509.005

DESIGN OF DRILLED SHAFT BRIDGE FOUNDATIONS

John F. Fischer, PE

I. DESIGN CRITERIA

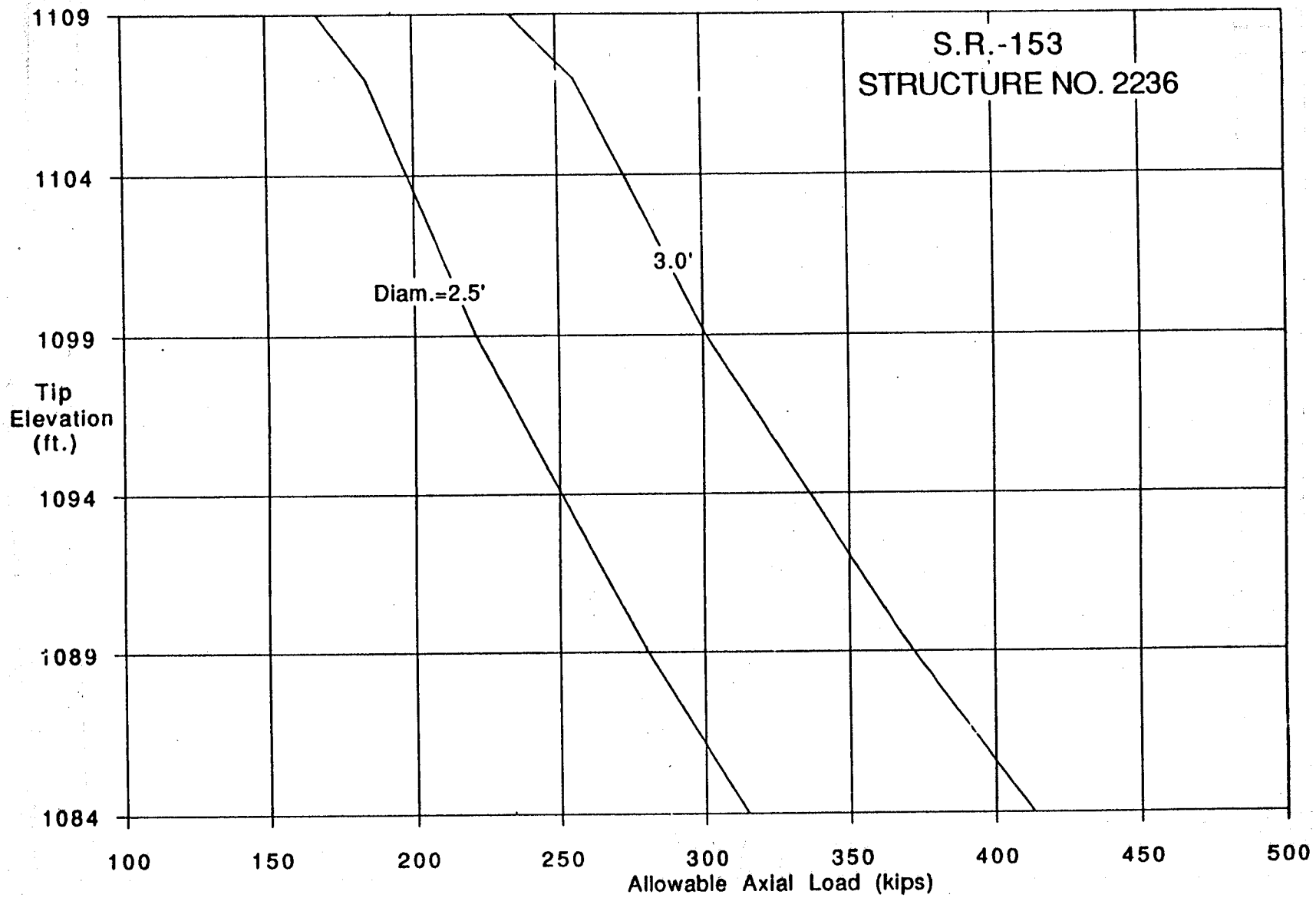
A. DESIGN LOADS
B. SOIL PARAMETERS
C. REINFORCING STEEL DETAILS
D. SCOUR

A. DESIGN LOADS

1. Dead Load
2. Live Load
   a. AASHTO HS20-44
   b. AREA Cooper E-80
3. Impact (neglected below ground)
4. Longitudinal Forces due to Live Load
5. Centrifugal Forces due to Live Load
6. Wind Loads
   a. On Structure
   b. On Live Load
7. Thermal Forces
8. Creep and Shrinkage Forces
9. Stream Flow Forces
10. Ice
11. Buoyancy
12. Earth Pressure
13. Earthquake

B. SOIL PARAMETERS

1. The center-to-center spacing of drilled shafts should be a minimum of 3 diameters.
2. The length of a shaft should be limited to 20 diameters.
3. The minimum nominal shaft diameter should be 30 inches (36 inches in SGC material).
4. Vertical Capacity (usually not a problem)
5. Lateral Capacity


