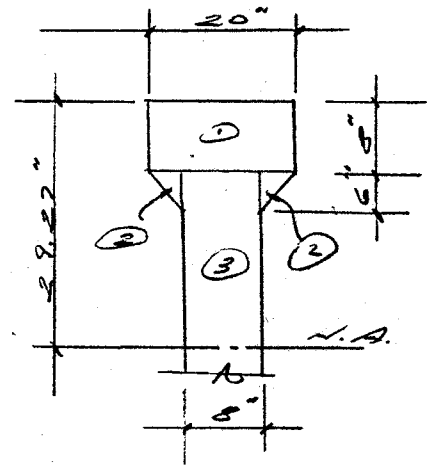


(Girder Design Con't.)

Section Properties For Tensile stress @ N.A.

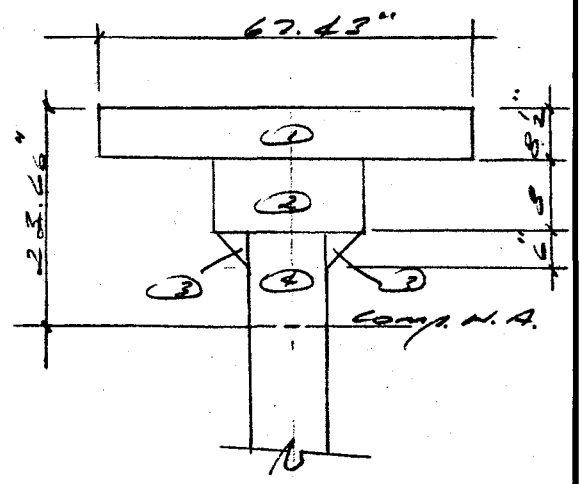
1. At Girder N.A

Sect.	A	Y	AY
1	160.0"	25.27"	4042.2
2	36	19.27	693.7
3	170.2	10.64	1810.9
	366.2"		6547.8
	A_G		Q_G



2. At Composite N.A.

Sect	A	Y	AY
1	573.0"	19.41	11126
2	160.0	11.16	1785
3	36.0	5.16	186
4	61.3	2.83	173
	830.3		13266
	A_G		Q_c



Tensile Shear stresses

Tendon to Horiz, $\alpha = \tan^{-1}\left(\frac{e_2 - e_1}{33.75 \times 12}\right)$

$= \tan^{-1}\left(\frac{18.85 - 4.72}{398.0}\right) = 2.08°$ Low

Neglect uplift force due to Prestress to Reduce V

(Shear for Girder Cont.)

For Tensile stress $V_c = .03\sqrt{f'_c} \times b'jd$

$V_c = .03 \times 5350 \times 8 \times 7/8 \times d$

$V_c = 1123.5\,d$ (psi)

@ ℄ $V_c = 1123.5(54" - 5.18") = \underline{54.1^k}$

@ Ends $V_c = 1123.5(54" - 20.0") = \underline{38.2^k}$

1. Ck. shear @ 1.5d from support

$1.5d = 1.5 \times 54"/12 = 6.75'$

V_{DL} @ 6.75' $= 100.7^k - 2.00^{k/'} \times 6.75' = 87.20^k$

$v_{DL} = \frac{V_{DL} Q_G}{I b} = \frac{87{,}200 \times 6547.8}{260{,}720 \times 8} = \underline{273.7^{\#/\square"}}$

V_{LL} @ 6.75' $= \frac{49.5^k}{33'} 26.9[33' - 6.75'] + 26.9 = 46.9^k$

$v_{LL} = \frac{V_{LL} Q_c}{I b} = \frac{46{,}900 \times 13{,}266}{260{,}720 \times 8} = \underline{298.2^{\#/\square"}}$

$v_{DL+LL+I} = 273.7 + 298.2 = 572.0^{\#/\square"}$

At $x = 6.75'$

$x' = 33.17' - 6.75' = 26.42'$

$y_x = \frac{44.83x}{33.17} + 5.88 = \frac{44.83 \times 26.42}{33.17} + 5.88 = 41.59"$

$x_0 = \frac{1}{48 \times 0.153}[18 \times 0.153 \times 41.48 + 20 \times 0.153 \times 5.05]$

$x_0 = \frac{1}{7.34}[114.24 + 23.18] = 19.15"$

$e = 24.73 - 18.72 = 6.01$

$P_{working} = 1023^k$

$M_{working} = 1023^k \times 6.01 = 6148^{"k}$

(Shear for Girder Con't.)

M_{DL} @ 6.75' from supt

$M_{DL\,\mathbb{E}} = 100.7^k \times \frac{99.5'}{2} - 2.0^k \times \frac{49.75^2}{2} - 2.75^k \times 16.6'$

$= 5009.8'^k - 2475.1'^k - 45.6'^k = 2489'^k$

M_c 6.75' $= \frac{.0678 \times 0.932}{0.25} \times 2489.0'^k = 628.1'^k$

$f_{DL} = \frac{Mc}{I} = \frac{628.1'^k \times 12}{260,730} \times 6.79$

$f_{DL} = 196.6\ \#/\square''$

$f_c = \frac{P}{A} - \frac{Mc}{I} + f_{DL}$

$f_c = \frac{1023}{789} - \frac{6148'^k \times 6.79}{260,730} + 0.196$

$f_c = 1.297 - .160 + 0.196 = 1334\ \#/\square''$

$S_t = \sqrt{v^2 + \left(\frac{f_c}{2}\right)^2} - f_c/2$

$S_t = \left[\left(5720^2 + \left(\frac{1334}{2}\right)^2\right]^{1/2} - \frac{1334}{2}$

$S_t = 879 - 667 = 213\ \#/\square''$

For #5 stirrups

$S = \frac{A_s f}{S_t b} = \frac{0.62 \times 20,000}{213 \times 8} = 7.2''$ (use 6")

2. Ck. shear @ 0.25L

$V_{DL} = 100.7^k - 2.0^{k/'} \times 24.88' = 50.9^k$

$v_{DL} = \frac{50,900 \times 6547.8}{260,730 \times 8} = 159.8\ \#/\square''$

V_{LL} @ 0.25L $= \frac{49.5 - 36.9}{33}(33' - 24.88) + 36.9 = 40.0^k$

24.88

$\sigma_{LL} = \frac{40000 \times 18.266}{260,730 \times 8} = 25.4$ #/□"

$\sigma_{TL} = 51 + 25.4 = 305$ #/□"

At $x = 24.88'$

$x' = 33.17' - 24.88' = 8.29'$

$y_x = \frac{44.83}{33.17} x + 5.88 = \frac{44.83}{33.17} \times 8.29 + 5.88 = 17.03"$

$x_0 = \frac{1}{48 \times 0.153} \left[18 \times 0.153 \times 17.07 + 30 \times 0.153 \times 5.05" \right] = 9.57"$ (47.01, 23.18)

$e = 24.73" - 9.57" = 15.16"$

$f_c = \frac{1023^k}{789} - \frac{1023^k \times 15.16" \times 6.79}{260,730} + 160$

$f_c = 1.297 - 0.400 + 0.160 = 1056$ #/□"

$S_t = \left[\overline{305}^2 + \left(\frac{1056}{2}\right)^2 \right]^{\frac{1}{2}} - \frac{1056}{2}$

$S_t = (93,025 + 278,784)^{\frac{1}{2}} - 528$

$S_t = 610 - 528 = 84$ #/□"

$S = \frac{0.62 \times 20,000}{84 \times 8} = 18.5"$ use 12"

3. LK shear @ 0.5L

$V_{DL} = 0$

$V_{LL+I} = 26.1^k$

$\sigma_{LL} = \frac{26.1}{40} \times 267 = 174$ #/□"

$e = 18.85"$

$P = 1023^k$

$f_c = \frac{1023}{789} - \frac{1023^k \times 18.85 \times 6.79}{260,730} + \frac{248.9^k \times 12 \times 6.79}{260,730}$

$f_c = 1.297 - 0.482 + 0.778 = 1573$ #/□"

$S_t = \left[\overline{174}^2 + \overline{786}^2 \right]^{\frac{1}{2}} - 786$

$S_t = 805 - 786 = 20$ #/□"

$S = 0.62 \times 20,000 / 20 \times 8 = 77"$ use Min.

ck ult. shear @ pts:

1. @ 1.5d = 6.75'

$U = 1.3[D + 2.2(LL + I)]$

$V_u = 1.3[87.20^k + 2.2 \times 46.90] = 247.5^k$ ✓

$V_c = 180\, b'jd = 180 \times 8'' \times \frac{7}{8} \times (54 - 16.96) = 44.15^k$

For #5 stirrups

$S = \frac{2 A_v f_v' d}{V_u - V_c} = \frac{2 \times 0.62 \times 40{,}000 \times (54 - 18.65)}{247{,}500 - 44{,}150}$

$S = 8.55''$ (use 6") ✓

ck. ult. Tensile stresses:

$V_u = \frac{247{,}500^{\#}}{8 \times 34.9} = 886\ \#/''$

$f_c = 1334\ \#/''$

$St_u = \left[886^2 + \left(\frac{1334}{2}\right)^2\right]^{\frac{1}{2}} = 666$

$St_u = 1108 - 666 = 442\ \#/''$

$S = \frac{A_v f_v'}{St_u} = \frac{0.62 \times 40{,}000}{442 \times 8} = 7.01''$ (6" OK)

2. @ 0.25L or 24.88'

$U = 1.3[D + 2.2(LL + I)]$

$U = 1.3[50.9 + 2.2(40.0)] = 189.6^k$

$V_c = 180\, b'jd = 180 \times 8 \times \frac{7}{8} \times (54 - 9.59) = 55.95^k$

$S = \frac{2 A_v f_v' d}{V_u - V_c} = \frac{2 \times 0.62 \times 40{,}000 \times (54 - 9.59)}{189{,}600 - 55{,}950}$

$S = 17.67''$ (use 12" OK)

ck ult. Tensile stresses @ ½ pk. –

$v_u = \frac{180,600}{8 \times 44.4} = 509\ \#/\square''$

$f_c = 1056\ \#/\square''$

$st_u = \left[509^2 + \left(\frac{1056}{2}\right)^2\right]^{1/2} - \frac{1056}{2}$

$st_u = 773 - 528 = 205\ \#/\square''$

$S = \frac{0.62 \times 40,000}{205 \times 8} = 15.1'' \text{ (12" used ok!)}$

3. ult shear @ E

$u = 1.3[D + 2.2(LL + I)]$

$u = 1.3[D + 2.2 \times 26.1^k] = 74.6^k$

$V_c = 180\ b'jd = 180 \times 6 \times 8'' \times (54 - 5.88) = 60.63^k$

$S = \frac{2 \times 0.62 \times 40,000 \times (54 - 5.88)}{74600 - 60,630} = 170''$ use min

ck. ult tensile stresses @ E:

$v_u = \frac{60,910}{8 \times 48.3} = 157.6\ \#/\square''$

$f_c = 1574\ \#/\square''$

$st_u = \left[158^2 + \left(\frac{1574}{2}\right)^2\right] - \frac{1574}{2}$

$st_u = 802 - 787 = 16\ \#/\square''$

$S = \frac{0.62 \times 40,000}{16 \times 8} = 193''$ use min

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SUBJECT "51st Ave Bridge
SHEET NO. 41 OF
BY EMP DATE 4/17/8
JOB NO.

DEFLECTION CONTROLLED BY HS20-44 LOADING (Interior)
COMPUTED CAMER @ REF. POINTS (INCHES)

POINT	DIST., FT TO L.END	AT RELEASE	PRIOR TO ERECTION	AT ERECTION DL + 0%LL	LONG TIME, DL + 0%PERM.LL	LONG TIME, + 0%PERM + 100%INST
1	0.000	0.000	0.000	0.000	0.000	0.000
2	4.975	0.297	0.463	0.209	0.155	0.063
3	9.950	0.574	0.893	0.392	0.279	0.097
4	14.925	0.828	1.288	0.554	0.381	0.113
5	19.900	1.058	1.644	0.696	0.466	0.118
6	24.875	1.259	1.956	0.819	0.537	0.116
7	29.850	1.428	2.218	0.920	0.594	0.110
8	34.825	1.561	2.423	0.996	0.632	0.097
9	39.800	1.654	2.567	1.046	0.653	0.080
10	44.775	1.709	2.652	1.074	0.663	0.066
11	49.750	1.728	2.680	1.083	0.666	0.060
12	54.725	1.709	2.652	1.074	0.663	0.065
13	59.700	1.654	2.567	1.047	0.654	0.080
14	64.675	1.561	2.423	0.996	0.632	0.097
15	69.650	1.428	2.218	0.920	0.594	0.110
16	74.625	1.259	1.956	0.819	0.537	0.117
17	79.600	1.058	1.644	0.696	0.466	0.118
18	84.575	0.828	1.288	0.554	0.381	0.113
19	89.550	0.574	0.893	0.392	0.279	0.098
20	94.525	0.297	0.463	0.209	0.155	0.063
21	99.500	0.000	0.000	0.000	0.000	0.000

SUSTAINED % LIVE LOAD= 0

DEFLECTION CONTROLLED BY HS20-44 LOADING (Exterior)
COMPUTED CAMBER @ REF. POINTS (INCHES)

POINT	DIST., FT TO L.END	AT RELEASE	PRIOR TO ERECTION	AT ERECTION DL + 0%LL	LONG TIME, DL + 0%PERM.LL	LONG TIME, + 0%PERM + 100%INST
1	0.000	0.000	0.000	0.000	0.000	0.000
2	4.975	0.297	0.463	0.198	0.136	0.040
3	9.950	0.574	0.893	0.371	0.242	0.051
4	14.925	0.828	1.288	0.523	0.327	0.045
5	19.900	1.058	1.644	0.657	0.397	0.031
6	24.875	1.259	1.956	0.772	0.454	0.012
7	29.850	1.428	2.218	0.866	0.499	-0.009
8	34.825	1.561	2.423	0.937	0.529	-0.034
9	39.800	1.654	2.567	0.984	0.543	-0.060
10	44.775	1.709	2.652	1.009	0.549	-0.079
11	49.750	1.728	2.680	1.017	0.550	-0.086
12	54.725	1.709	2.652	1.009	0.549	-0.079
13	59.700	1.654	2.567	0.984	0.543	-0.060
14	64.675	1.561	2.423	0.937	0.529	-0.034
15	69.650	1.428	2.218	0.866	0.499	-0.009
16	74.625	1.259	1.956	0.772	0.454	0.013
17	79.600	1.058	1.644	0.657	0.397	0.031
18	84.575	0.828	1.288	0.523	0.327	0.046
19	89.550	0.574	0.893	0.371	0.242	0.051
20	94.525	0.297	0.463	0.198	0.136	0.040
21	99.500	0.000	0.000	0.000	0.000	0.000

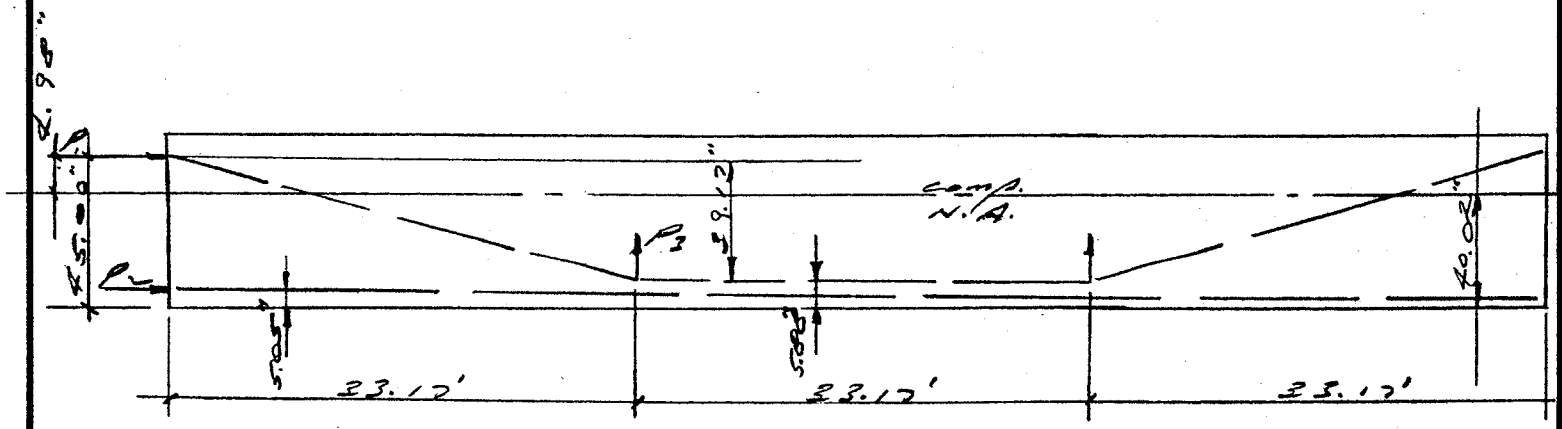
SUSTAINED % LIVE LOAD= 0

Positive Mom. @ Piers due to continuity

Ref. PCA Eng. Bulletin

$P_1 = 18 \times 19.6^k = 352.8^k$

$P_2 = 30 \times 19.6^k = 588.0^k$



$P_3 = 352.8^k \times \frac{39.12''}{33.17' \times 12} = 34.67^k$ ✓

$(P/S\ slope) = \frac{P_1 d_1 L}{2EI} - \frac{P_2 d_2 L}{2EI} - \frac{P_3 L_1^2}{2EI} - \frac{P_3 L_1 L_2}{2EI}$

$\frac{P_1 d_1 L}{2EI} = 352.8^k \times 4.98'' \times 99.5' \times 12/2 = (+)\ 1{,}048{,}896\ ''^k$

$-\frac{P_2 d_2 L}{2EI} = -588.0^k \times 34.97'' \times 99.5' \times 12/2 = (-)\ 12{,}275{,}728$

$-\frac{P_3 L_1^2}{2EI} = -34.67^k \times 398^2/2 = (-)\ 2{,}745{,}933$

$-\frac{P_3 L_1 L_2}{2EI} = -34.67^k \times 398 \times 398/2 = (-)\ 2{,}745{,}933$

$[P/S\ slope]$ —— $= (-)\ \frac{16{,}718{,}698\ ''}{EI}$

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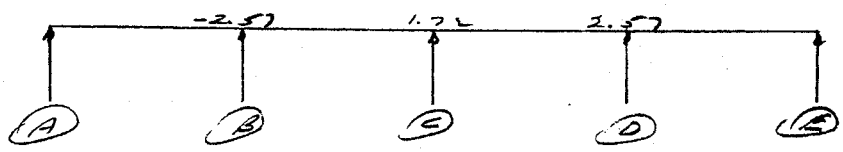
SUBJECT 51st Ave Bridge SHEET NO 43 OF
BY EMP DATE 1/4/80
JOB NO

4 Span Cond.



At B = $(-)\frac{2.57\,EI}{99.5' \times 12}\left[\frac{-16,718,699}{EI}\right]$ = 35,985 "k or 2998 'k

At C = $-\frac{1.72\,EI}{99.5' \times 12}\left[\frac{-16,718,699}{EI}\right]$ = 24,084 "k or 2006 'k

D.L. Creep Restraint Moments (not Adjusted by creep factor)
Assume Continuity Connection made 28 days After prestress Release.
Exposure @ 40% Relative Humidity, and ultimate Skrinkage = 0.0006 in/in.

$\epsilon_s = 0.0006''/'' \times 40\% \times 1.1 = 0.00026$ in/in

$M_s = \epsilon_s E_b A_b \left(e_2 + \frac{t}{2}\right)$

$M_s = 0.00026 \times 3.8 \times 10^6 \times 77.87'' \times 8.5\left(13.98'' + \frac{8.50''}{2}\right)$

$M_s = 11,921,550$ "k or 994 'k

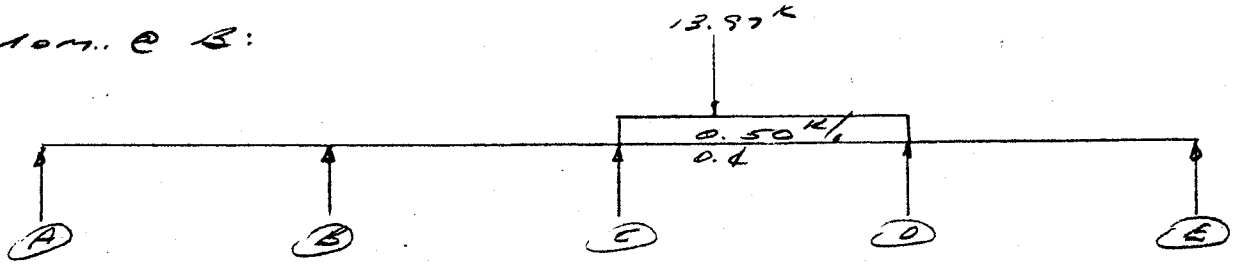
Final Elastic Skrinkage Restraint Moms:

@ B = -1.286×994 'k = (-) 1278.3 'k ←

@ C = -0.857×994 'k = (-) 851.8 'k ←

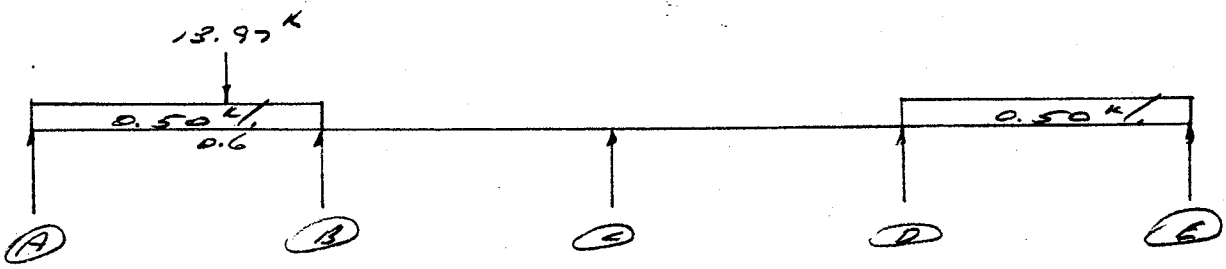
LL. Pos Moms @ Piers

Pos Mom. @ B:



w (span #3) = .0136 × 0.50^k/' × 100^2 = 67.0^'k
Pe 0.6 = .0217 × 13.97^k × 100 = 29.9
96.9^'k ←

Pos Mom @ C:



Pe 0.6 = .0277 × 13.97^k × 100' = 38.3^'k
w = .0179 × 2 × 0.50^k/' × 100^2 = 179.0
217.3^'k ←

For Elastic Modulus Release @ strand = 3.8×10^6 psi
Creep @ 20 years = 0.4×10^-6 in/in/psi
For Release @ 28 Hrs
1.8 × 0.40×10^-6 = 0.72×10^-6
Vol/Surface correction for Type IV AASHTO Girder
1.16 × 0.72×10^-6 = 0.84×10^-6
At 28 days 40% of Creep Has occurred
Leaving 60%
∴ 0.6 × 0.84×10^-6 = 0.50×10^-6

(Pos. Mom. @ Piers Cont'd.)

$\phi = \epsilon_c/\epsilon_e$ @ 28 days

$\therefore \phi = \epsilon_c/\epsilon_e = \epsilon_c \times E = 0.5\times10^{-4} \times 4.0\times10^{6} = 2.0$

$(1-e^{-\phi}) = 0.87$

$\left(\frac{1-e^{-\phi}}{\phi}\right) = 0.43$

Σ of Pos Restraint Moms. @ Piers

Shrinkage plus Creep:

@ B = $(2998 - 2183\times0.66)\times0.87 - 1278\times.43 = 426^{'k}$

@ C = $(2006 - 2183\times0.572)\times0.87 - 852\times.43 = 292^{'k}$

Add LL+I

@ B = $426^{'k} + 97^{'k} = 523^{'k}$ — Max

@ C = $292^{'k} + 217^{'k} = 509^{'k}$

For Ult Grade of Stl. (ult. Design)

$M_u = 1.3[DL + 2.2(L+I)]$

@ B $M_u = 1.3[426 + 2.2\times97] = 881.6$

@ C $M_u = 1.3[292 + 2.2\times217] = 1000^{'k}$

For $b = 26''$ $d = 51''$ $F = \frac{bd^2}{12000}$

$F = \frac{26\times51^2}{12000} = 5.64$

For $f'_c = 5000^{\#/\square''}$ $f_{stl} = 60{,}000^{\#/\square''}$

$K_u = \frac{1000}{5.64} = 177$ $A_u = 4.13$

$A_s = \frac{1000}{4.13\times51} = 4.75''$

For #7 Bars $A_s = \frac{4.75''}{0.6} = 7.91$ use 8-#7 ϕ

(Pos. Mom. Cont'd.)

using Prestress cables

$A_s = \frac{1000^k}{270^{ksi} \times 0.9} = 4.12$ wires

Extend min of 5 strands for Pos. Mom Conn.

Neg. Mom. Reinf over Piers

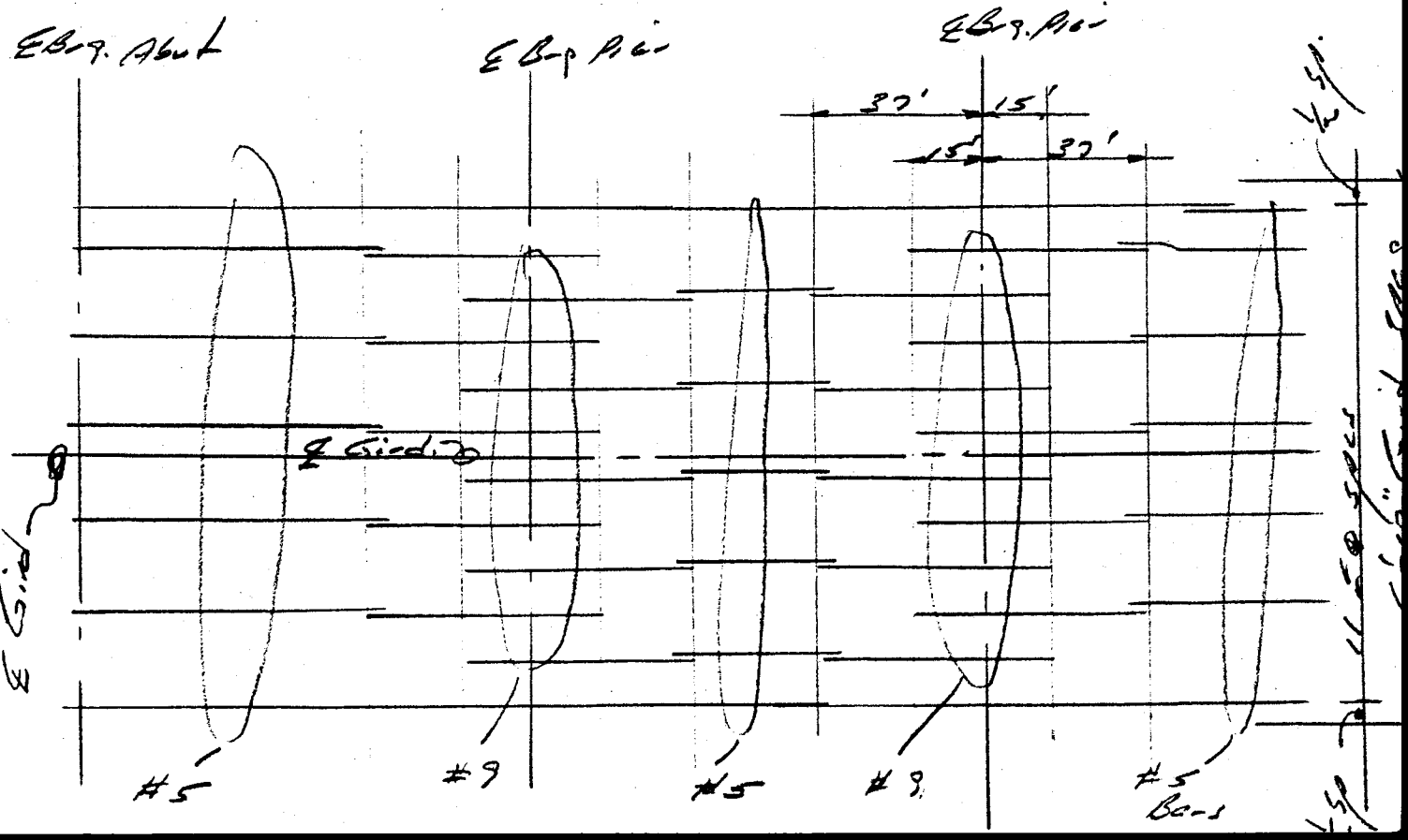
Max. Neg. LL+I Mom = 806.8'k

$M_u = 1.3[D + 2.2(LL+I)] = 1.3 \times 2.2 \times 806.8'^k = 2307'^k$

For b = 26" d = 57.75" $F = \frac{26 \times 57.75^2}{12000} = 7.23$

$K_u = \frac{2307'^k}{7.23} = 319$ $A_u = 4.29$

$A_s = \frac{2307}{4.29 \times 57.75} = 9.31''$ (use 10-#9)



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uplift Due to E.Q @ Fixed Pier

DL to Pier = 1445k

EQ = 0.25 x 1445 = 361.3k

#7 Bar Capacity = 0.6 □" x 20 k/□" = 12k/Bar

$\frac{361.3^k}{12}$ = 30 Bars Req'd

use #7 [@ 12" Alt [&]

uplift Due to E.Q. @ Exp. End

DL = 722.3k use #7 ⌀

EQ = 722.3k x 0.25 = 180.5k

$\frac{180.5}{14} = \frac{12.89}{12} = 1.07$ 7% over OK.

use 14 - #7 ⌀ @ Ea. Diaph.