S.R.-153
STRUCTURE NO. 2236
Diam.=2.5'
3.0'
1109
1104
1099
1094
1089
1084
Tip Elevation (ft.)
100
150
200
250
300
350
400
450
500
Allowable Axial Load (kips)

C. REINFORCING STEEL DETAILS

1. Drilled shaft main vertical reinforcement should have a minimum clear spacing of 4 1/2 inches.
2. Lateral reinforcement ties or spirals should have a spacing or pitch of not less than 6 inches center-to-center.
3. Shafts which will remain open in the dry should have 3 inches minimum clear cover between the reinforcing cage and the nominal shaft surface.
4. Where caving conditions are anticipated, which may require the use of slurry, the clear cover between the reinforcing cage and the nominal shaft surface should be increased to 6 inches minimum.

D. SCOUR

1. General
2. Local
3. Mining Allowance

II. TYPICAL BRIDGE FOUNDATION APPLICATIONS

A. PIERS
B. ABUTMENTS (should be same as piers in case approach washes out)
C. ABUTMENT WINGWALLS
D. RETAINING WALLS

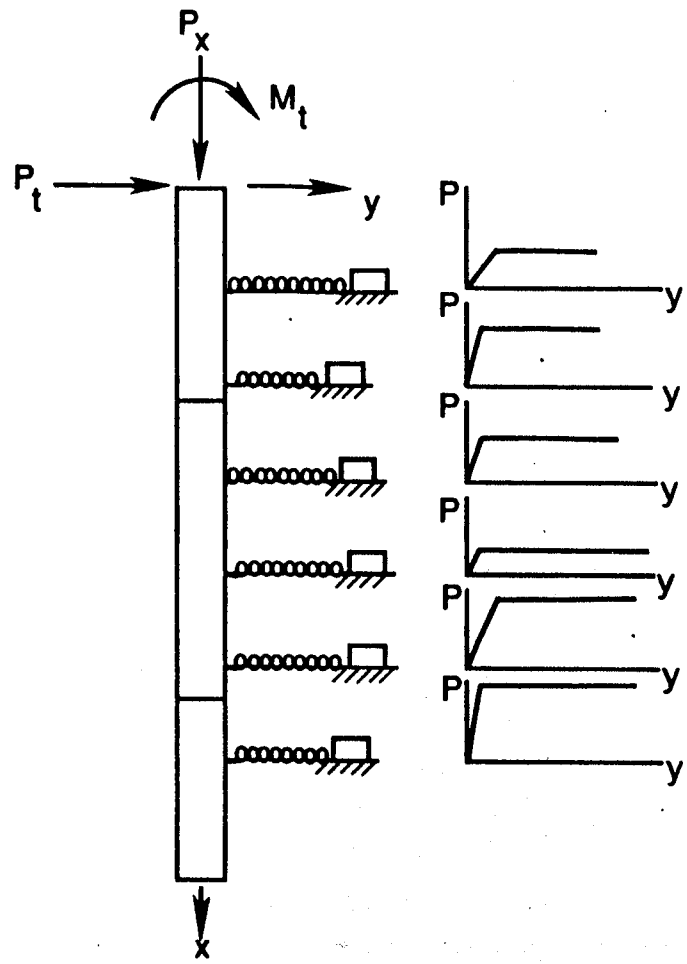
III. METHODS OF ANALYSIS

Vert. loads usually not a problem.