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Substructure Design (Piers)

1. Superstructure Loads

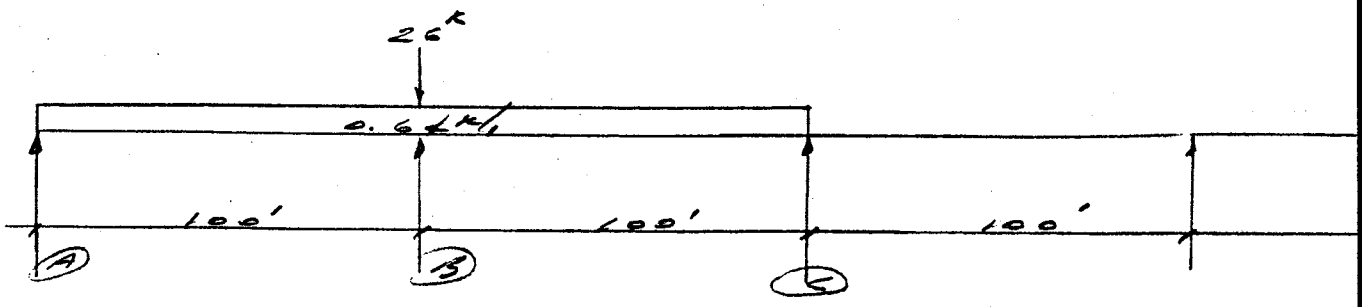
DL to Piers:

Ext. Girders R = 100.73k × 2 = 201.46k
Int. Girders R = 86.8k × 6 = 520.80
722.26k
× 2 For Total React @ Piers
1444.52k

DL to Abuts:

Ext Gird R = 100.73k × 2 = 201.46
Int. Gird R = 86.80k × 6 = 520.80
722.26k

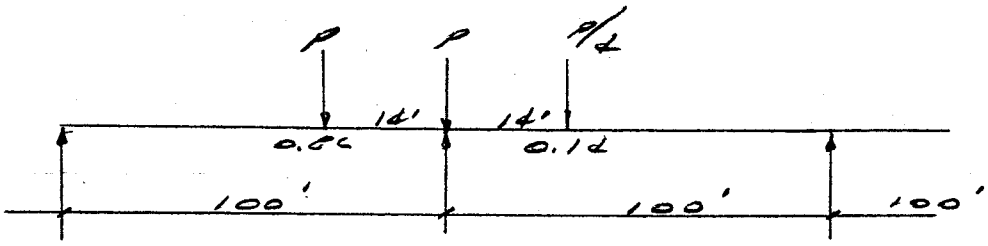
LL to Piers:



Span #1 Loaded - ΔM/L = 0.0670/100 = 0.00067
P = 0.00067 × 0.64k/' × 100' = 4.29k
S.Bm = 0.64k/' × 100' = 64.00
P = 26.00
94.29k
× 4 Lanes
377.16
Max Pier React

LL to Piers:

SB:	1.000
Pe 0.86:	0.860
P/2 @ 0.12:	0.220
	2.080



P: ΔM/L, w/ Pe 0.86: .0584/100' — : 0.00058

P/2: ΔM/L, w/ P/2 @ 0.12: $\left(\frac{.0586 - .0271}{100}\right)/2$: 0.00007

0.00065

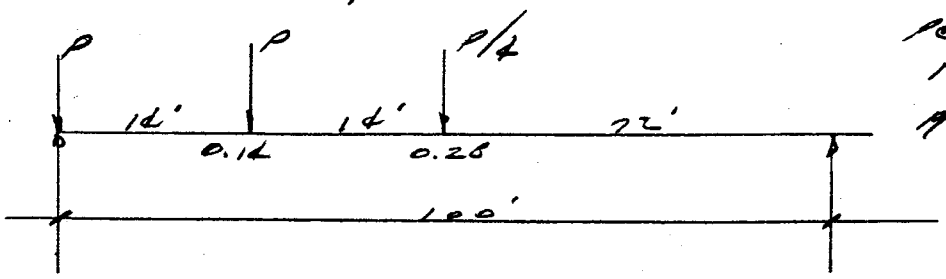
P: 32^k × 2.08 × 4 Lanes : 266.24^k

ΔM/L: .00065 × 266.24 × 100' : 17.31

283.55^k (Lane Ldg Controls.)

LL to Abuts

Truck Ldg.:



Pe Abut.:	1.000
Pe 0.12:	0.860
P/2 @ 0.28:	0.180
	2.040

P: 2.04 × 32^k × 4 Lanes : 261.1^k

P: ΔM/L, w/ Pe 0.12 : 0.03644

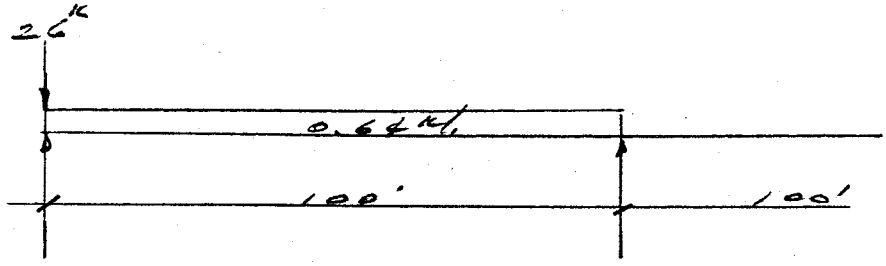
P: ΔM/L w/ P/2 @ 0.28 : $\frac{0.06880}{0.10524}$/100' : 0.00105

ΔM/L: 0.00105 × 261.1 × 100' : 27.4^k

LL @ A: 261.1^k − 27.4^k : 233.7^k — Max Abut LL React

(LL to Abuts. con't.)

Lane Ldg.:



Mom corr. for unif. Ld.

$\Delta M/L = .0670 \times 0.64^{k/'} \times 100^2/100 =$ (-) 4.29

$S.Bm. = 0.64^{k/'} \times 100'/2$ —— = +32.00

P = +26.00

58.71

× 4 Lanes

214.84k

2. Wind on superstructure Transv.

Barrier = 32.0"
Deck = 8.5
Gird = 54.0

94.5/12 = 7.88'

Wind to Pier:

Area = 7.88' × 100' = 788□'

$P_{\perp}$ = 788□' × 50#/□' = 39.4k/Pier

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3. Long. Wind

$w = 0.012^{k}/_{\square'} \times 7.88^{\square'} \times 400' = 37.82^{k}$

Wind/Pier = 37.82^{k}/3 Piers = 12.61^{k}

$\therefore P_{\parallel} = 12.61^{k}$/Pier

4. Net Wind Forces:

$P_{\perp} = 39.4^{k}$ —

$P_{\parallel} = 12.61^{k}$ —

5. Long. Force:

$P = 640^{\#}/_{\square'} \times 400' \times 4$ Lanes/3 Piers = 341.3^{k}/Pier

$P(\text{Long.})_{\parallel} = 341.3^{k} \times .05 = \underline{17.07}^{k}$ —

6. Wind on LL:

A. Long.

$P_L = 0.04^{k}/_{\square'} \times 400' = 16.0^{k}$/3 Piers

$P_{\parallel} = \underline{5.33}^{k}$/Pier —

B. Transverse

$P_T = 0.10^{k}/_{\square'} \times 100' = \underline{10.0}^{k}$/Pier —

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7. Substructure Wind

Cap Bm Area ⊥ to Face:

$A = 4' \times 55' = 220^{\square'} \times 40^{\#}/_{\square'} = 8.8^k$

Cols — $\frac{\pi \times \overline{4.0}^2}{4} \times 5 \times 30' = 1884^{\square'} \times \frac{2}{3} \times 40^{\#}/_{\square'} = 50.3^k$

Bm $P_\perp = 8.8^k$ ←

Cols $P_\perp = 50.3^k$ ←

End Area:

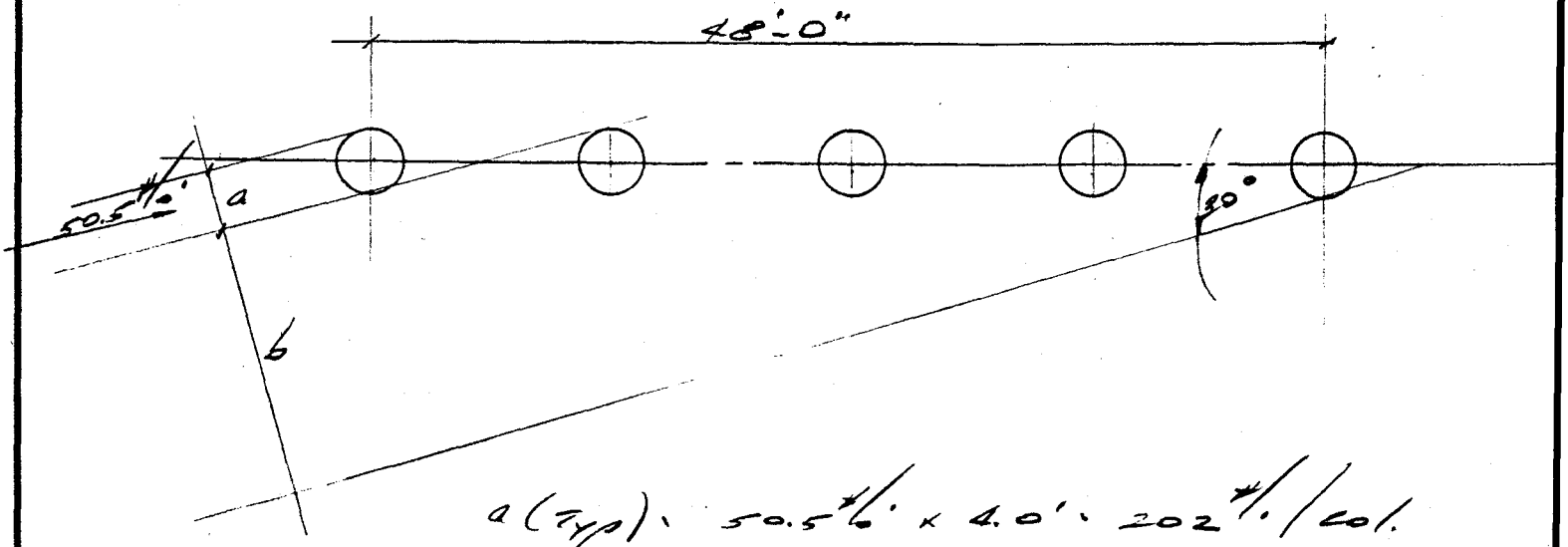
Bm $= 4.5' \times 4' \times 40^{\#}/_{\square'} = 0.72^k$

Col — $= \frac{\pi \times \overline{4.0}^2}{4} \times 30' \times \frac{2}{3} \times 40^{\#}/_{\square'} = 10.1^k$ ← Max

8. Stream Flow (Assume Max 30°)

Velocity from S.W. Computing = 8.7 ft/sec.

$P = KV^2 = \frac{2}{3} \times \overline{8.7}^2 = 50.5^{\#}/_{\square'}$



a (Typ) = $50.5^{\#}/_{\square'} \times 4.0' = 202^{\#}/_{\square'}$/col.

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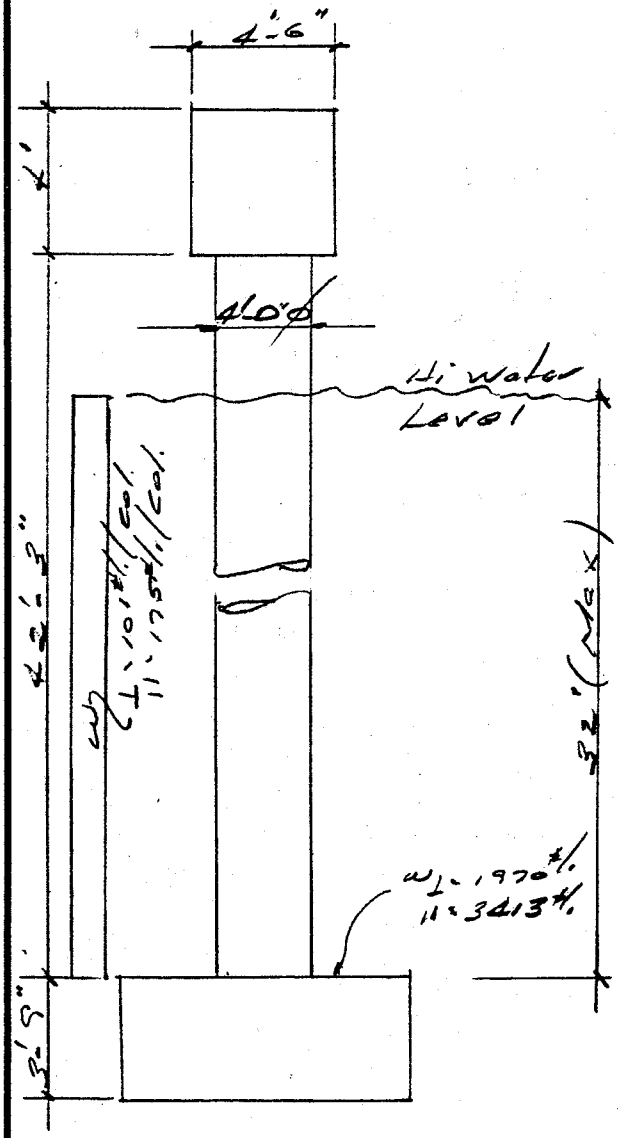
(Stream Flow con't.)

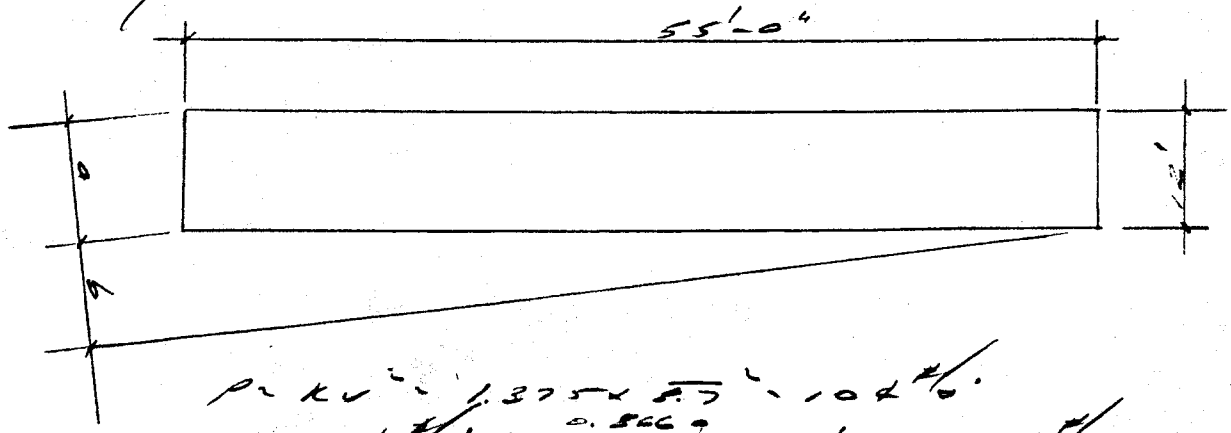


Col. Lds. & Mom's to Top of Pile cap.

$P_{\parallel} = 202\#/' \times \overset{0.8660}{\cos 30°} = 175\#/'/col$

$P_{\perp} = 202\#/' \times \overset{0.50}{\sin 30°} = 101\#/'/col.$

Pile cap



$P = kv^2 = 1.375 \times \overline{8.7}^2 = 104\#/'$

$a = 104\#/' \times \overset{0.8660}{\cos 30°} \times 12' = 1081\#/'$

$b = 104\#/' \times \overset{0.5}{\sin 30°} \times 55' = 2860\#/'$

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(Stream Flow Con't.)

Pile Cap –

$P_{\parallel} = 3941^{\#/'} \times \overset{0.8660}{\cos 30^\circ} = 3413^{\#/'}$

$P_{\perp} = 3941^{\#/'} \times \overset{0.50}{\sin 30^\circ} = 1970^{\#/'}$

Mom. Dist Parallel to bent due to stream flow

$\frac{a}{L} = \frac{32}{42.3} = 0.75$

$FEM_{Top} = .0615 \times 175^{\#/'} \times \overline{42.3}^2 = 19.26^{'k}$ ✓

$FEM_{Bott} = .0791 \times$ ✓ $\times$ ✓ $= 24.77^{'k}$ ✓

Bm $I = \frac{1}{12} \times 4.5 \times \overline{4}^3 = 24.0\ ft^4$

Col. $I = .04908 \times \overline{4.0}^4 = 12.56\ ft^4$

Ext

$K_B = \frac{I}{L} = \frac{24.0}{12} = 2.00 \div 2.30 = 0.87$

$K_C = \frac{I}{L} = \frac{12.56}{42.3} = \frac{0.30}{2.30}$ ✓ $= \frac{0.13}{1.00}$ ✓

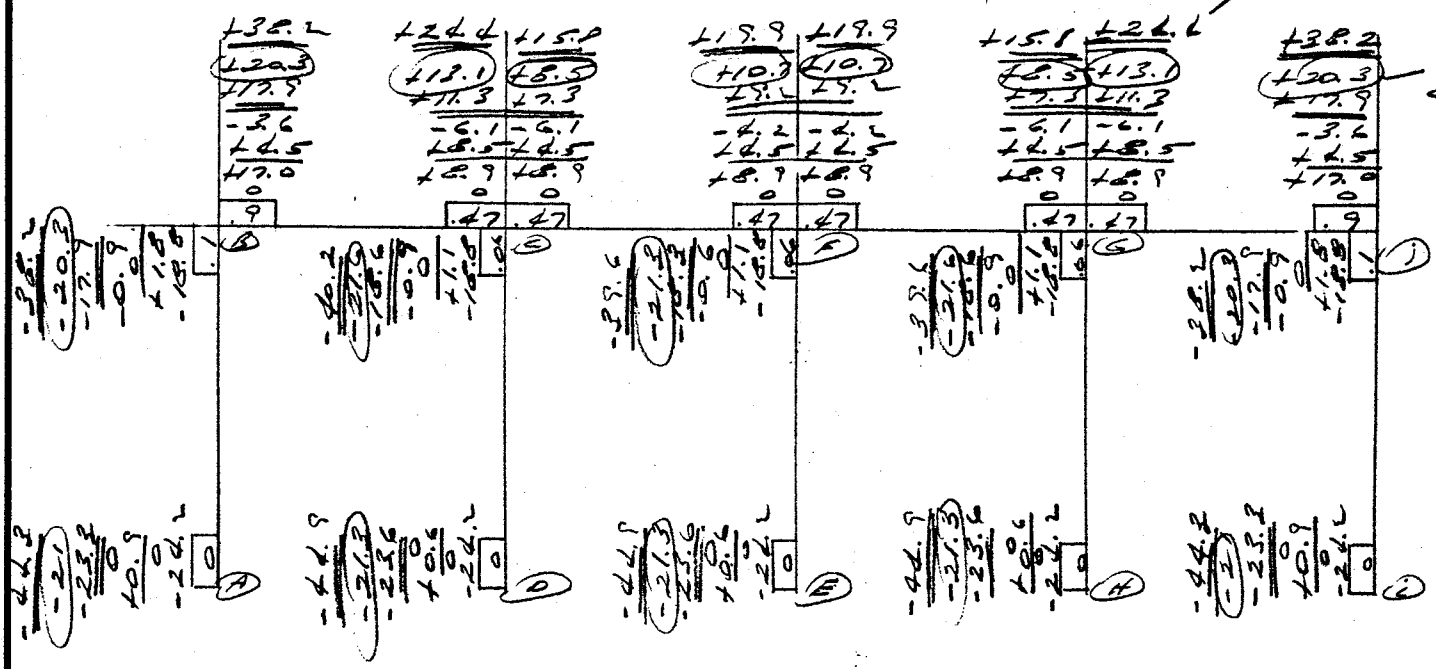
Int.

$K_B = 2.00 \div 4.30 = 0.47$

$K_C = 0.30$ ✓ $= 0.06$

$K_B = \frac{2.00}{4.30}$ ✓ $= \frac{0.47}{1.00}$

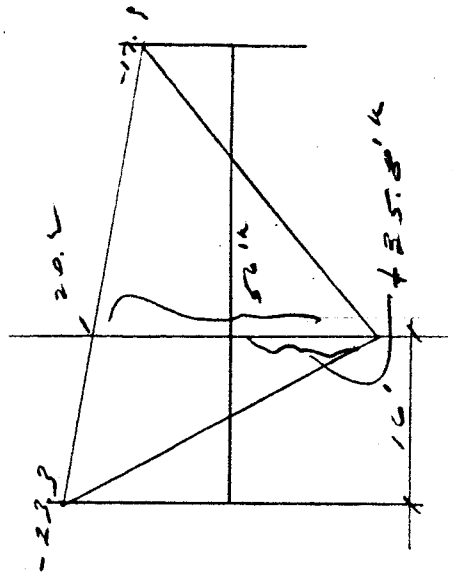
(Stream Flow Con't.) Note: FEM Revised see above's below.



$H_A = H_C = \left(\frac{23.3 + 17.9}{42.2}\right) 2 = 1.95^k$

$H_D = H_H = \left(\frac{23.6 + 18.6}{42.2}\right) 2 = 2.00$

$H_E = \left(\frac{23.6 + 18.3}{42.2}\right) 1 = \frac{1.00}{4.95^k}$



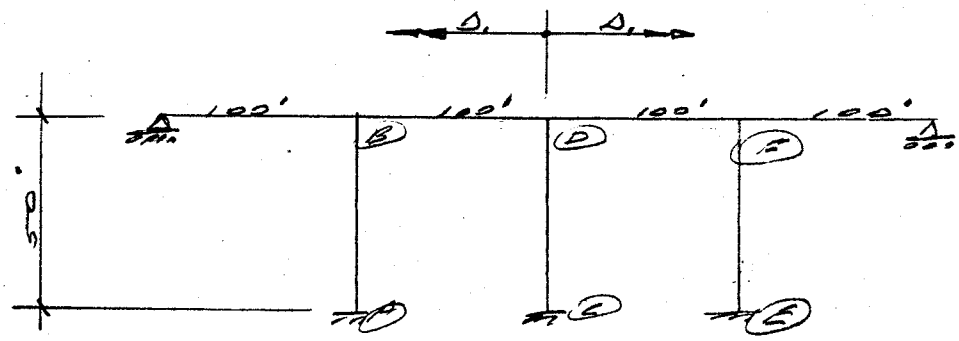
$P = 175^{\#}/1 \times 32' = 5.60^k$

$SBM = 5.60^k \times \frac{16' \times 27}{42} = 57.6'^k$

8. Thermal Exp. & contraction

A. 4 span condition

Assume no movement @ Bent D-C:



I of cols
$I = 0.0491 \times 48^4 \times 5 = 62.8$

$I_{cols} = .0491 \times \overline{48}^4 = 260,643 \text{ in}^4 \times 5 = 1,303,216 \text{ in}^4$

I_{bm} + slab comp. section:

$I_{int} = 669,182 \text{ in}^4 \times 6 = 4,015,092$
$I_{ext} = 637,173 \text{ in}^4 \times 2 = 1,274,346$
$5,289,438$

Dist. @ B-

$K_{cols} = \frac{I}{L} = \frac{1,303,216}{50} = 26,064 \div 131,852 = 0.20$

$K_{bm} = \frac{I}{L} = \frac{5,289,438}{100} = 52,894 \quad \text{"} = 0.40$

$K_{bm} = \frac{I}{L} = \frac{5,289,438}{100} = \frac{52,894}{131,852} \quad \text{"} = \frac{0.40}{1.00}$

Δ of Bents A-B & E-F = 0.00024 × 100' = .024'

$\Delta M = \frac{6EI\Delta}{L^2} = \frac{6 \times 3.5 \times 10^3 \times 62.8 \text{ ft}^4 \times 0.024 \times 144}{50^2} = 1822^{'k}$

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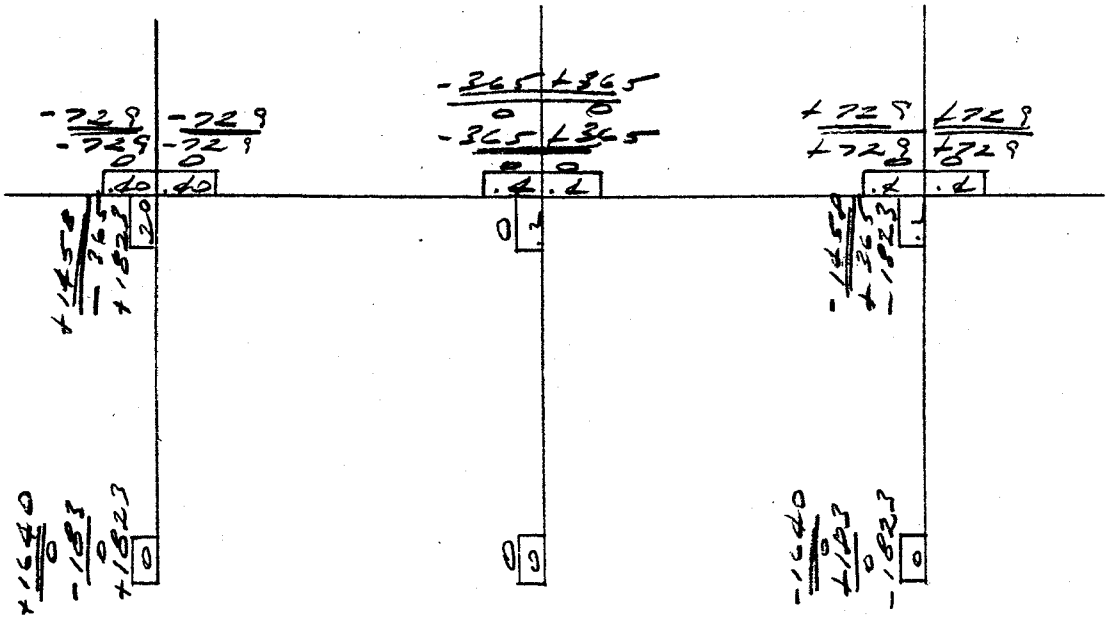
(Thermal Exp. & Contr. Con't.)



Final Moms 11/col. – Top = 1458'k/5 cols = 292'k/col.
Bott = 1640'k/ – = 328'k/col.