lateral load analysis

A. BROMS' METHOD
B. CZERNIAK METHOD
C. p-y METHOD

only good for shallow shafts - assume rigid


P_x
M_t
P_t
y
x
P
y
P
y
P
y
P
y
P
y
P
y

p-y METHOD

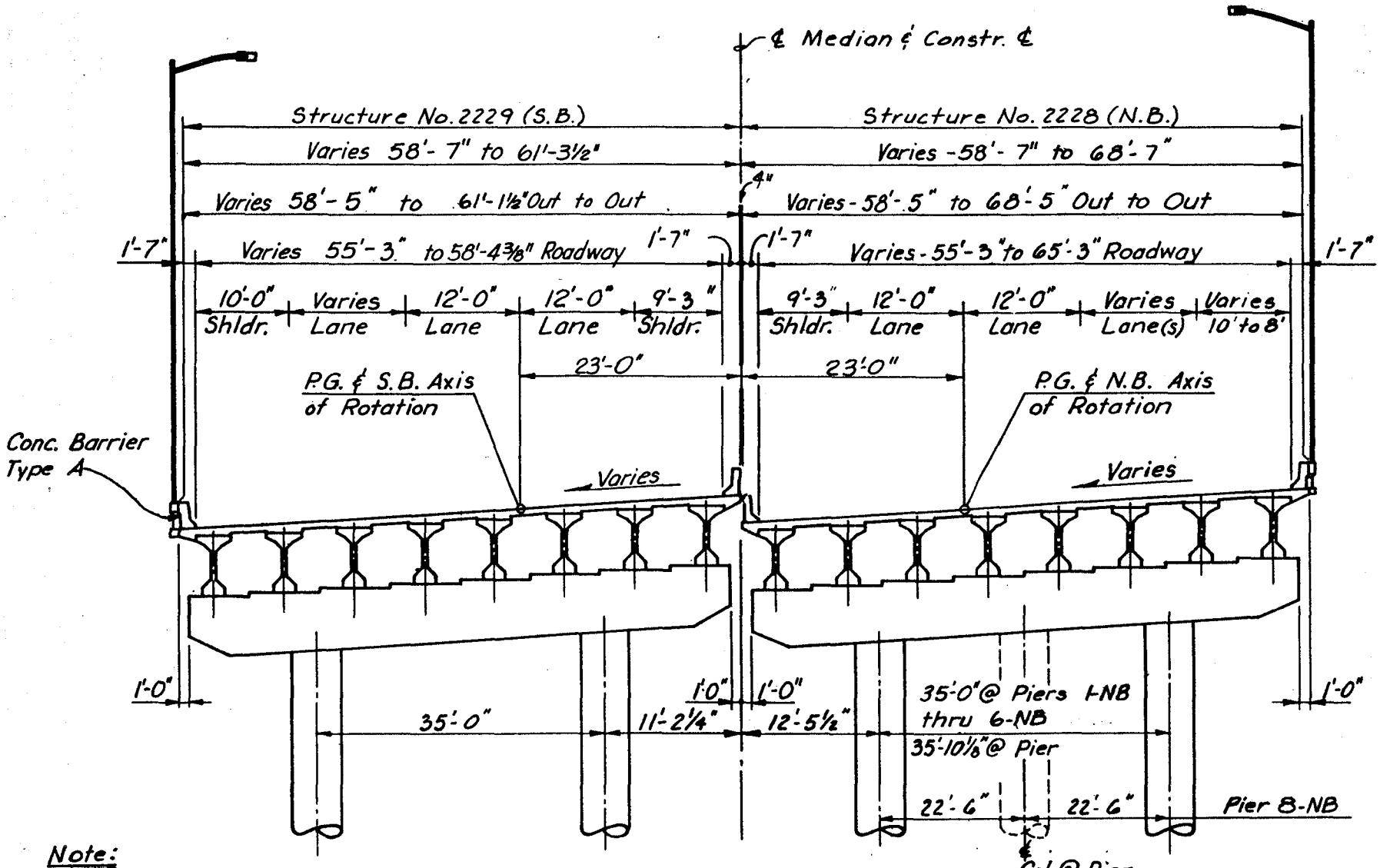
Federal Highway Administration, "Handbook on Design of Piles and Drilled Shafts Under Lateral Load", FHWA-IP-84-11, Federal Highway Administration, Department of Research, Development, and Technology, McLean, Virginia, July 1984.

Federal Highway Administration, "Behavior of Piles and Pile Groups Under Lateral Load", FHWA-RD-85-106, Federal Highway Administration, Department of Research, Development, and Technology, McLean, Virginia, March 1986.