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10. Seismic Force:

superstructure DL = 1445k
V = 1445k × 0.1 = 144.5k
say 145k

A. Forces ⊥ = 145k ←
2

B. Forces ∥ = 145k ←
2

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11. Buoyancy

volume of water displaced

cols. – $\frac{\pi \times \Phi^2}{4} \times 42' \times 5$ cols = 2638 ft³

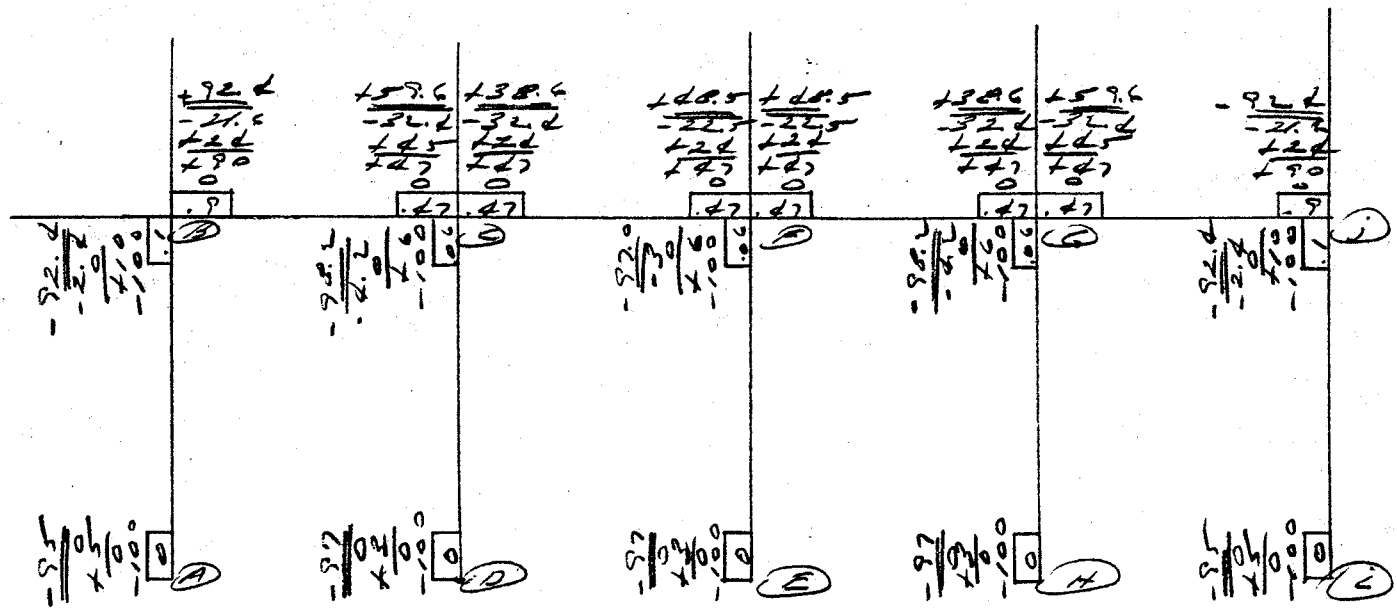
pile cap = 12' × 55' × 3.75' = 2475

5113 ft³

uplift = 5113 ft³ × .0625 = 320^k ↑

12. Unit Moms to Bent for Sidesway

Note: Dist. Factors changed due to increase in col. dia. – however use:



$H_A = H_i = \left(\frac{95 + 92.4}{42.2}\right) 2 = 8.88^k$

$H_D = H_H = \left(\frac{97 + 98.2}{42.2}\right) 2 = 9.25$

$H_E = \left(\frac{97 + 97}{42.2}\right) 1 = 4.60$

22.73^k ← P (Assumed V)

Mom Corr = $\frac{V}{22.73}$ × Assumed Moms

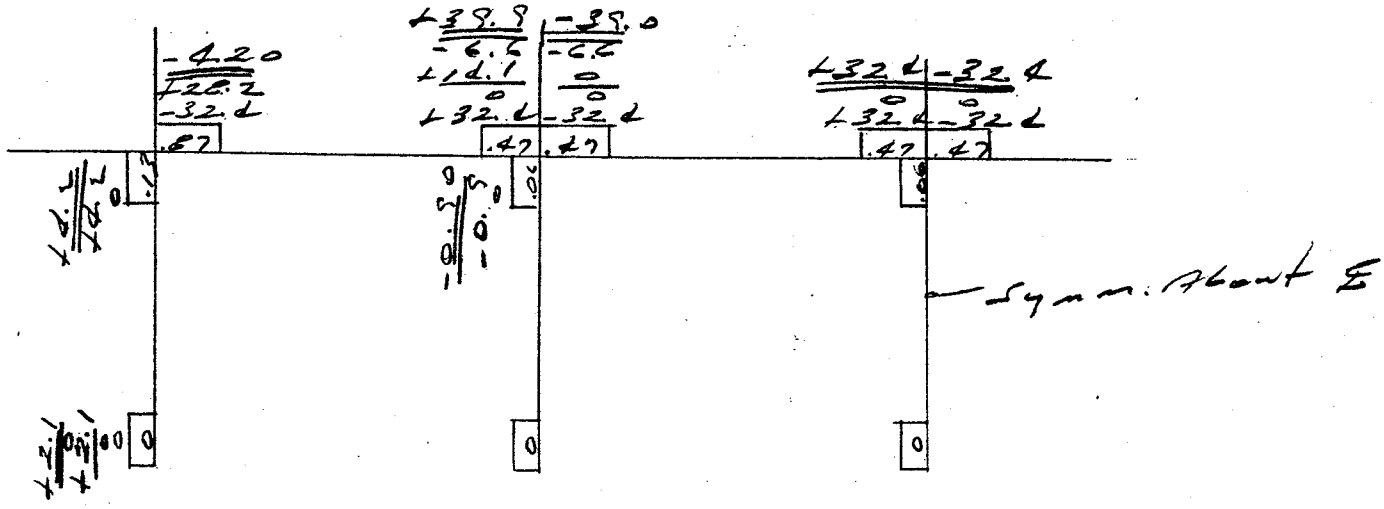
13. Cap Bm. DL

Bm DL = 4' x 45' x 150 = 2.70 k/'

FEM = 2.7 k/' x 12.00²/12 = 32.40 'k

I_{bm} = 1/12 x 45 x 4³ = 24.0 ft⁴

I_{col} = .0491 x 4.0⁴ = 12.57 ft⁴

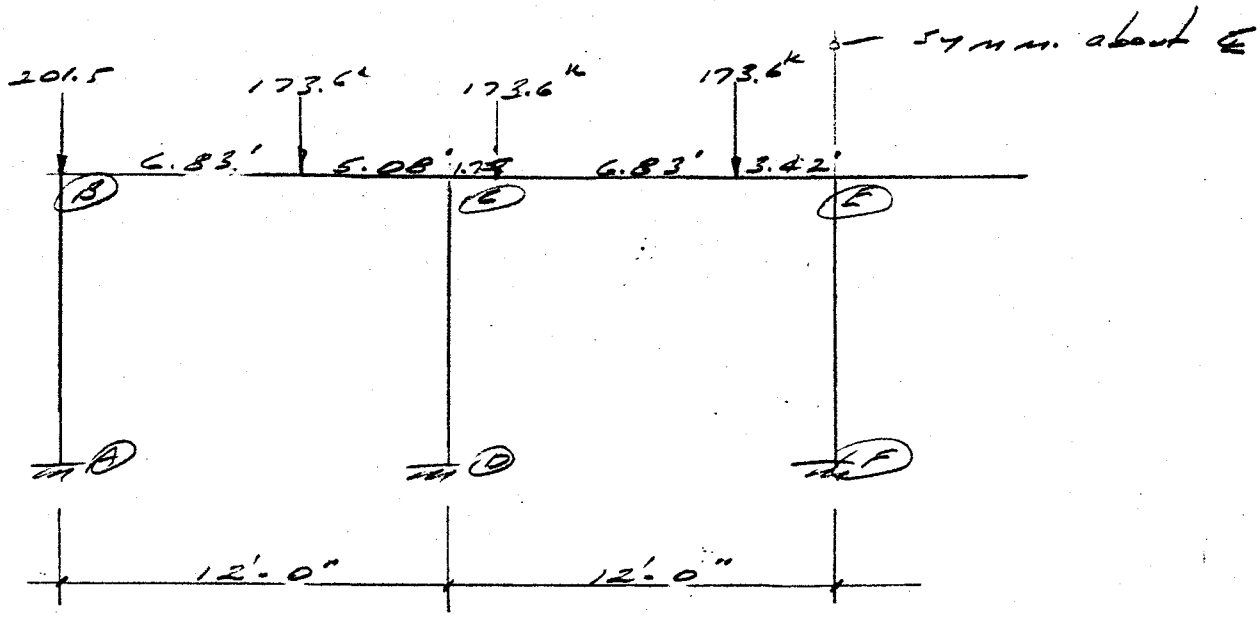


SBM = 2.70 k/' x 12.0²/8 = 48.60 'k

(-) [4.2 + 39.9 / 2] = (-) 21.95 / 26.65 'k ← + Mom

1k superstructure DL:

Ext Girder R = 100.73k × 2 = 201.5k
Int Girder R = 86.8k × 2 = 173.6k



FEM_{BC} — $\frac{a}{L} = \frac{6.83}{12.0} = 0.57$ FEM = 0.1052 × 173.6k × 12.0' / 0.1396

FEM = 219.2'k 290.8'k

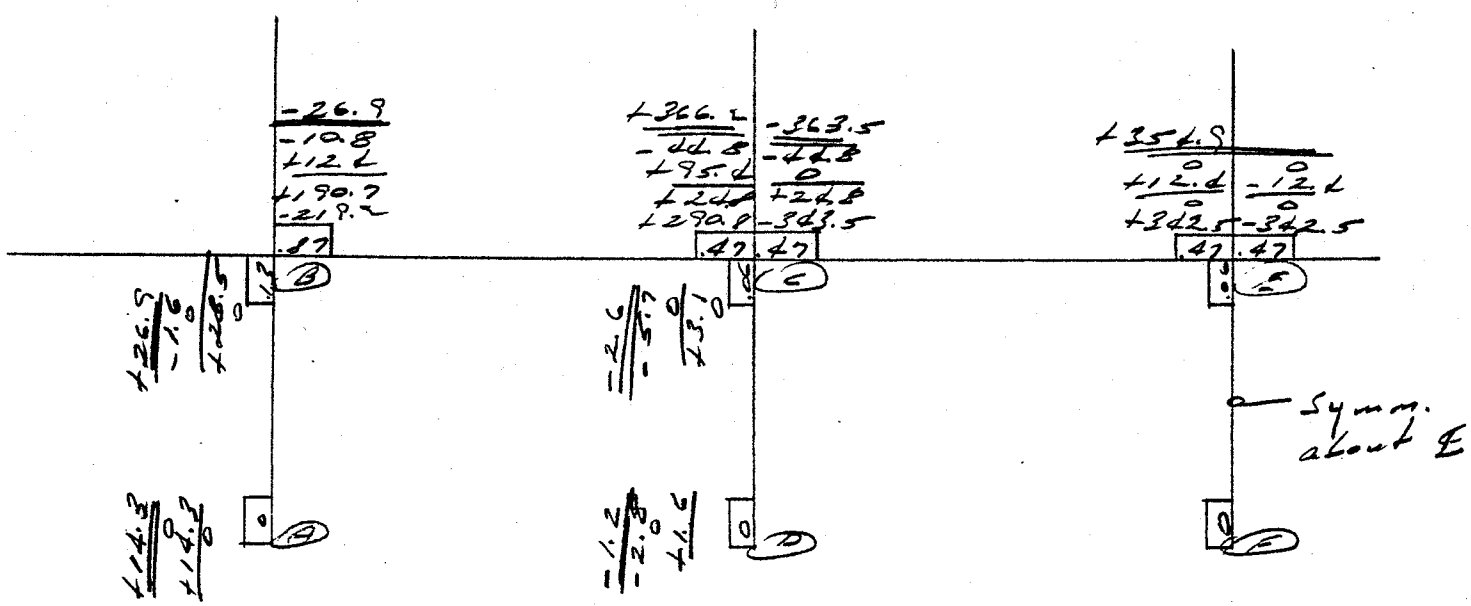
FEM_{CE} — $\frac{a}{L} = \frac{1.75}{12.0} = 0.15$ FEM = 0.1084 × 173.6k × 12.0' / .0190

FEM = 225.8'k 89.6'k

FEM_{CB} — $\frac{a}{L} = \frac{5.08}{12.0} = 0.42$ FEM = 0.565 × 173.6k × 12.0' / .1454

FEM = 117.7'k 302.9'k

(1. superstructure DL cont'd)



$+M_{BC} = 173.6^{k} \times \frac{6.92' \times 5.08}{12.0} = 508.56^{'k}$

$(-)\left[\frac{26.9 + 366.2}{2}\right] = (-)\ 196.55$

$312^{'k}$ — MAX

$+M_{CE} = 173.6^{'k} \times \frac{1.75 \times 10.25}{12.0} = 259.5^{'k} \times \frac{3.42}{10.25} = 86.6^{'k}$

$173.6 \times \frac{6.58 \times 3.42}{12.0} = 424.5$ — $\frac{424.5}{511.1^{'k}}$

$(-)\ 254.9$

$(363.5 - 354.9) \times \frac{3.42}{12} = (-)\ \frac{2.5}{153.7^{'k}}$

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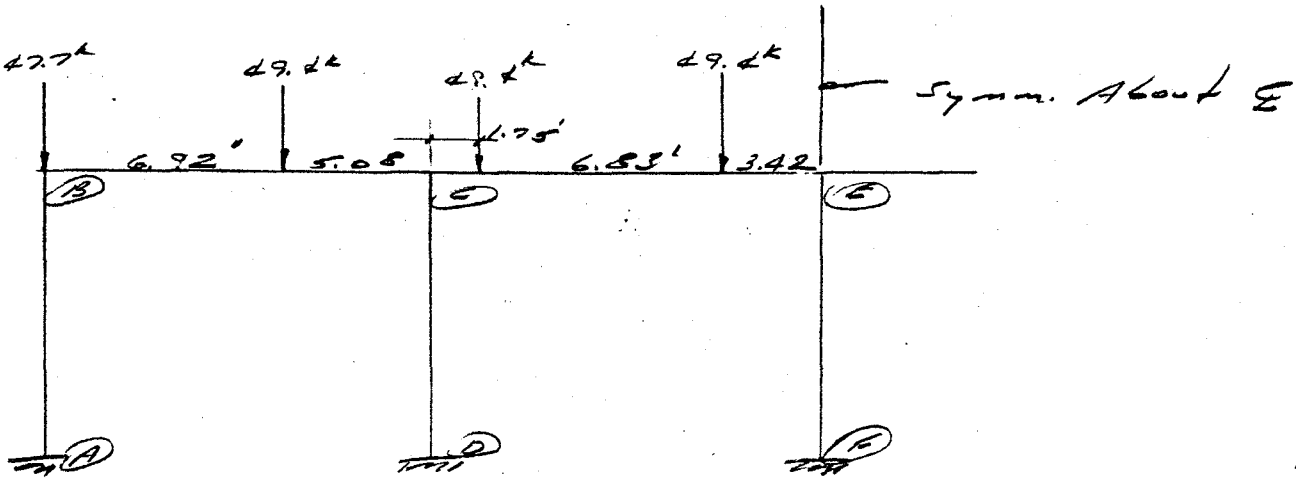
15. Superstructure LL

LL + I React/Gird Ext = 2.04 × 23.4^k = 47.7^k
LL + I React/Gird Int = 2.04 × 24.2^k = 49.4^k



$FEM_{BC} = \frac{a}{L} = \frac{6.92}{12.0} = 0.57$ $FEM = \frac{0.1056}{0.1396} \times 49.4^k \times 12.0'$

$FEM = 62.4'^k$ $82.8'^k$

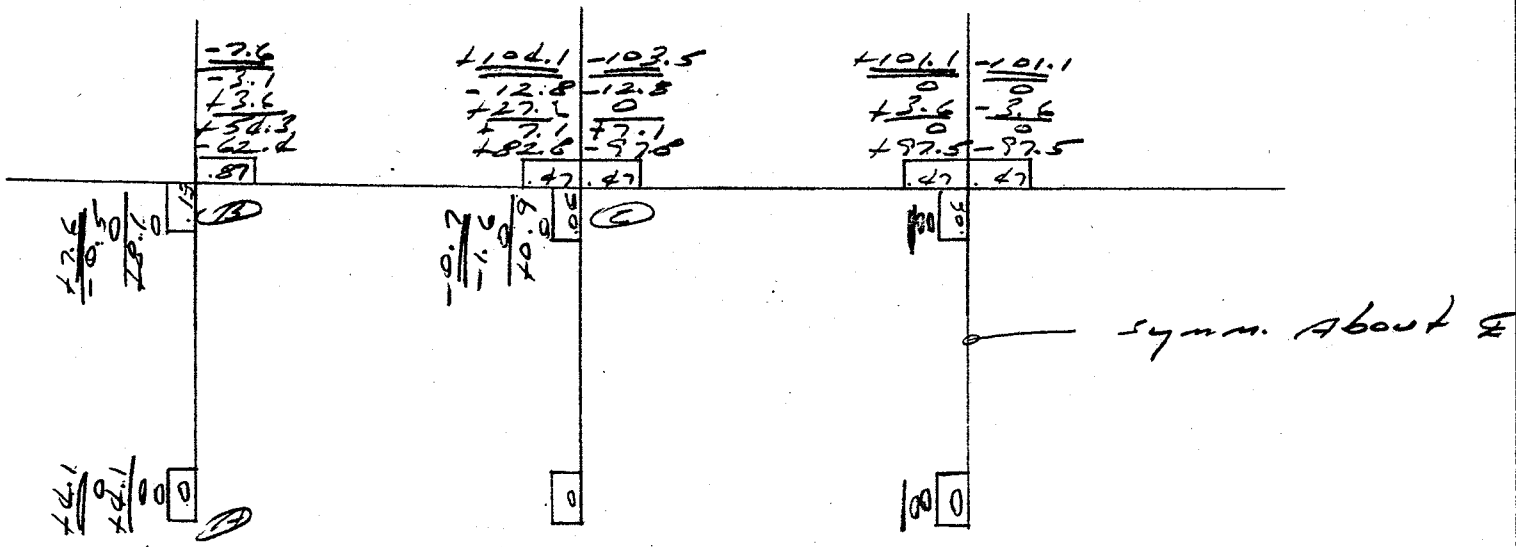
$FEM_{CE} = \frac{a}{L} = \frac{1.75}{12.0} = 0.15$ $FEM = \frac{0.1084}{.0190} \times 49.4^k \times 12.0'$

$FEM = 64.3'^k$ $11.3'^k$

$FEM_{CE} = \frac{a}{L} = \frac{8.58}{12.0} = 0.72$ $FEM = \frac{.0565}{.1454} \times 49.4^k \times 12.0'$

$FEM = 33.5'^k$ $86.2'^k$

(15. superstructure LL con't.)



(+) $M_{BC} = \frac{49.4^k \times 6.92' \times 5.08'}{12.0} = 144.7'^k$

(−) 7.6

$(104.1 - 7.6) \times \frac{6.92}{12.0}$ (−) 55.6

81.5'k ← Max

(+) $M_{CE} = \frac{49.4^k \times 1.75 \times 10.25}{12.0} = 73.8'^k \times \frac{3.42}{10.25} = 24.6'^k$

$\frac{49.4^k \times 8.58' \times 3.42}{12.0} = 120.8'^k$ — 120.8

(−) 101.1

$(103.5 - 101.1) \times \frac{3.42}{12} =$ (−) 0.2

44.1'k

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1. Group I: TL = DL + LL + I + E + B + SF (100%)

Mom. Corr. = $\frac{V}{22.7}$ × M (Assumed)

	Loading	Total Vert. Ld.	V	Col. Transv. Mom's.	Cap Bm Moms Neg.	Cap Bm Moms Pos.	
DL	Cap Bm + cols	547k	–	4.2'k	39.9'k	26.6'k	✓
DL	superst.	1445k	–	26.9	366.2	312.0	✓
LL	superst.	377		7.6	104.1	86.5	✓
SF	stream flow	–	4.95	20.7	20.2	–	
		2369k		59.4'k/col	530.4'k	420.1'k	

col. Moms. Long.
S.F. 101#/' × 32' × 32'/2 = 51.7'k/col.
vert Ld. = 2384k/5 cols = 476.8k/col.

2. Group II TL = DL + E + B + SF + W (125%)

Mom Corr = $\frac{V}{22.7}$ × Mom (Assumed)

	Ldg	Total vert Ld	V	Col. Transv. Mom	Cap Bm Moms Neg	Cap Bm Moms Pos.	
DL	Cap Bm + cols	547.0k	–	4.2	39.9	26.6	✓
DL	superst.	1445.0	–	26.9	366.2	312.0	✓
SF	stream flow	–	4.95	20.7	20.2	–	✓
W	wind (superst.)	–	12.60	51.4	23.4	–	
W	wind (substr.)	–	8.95	38.6	23.4	–	
				141.8'k	453.1'k	338.6'k	

col. Long. Mom's.
superst. wind = 39.4k × 46.25'/5 cols = 364.5'k
sub. wind$_{Bm}$ = 8.80k × 44.25'/5 cols = 77.9
– – cols = 50.3'k × (20'/2 + 14.3')/5 = 294.8
stream flow = 101#/' × 32' × 32'/2 = 51.7
786.9'k

3. Group III TL = Group I + LF + 30% W + WL (125%)

Mom corr = $\frac{V}{22.7}$ × M(Assumed) + Mom.

	Ldg	Total Vert Ld	V	Col. Transv. Mom's	Cap Bm Moms. Neg.	Pos.
DL + LL	Group I	2369^k	–	59.4$^{'k}$	530.4$^{'k}$	420.1$^{'k}$
LF	Long. Force	–	–	–	–	–
30% W	Wind	–	–	27.0	17.0	–
WL	Wind on LL	–	5.32	21.7	13.9	
		2369^k		108.1	561.3	420.1$^{'k}$

Col. Moms. Long.

L.F. = 17.07^k × 46.25'/5 cols = 157.9$^{'k}$/col. ✓
30% W = 21.55^k × 46.25'/5 cols = 199.3
WL = 10.0^k × 46.25'/5 cols = 92.5
449.7$^{'k}$/col. ✓

4. Group IV TL = DL + LL + CF + B + SF + T (125%)
Mom. Corr = $\frac{V}{25.3}$ × M (Assumed)

	Ldg.	Total Vert Ld.	V	Col. Transv Mom.	Cap Bm Moms Neg.	Pos.
DL + LL	Sulf Supstr.	2384^k	–	32.7$^{'k}$	510.2$^{'k}$	420.1$^{'k}$
SF	Stream flow	–		20.7	20.2	–
T	Temp.	–		–	–	–
				59.4$^{'k}$	530.4$^{'k}$	420.1$^{'k}$

Col. Long. Moms –

Temp — 328.0$^{'k}$
S.F — 51.7
379.7$^{'k}$

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5. Group V – TL = D+E+B+SF+W+T (140%)

	Ldg.	Total Vert Ld.	V	Col. Transv Mom.	Cap. Bm Mom's Neg.	Pos.
DL	Dead Ld.	1992	–	31.1	406.1	338.6
S.F.	Stream Flow	–	4.95	20.7	20.2	–
W	Wind (sub & super)	–	17.55	90.0	56.8	–
T	Temp.	–	–	–	–	–
				141.8 ik	483.1 ik	338.6 ik

Col. Long. Mom:
SF = 51.7 ik
T = 328.0
379.7 ik

6. Group VI – TL = D+L+CF+B+SF+0.3W+WL+LF+T (140%)

	Ldg.	Total Vert Ld	V	Col. Transv Mom	Cap. Bm Mom's Neg	Pos.
DL	Dead Ld	1992		31.1	406.1	338.6
LL	Live Ld	377		7.6	104.1	81.5
SF	Stream Flow			20.7	20.2	–
0.3W	Wind	–		27.0	17.0	–
WL	Wind on LL	–		21.7	13.9	–
LF	Long. Force	–		–	–	–
T	Temp.	–		–	–	–
		2369.0 k		81.1 ik	561.3 ik	420.1 ik

Col. Long Mom
SF = 51.7 ik
0.3W = 199.3
WL = 92.5
LF = 157.9
501.4 ik

7. Group III TL = DL + E + B + SF + EQ (133%)

	Ldg.	Total Vert Ldg.	V	Col. Trans Mom	Cap. Bm Moms Neg	Pos.
DL	Dead Ld	1992		31.1	406.1	338.6'k
SF	Stream Flow	–		20.7	20.2	–
EQ	Earthquake	–	145	589.4	380.7	
		1992k		641.2'k	807.0'k	338.6'k

Col. Long. Mom

E.Q = $\frac{1450^k \times 46.25'}{5 \text{ cols.}}$ = 1341'k/col.

SF = $\frac{52}{1393}$

8. Group VIII – TL = DL + LL + CF + E + B + SF + ICE

By Insp ok!

9. Group IX – TL = DL + E + B + SF + W + ICE

By Insp ok!

Summary of Lds. & Moms –

Max Neg Mom = 807'k

$M_u = 1.3 \times 807'^k = 1049'^k$

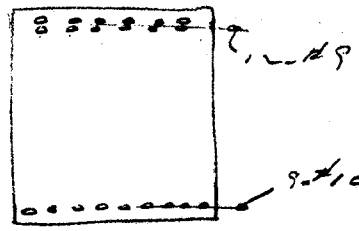
For b = 48" d = 48" - 3" = 45" f'c = 8.10

$K_u = \frac{1049}{8.1} = 130$ $a_u = 2.91$

$A_s = \frac{1049'^k}{2.91 \times 45} = 8.01^{\square"}$

Min $A_s = \frac{200}{40{,}000} = .005 \times 48" \times 45" = 10.8^{\square"}$

use 12 - #9 Min



$V = \frac{173.6^k \times 10.61}{12.3} + \frac{173.6 \times 3.5d}{12.3} + \left(\frac{370.5'^k - 321.1}{12.3}\right)$

$V = 148.8^k + 49.9 + 0.76 = 200.5^k$

$V_u = 200.5^k \times 1.3 = \underline{261^k}$

$v_u = \frac{261{,}000}{0.85 \times 48 \times 45} = 142 \#/\square"$ $v_c = 2(3000)^{1/2} = 110$

$s = \frac{A_v f_y}{(v - v_c) b_w} = \frac{0.31 \times 40{,}000}{(142 - 110) \times 48} = 8.07"$

use Min
#5 dblo
stirrups @ 8"

Col. Design (Design for Group VII

$M_{\parallel} = 641^{'k}$

$M_{\perp} = 1393^{'k}$

$K = [641^2 + 1393^2]^{1/2} = 1533^{'k}$

$\text{Cols.} - \frac{I}{L} = \frac{12.56}{46.25} \times 5\text{ cols}$

$= 1.36$

$\psi_A = \frac{\Sigma \frac{EI}{l_c} \text{ cols.}}{\Sigma \frac{EI}{l} \text{ Bms}}$

Top Bm $= \frac{I}{L} = \frac{240}{52} = 0.46$

$\psi_B = \frac{\Sigma \frac{EI}{l_c} \text{ cols}}{\Sigma \frac{EI}{l} \text{ Bm}}$

Both Pile Cap $I = \frac{1}{12} \times 12' \times 3.75^3 = 52.7$

$\frac{I}{L} = \frac{52.7}{52} = 1.01$

$\psi_A = \frac{1.36}{0.46} = 2.96$

$\psi_B = \frac{1.36}{1.01} = 1.35$

$K = 1.6$ $\quad r = 0.25 \times 48 = 12.0$

$Kl_u/r = 1.6 \times \frac{46.25 \times 12}{12.0} = 74 < 100$ OK!

$I_g = 0.049 \times 16^4 = 260,112 \text{ in}^4$

$\beta_d = \frac{1.3D}{1.3D + 1.3L} = \frac{1.3D}{1.3D + 1.3L0} = 1.0$

$EI = \frac{E_c I_g / 2.5}{1 + \beta_d} = \frac{(3.6 \times 10^6 \times 260,112)/2.5}{1 + 1.0}$

$EI = 1.87 \times 10^{11}$

$P_c = \frac{\pi^2 EI}{(Kl_u)^2} = \frac{3.14^2 \times 1.87 \times 10^{11}}{(1.6 \times 46.25 \times 12)^2} = 2842^k$

$\delta = \frac{C_m}{1 - \frac{P_u}{\phi P_c}} = \frac{1.0}{1 - \frac{1.3 \times 1952/5\text{ cols}}{0.75 \times 2842}} = 1.41$

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(Col. Design con't)

$M = \delta M = 1.41 \times 1533'^k = 2162'^k$

$M_u = 1.3 \times 2162'^k = 2810'^k$

$P = 1992/5\text{ cols} \times 1.3 = 518^k$

$e = \frac{2810'^k \times 12}{518} = 65.1''$

$\frac{e}{D} = \frac{65.1}{48} = 1.36$

$K = P_u / f_c D^2 = \frac{518}{3.5 \times 48^2} = .064$

$P_t = .02$

$A_s = P_t A_g = 0.022 \times 0.7854 \times 48^2 = 39.8^{\square''}$

use 48"φ Cols.
w/ 36-#10 Bars
bundled 2 Ea.
@ 20° Increments

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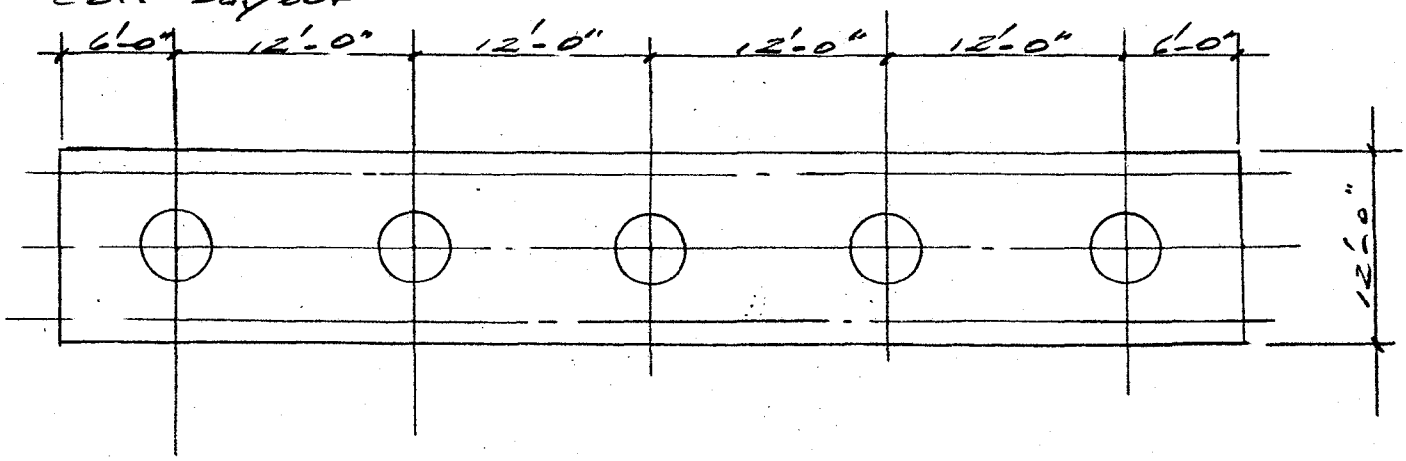
Pier Pile Cap & Pile Design

Col. Layout



1. Group I: TL = D+L+E+B+SF

Total DL to Piles:

Cap Bm 4'x4.5'x 55'x 150 = 148.5k
Cols. - $\frac{\pi \times 4.0^2}{4}$ x 42'x 150 x 5 = 395.0
Pile Cap - 3.75'x 12'x 60'x 0.15 = 405.0
948.5k

say 950k

Total Vert. Ld:

	DL	TL
Superst. DL =	1445	144
Pier	950	95
LL =	-	37
	2395k	2772

Mom to Piles: (⊥)

SF - Cols: 101#/' x 5 cols x 32' x 19.75' = 319.2'k
Cap Bm = 1970#/' x 3.75' x 3.75'/2 = 13.8
333.0'k

Mom to Piles: (||)

SF - Cols: 175#/' x 5 cols x 32' x 19.75' = 553.0'k
Cap Bm: 3413#/' x 3.75' x 3.75'/2 = 23.9
576.9'k

2. Group II: TL = DL + E + B + SF + W

Vert. DL = 2395^k

Mom to Piles: (⊥)

Wind Superst.	= 39.4^k × 50' =	1970^'k
Wind Substr. (Bm.)	= 8.8^k × 48' =	422
(Col.)	= 50.8^k × 46' =	1157
		3549^'k

Mom. to Piles (II)

Wind Superst.	= 12.61^k × 50' =	630.5^'k
Wind Substr. (Bm.)	= 0.72^k × 50' =	36.0
(Col.)	= 10.1^k × (30' + 20') =	353.5
		1020.0^'k

3. Group III: TL = Group I + LF + 0.3W + WL

Vert Ld DL 2395^k TL 2772

Mom to Piles (⊥):

L. Force =	12.61 × 50' =	631^'k
W.L =	5.33^k × 50' =	267
0.3W =	———	1065
SF =	———	323
		2286^'k

Mom to Piles (II)

L. Force =	———	0
W.L =	10.0^k × 50' =	500^'k
0.3W =	———	306
SF =	———	577
		1383^'k

4. Group IV TL = DL + LL + CF + B + SF + T

Vert DL + LL = 2772^k

Mom to Piles (⊥)
Temp = 328.0^k × 5 cols = 1640^k
SF = 333
1973^k

Mom. to Piles (∥)
Temp = 0
SF = 577
577^k

5. Group V: TL = DL + E + B + SF + W + T

Vert DL = 2395

Mom. to Piles (⊥)
SF = 333^k
W = 3549
T = 1640
5520

Mom. to Piles (∥)
SF = 577^k
W = 1020
T = 0
1597^k

6. Group VI TL = DL + LL + CF + B + SF + 0.3W + WL + LF + T

Vert DL + LL = 2772

Mom. to Piles (⊥)
SF = 333^k
0.3W = 1065
WL = 267
LF = 631
T = 1640
3936^k

Mom. to Piles (∥)
S.F. = 577^k
0.3W = 306
WL = 500
LF = 0
T = 0
1383^k

7. Group VII TL = D + E + B + SF + EQ

vert DL = 2395^k

Mom to Piles (⊥)

EQ = 1450^k × 50' = 7250'^k

SF = 333

7583'^k

or

EQ = 0

SF = 333

Mom to Piles (∥)

EQ = 0

SF = 577

or

EQ = 7250'^k

SF = 577

7827'^k

8. Group VIII TL = D + L + CR + E + B + SF + ICE

vert TL = 2772^k

Mom to Piles (⊥)

SF = 333'^k

Mom. to Piles (∥)

SF = 577'^k

9. Group IX TL = D + E + B + SF + W + ICE

vert DL = 2395

Mom to Piles (⊥)

SF = 333'^k

W = 3549

3882'^k

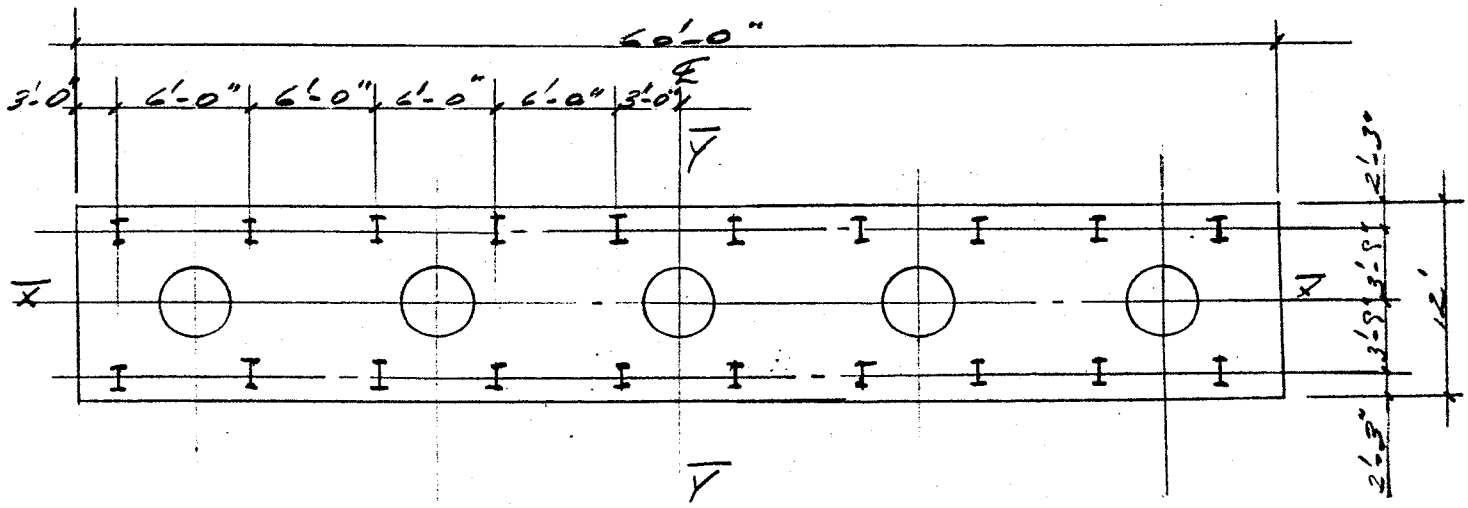
Mom. to Piles (∥)

SF = 577'^k

W = 1020

1597

Pile Design



I_{YY} = 4 × 3² = 36
= 4 × 9² = 324
= 4 × 15² = 900
= 4 × 21² = 1764
= 4 × 27² = 2916
5940 ft²

I_{XX} = 20 × 3.75² = 281.3

Ld to Piles @ Group Ldgs.

1. $f = \frac{P}{A} + \frac{M_{xx}d}{I_{xx}} + \frac{M_{yy}d}{I_{yy}}$

$f = \frac{2222^k}{20} + \frac{333^{'k} \times 3.75}{281.3} + \frac{567^{'k} \times 27}{5940}$

$f = 138.6^k + 4.4 + 2.6 = 145.6^k$ (100%)

2. $f = \frac{2395}{20} + \frac{354.9^{'k} \times 3.75}{281.3} + \frac{1020^{'k} \times 27}{5940}$

$f = 119.8^k + 47.3 + 4.6 = 171.7^k$ (125%)
137.4^k (100%)

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3. $f = \frac{2772}{20} + \frac{2296^{'k} \times 3.75}{281.3} + \frac{1383^{'k} \times 27}{5940}$

$f = 138.6^k + 30.6^k + 6.3^k = 175.5^k (125\%)$
$140.4^k (100\%)$

4. $f = \frac{2772}{20} + \frac{1973^{'k} \times 3.75}{281.3} + \frac{577^{'k} \times 27}{5940}$

$f = 138.6 + 26.3 + 2.6 = 167.5^k (125\%)$
$134.0^k (100\%)$

5. $f = \frac{2395}{20} + \frac{5520^{'k} \times 3.75}{281.3} + \frac{1577^{'k} \times 27}{5940}$

$f = 119.8 + 73.6 + 7.3^k = 200.7^k (140\%)$
$143.4^k (100\%)$

6. $f = \frac{2772}{20} + \frac{3936^{'k} \times 3.75}{281.3} + \frac{1383^{'k} \times 27}{5940}$

$f = 138.6^k + 52.5 + 6.3 = 197.4^k (140\%)$
$141.0^k (100\%)$

7. $f = \frac{2395^k}{20} + \frac{7583^{'k} \times 3.75}{281.3} + \frac{577^{'k} \times 27}{5940}$

$f = 119.8^k + 101.1 + 2.6 = 223.5^k (133\%)$
$168^k (100\%)$ — Max

$f = \frac{2395}{20} + \frac{333^{'k} \times 3.75}{281.3} + \frac{7827 \times 27}{5940}$

$f = 119.8 + 4.4 + 35.6 = 159.6^k (133\%)$
$120.2^k (100\%)$

8. $f = \frac{2772}{20} + \frac{333^{'k} \times 3.75}{281.3} + \frac{577 \times 27}{5940}$

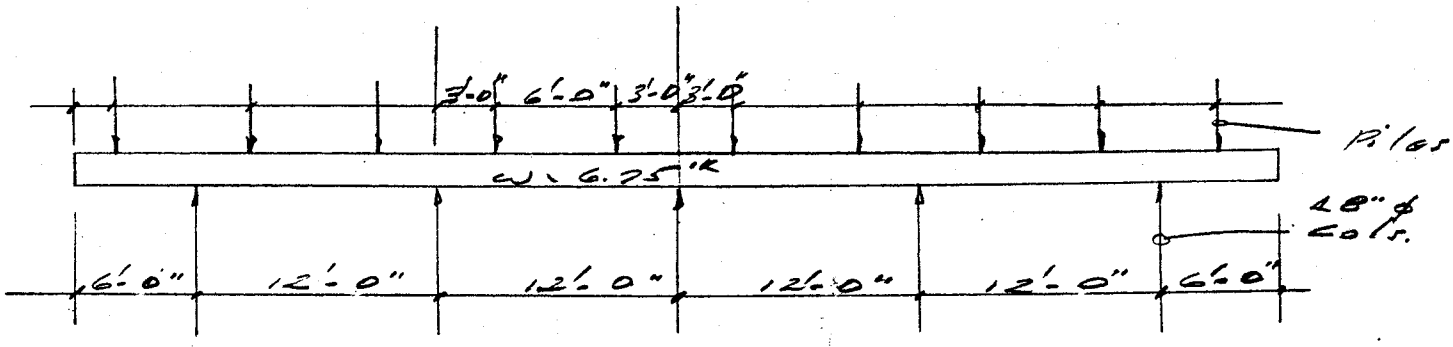
$f = 138.6 + 4.4 + 2.6 = 145.6^k (140\%)$
$104^k (100\%)$

9. $f = \frac{2395}{20} + \frac{388^{'k} \times 3.75'}{281.3} + \frac{1597^{'k} \times 27}{5940}$

$f = 119.8^k + 51.8^k + 7.3 = 176.9^k$ (140%)
89.5^k (100%)

Pile Cap Design

$P = 168^k \times 2 = 336^k$ Cap Bm $w = 3.75' \times 12 \times 150 = 6.75^k$



$FEM \sim \frac{a}{L} = \frac{3.0}{12} = 0.25 = \frac{0.1408}{.0468} \times 336^k \times 12.0' = 567.7$ $188.7'$

$\frac{a}{L} = \frac{9.0}{12} = 0.75 = \frac{0.0468}{0.1408} \times 336^k \times 12.0' = 188.7$ 567.7

$FEM_w = 6.75^k/' \times 12.0^2/12$ ——— $= \frac{81.0}{837.k}$ $\frac{81.0}{837.k}$

Cant Mom:

$M_p = 336^k \times 3.0' = 1008.0^{'k}$
$M_w = 6.75^k/' \times 6.0^2/2 = \frac{121.5}{1129.5}{}^{'k}$

say $1120^{'k}$

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(Pile cap Bm Design con't.)

1	1	0.5	0.5	0.5	0.5	0.5	0.5	1.0	1.0
+1130	-837.4	+837.4	-837.4	+837.4	-837.4	+837.4	-837.4	+837.4	-1130
	-292.6	0	0	0	0	0	0	+292.6	
		-146.2	0				+143.6		
+1130	-1130	+73.1	+73.1			-73.1	-73.1	+1130	-1130
		+764.3	-764.3	+35.9	-35.9	+764.3	-764.3		
				0	0				
				+873.9	-873.3				

Pos. Mom. = $\frac{336^k \times 3.0' \times 9.0}{12.0}$ = $756.0^k \times \frac{6}{9} \times 2$ = $1008'^k$

SBM = $6.75^{k/'} \times \overline{12.0}^2/8$ = ——— = $\frac{122}{1130'^k}$

$(-)[764.3 + (873.3 - 764.3) \times \frac{6}{12}]$ = $(-)\frac{818.8}{311.2'^k}$

Bott. A_s = $\frac{1130.0}{1.76 \times 30}$ = $21.4^{\square''}$ use 22-#9 (#9 @ 6")

Top A_s = $\frac{311.2}{1.76 \times 30}$ = $5.89^{\square''}$

Min Stl. = $30'' \times 12' \times 12 \times .00333$ = $14.4^{\square''}$
15-#9 (#9 @ 9")

CK V = $6.75^{k/'} \times 6.33'$ = 42.7^k
$+336.0$
378.7^k

$v = \frac{378{,}700}{144 \times 30.0}$ = $87.7^{\#/\square''}$ $V_c = 1.8(3000)^{1/2}$ = $98^{\#/\square''}$
ok!

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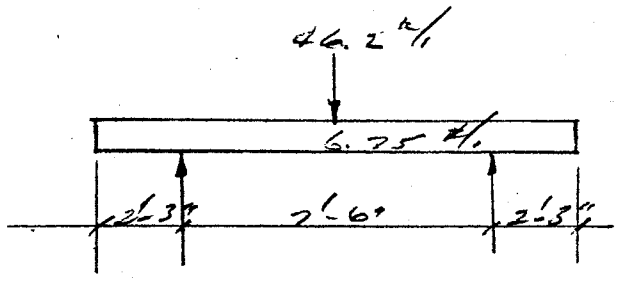
JOB NO

Transv. stl. in Pile Cap



Max col. R = 277 k / 5 = 55 k/c

w = 55 k / 12.0' = 46.2 k/'

Cant. Mom:

M = 6.75 k/' × 2.25²/2 = 17.1 'k

SBM = 6.75 k/' × 7.5²/8 = 47.5 'k

+ 46.2 k × 7.5'/4 = 86.6

124.1

(−) 17.1

117.0 'k

As = 117.0 / 1.76 × 33 = 2.01 in²/'

use #9
@ 6"

E.M. PLUMMER
CONSULTING ENGINEERS
STRUCTURAL . CIVIL ENGINEERS
CLIENT:

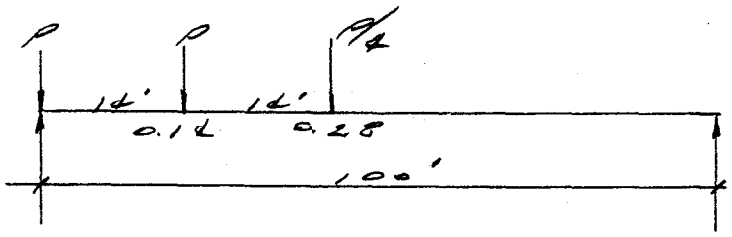
SUBJECT 51st Ave Bridge SHEET NO 81 OF
BY EMP DATE 2/20/8
JOB NO

Abut. Design

1. Superstructure DL:

Ext. Girders 2 × 100.73^k × 2 = 201.5^k
Int. Girders 2 × 86.8^k × 6 = 520.8
722.3^k — P_{DL}

2. Superstructure LL:



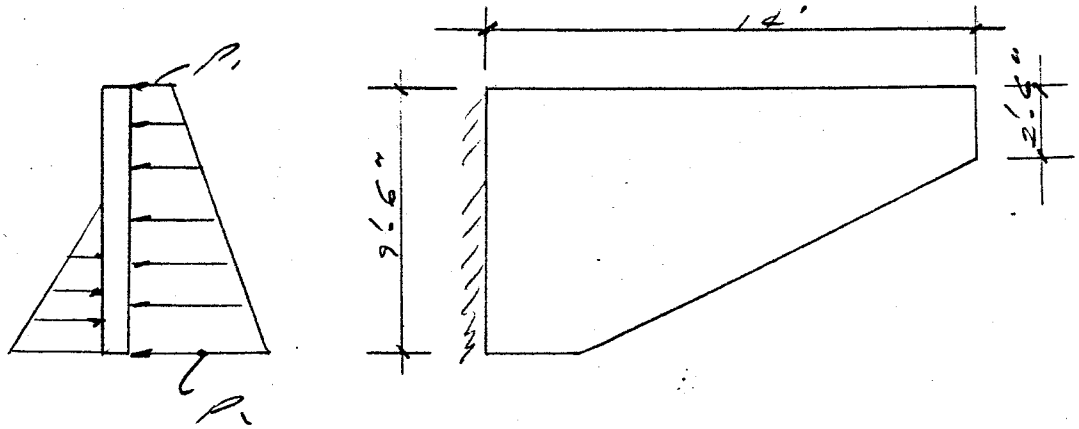
P = 1.000
P = 0.820
$\frac{0.72}{L}\frac{P}{2}$ = 0.180
2.020 × 32^k × 4 Lanes = 259^k — P_{LL}

3. Abut DL

8½" Deck = 8.5
Girder = 54.0
62.5/12 = 5.21'
26.5' × .02 — = 0.53
5.74'
+ 4.00
9.75'

9.75' × 4' × 53'/cos 15° × 150#/ft³ = 320.9^k
cos 15° = 0.9659

Abutment Wing Design



$P_1 = 150 \times 0.333 = 50^{\#}/o'$

$P_2 = 50 + 33.33 \times 9.5' = 350^{\#}/o'$

$P_3 = 50 + 33.33 \times 2.5 = 117^{\#}/o'$

V_u varies from $117^{\#}/o'$ to $350^{\#}/o'$

use Avg. $= \left(\frac{350+117}{2}\right) = 234^{\#}/o'$

$M_u = 234^{\#}/o' \times 14^2/2 = 22.9^{'k} \times 1.7 = 38.9^{'k}$

18" Wall $d = 18 - 2 - 1" - \frac{1}{2} = 14.5"$

$K_u = \frac{38.9 \times 1000}{14.5^2} = 185$ $a_u = 2.88$

$A_s = \frac{38.9}{2.88 \times 14.5} = 0.93^{\square"}/'$

use 18" wall
w/ #9 @ 12" Horiz
& #5 @ 12" Vert.

E.M. PLUMMER
CONSULTING ENGINEERS
STRUCTURAL . CIVIL ENGINEERS

SUBJECT 51st Ave Bridge SHEET NO 83 OF
BY EMP DATE 5/12/8[illegible]
JOB NO
CLIENT:

Group IV:
TL = DL + LL + CF + B + SF + T (No need to ck)

Group V:
TL = DL + E + B + SF + W + T (✓)

Group VI:
TL = DL + LL + CF + B + SF + 0.3W + WL + LF + T
(No need to ck)

Group VII:
TL = DL + E + B + SF + EQ
OTM = 72.3k × 9.5' = 686.8'k
$f = \frac{1091.2}{8} + \frac{686.5'k \times 23.92}{1961}$
f = 136.4k + 8.4k = 144.8k (133%)
or 108.8k or 54.5T

Group VIII:
TL = D + L + CF + E + B + SF + Ice (No need to ck)

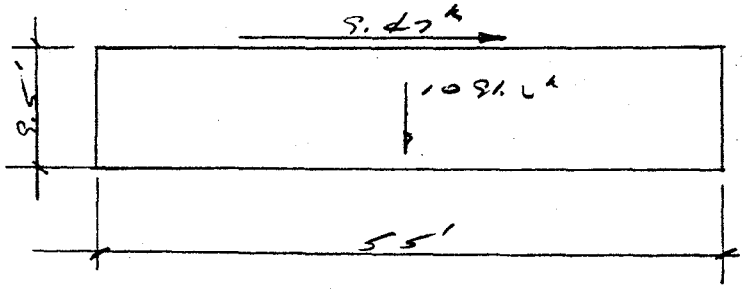
Group IX:
TL = D + E + B + SF + W + Ice (No need to ck)

Group II:

TL = D + E + B + SF + W

Vert. DL = 1091.2 k

Wind Horiz P_{11} = 9.47 k



OTM = 9.47 k × 9.5' = 89.9 'k

M_R = 1091.2 k × 55'/2 = 30,000 'k

OK!

I of Piles:

2 × 3.42² = 23.4

2 × 10.25² = 210.1

2 × 17.08² = 583.5

2 × 23.92² = 1142.3

1961.3

$f = \frac{1091.2}{8} + \frac{89.9^{'k} \times 23.92'}{1961}$

f = 136.4 + 1.10 = 137.5 k

= 68.8 T

Group III:

TL = Group I + LF + 0.3W + WL

P_{11} to Abut:

LF = 12.8 k

0.3W = 2.8

WL = 5.0

20.6 k × 9.5 = 195.7 'k

Σ TL = 1350.2 k

$f = \frac{1350.2}{8} + \frac{195.7^{'k} \times 23.92}{1961}$

f = 168.8 k + 2.4 k = 171.2 k (125%)

136.9 k (100%)

= 69 T

E.M. PLUMMER
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STRUCTURAL . CIVIL ENGINEERS

SUBJECT 51st Ave Bridge SHEET NO 85 OF
BY EMP DATE 5/14/8
JOB NO
CLIENT:

7. Seismic Force:

Superst. DL React = 723^k

$V_\perp = 723^k \times 0.10 = \underline{72.3^k}$ ←

$V_{\parallel} = \underline{72.3^k}$ ←

Group I Loads:

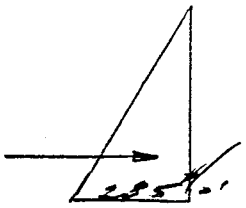
TL = DL + LL + E + B + SF

	DL	TL
Superst. DL =	722.3^k	722.
Superst. LL =		259.
Abut DL —— =	318.0	318.
Wings $[14' \times 1.50 \times 25 + \frac{14' \times 7.5}{2} \times 1.50] 2 \times .15$ =	39.4	39.
Barriers = $360^{\#}/' \times 16' \times 2$ =	11.5	11.
	1091.2^k	1350

For 8 Piles ~ Ld = $\frac{1350.2}{8}$ = 168.8^k or 85^T

Earth Press. = $30^{\#}/ft^3 \times 9.5 = 285^{\#}/'$

$P = 285^{\#}/' \times \frac{9.5}{2} = 1354^{\#}$



Passive Press = $240^{\#}/' \times 0.333 \times 9.5 = 760^{\#}$

As Bms & Abut
Locked Together - ok

d. Wind on superstructure:

Barrier : 22.0"
Deck : 8.5
Girder : 54.0
94.5/12 = 7.88'

Transverse Wind –

$A = 7.88' \times 100'/2 = 394^{\circ}$

$P_{\perp} = 394^{\circ} \times 50^{\#}/\square = 19.7^{k}$ ←

Long. Wind –

$W = 0.012 \times 7.88' \times 400' = 37.8^{k}$

Ld to Abut = $37.8^{k}/4 = 9.47^{k}$

$P_{\parallel} = 9.47^{k}$ ←

5. Long. Force –

$P = 640^{\#}/\square \times 400' \times 4 \text{ Lanes}/4 = 256^{k}$

$P_{\parallel} = 256^{k} \times .05 = 12.8^{k}$ —

6. Wind on LL –

A. Long.

$P_{\perp} = .04^{k}/\square \times 400'/4 = 4.0^{k}$ —

B. Transverse

$P_{\parallel} = 0.10^{k}/\square \times 100'/2 = 5.0^{k}$ —

SOILS INVESTIGATION REPORT

FOR

51ST AVENUE-SALT RIVER BRIDGE
MARICOPA COUNTY, AZ

PREPARED FOR

E.M. PLUMMER CONSULTING ENGINEERS, INC.
3666 N. MILLER ROAD
SUITE 105
SCOTTSDALE, AZ 85251

SOILS INVESTIGATION REPORT
NCA NO. S-79566

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Registered Professional Engineer (Civil)
CERTIFICATE NO.
8797
LARRY F.
NICHOLAS
Date Signed
ARIZONA, U.S.A.

SOILS INVESTIGATION REPORT
NCA NO. S-79566

INTRODUCTION

A FOUNDATION INVESTIGATION FOR THE PROPOSED BRIDGE CONSTRUCTION IN MARICOPA COUNTY, ARIZONA HAS BEEN AUTHORIZED BY E.M. PLUMMER CONSULTING ENGINEERS, INC., THE PROJECT STRUCTURAL ENGINEERS. INFORMATION RECEIVED INDICATES THAT THE BRIDGE WILL BE 1000 FEET IN LENGTH AND 50 FEET IN WIDTH, SPANNING THE SALT RIVER AT 51ST AVENUE. IT IS FURTHER NOTED THAT THE BRIDGE WILL CONSIST OF 9 PIERS APPROXIMATELY 100 FEET APART WITH AN ABUTMENT AT EACH END.

SITE CONDITIONS

AT THE TIME OF THIS INVESTIGATION, THE SALT RIVER AT 51ST AVENUE IS MEANDERING AND MULTICHANNELED, WITH A WIDE ALLUVIUM AND LAG DEPOSITED FLOOD PLAIN. THE RIVER FLOWS IN A WESTERLY DIRECTION AT THIS POINT. THE EXISTING RIVER BED IS RELATIVELY LEVEL EXCEPT WHERE THE WATER FLOWS IN A DEEPER CHANNEL BELOW THE EXISTING BRIDGE. MANY OTHER SURFACE IRREGULARITIES OCCUR WHERE SAND AND GRAVEL HAVE RECENTLY BEEN QUARRIED.

FIELD AND LABORATORY INVESTIGATION

THIS INVESTIGATION CONSISTED OF THE DRILLING AND SAMPLING OF 8 BORE HOLES, DRIVEN TO DEPTHS FROM 70 TO 86 FEET. ALL SOIL BORINGS WERE PERFORMED WITH A TRUCK MOUNTED BECKER HAMMER DRILL RIG UTILIZING THE REVERSE CIRCULATION METHOD. THE BORINGS WERE ADVANCED WITH A 6 5/8 INCH OUTSIDE DIAMETER DOUBLE WALL DRIVE PIPE UTILIZING A ROCK BIT TO PENETRATE THE UNCONSOLIDATED RIVER BED DEPOSIT. THIS PIPE WAS DRIVEN WITH AN 8000 FOOT LB./SQ. IN DIESEL POWERED

PILE HAMMER. BLOW COUNTS WERE RECORDED AT 1 FOOT INTERVALS TO DETERMINE THE CONSISTENCY OF COHESIVE SOILS AND/OR THE RELATIVE DENSITY OF COHESIONLESS SOILS. SAMPLES WERE OBTAINED AT APPROXIMATELY 5 FOOT DEPTH INTERVALS. REFERENCE IS MADE TO THE SOIL BORING LOCATION SKETCH IN THE APPENDIX TO THIS REPORT.

LABORATORY TESTING WAS PERFORMED IN ORDER TO DETERMINE THE INDEX PROPERTIES FOR PROPER CLASSIFICATION OF THE SOILS AND THE ENGINEERING PROPERTIES OF THE SOILS IN ORDER TO PREDICT THE BEHAVIOR OF THE BEARING SOILS. ATTERBERG LIMIT TESTS AND GRAIN SIZE ANALYSES WERE PERFORMED WHERE APPLICABLE IN ORDER TO PROPERLY CLASSIFY ALL SOILS INTO THE UNIFIED SOIL CLASSIFICATION SYSTEM. ALL LABORATORY TESTING WAS ACCOMPLISHED IN ACCORDANCE WITH THE LATEST STANDARD METHODS OF TESTING AS ADOPTED BY THE AMERICAN SOCIETY FOR FOR TESTING AND MATERIALS (A.S.T.M.).

GENERAL SUBSURFACE CONDITIONS

THE SOILS FROM GROUND SURFACE TO THE BOTTOM OF ALL BORE HOLES CONSISTS GENERALLY OF A BROWN TO LIGHT BROWN SANDY GRAVEL (GW) AND/OR GRAVELLY SAND (SP) OF NON-PLASTIC NATURE WITH COBBLES NOTED. INTERBEDDED CLAY LENSES AND/OR SEAMS WERE NOTED IN ALL BORE HOLES AT VARIOUS DEPTHS. THE CLAY LENSES VARIED IN THICKNESS FROM ONE TO SIX FEET. REFERENCE IS MADE TO THE INDIVIDUAL SOIL BORING LOGS AND SOILS PROFILE IN THE APPENDIX TO THIS REPORT. HOWEVER, AT AN ELEVATION OF APPROXIMATELY 950, A CLAY LAYER WITH A THICKNESS OF APPROXIMATELY FOUR TO SIX FEET APPEARS TO BE SOMEWHAT CONTINUOUS THROUGHOUT

THE LENGTH OF THE INVESTIGATION. WATER LEVELS WERE NOTED AT VARIOUS DEPTHS IN BORE HOLES B-1, B-3, B-5 AND B-7, BUT SEEMED TO INVERSELY FOLLOW THE BANK PROFILE WITH THE HIGHEST LEVEL BELOW THE MAIN CHANNEL AT AN APPROXIMATE ELEVATION OF 981 FEET (B-3).