Computer Program COM624

IV. DESIGN EXAMPLE

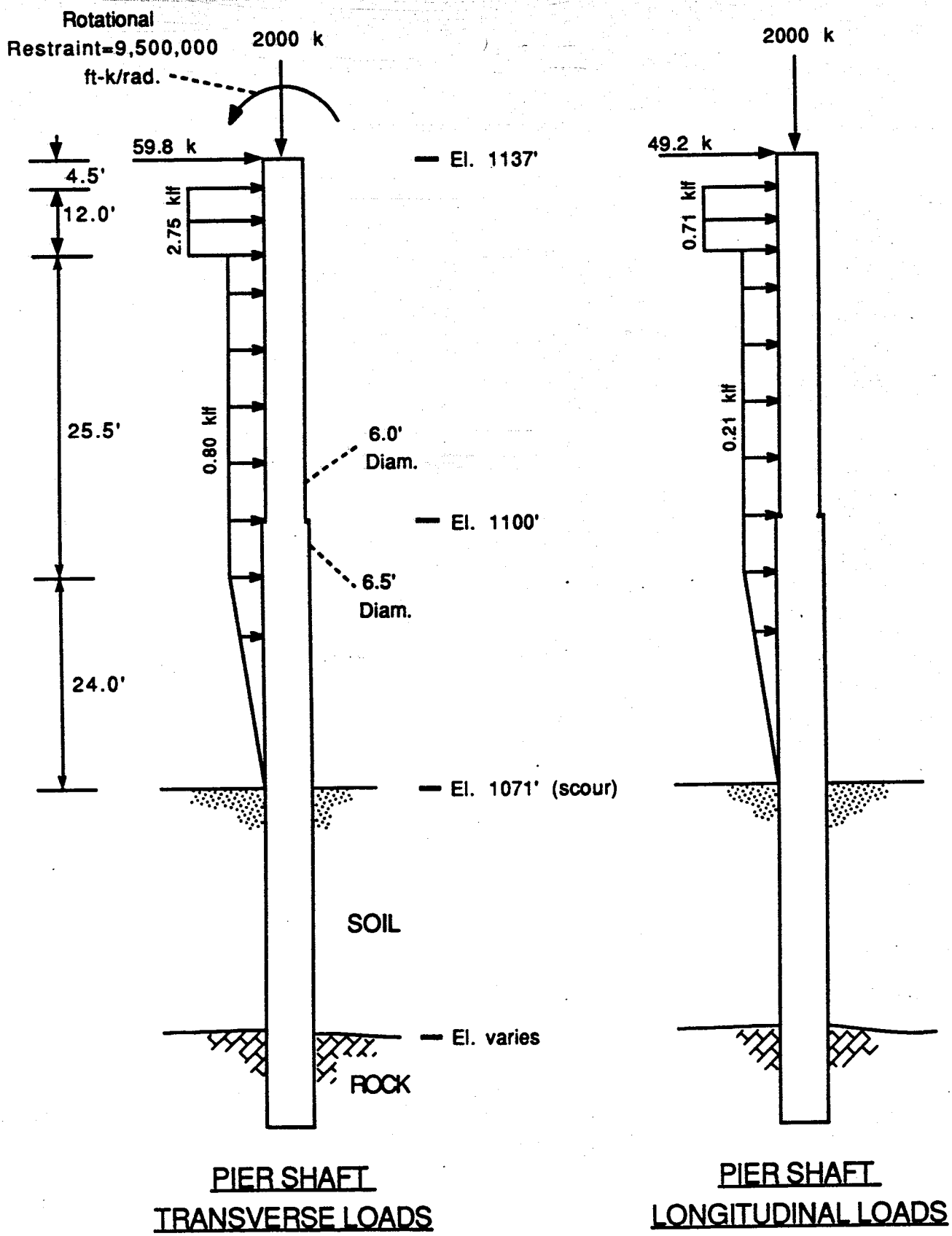
SR 153 SALT RIVER BRIDGES
NB AND SB



Note:
All transverse dimensions are measured normal to Constr. ℄.

TYPICAL SECTION
Scale: 1" = 10'-0"

Sverdrup



Note: Load shown on pile head includes weight of concrete above scour level.

Figure 1.Drilled Shaft Loads, Salt River Bridge Piers, SR-153
Project No. 89-0552

THOMAS-HARTIG & ASSOCIATES, INC.

PIER CAP AND COLUMN DESIGN

GEOMETRY

ALL PIERS ARE PARALLEL WITH VARYING SKEW; THEREFORE PIERS VARY IN LENGTH.

COLUMNS ARE LOCATED AT A CONSTANT OFFSET FROM THE CONSTRUCTION ℄ AND ARE CENTERED UNDER THE GIRDER REACTIONS.

PIER CAP DIMENSIONS: DEPTH = 8'-0" MIN.
WIDTH = 6'-6"
LENGTH VARIES

FORMED COLUMNS: 6'-0" DIAMETER TO 10'-0" BELOW FINISHED GROUND ELEVATION

DRILLED SHAFTS: 6'-6" DIAMETER

MATERIALS

CAP BEAM CONCRETE: $f'_c = 3500$
FORMED COLUMN CONCRETE: $f'_c = 3500$
DRILLED SHAFT CONCRETE: $f'_c = 3500$

REINFORCING STEEL: $f_y = 60$ KSI FOR #7 AND LARGER
$f_y = 40$ KSI FOR #6 AND SMALLER

LOADS

AASHTO LOAD CASES I THROUGH VI
DESIGN FOR SEISMIC LOADS (GROUP VII) IS NOT REQUIRED PER AASHTO SEISMIC GUIDELINES SEC. 4.2, SEISMIC PERFORMANCE CATEGORY A.

DESIGN METHOD AND PROCEDURE

PIER CAPS : SERVICE LOAD DESIGN
COLUMNS: LOAD FACTOR (STRENGTH) DESIGN

LOADS FOR EACH PIER ARE DETERMINED BY TRIBUTARY LENGTH. LONGITUDINAL AND TRANSVERSE FORCES ARE RESOLVED INTO COMPONENTS NORMAL AND PARALLEL TO THE PIER CENTERLINE AS A FUNCTION OF THE SKEW OF THE PIER RELATIVE TO A TANGENT TO THE CONSTRUCTION CENTERLINE AT ITS INTERSECTION WITH THE PIER CENTERLINE.

PIERS ARE MODELLED INDIVIDUALLY AS FRAMES IN 3 DIMENSIONS WITH THE FINITE ELEMENT PROGRAM STAAD 3. INPUT IS THE PIER GEOMETRY, MEMBER PROPERTIES, AND LOADS. OUPUT ARE THE CAP AND COLUMN FORCES FOR EACH LOAD CASE. AASHTO LOAD COMBINATIONS ARE FORMED BY SVERDRUP PROGRAM "COMBINE", CONSIDERING REVERSIBILITY OF WIND AND LONGITUDINAL FORCES.