BORE HOLES B-2, B-4, B-6 AND B-8 WERE DRY UPON COMPLETION OF DRILLING OPERATIONS. IT IS POINTED OUT THAT THIS METHOD OF DRILLING ALLOWS A MAXIMUM PARTICLE DIAMETER OF 3 INCHES TO BE RETRIEVED DURING SAMPLING. THEREFORE, ALL LARGE COBBLES ARE BROKEN UP BY THE ACTION OF THE ROCK BIT. THE GRAIN SIZE ANALYSES FOUND IN THE APPENDIX TO THIS REPORT REFLECT ONLY THE RECOVERED SAMPLES. IN AN ATTEMPT TO ESTABLISH THE PERCENT OF COBBLES LARGER THAN THE 3 INCH DIAMETER SIZE, A VISUAL INSPECTION WAS MADE ON ALL THE RECOVERED SAMPLES. THE BROKEN PIECES WERE EXAMINED IN SUCH A WAY AS TO ESTIMATE THE APPROXIMATE DIAMETER PRIOR TO HAVING BEEN BROKEN DURING THE DRILLING OPERATIONS. RESULTS OF THIS EFFORT ARE FOUND ON THE INDIVIDUAL BORING LOGS IN TERMS OF AN ESTIMATED PERCENT COBBLES IN THAT PARTICULAR LAYER. FOR A SCOUR ANALYSIS, AN AVERAGE GRAIN SIZE CURVE HAD TO BE DEVELOPED. TO DO THIS, INDIVIDUAL GRAIN SIZE CURVES WERE DRAWN FOR ALL SAMPLES TESTED. THEY WERE ALL GROUPED BASED ON CLASSIFICATION AND THEN EACH CLASSIFICATION GROUP PLOTTED AS A COMPOSITE CURVE. THE MAJOR CLASSIFICATION GROUP WAS SELECTED FOR USE IN THE SCOUR ANALYSIS. THE TOP PORTION OF THAT CURVE WAS THEN ALTERED TO ACCOUNT FOR THE ESTIMATED PERCENT OF COBBLES LARGER THAN 3 INCHES IN DIAMETER. ON THE CURVE THUS

DEVELOPED, THE MID-POINTS OF EACH PERCENTAGE RANGE WERE THEN PLOTTED SEPARATELY TO ESTABLISH AN "AVERAGE" CURVE WHICH WAS ULTIMATELY UTILIZED FOR THE SCOUR ANALYSIS.

ANALYSIS AND RECOMMENDATIONS

AN ANALYSIS OF THE FIELD AND LABORATORY INVESTIGATION INDICATES THAT THE SUBSURFACE CONDITIONS ARE GENERALLY FAVORABLE FOR THE DESIGN AND CONSTRUCTION OF DRILLED CAISSONS OR DRIVEN PILES. FOR THIS PROJECT, IT IS RECOMMENDED THAT STEEL H-PILES BE UTILIZED FOR SUPPORTING THE BRIDGE STRUCTURE. RESULTS OF THE GRAIN SIZE ANALYSES INDICATE THAT THE PILES CAN PROBABLY BE DRIVEN WITHOUT SIGNIFICANT DIFFICULTY. IN ORDER TO DETERMINE SAFE ALLOWABLE PILE CAPACITIES, A STEEL H-PILE WITH A DESIGNATION OF HP 14 X 117 WAS CONSIDERED. FOLLOWING IS A SUMMARY OF SAFE ALLOWABLE PILE CAPACITIES FOR VARIOUS LENGTH PILE IMBEDMENTS.

LENGTH OF H-PILE (FT.)	SAFE ALLOWABLE CAPACITY (TONS)
30	40
35	60
40	75
50	100

BASED ON A REVIEW OF THE SOILS PROFILE AND CONSIDERING THE MAXIMUM SCOUR DEPTHS, IT IS RECOMMENDED THAT PILES BE DRIVEN THROUGH THE COMPRESSIBLE CLAY LAYERS THAT BEGIN AT APPROXIMATELY ELEVATION 950 AND 940. BASED ON

THE SOIL BORING INFORMATION, THE UPPER LAYER SEEMS TO UNDERLY THE ENTIRE SPAN OF THE PROPOSED STRUCTURE AND IS APPROXIMATELY 4.0 TO 7.0 FEET THICK, WHILE THE LOWER LAYER EXISTS IN THE AREA OF THE MAIN CHANNEL AND APPEARS TO BE ON THE ORDER OF 1.0 TO 2.0 FEET THICK. FOR THE SOUTH ABUTMENT AND THE ADJACENT SIX PIERS (STATIONS 24 + 00 THRU 30 + 00) THIS REQUIRES A MINIMUN TIP ELEVATION OF 940 NECESSITATING A 40 FOOT IMBEDMENT LENGTH. FOR THE BALANCE OF THE PIERS AND THE NORTH ABUTMENT, A MINIMUM TIP ELEVATION OF 930 IS NEEDED TO GET BELOW THE LOWER CLAY SEAM, AND THAT WOULD REQUIRE A MINIMUM IMBEDMENT LENGTH OF 50 FEET.

CORROSION SHOULD NOT SIGNIFICANTLY AFFECT THE STRENGTH OF THE H-PILES AND THEREFORE MAY BE NEGLECTED. ANY ATTEMPT TO TREAT THE PILES WITH ANY TIPE OF CORROSION RESISTANT COATING WOULD REQUIRE A CONCRETE ENCASEMENT OR SIMILAR PROTECTION THAT WOULD PROBABLY BE UNECONOMICLY FEASIBLE.

IT IS RECOMMENDED THAT TEST PILES BE DRIVEN TO DETERMINE IF MAXIMUM IMBEDMENT LENGTHS CAN BE ACCOMPLISHED AND WHAT THE DRIVING RESISTANCE WILL BE AT DEPTH TO ESTABLISH PILE DRIVING CRITERIA FOR THE BALANCE OF THE PROJECT.

SITE PREPARATION

IN ORDER TO ACCOMMODATE THE CONSTRUCTION ACTIVITY ASSOCIATED WITH THE NEW BRIDGE, TRAFFIC WILL NEED TO BE REROUTED. ONCE THIS HAS BEEN ACCOMPLISHED, THE EXISTING BRIDGE AND PAVEMENT MAY BE REMOVED. IT IS RECOMMENDED THAT THE ENTIRE PROPOSED ALIGNMENT BE EXCAVATED TO THE MAXIMUM DEPTH OF SCOUR, WHICH HAS BEEN ESTABLISHED TO BE ELEV. 980 FEET. THE MINIMUM WIDTH OF THE EXCAVATION WILL HAVE TO BE SET ACCORDING TO HOW MUCH ROOM WILL BE NEEDED TO

ACCOMMODATE CONSTRUCTION EQUIPMENT. THE DEPTH OF EXCAVATION WILL BE ON THE ORDER OF 25 TO 30 FEET BELOW EXISTING CHANNEL BOTTOM. BASED UPON THE UNCONSOLIDATED NATURE OF THE RIVER BED MATERIAL, SIDE SLOPES OF THE EXCAVATION SHOULD BE 3 HORIZONTAL TO 1 VERTICAL.

THE GROUND WATER TABLE MOST LIKELY FLUCTUATES WITH THE SEASON. THE GROUND WATER TABLE FOR THE MAJORITY OF THE PROPOSED STRUCTURE WAS FAR BELOW THE ANTICIPATED EXCAVATION DEPTH AT THE TIME OF THIS INVESTIGATION. DEWATERING MAY BE NECESSARY DEPENDING ON THE SEASON DURING WHICH CONSTRUCTION BEGINS. HOWEVER, IN THE AREA OF THE EXISTING BRIDGE WHERE THE RIVER IS CURRENTLY FLOWING, THE MAIN CHANNEL WILL HAVE TO BE REROUTED TO ACCOMMODATE INSTALLATION OF FOUNDATIONS. ALSO IN THIS AREA, DEWATERING WILL PROBABLY BE REQUIRED TO ACCOMMODATE CONSTRUCTION.

BACKFILL

BACKFILLING OPERATIONS WILL REQUIRE SPECIAL CARE TO AVOID DAMAGING THE CONCRETE PIERS. THE LARGER ROCKS WILL HAVE A TENDENCY TO FALL AGAINST THE CONCRETE AND CHIP IT. IF A METHOD OF PROTECTION IS DESIRED, A BITUMINOUS WATER PROOFING MATERIAL IS SUGGESTED. SUCH MATERIAL IS MANUFACTURED IN SHEETS OF VARYING SIZES AND THICKNESSES AND, ALTHOUGH IT IS BASICALLY A WATER PROOFING PRODUCT, IT WOULD WORK AS A CUSHION AGAINST THE CONCRETE DURING BACKFILLING OPERATIONS.

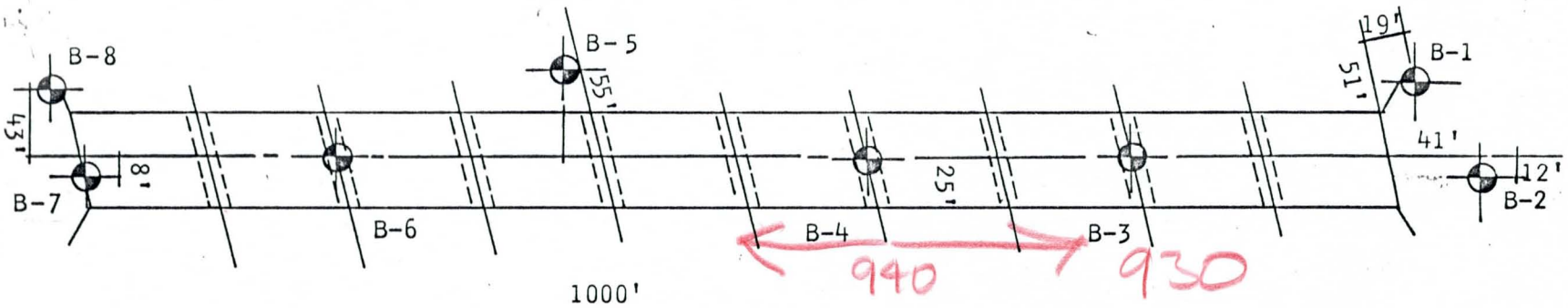
IT IS RECOMMENDED THAT EXCAVATED RIVER BED MATERIALS BE USED AS BACKFILL IN THE PIER EXCAVATIONS. COMPACTION OF THESE MATERIALS SHOULD BE AC-

COMPLISHED BY UTILIZING A GRID TYPE ROLLER. THIS MATERIAL SHOULD BE COMPACTED TO 95 PERCENT OF MAXIMUM DENSITY AS DETERMINED BY ASTM D-698 METHOD OF COMPACTION AT OPTIMUM MOISTURE ± 3 PERCENT. AS TESTING OF THESE MATERIALS WILL BE DIFFICULT BECAUSE OF THE PERCENTAGE OF COBBLES, IT IS EMPHASIZED THAT COMPACTION OPERATIONS SHOULD BE UNDER FULL TIME OBSERVATION AND SUPERVISION OF A SOILS ENGINEER.

GENERAL

IT IS RECOMMENDED THAT A SOILS ENGINEER SUPERVISE THE EARTHWORK PORTIONS OF THIS PROJECT TO ENSURE COMPLIANCE TO LOCAL SPECIFICATIONS AND THE RECOMMENDATIONS PRESENTED IN THIS REPORT. IF ANY SIGNIFICANT CHANGES ARE MADE IN THE SCOPE OF WORK OR TYPE OF CONSTRUCTION THAT WAS ASSUMED IN THE "INTRODUCTION" OF THIS REPORT, WE WOULD APPRECIATE THE OPPORTUNITY TO REVIEW AND POSSIBLY MODIFY OUR CONSLUSIONS AND RECOMMENDATIONS PRESENTED IN THIS REPORT.

A P P E N D I X



APPROXIMATE SOIL BORING LOCATION

SOILS BORING LOCATION SKETCH
E.M. PLUMMER CONSULTING ENGRS.
51ST AVENUE SALT RIVER BRIDGE
NCA NO. S-79566

NICHOLAS COWIE & ASSOCIATES
SOILS ENGINEERS INC.
49 E. THOMAS SUITE 107 •
PHOENIX, AZ 85012 • (602) 265-1066

PLATE A

BORING B-1
DRILLING COMPLETED ON DECEMBER 12, 1979
FIELD ENGINEER: T.M.

ELEV.	Symbol	SOIL DESCRIPTION
1011.0		BROWN SANDY GRAVEL COBBLES NOTED 10% (GW)
		Scour 980
948		BROWN SANDY GRAVEL (GW)
938		BROWN SANDY GRAVEL SILT & CLAY NOTED (GW-GM) GRADES WITH CLAY AT ELEV. 938 - COBBLES NOTED
936		END OF BORING.
		Tip of pile 930

* WATER ENCOUNTERED AT ELEVATION 948 FEET DURING DRILLING

BORING B-2
DRILLING COMPLETED ON DECEMBER 12, 1979
FIELD ENGINEER: T.M.

ELEV.	Symbol	SOIL DESCRIPTION
1011.0		BROWN SANDY GRAVEL COBBLES NOTED 10% (GW)
		Scour 980
970		BROWN SILTY CLAYEY SAND (SP) COBBLES NOTED 5%
		CLAY SEAM FROM ELEVATION 956 TO 955 FEET
946		BROWN SANDY GRAVEL (GW) COBBLES NOTED 10%
		CLAY SEAM NOTED AT ELEV. 935
934		END OF BORING. HOLE DRY UPON COMPLETION
		Tip of pile 930

- Denotes standard penetration test with blow counts for each 6 inches of penetration by 2 inch O.D. split spoon sampler being driven by a 140 pound weight falling 30 inches.
- Denotes driven ring sample.
- Denotes bag sample from auger cuttings.

LL = LIQUID LIMIT
PL = PLASTIC LIMIT
PI = PLASTICITY INDEX
WC = WATER CONTENT

SOIL BORING LOGS
E.M. PLUMMER CONSULTING ENGRS.
51ST AVENUE SALT RIVER BRIDGE
NCA NO. S79566

NICHOLAS COWIE & ASSOCIATES
SOILS ENGINEERS INC.
43 E. THOMAS SUITE 107 •
PHOENIX, AZ 85012 • (602) 265-1086

BORING B-3
DRILLING COMPLETED ON DECEMBER 12, 1979
FIELD ENGINEER: T.M.

ELEV.	Symbol	SOIL DESCRIPTION
1010.7		BROWN SANDY GRAVEL WITH SILT AND CLAY COBBLES NOTED 5-30% (GW-GM)
		Scour 980
980.7		BROWN SANDY GRAVEL COBBLES NOTED 25% (GW)
		WATER ENCOUNTERED AT ELEV. 993 DURING DRILLING.
		CLAY SEAM NOTED AT ELEV. 940
936.7		END OF BORING
		Tip of pile 930
		*WATER ENCOUNTERED AT ELEV. 980 DURING DRILLING

BORING B-4
DRILLING COMPLETED ON DECEMBER 12, 1979
FIELD ENGINEER: T.M.

ELEV.	Symbol	SOIL DESCRIPTION
1009.9		BROWN SANDY GRAVEL (GW) COBBLES NOTED 5-10%
		Scour 980
951		BROWN SILTY CLAY (CL)
948		SANDY GRAVEL (GW) COBBLES NOTED 5%
936		END OF BORING. HOLE DRY UPON COMPLETION
		Tip of pile 930

- Denotes standard penetration test with blow counts for each 6 inches of penetration by 2 inch O.D. split spoon sampler being driven by a 140 pound weight falling 30 inches.
- Denotes driven ring sample.
- Denotes bag sample from auger cuttings.

LL = LIQUID LIMIT
PL = PLASTIC LIMIT
PI = PLASTICITY INDEX
WC = WATER CONTENT

SOIL BORING LOGS
E.M. PLUMMER CONSULTING ENGRS.
51ST AVENUE SALT RIVER BRIDGE
NCA NO. S-79566

NICHOLAS COWIE & ASSOCIATES
SOILS ENGINEERS INC.
49 E. THOMAS SUITE 107
PHOENIX, AZ 85012 • (602) 265-1066

PLATE C

BORING B-5
DRILLING COMPLETED ON DECEMBER 12, 1979
FIELD ENGINEER: T.M.

ELEV.	Symbol	SOIL DESCRIPTION
1008.0		BROWN SANDY GRAVEL COBBLES NOTED 5% (GW)
		Scour 980
976		BROWN GRAVELLY SAND COBBLES NOTED 5% (SP)
945		
942		BROWN SILTY CLAY (CL)
		BROWN SANDY GRAVEL COBBLES NOTED 10% (GW)
		Bottom of pile 940
922		END OF BORING

WATER ENCOUNTERED AT ELEV. 945 DURING DRILLING
WATER BECAME BLACK IN COLOR AT ELEV. 924

BORING B-6
DRILLING COMPLETED ON DECEMBER 12, 1979
FIELD ENGINEER: T.M.

ELEV.	Symbol	SOIL DESCRIPTION
1007.5		SANDY GRAVEL WITH SILT AND CLAY (GW-GM)
		COBBLES NOTED 5%
986		BROWN SANDY GRAVEL (GW) COBBLES NOTED 5-20%
		CLAY SEAM NOTED AT ELEV. 982
		Scour 980
953		BROWN SANDY GRAVEL (GW)
		Bottom of pile 940
936		END OF BORING. HOLD DRY UPON COMPLETION.

- Denotes standard penetration test with blow counts for each 6 inches of penetration by 2 inch O.D. split spoon sampler being driven by a 140 pound weight falling 30 inches.
- Denotes driven ring sample.
- Denotes bag sample from auger cuttings.

LL = LIQUID LIMIT
PL = PLASTIC LIMIT
PI = PLASTICITY INDEX
WC = WATER CONTENT

SOIL BORING LOGS
E.M. PLUMMER CONSULTING ENGRS.
51ST AVENUE SALT RIVER BRIDGE
NCA NO. S-79566

NICHOLAS COWIE & ASSOCIATES
SOILS ENGINEERS INC.
49 E. THOMAS SUITE 107 •
PHOENIX, AZ 85012 • (602) 265-1025

PLATE D

BORING B-7
DRILLING COMPLETED ON DECEMBER 12, 1979
FIELD ENGINEER: T.M.

ELEV.	Symbol	SOIL DESCRIPTION
1007.4		BROWN SANDY GRAVEL (GW) COBBLES NOTED 5%
		Slope 980
952		BROWN SILTY CLAY (CL)
945		BROWN SANDY GRAVEL (GW) COBBLES NOTED 5%
		Bottom of pile 940
921		END OF BORING
		WATER ENCOUNTERED AT ELEV. 921 FEET DURING DRILLING

BORING B-8
DRILLING COMPLETED ON DECEMBER 12, 1979
FIELD ENGINEER: T.M.

ELEV.	Symbol	SOIL DESCRIPTION
1007.4		BROWN SANDY GRAVEL (GW) 5-30% COBBLES
		Slope 980
		LARGER COBBLES NOTED AT ELEV. 972
949		BROWN SILTY CLAY (CL)
945		BROWN SANDY GRAVEL (GW) COBBLES NOTED 5%
		Bottom of pile 940
933.4		END OF BORING. HOLE DRY UPON COMPLETION.

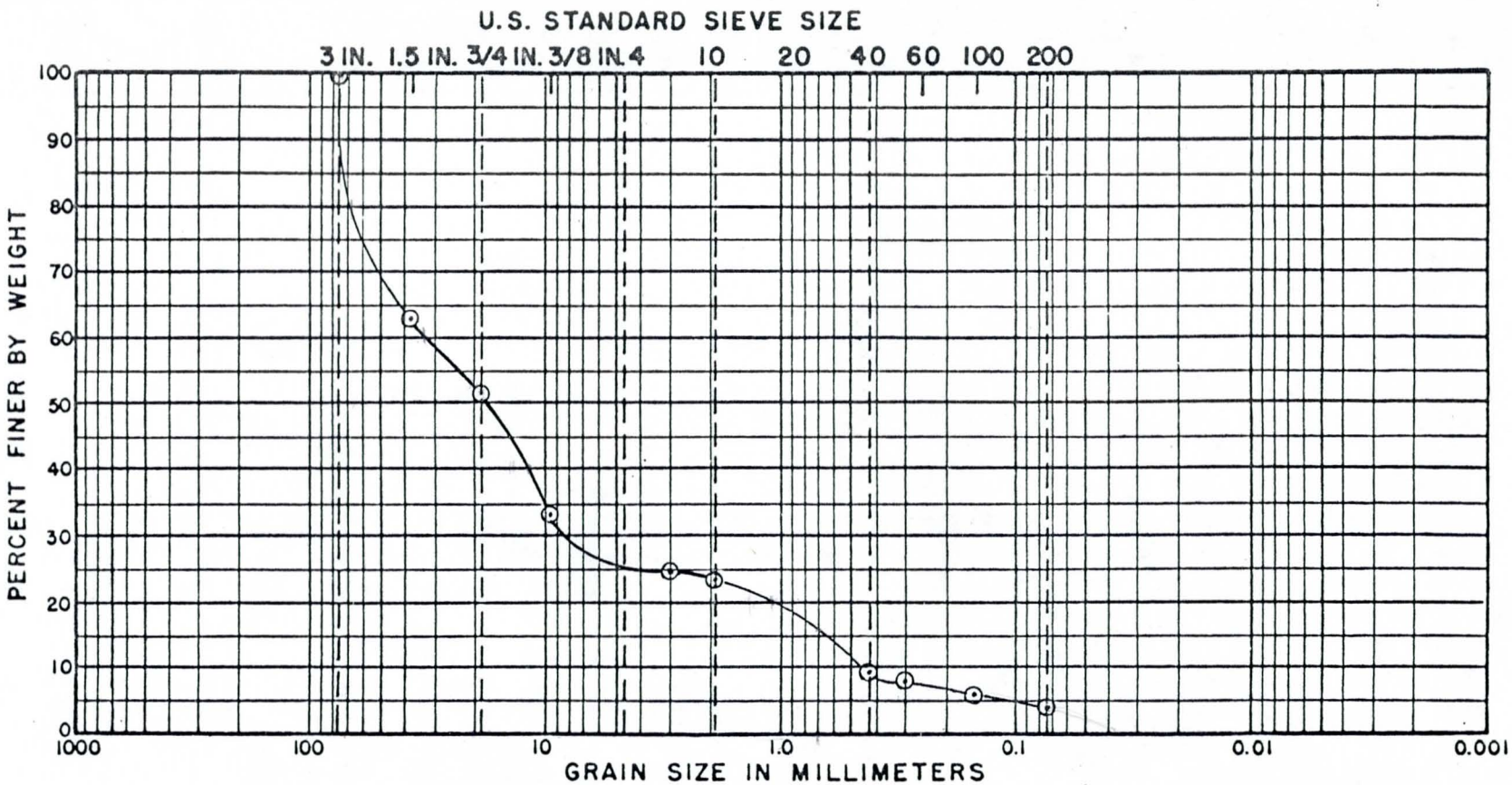
- Denotes standard penetration test with blow counts for each 6 inches of penetration by 2 inch O.D. split spoon sampler being driven by a 140 pound weight falling 30 inches.
- Denotes driven ring sample.
- Denotes bag sample from auger cuttings.

LL = LIQUID LIMIT
PL = PLASTIC LIMIT
PI = PLASTICITY INDEX
WC = WATER CONTENT

SOIL BORING LOGS
E.M. PLUMMER CONSULTING ENGRS.
51ST AVENUE SALT RIVER BRIDGE
NCA NO. S-79566

NICHOLAS COWIE & ASSOCIATES
SOILS ENGINEERS INC.
49 E. THOMAS SUITE 107 •
PHOENIX, AZ 85012 • (602) 265-1066

PLATE E



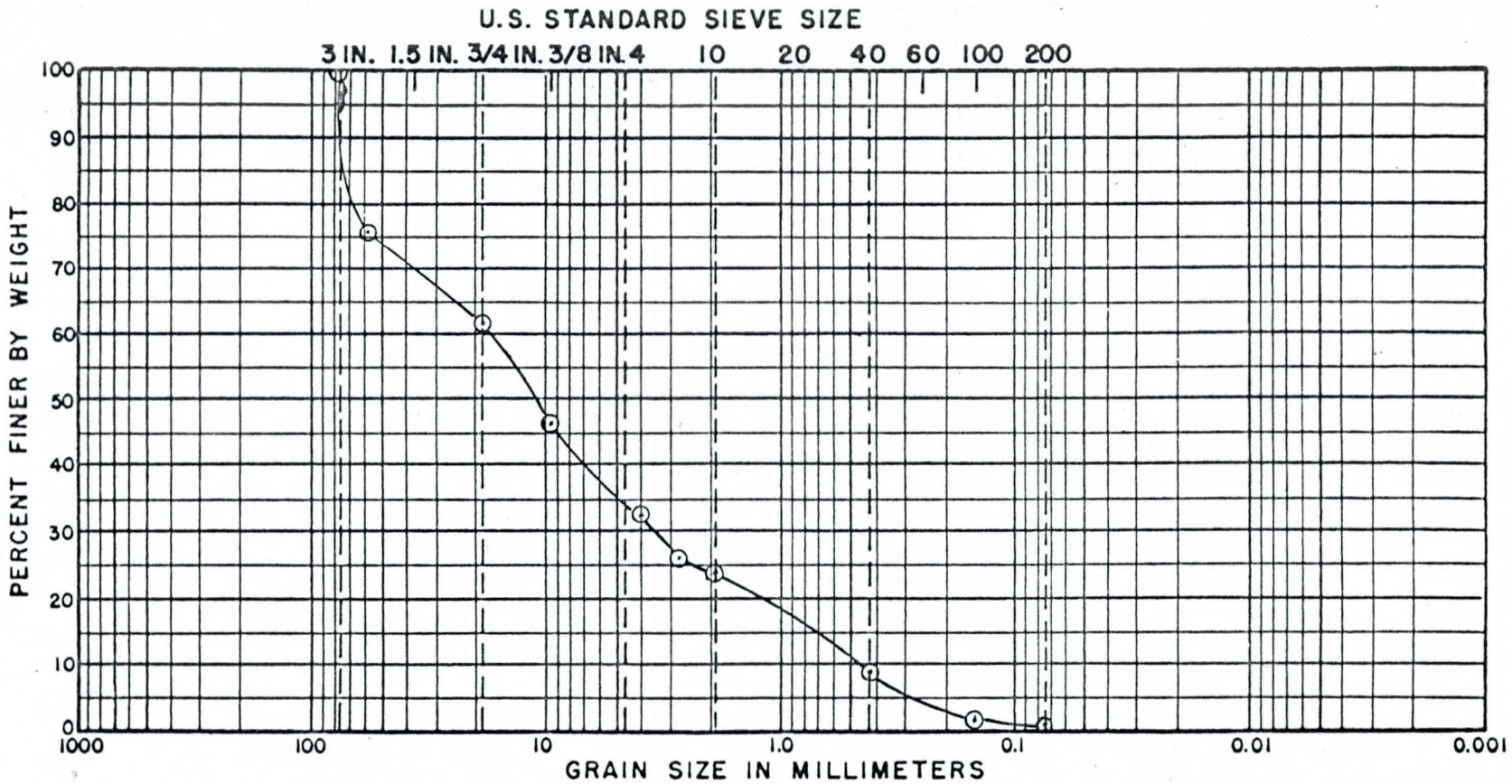
COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
B-1	25'	GW	SANDY GRAVEL					

GRADATION CURVE

NICHOLAS COWIE & ASSOCIATES

PLATE F-1



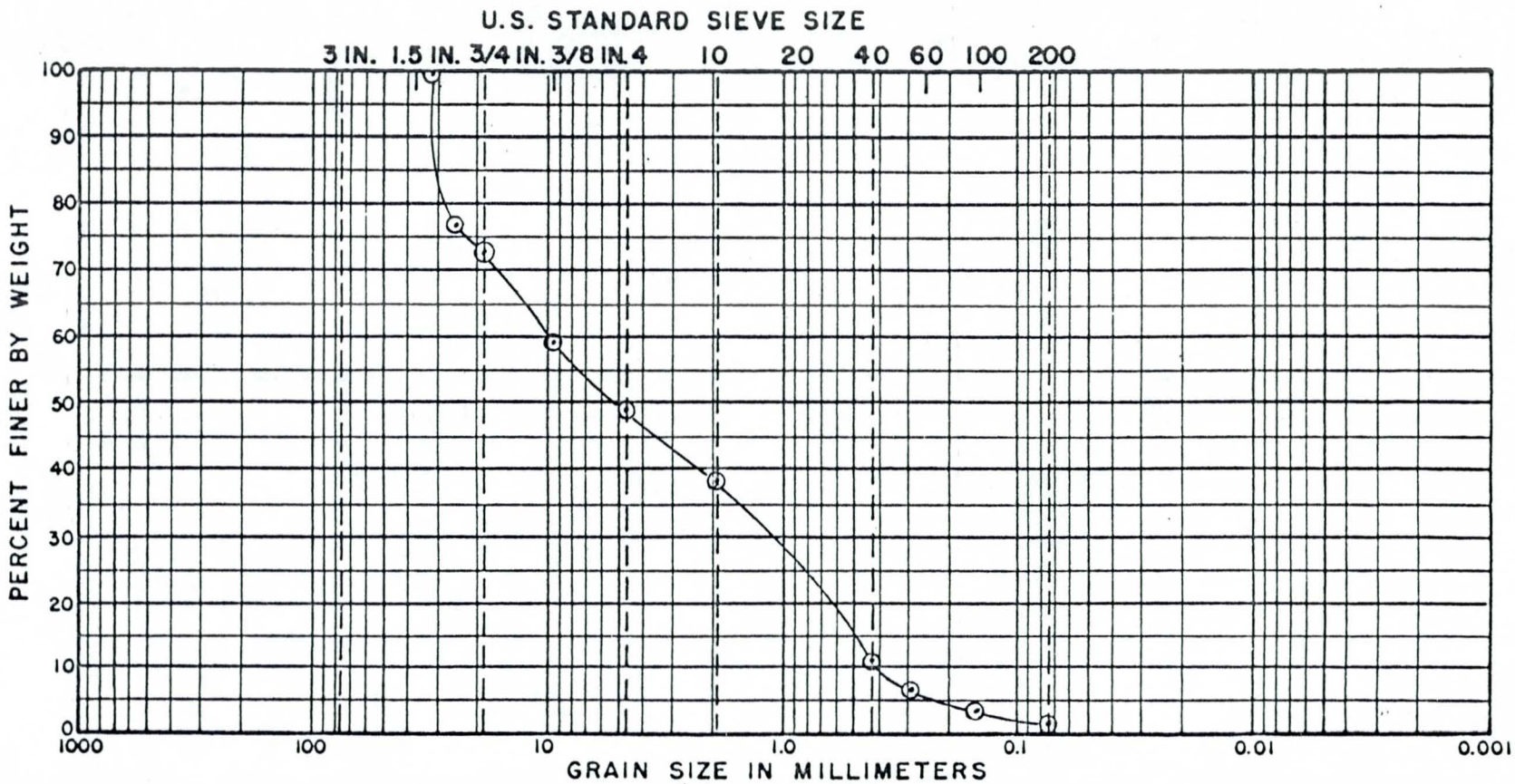
COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
B-1	40'	GW	SANDY GRAVEL					

GRADATION CURVE

NICHOLAS COWIE & ASSOCIATES

PLATE F-2



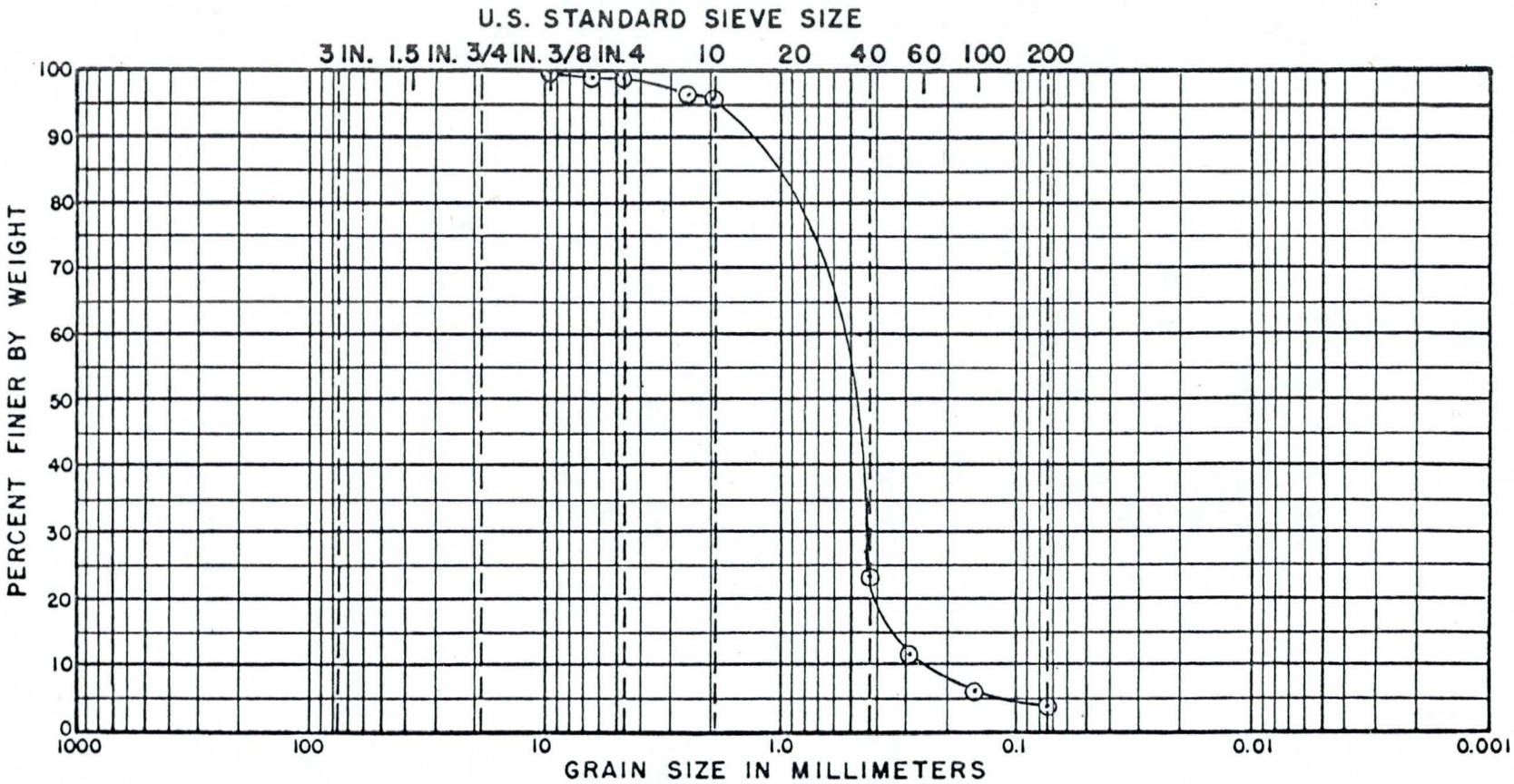
COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
B-1	75'	GW	SANDY GRAVEL					

GRADATION CURVE

NICHOLAS COWIE & ASSOCIATES

PLATE F-3



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

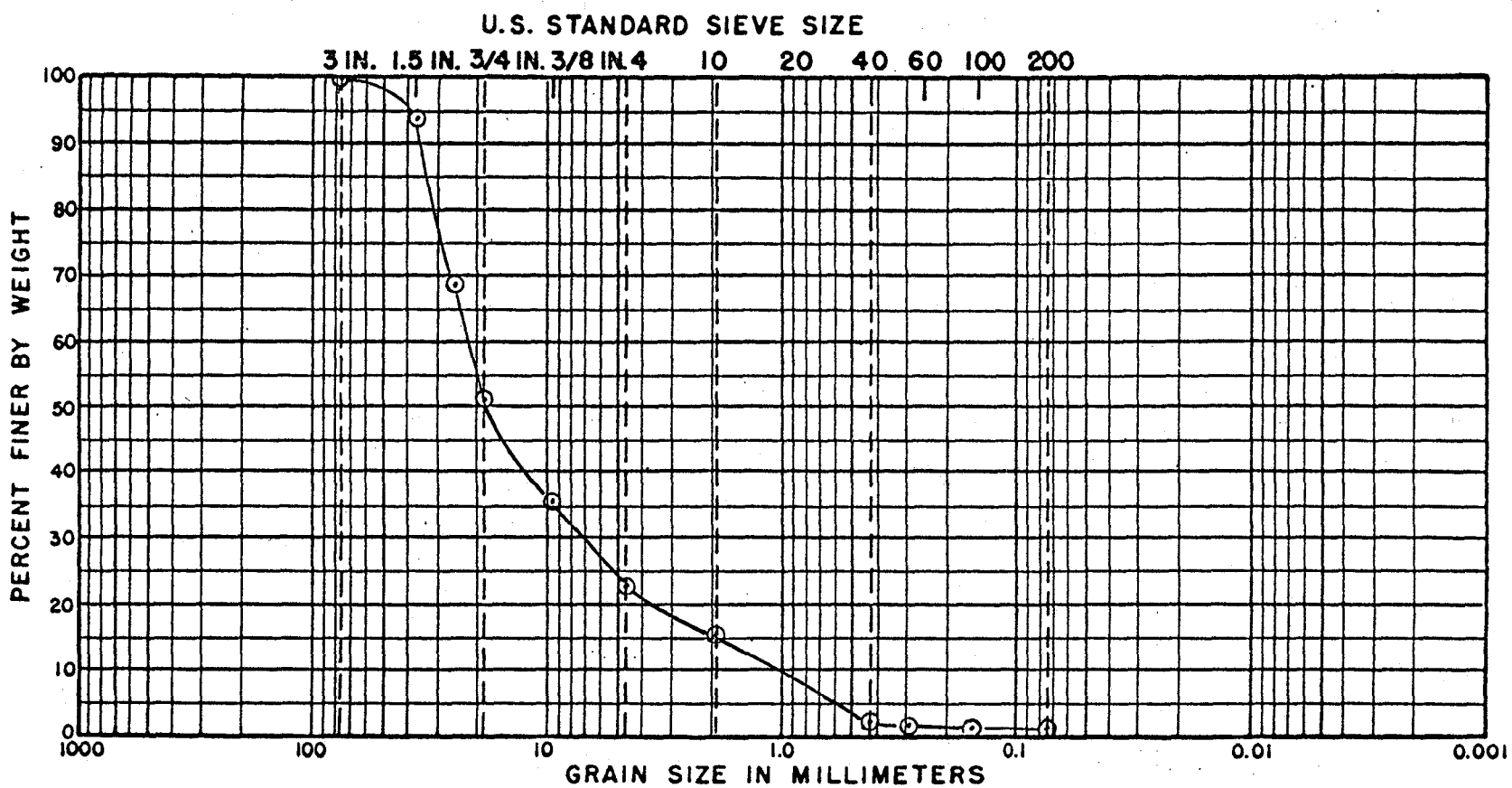
	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
B-2	40'	SP	SILTY SAND					

SILTY SAND IS 12% < 200

GRADATION CURVE

NICHOLAS COWIE & ASSOCIATES

PLATE F-4



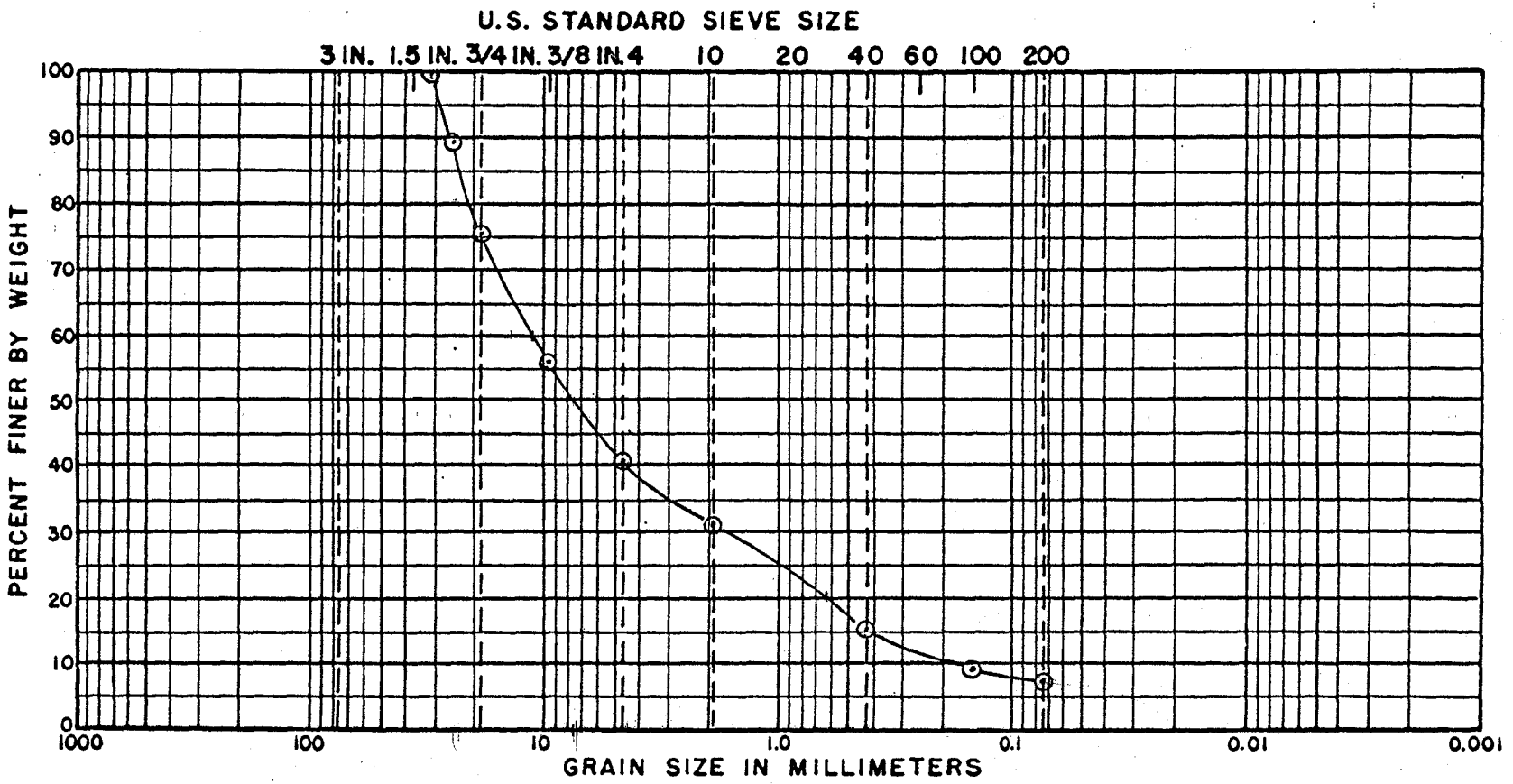
COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
B-2	70'	GW	SANDY GRAVEL					

NICHOLAS COWIE & ASSOCIATES

PLATE F-5

GRADATION CURVE

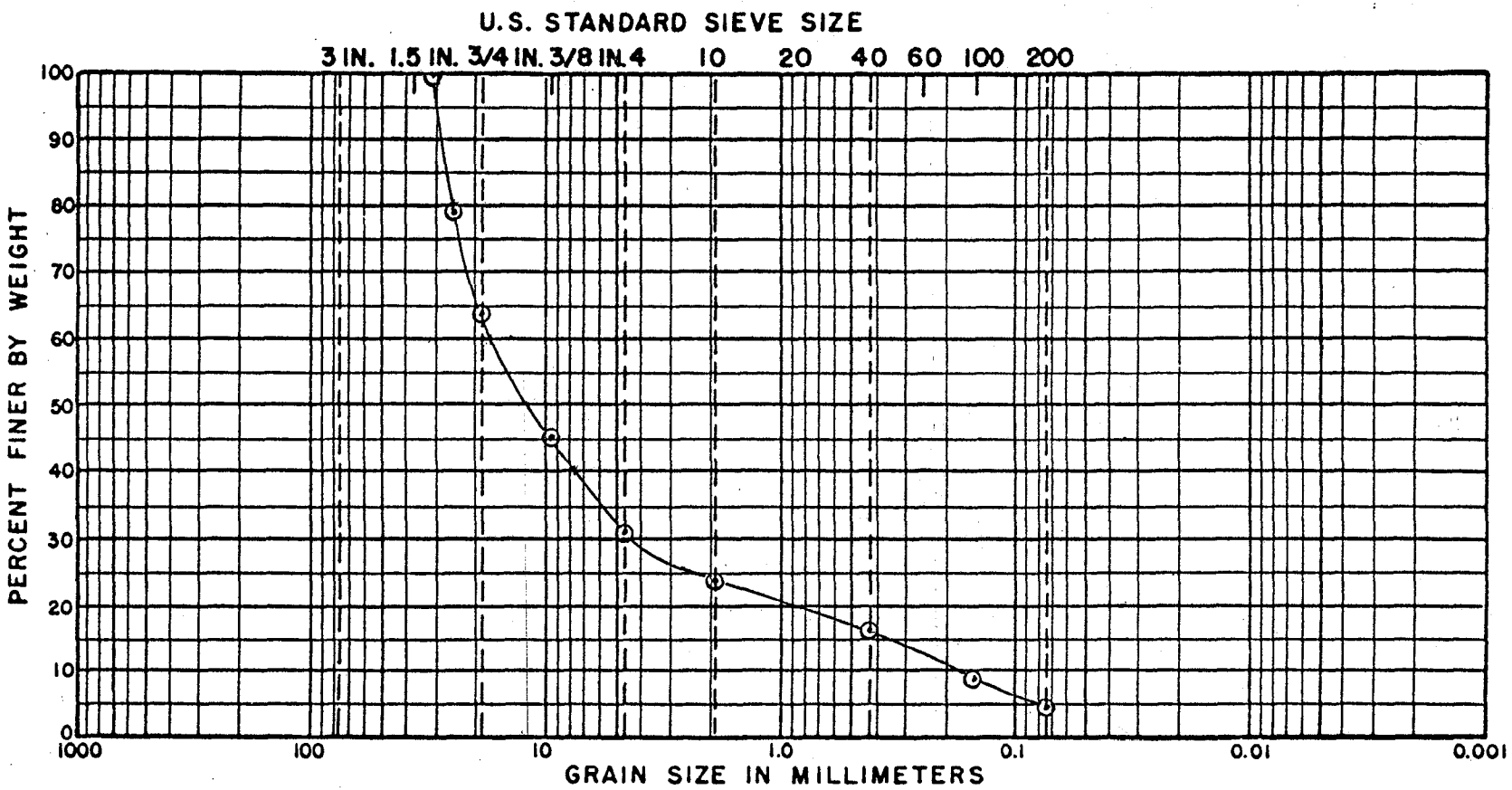


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
B-3	5'	GW-GM	SANDY GRVL. W/LT.SILTY	CLAY				

GRADATION CURVE

NICHOLAS COWIE & ASSOCIATES



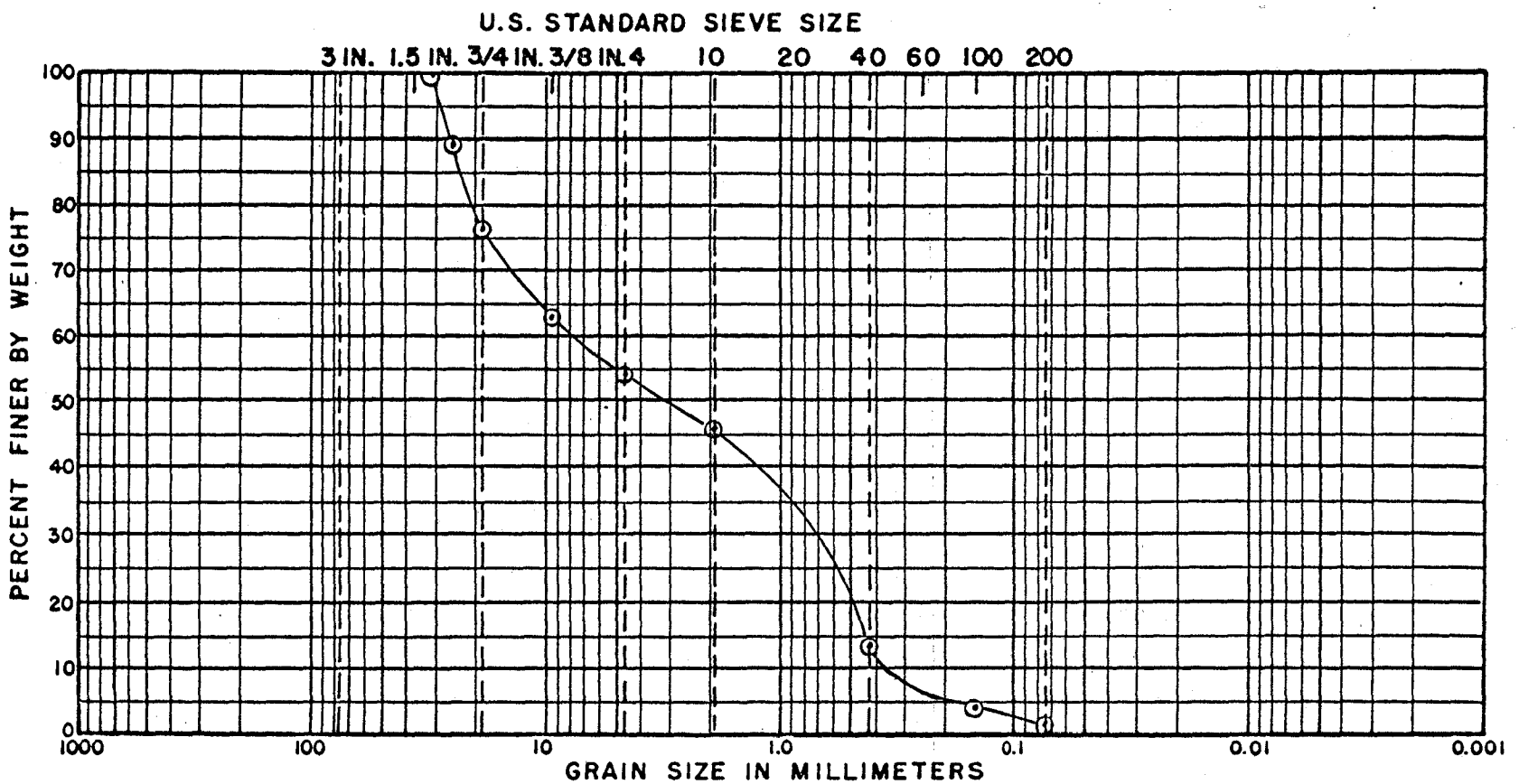
COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
B-3	20'	GW	SANDY GRAVEL					

GRADATION CURVE

NICHOLAS COWIE & ASSOCIATES

PLATE F-7

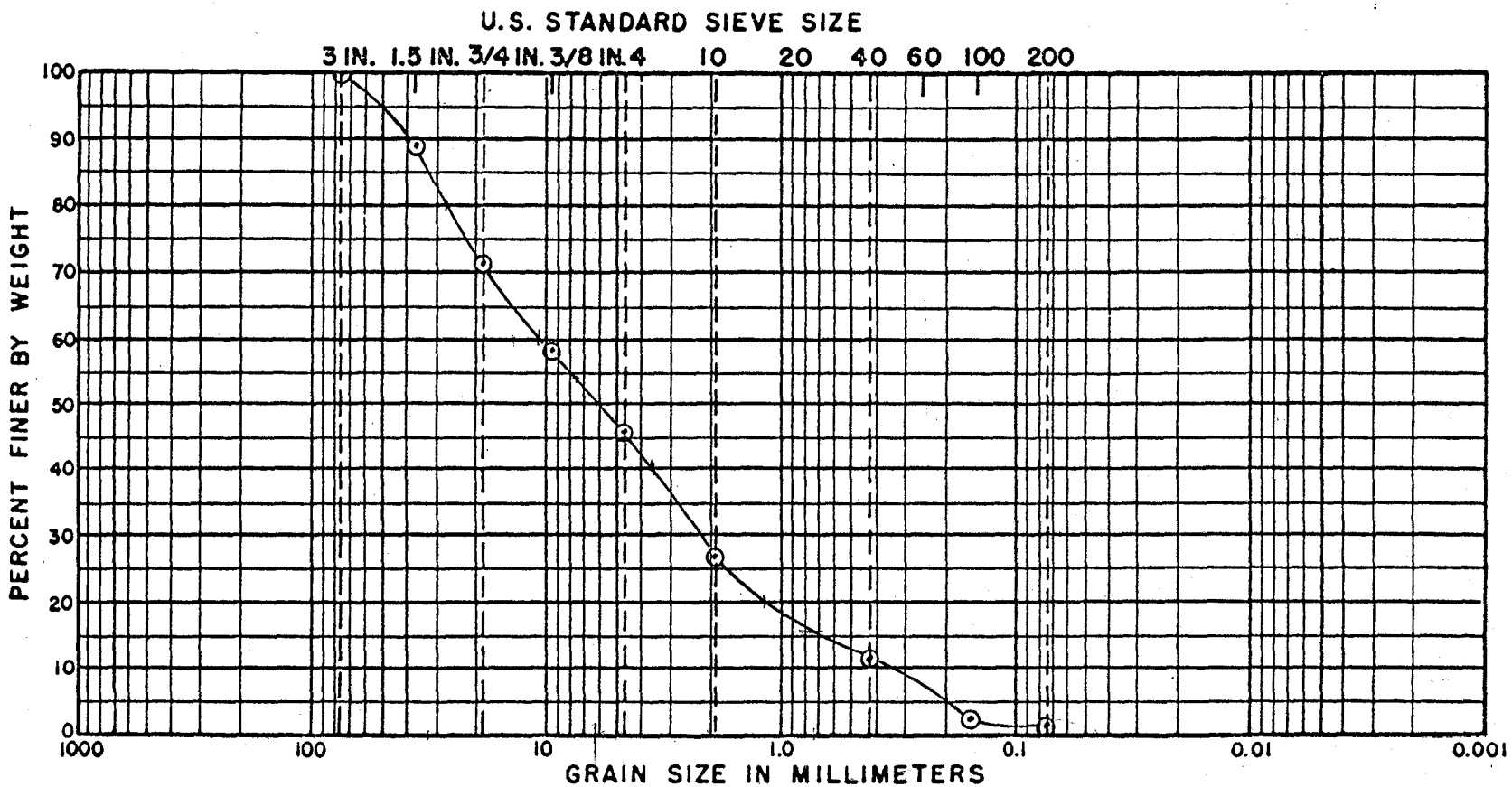


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
B-3	50'	SW	GRAVELLY SAND					

GRADATION CURVE

NICHOLAS COWIE & ASSOCIATES



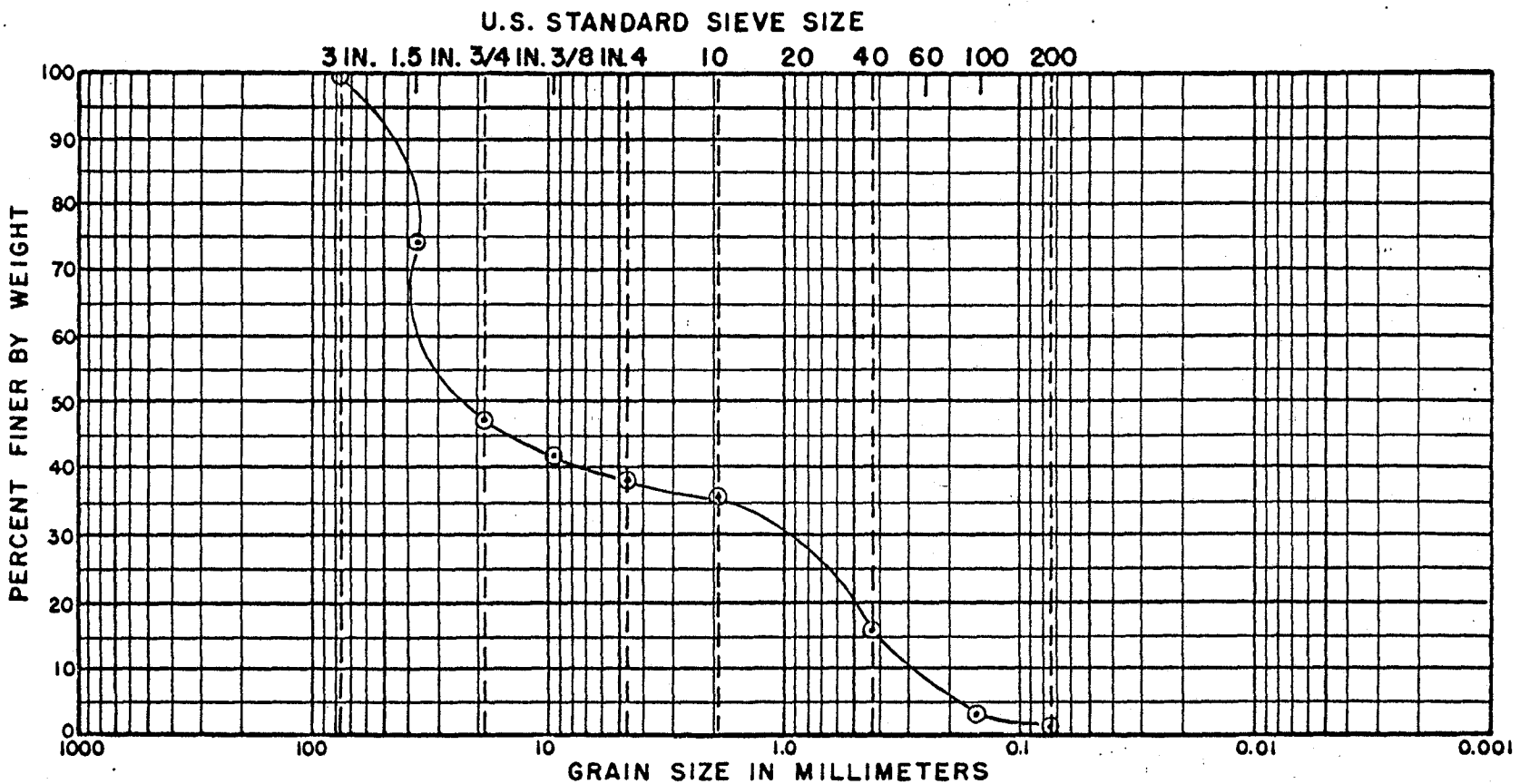
COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
B-4	10'	GW	SANDY GRAVEL					