SOIL STABILITY AND COLUMN DESIGN FORCES ARE INVESTIGATED WITH SVERDRUP PROGRAM P7038, COLUMNS

ARE MODELLED AS BEAMS CANTILEVERED FROM AN ELASTIC FOUNDATION. INPUT CONSISTS OF SOIL PROPERTIES, COLUMN GEOMETRY AND PROPERTIES, AND THE SHEAR, MOMENT, AND AXIAL FORCE AT THE TOP OF THE COLUMN FROM THE STAAD 3 OUTPUT. OUTPUT CONSISTS OF FACTORED COLUMN DESIGN FORCES

COLUMN STRENGTH ANALYSIS IS PERFORMED BY SVERDRUP PROGRAM P2314. INPUT IS THE COLUMN GEOMETRY AND REINFORCING DATA. OUTPUT IS THE AXIAL FORCE - MOMENT CAPACITY, FACTORED FOR SLENDERNESS EFFECTS.

SCOUR CONSIDERATION

DEPTH OF SCOUR AND LOADING UNDER SCOURED CONDITIONS IS IN ACCORDANCE WITH ADOT "PROCEDURE FOR DEVELOPMENT OF STRUCTURE PLANS BY CONSULTANTS", APPENDIX VIII. THE GOVERNING SCOUR CONDITION FOR CAP AND COLUMN DESIGN IS LOAD CASE 4 -- "SUPERFLOOD" SCOUR, WHICH FOR THIS PROJECT IS THE STANDARD PROJECT FLOOD. ALL CAP AND COLUMN ANALYSIS IS PERFORMED FOR THE SUPERFLOOD CONDITION.

SVERDRUP

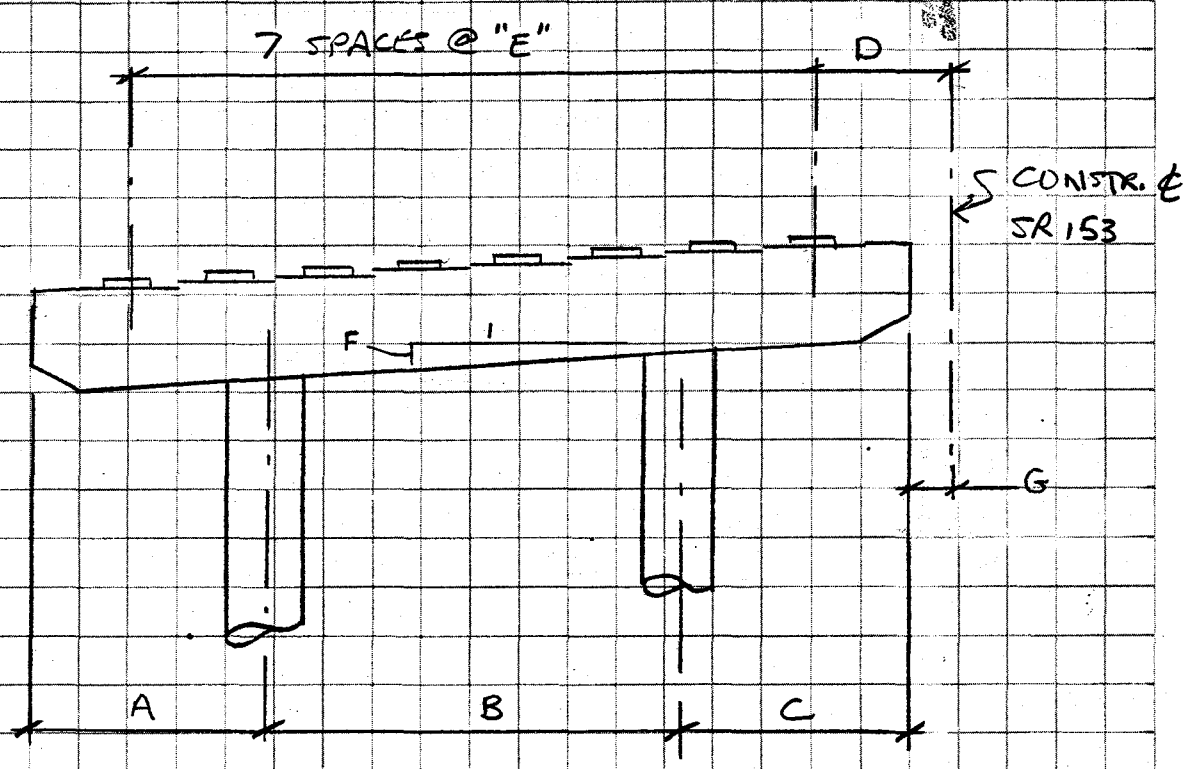
JOB 50106-B802

SHEET NO. 95 OF

DATE 5-89

COMPUTATIONS FOR PIER CAPS & COLUMNS

BY RCS CHKD PBB



SOUTHBOUND PIERS

LOOKING AHEAD ON STATION

DIMENSIONS IN FEET

PIER	A	B	C	D	E	F	G
1	13.10	40.01	11.58	3.84	8.264		1.14
2	12.52	38.29	11.10	3.68	7.910		1.09
3	12.08	36.99	10.74	3.56	7.641		1.05
4	11.76	36.05	10.48	3.47	7.447		1.03
5	11.54	35.42	10.30	3.41	7.317		1.01
6	11.43	35.08	10.20	3.38	7.246		1.00
7	11.41	35.01	10.18	3.38	7.231		1.00
8	11.47	35.21	10.24	3.39	7.273		1.01

SVERDRUP

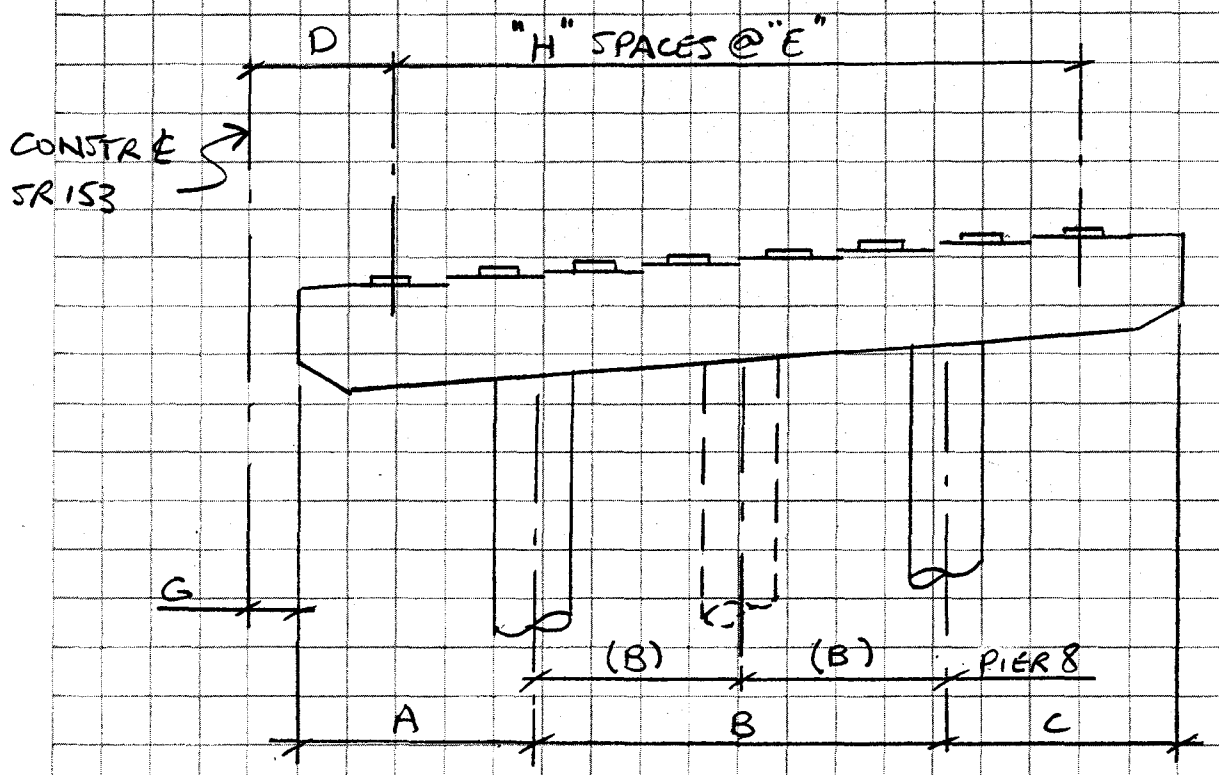
JOB 50106-B802

SHEET NO. 96 OF

DATE 5-89

COMPUTATIONS FOR PIER CAPS & COLUMNS

BY RCS CHKD PBB



NORTHBOUND PIERS
LOOKING AHEAD ON STATION

DIMENSIONS IN FEET

PIER	A	B	C	D	E	F	G	H
1	12.99	39.53	11.40	5.27	8.167		1.14	7
2	12.47	38.00	10.97	5.06	7.849		1.09	7
3	12.07	36.82	10.64	4.89	7.607		1.05	7
4	11.78	35.96	10.40	4.77	7.429		1.03	7
5	11.58	35.39	10.24	4.70	7.310		1.01	7
6	11.47	35.07	10.15	4.65	7.245	RCS PBB 351	1.00	7
7A	11.45	35.85	10.14	4.64	~~7.231~~		1.00	7
7B	"	"	"	"	6.433		"	8
8A	11.51	22.62	10.19	4.67	7.617		1.01	8
8B	"	"	"	"	7.617		"	8

A = SOUTH SIDE B = NORTH SIDE

SVERDRUP

JOB 50106 B802

SHEET NO. 97 OF

DATE 4.91

COMPUTATIONS FOR PIER CAPS & COLUMNS

BY RCS CHKD PBB

SCOUR @ DRILLED SHAFTS (SEE FOLLOWING PAGE)

SCOUR COMPONENT	STANDARD PROJECT FLOOD	100 YEAR FLOOD
GENERAL + ½ DUNE HEIGHT + 30% SAFETY FACTOR	6.0	6.0
LOCAL w/ DEBRIS	24.0	21.3
ALLOWANCE FOR LOSS OF 2 GRADE CONTROL STRUCTURES	8.0	—
ADDITIONAL SAFETY MARGIN	—	4.7
TOTAL	38.0'	32.0'