NICHOLAS COWIE & ASSOCIATES

PLATE F-9

GRADATION CURVE

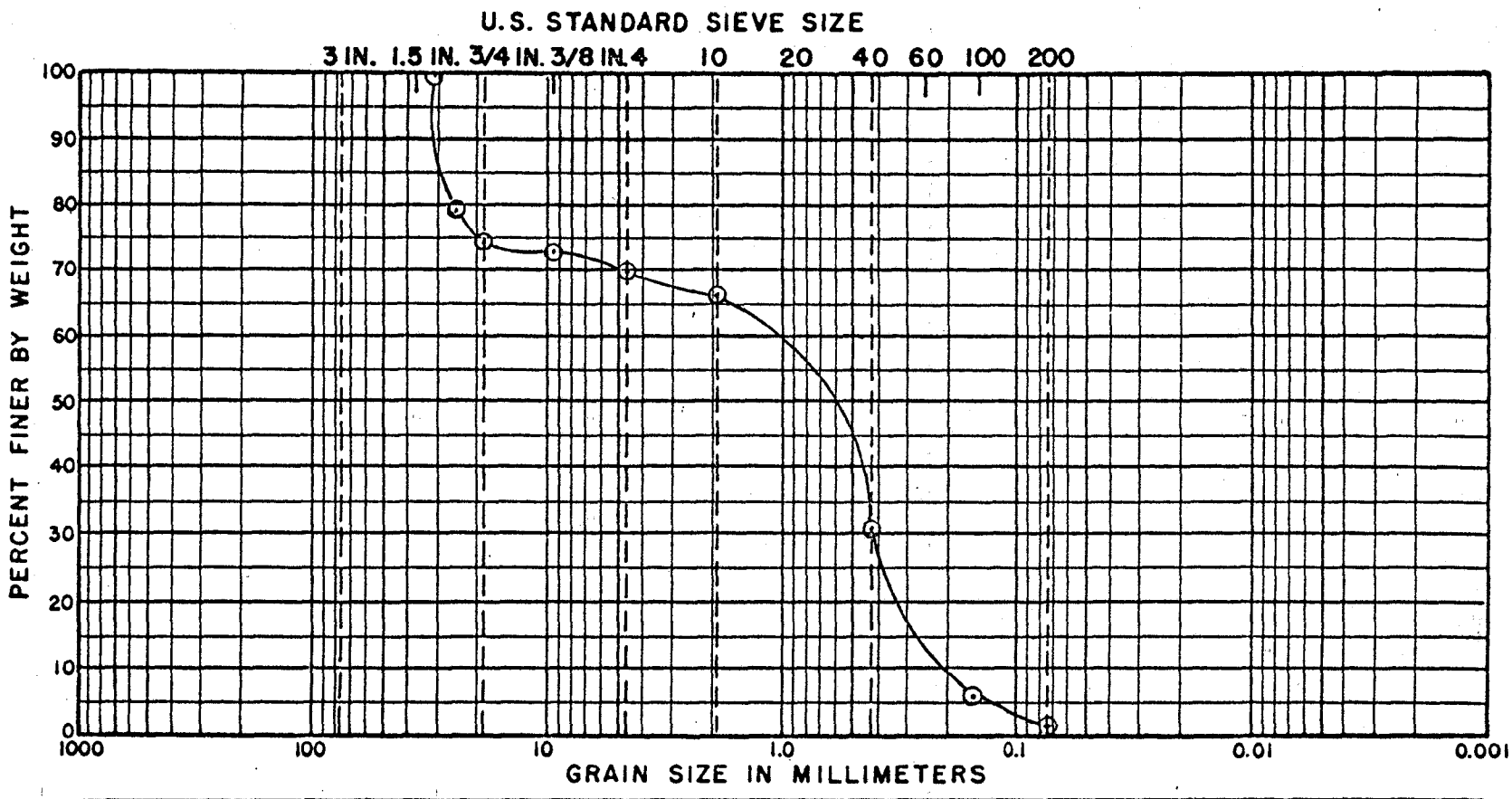


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
B-4	40'	GW	SANDY GRAVEL					

GRADATION CURVE

NICHOLAS COWIE & ASSOCIATES

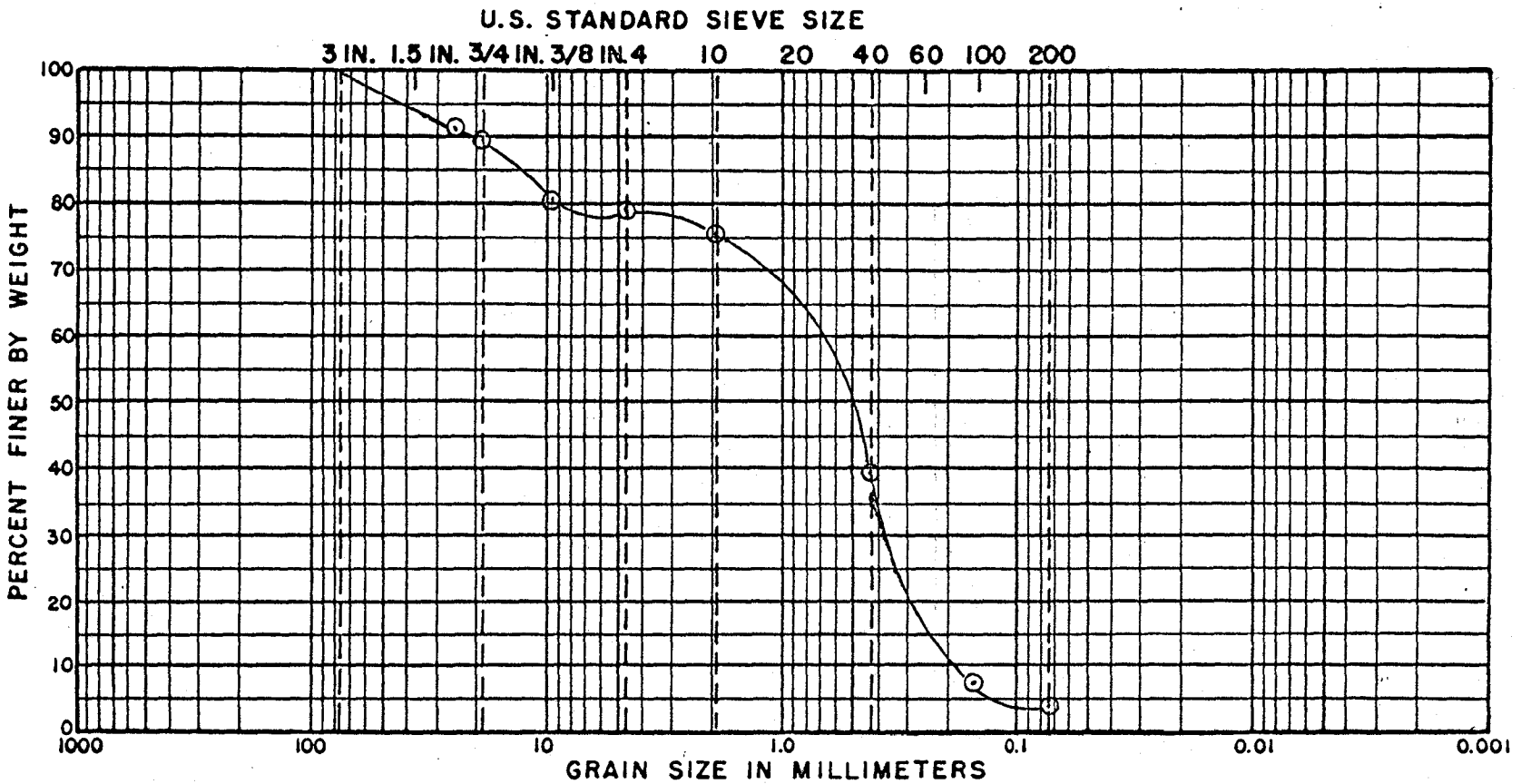


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
B-5	35'	SP	GRAVELLY SAND					

GRADATION CURVE

NICHOLAS COWIE & ASSOCIATES



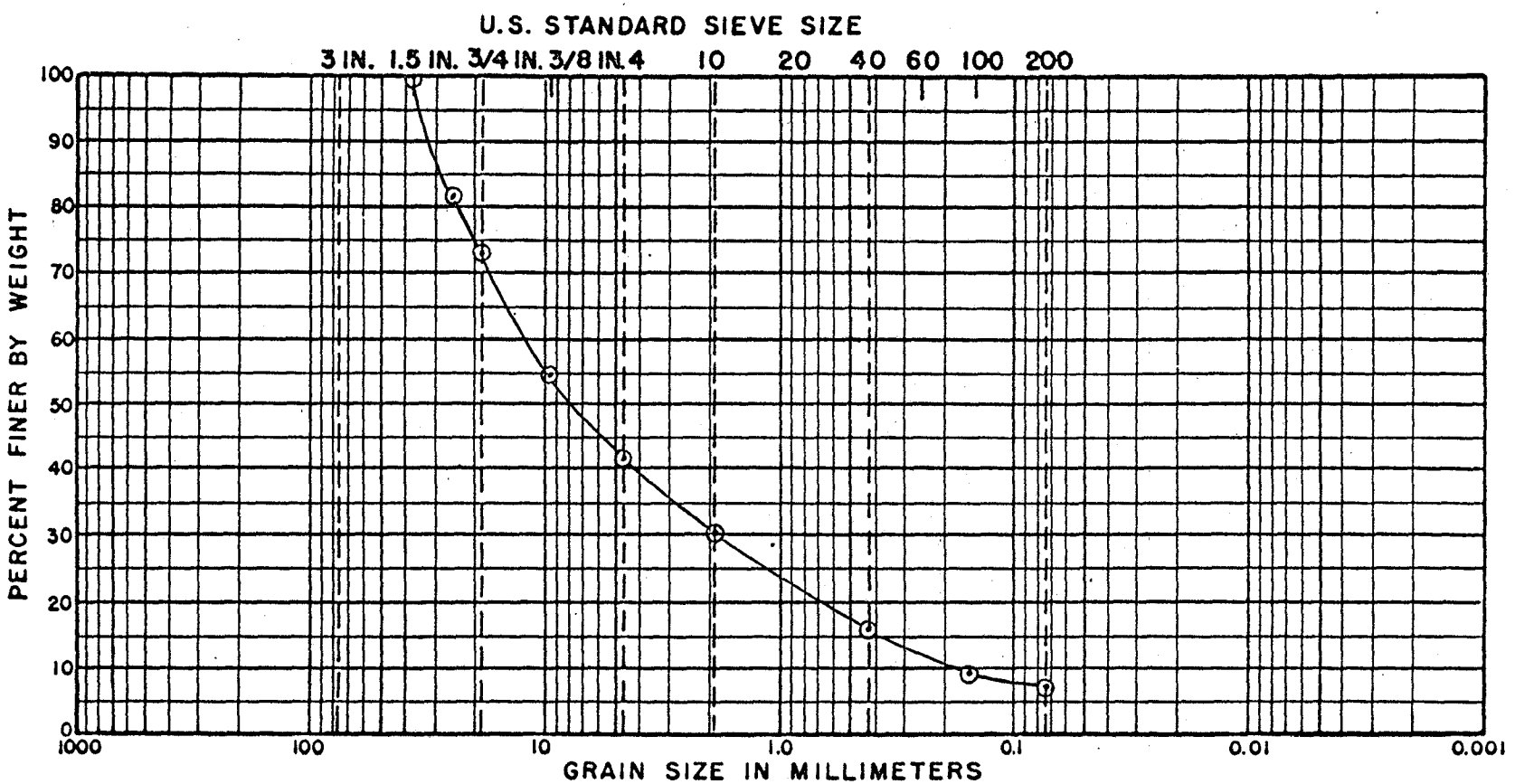
COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
B-5	40'	SP	GRAVELLY SAND					

NICHOLAS COWIE & ASSOCIATES

PLATE F-12

GRADATION CURVE

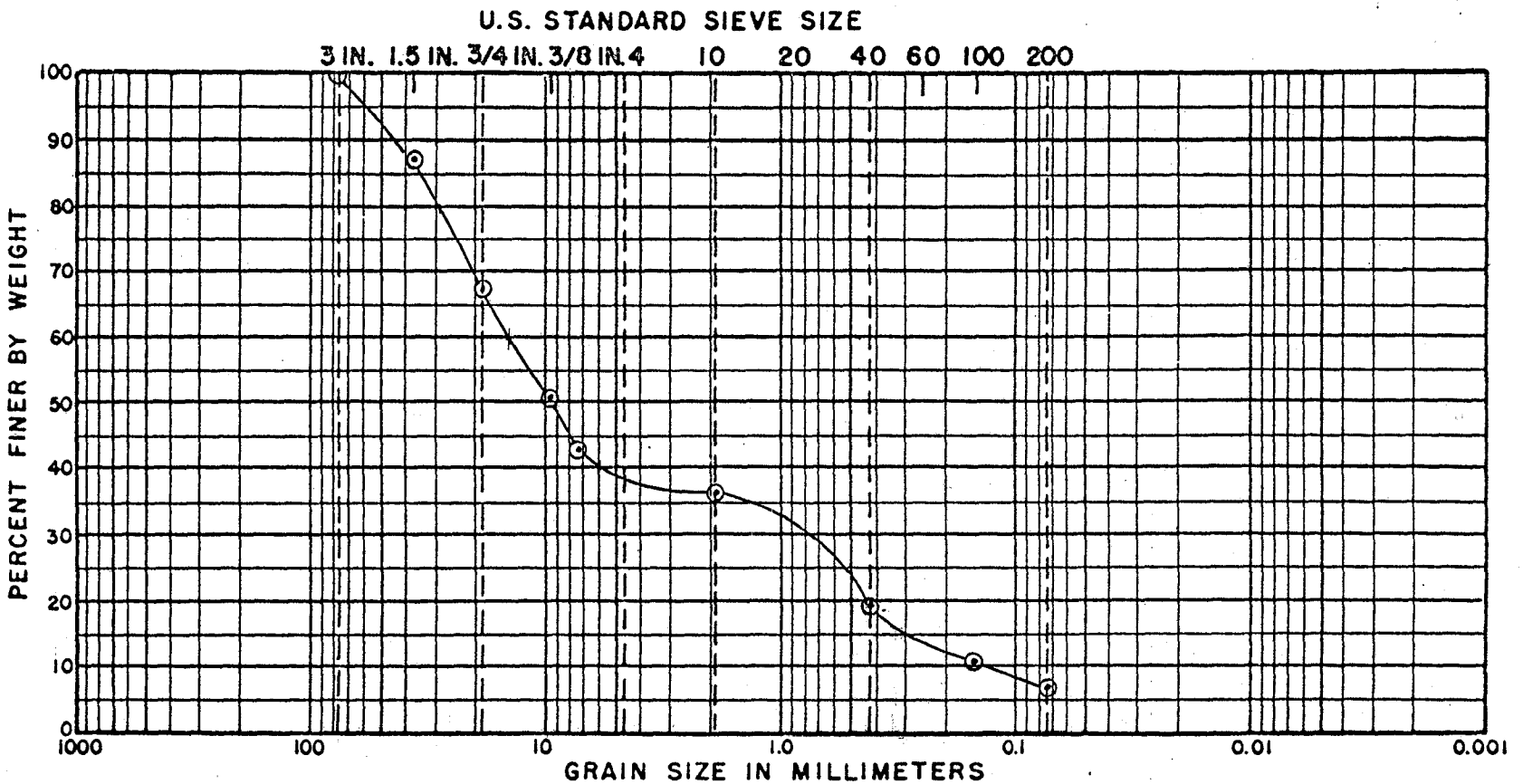


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
B-5	45'	GW	SANDY GRAVEL					

GRADATION CURVE

NICHOLAS COWIE & ASSOCIATES

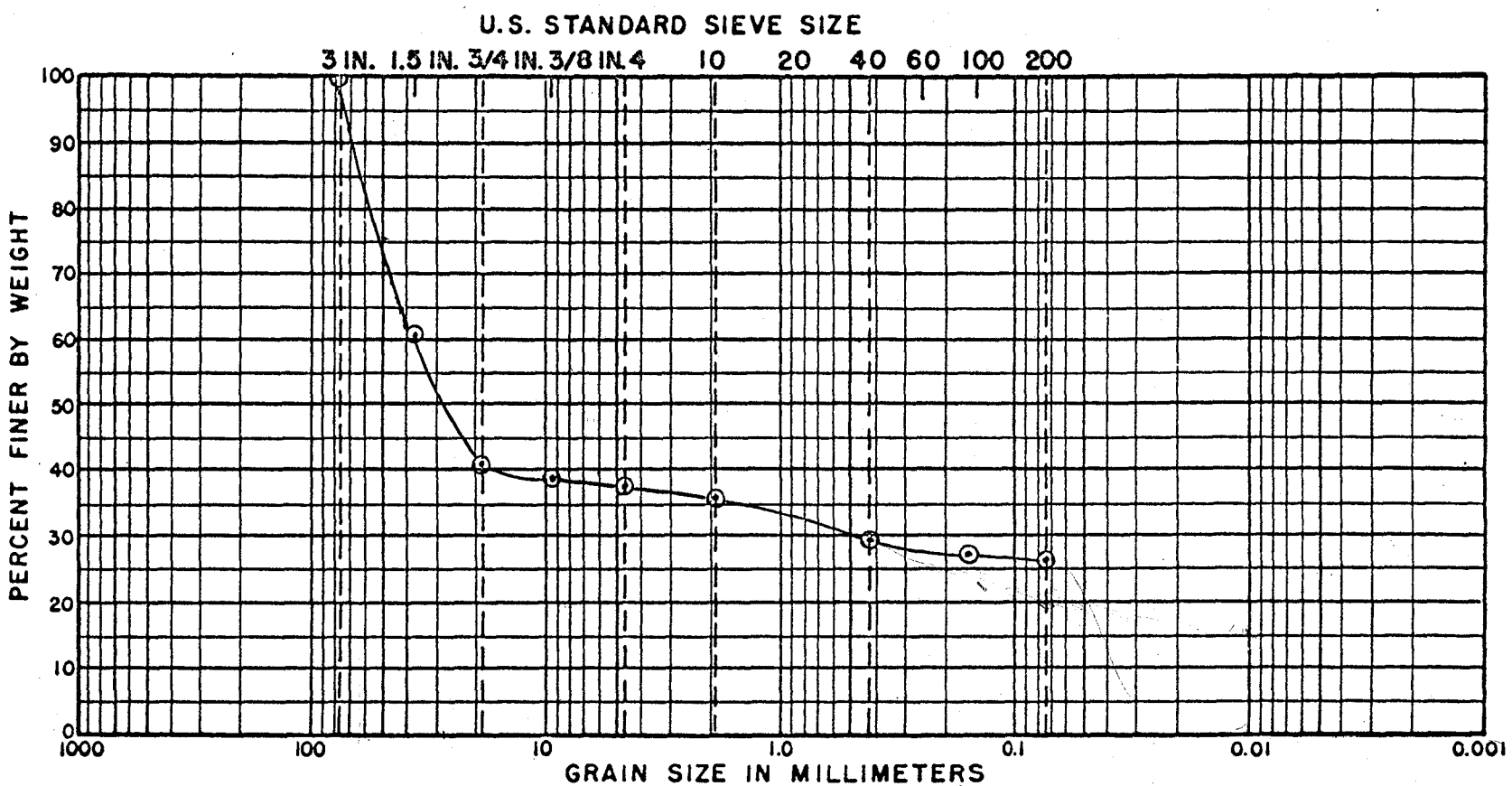


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
B-6	20'	GW-GM	SANDY GRAVEL					

GRADATION CURVE

NICHOLAS COWIE & ASSOCIATES

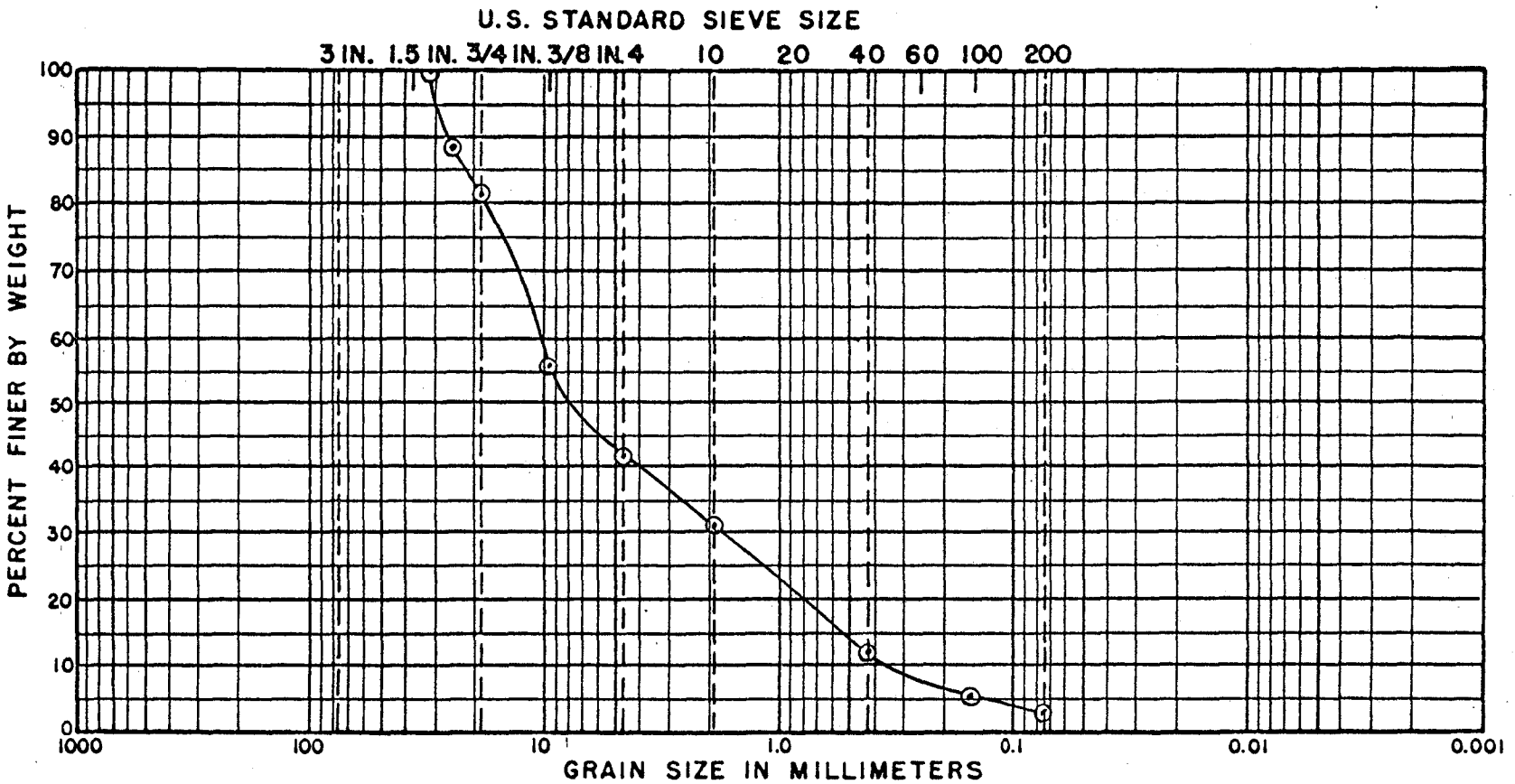


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
B-6	25'	GC	CLAYEY GRAVEL					

GRADATION CURVE

NICHOLAS COWIE & ASSOCIATES

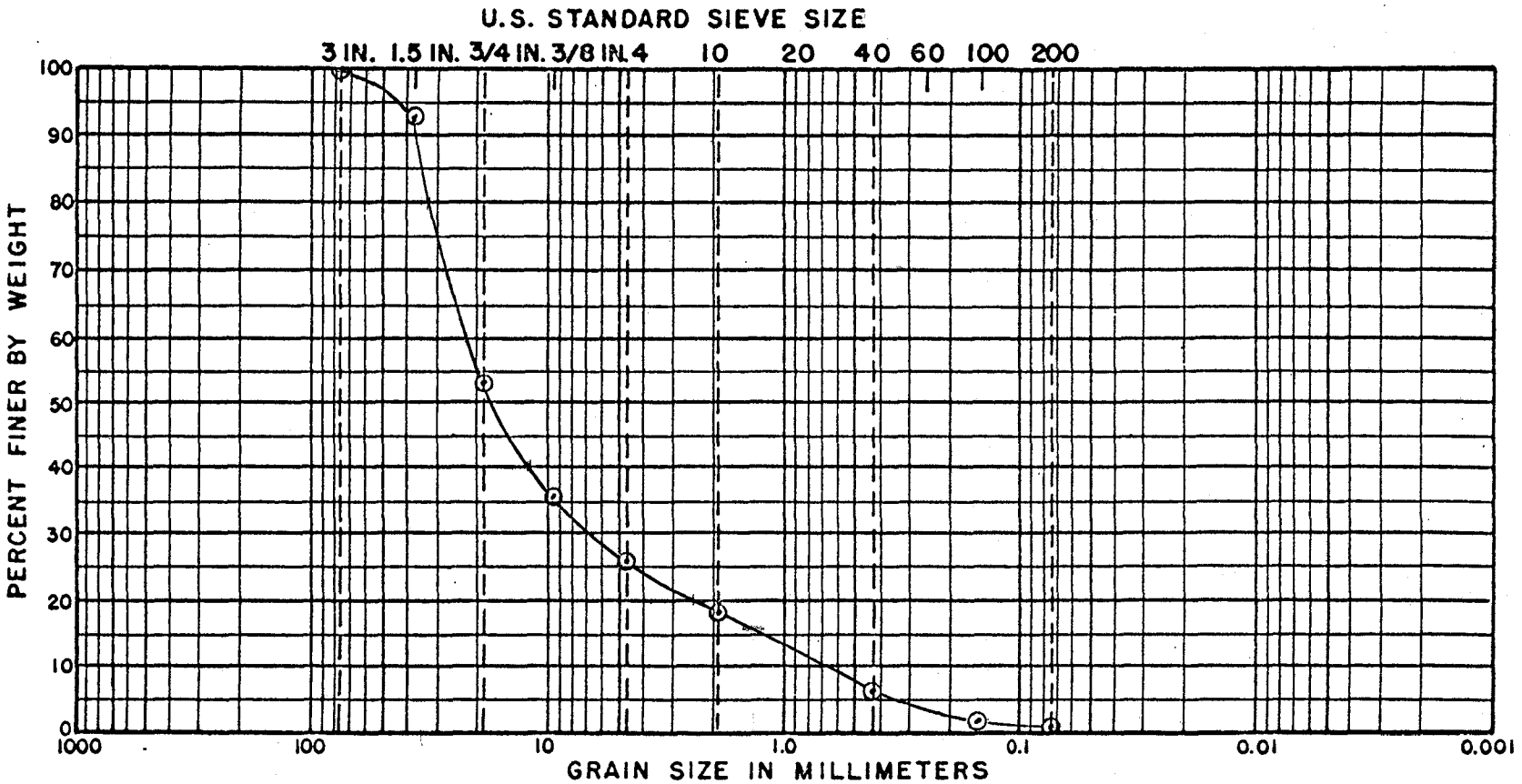


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
B-6	30'	GW	SANDY GRAVEL					

GRADATION CURVE

NICHOLAS COWIE & ASSOCIATES



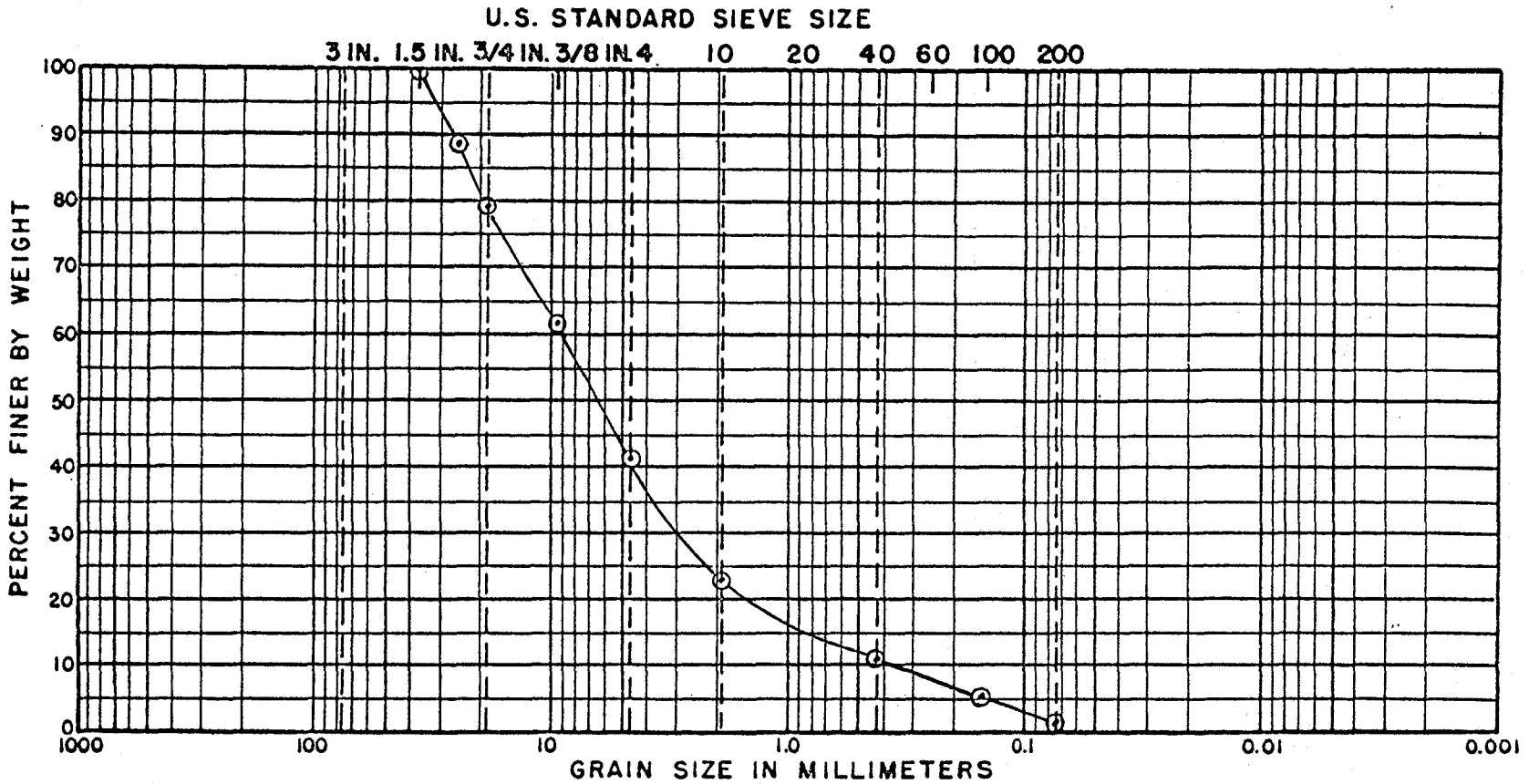
COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
B-7	25'	GW	SANDY GRAVEL					