MINIMUM GROUNDLINE ELEVATIONS

ELEVATION OF LOW-FLOW CHANNEL = 1108.90

STANDARD PROJECT FLOOD, MIN. ELEV. = 1070.90 SAY 1071.00

100 YR FLOOD, MIN ELEV. = 1076.90 SAY 1077.00

SVERDRUP

JOB 50106 8802

SHEET NO. 100 OF

DATE 5-91

COMPUTATIONS FOR PIER CAPS & COLUMNS

BY RCJ CHKD PBB

PIER & COLUMN ANALYSIS - ADDITIONAL NOTES

SINCE THE PIER DIMENSIONS, LOADS & DEPTH OF DRILLED SHAFT EMBEDMENT ARE DIFFERENT FOR EACH PIER, EACH IS ANALYZED SEPARATELY. THE HORIZONTAL DIMENSIONS OF THE SOUTHBOUND PIERS ARE TAKEN AS TYPICAL FOR THE NORTHBOUND PIERS AS WELL, AND ONLY THE SOUTHBOUND PIERS ARE ANALYZED (WITH THE EXCEPTION OF PIER 8 N.B.).

PIER CAP REINFORCING IS DESIGNED SEPARATELY FOR EACH PIER.

COLUMN AND DRILLED SHAFT REINFORCING IS DESIGNED FOR THE MOST HIGHLY LOADED COLUMN / SHAFT ONLY. FOR SCREENING PURPOSES, THE FACTORED FORCES IN MEMBERS 14 & 19 ARE OBTAINED FOR EACH PIER. THE COLUMN / SHAFT WITH THE HIGHEST FORCES AT THE SCOURED GROUND ELEV. IS ANALYZED FOR SOIL-STRUCTURE INTERACTION AND P-DELTA EFFECTS IN SVERDRUP PROGRAM P7038.

PIER RESPONSES TO APPLIED LOADS ARE OBTAINED BY STAAD III. COMBINED & FACTORED DESIGN FORCES ARE OBTAINED WITH SVERDRUP PROGRAM "COMBINE".

ALL COMPUTER OUTPUT IS PRESENTED IN THE APPENDICES.

SVERDRUP

JOB 50106 B802

COMPUTATIONS FOR PIER CAPS & COLUMNS

SHEET NO. 103 OF

DATE 4-91

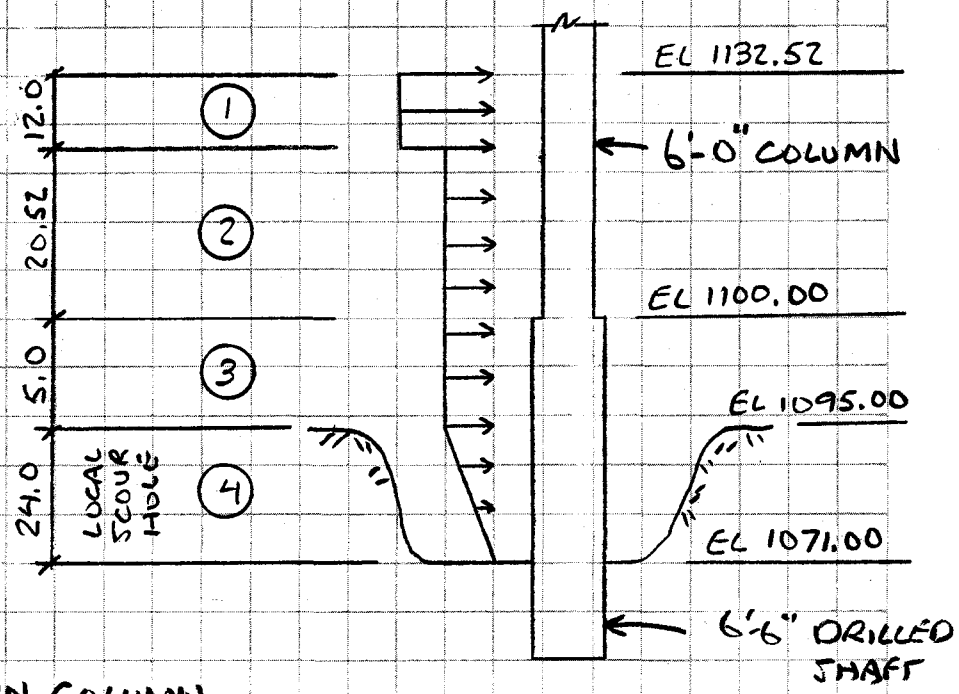
BY RCS CHKD PBB

2. STREAM FLOW

STANDARD PROJECT FLOOD:

WS ELEV. = 1132.52

VELOCITY = 14.14 FT/SEC



DEBRIS ACCUMULATION:

ASSUME 4' INCREASE IN COLUMN WIDTH TO A DEPTH OF 12'