GRADATION CURVE

NICHOLAS COWIE & ASSOCIATES

PLATE F-17



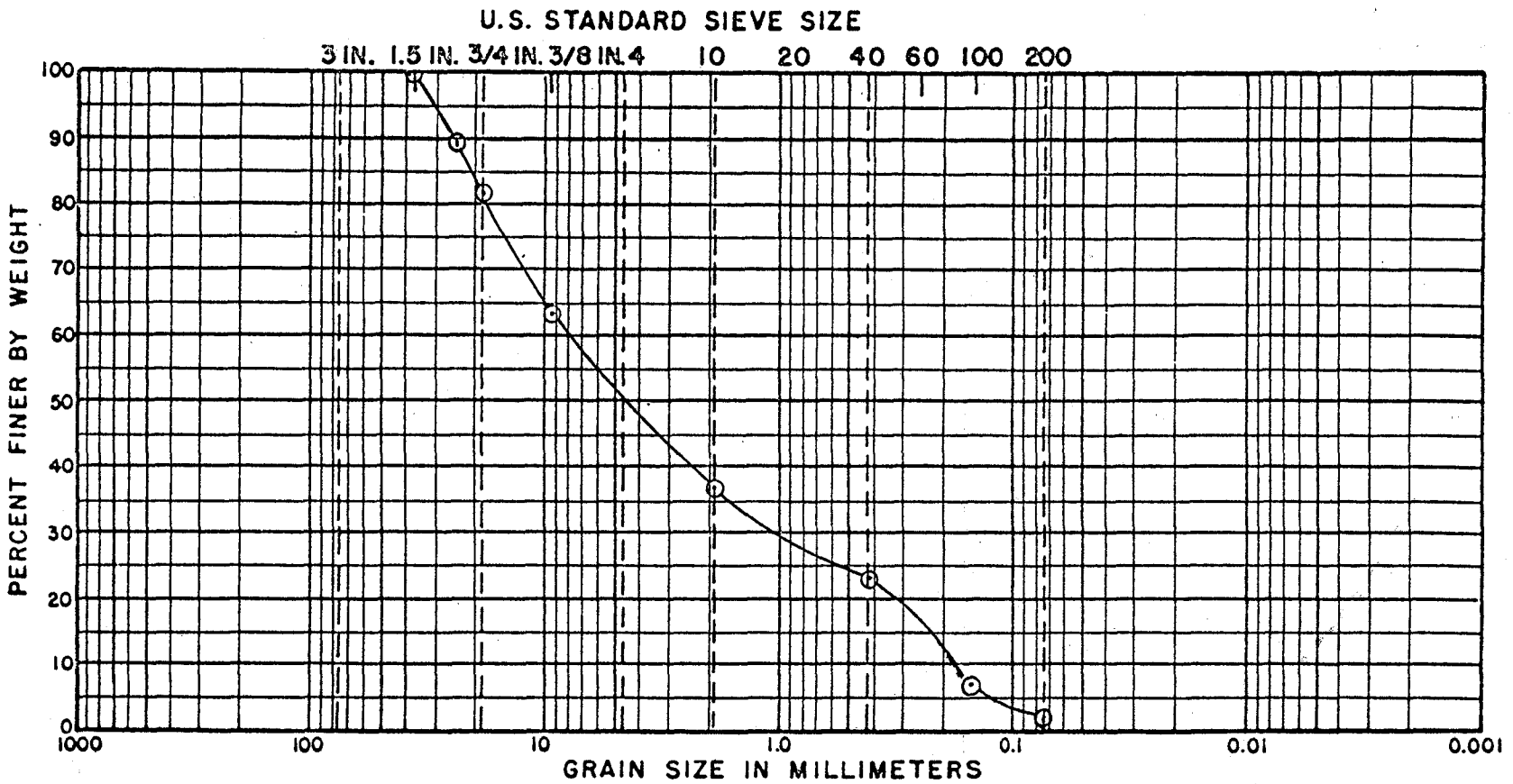
COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
B-7	80'	GW	SANDY GRAVEL					

NICHOLAS COWIE & ASSOCIATES

PLATE F-18

GRADATION CURVE

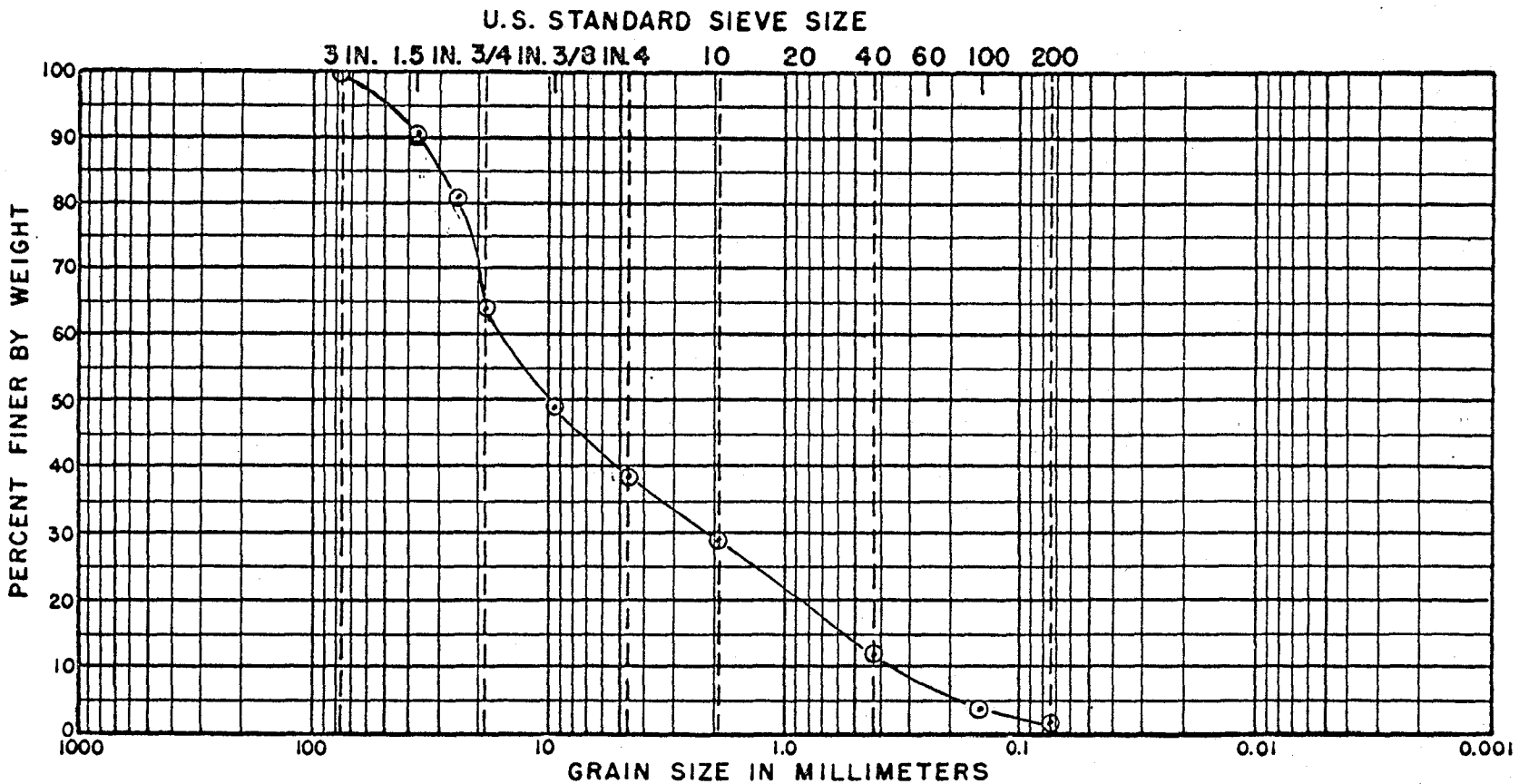


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
B-8	30'	GW	SANDY GRAVEL					

GRADATION CURVE

NICHOLAS COWIE & ASSOCIATES

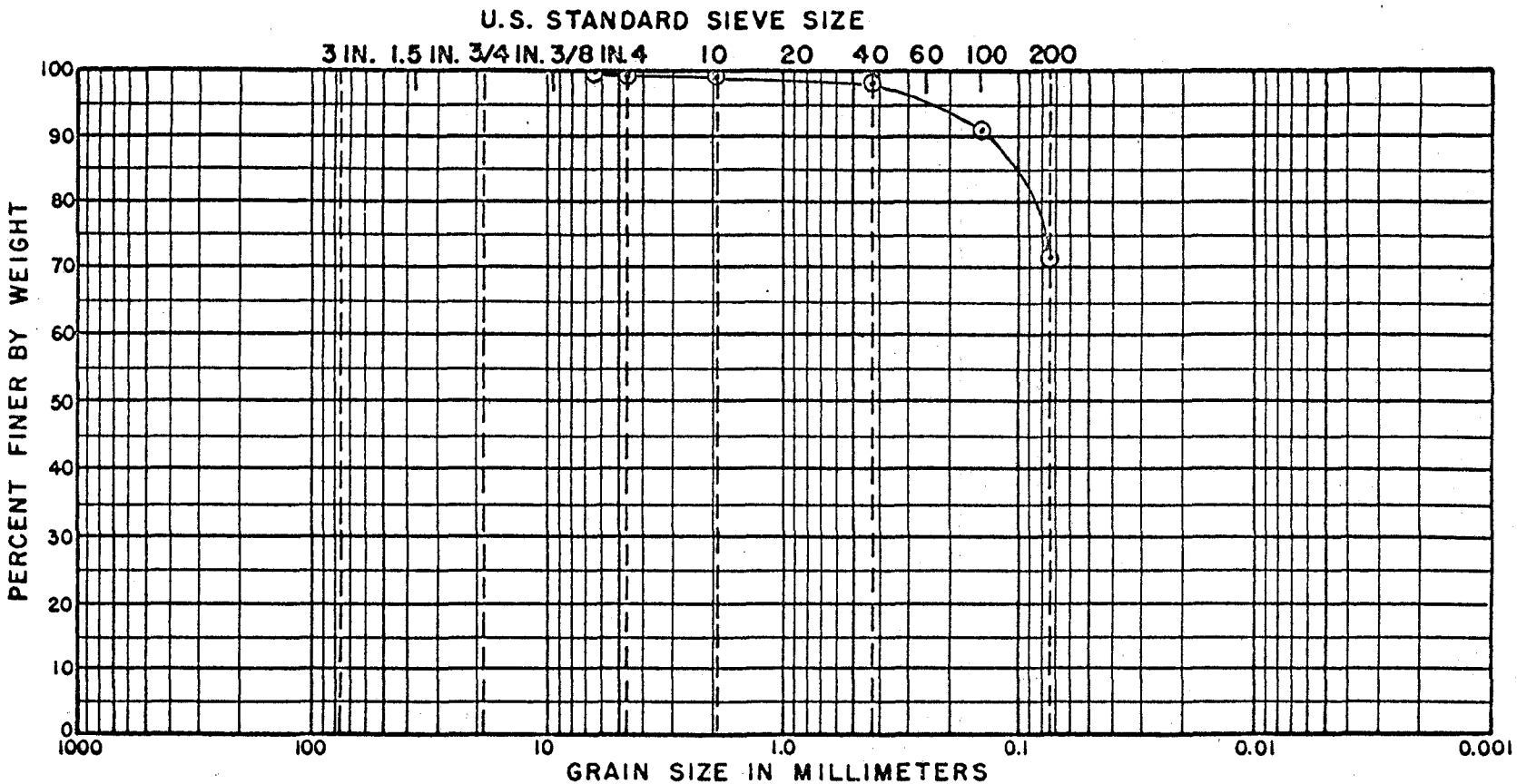


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
B-8	55'	GW	SANDY GRAVEL					

GRADATION CURVE

NICHOLAS COWIE & ASSOCIATES



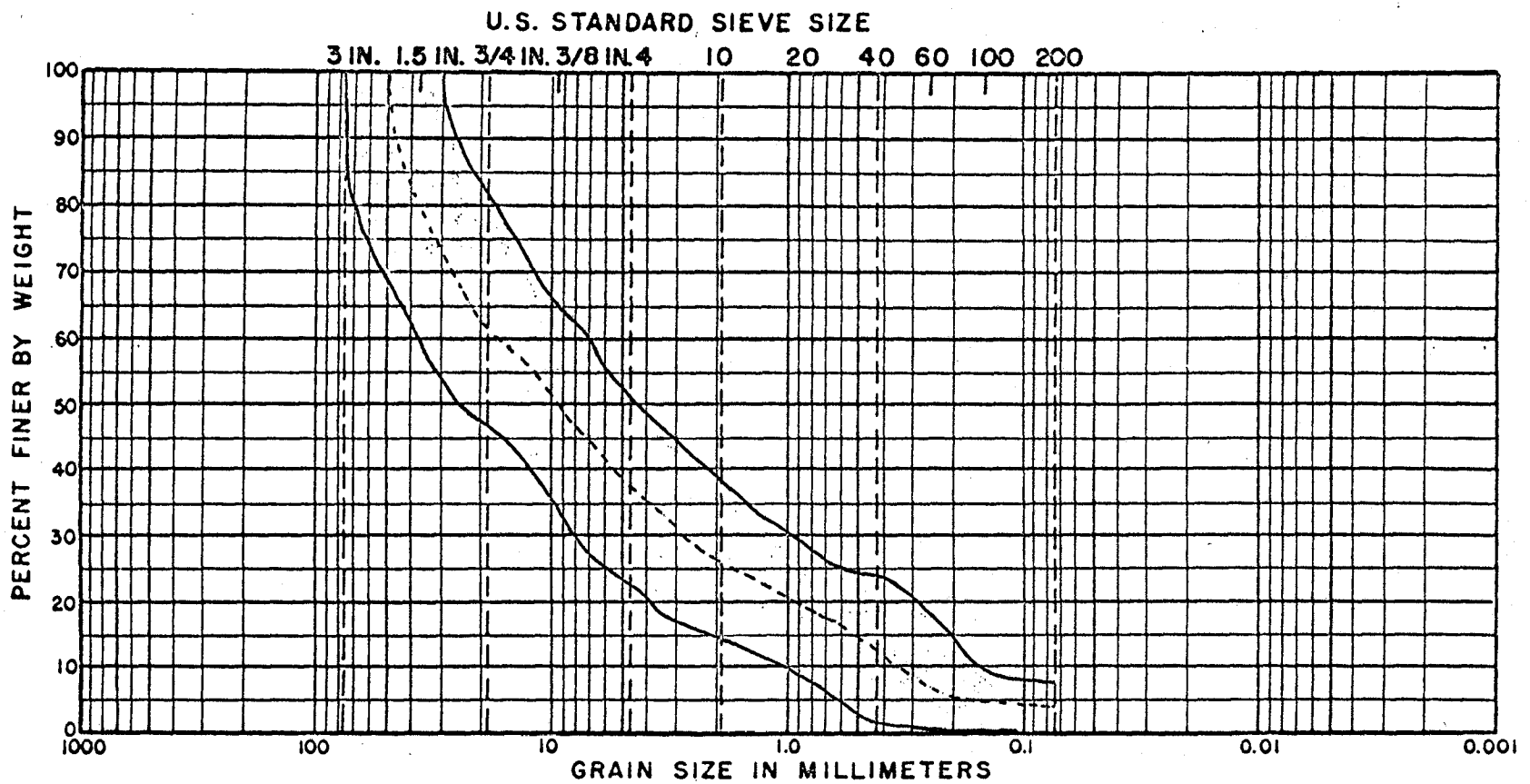
COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
B-8	60'	CL	SANDY CLAY					

NICHOLAS COWIE & ASSOCIATES

PLATE F-21

GRADATION CURVE



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

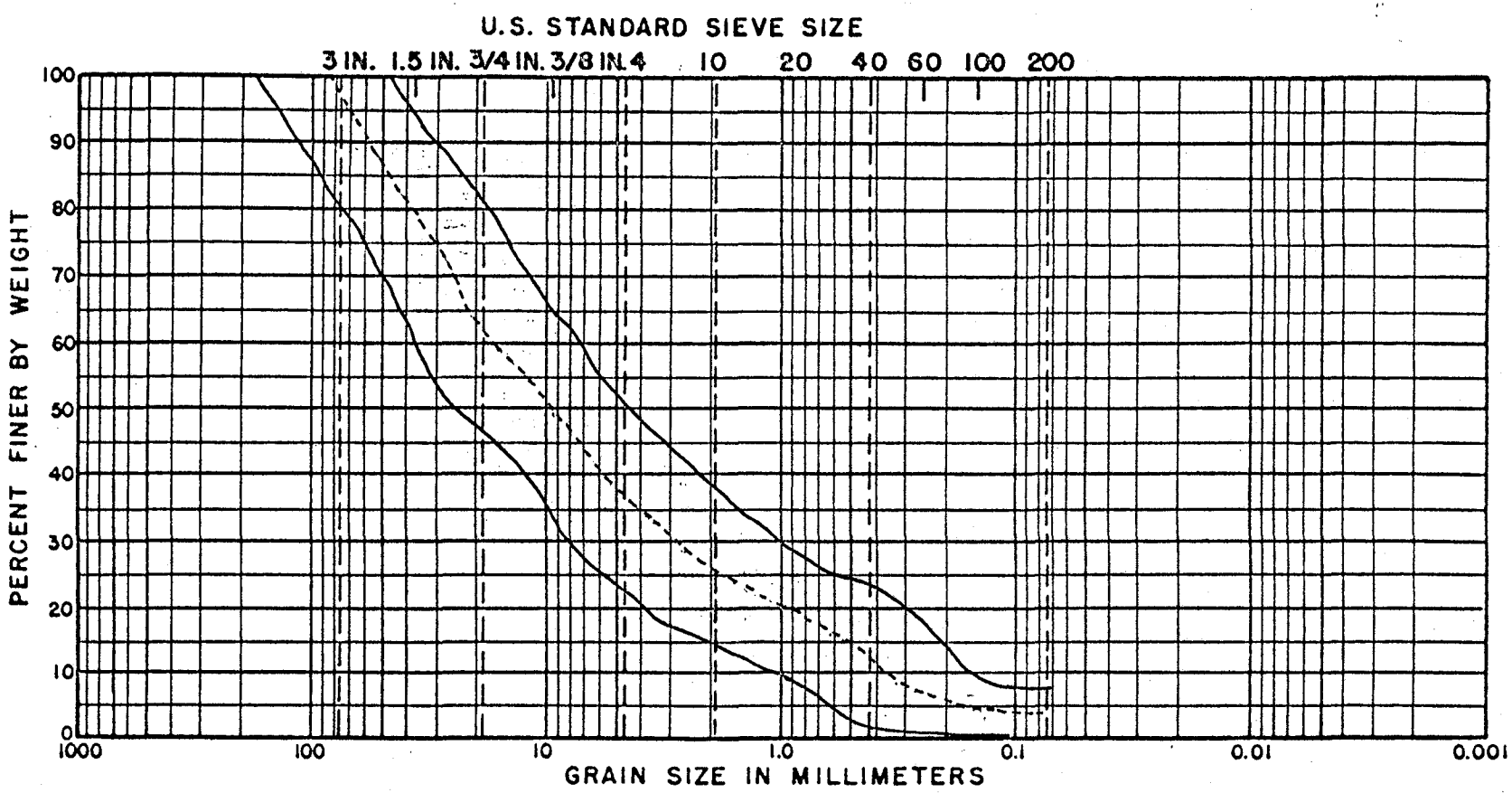
	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
		GW						

COMPOSITE OF GW GROUP

GRADATION CURVE

NICHOLAS COWIE & ASSOCIATES

PLATE G



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
		GW	SANDY GRAVEL					

MODIFIED COMPOSITE OF GW GROUP TO ESTIMATE PERCENTAGE OF COBBLES FOR SCOUR ANALYSIS.

GRADATION CURVE

NICHOLAS COWIE & ASSOCIATES

PLATE H

SUMMARY OF BLOW COUNTS

ELEVATION (FT.)	NUMBER OF BLOWS B-1	B-2	B-3	B-4	B-5	B-6	B-7	B-8
1011	-	-	8	-	3	-	13	-
1010	-	17	17	30	3	16	34	-
1009	66	34	22	47	3	34	36	42
1008	-	67	23	59	4	52	39	165
1007	33	64	26	62	6	34	32	90
1006	49	49	15	53	12	30	28	31
1005	81	33	14	48	13	25	31	52
1004	95	30	19	49	96	21	18	35
1003	110	33	29	57	123	19	26	63
1002	95	64	48	61	117	36	36	72
1001	101	45	23	62	98	35	39	87
1000	68	52	17	81	61	41	57	85
999	47	52	11	66	53	37	60	85
998	78	54	12	77	52	38	101	103
997	78	48	18	93	86	31	91	69
996	83	36	21	121	161	46	107	69
995	65	23	34	106	222	56	109	65
994	66	33	18	82	121	96	84	70
993	25	43	20	82	142	109	64	72
992	46	93	46	80	115	95	65	69
991	43	87	65	95	99	60	49	50
990	39	96	52	55	77	35	41	50
989	54	75	67	84	133	33	51	46
988	87	82	71	73	129	33	35	26
987	78	65	52	68	95	15	53	25
986	83	66	72	65	55	10	57	46
985	92	58	52	42	64	21	58	62
984	80	53	52	40	56	25	54	87
983	78	49	56	64	61	55	53	99
982	75	56	32	63	51	76	75	97
981	96	61	58	57	60	109	86	100
980	110	39	61	65	75	69	79	84
979	91	75	73	58	61	85	56	102
978	92	85	69	70	66	138	94	222
977	127	79	60	82	77	101	107	190
976	60	70	79	100	73	133	210	137
975	83	44	98	132	78	65	168	73
974	135	48	116	98	83	116	136	76
973	230	71	86	105	87	98	74	70
972	234	95	69	97	111	91	78	109
971	194	124	112	58	83	88	158	122
970	224	203	133	64	92	82	104	129
969	165	122	135	55	35	88	97	191
968	86	132	151	57	98	91	110	145
967	91	140	89	65	99	152	124	115
966	114	139	103	61	81	108	225	132

CONTINUED ...

ELEVATION (FT.)	B-1	B-2	B-3	B-4	B-5	B-6	B-7	B-8
965	129	108	89	71	63	114	104	126
964	190	140	157	81	51	106	154	78
963	176	100	91	97	28	112	81	49
962	255	102	65	115	81	75	33	61
961	257	75	96	161	49	63	79	108
960	122	58	151	181	101	90	100	154
959	84	59	121	155	203	148	129	113
958	57	65	240	69	230	105	77	47
957	63	56	68	95	133	169	42	141
956	108	55	84	128	146	157	52	166
955	115	51	173	119	187	98	43	50
954	175	41	226	68	210	100	46	13
953	120	32	822	23	66	65	47	21
952	94	142	292	34	55	116	43	23
951	91	80	111	45	59	210	53	31
950	122	95	197	47	50	153	42	85
949	126	116	80	126	55	73	123	79
948	105	88	67	111	175	52	162	148
947	92	75	65	105	165	36	147	110
946	96	123	101	132	170	23	103	122
945	109	84	180	240	608	17	100	170
944	77	91	116	163	565	18	102	161
943	83	113	64	167	181	25	111	135
942	112	104	51	71	151	27	148	187
941	90	81	105	80	163	35	100	215
940	110	90	76	98	149	230	95	281
939	64	57	103	107	111	747	72	265
938	45	46	169	85	110	213	83	223
937	–	41	–	–	–	–	76	–

CLAY

SOILS CLASSIFICATION CHART

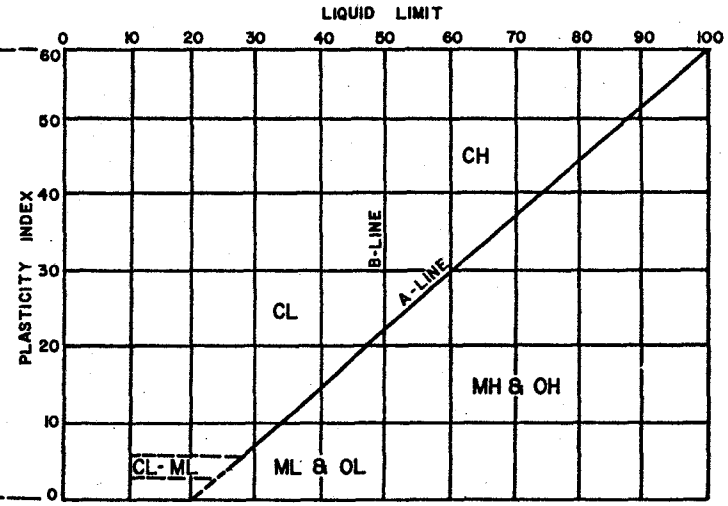
MAJOR DIVISIONS			GRAPH SYMBOL	LETTER SYMBOL	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS MORE THAN 50% OF MATERIAL IS LARGER THAN NO. 200 SIEVE SIZE	GRAVEL AND GRAVELLY SOILS MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	CLEAN GRAVELS (LITTLE OR NO FINES)		GW	WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
				GP	POORLY-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
		GRAVEL WITH FINES (APPRECIABLE AMOUNT OF FINES)		GM	SILTY GRAVELS, GRAVEL-SAND SILT MIXTURES
				GC	CLAYEY GRAVELS, GRAVEL-SAND CLAY MIXTURES
	SAND AND SANDY SOILS MORE THAN 50% OF COARSE FRACTION PASSING ON NO. 4 SIEVE	CLEAN SAND (LITTLE OR NO FINES)		SW	WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
				SP	POORLY-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
		SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		SM	SILTY SANDS, SAND-SILT MIXTURES
				SC	CLAYEY SANDS, SAND-CLAY MIXTURES
FINE GRAINED SOILS MORE THAN 50% OF MATERIAL IS SMALLER THAN NO. 200 SIEVE SIZE	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50		ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
				CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
				OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILTY SOILS
				CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
				OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
HIGHLY ORGANIC SOILS				PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

GRADATION CHART

MATERIAL SIZE		PARTICLE SIZE			
		LOWER LIMIT		UPPER LIMIT	
		MILLIMETERS	SIEVE SIZE*	MILLIMETERS	SIEVE SIZE *
SAND	FINE	.074	#200*	0.42	#40*
	MEDIUM	0.42	#40*	2.00	#10*
	COARSE	2.00	#10*	4.76	#4*
GRAVEL	FINE	4.76	#4*	191	3/4"●
	COARSE	191	3/4"●	76.2	3"●
COBBLES		762	3"●	304.8	12"
BOULDERS		304.8	12"●	914.4	36"

*U.S. Standard ●Clear Square Openings

PLASTICITY CHART



FOR LABORATORY CLASSIFICATION OF FINE GRAINED SOILS

UNIFIED SOIL CLASSIFICATION SYSTEM

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PLATE J