FORCE IN LOCAL SCOUR HOLE VARIES LINEARLY TO ZERO AT BOTTOM

INCREASE DRILLED SHAFT DIAMETER BY FACTOR OF 1.20 TO ACCOUNT FOR HOLE OVERSIZING

AASHTO 3.18.1: $SF = KV^2 \times \text{WIDTH} \times \text{LENGTH}$

SECTION	K	EFF. WIDTH	LENGTH	SF (K)	SF (KLF)
1	1.375	10.0	12.0	33.0	2.749
2	.67	6.0	20.52	16.5	.804
3	.67	7.8	5.0	5.2	1.045
4	.67	7.8	24.0	12.5	1.045 - 0

SVERDRUP

JOB 5010L SALT RIVER BRIDGE

COMPUTATIONS FOR PIER CAPS & COLUMNS

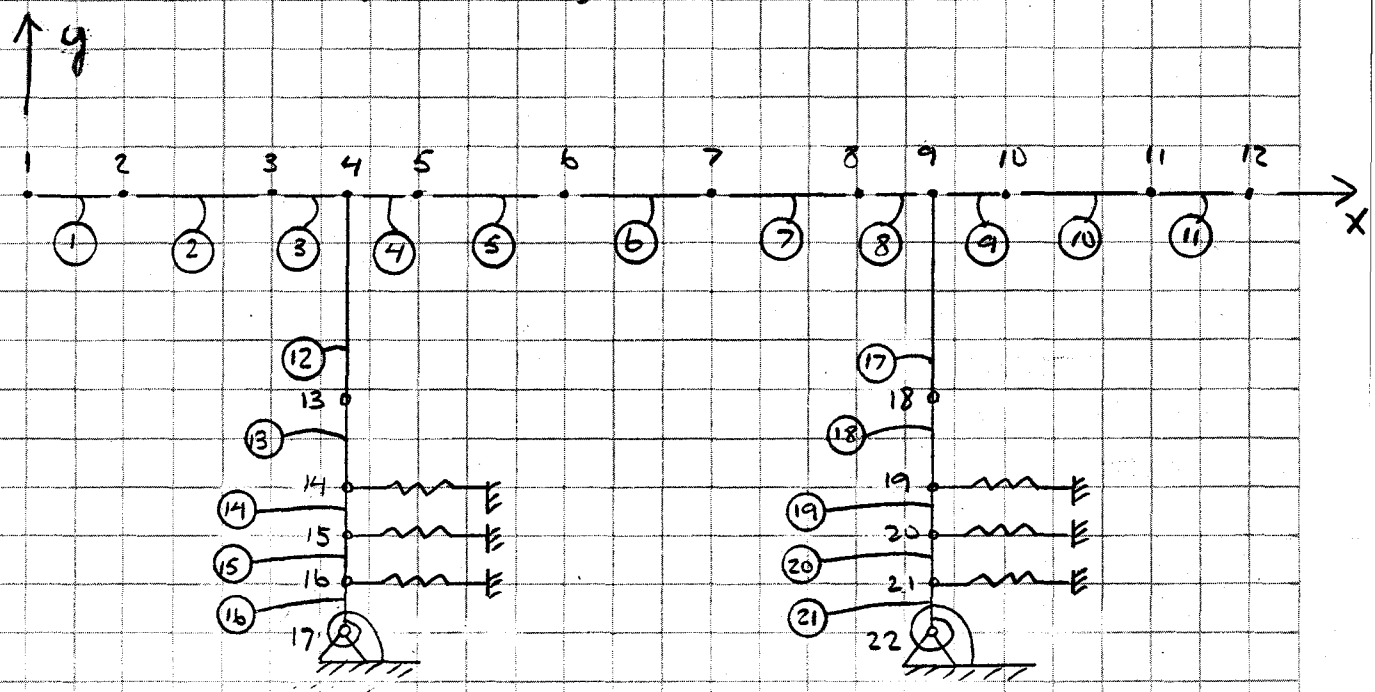
SHEET NO. 114 OF

DATE 5-89

BY RCS CHKD PBB

STAAD MODEL (ALL EXCEPT PIER 8 NB)

used STAAD 3



MEMBER PROPERTIES

1-11 (PIER CAP) $A = (6.5)(8) = 52\ ft^2$

$I_z = 6.5(8^3)(1/12) = 277\ ft^4$

$I_y = 8(6.5)^3(1/12) = 183\ ft^4$

12, 13, 17, 18 (FORMED COLUMN) $A = \pi(6^2)(1/4) = 28.3\ ft^2$

$I_y = I_z = \pi(6)^4(1/64) = 63.6\ ft^4$

14, 15, 16
19, 20, 21 (DRILLED SHAFT) $A = \pi(6.5)^2(1/4) = 33.2\ ft^2$

$I_y = I_z = \pi(6.5)^4(1/64) = 87.6\ ft^4$

$f'_c = 3500$ psi: ALL MEMBERS

$E = 33(145)^{3/2}(3500)^{1/2}\left(\frac{144}{1000}\right) = 491{,}000\ k/ft^2$

SVERDRUP

JOB 50106 B802

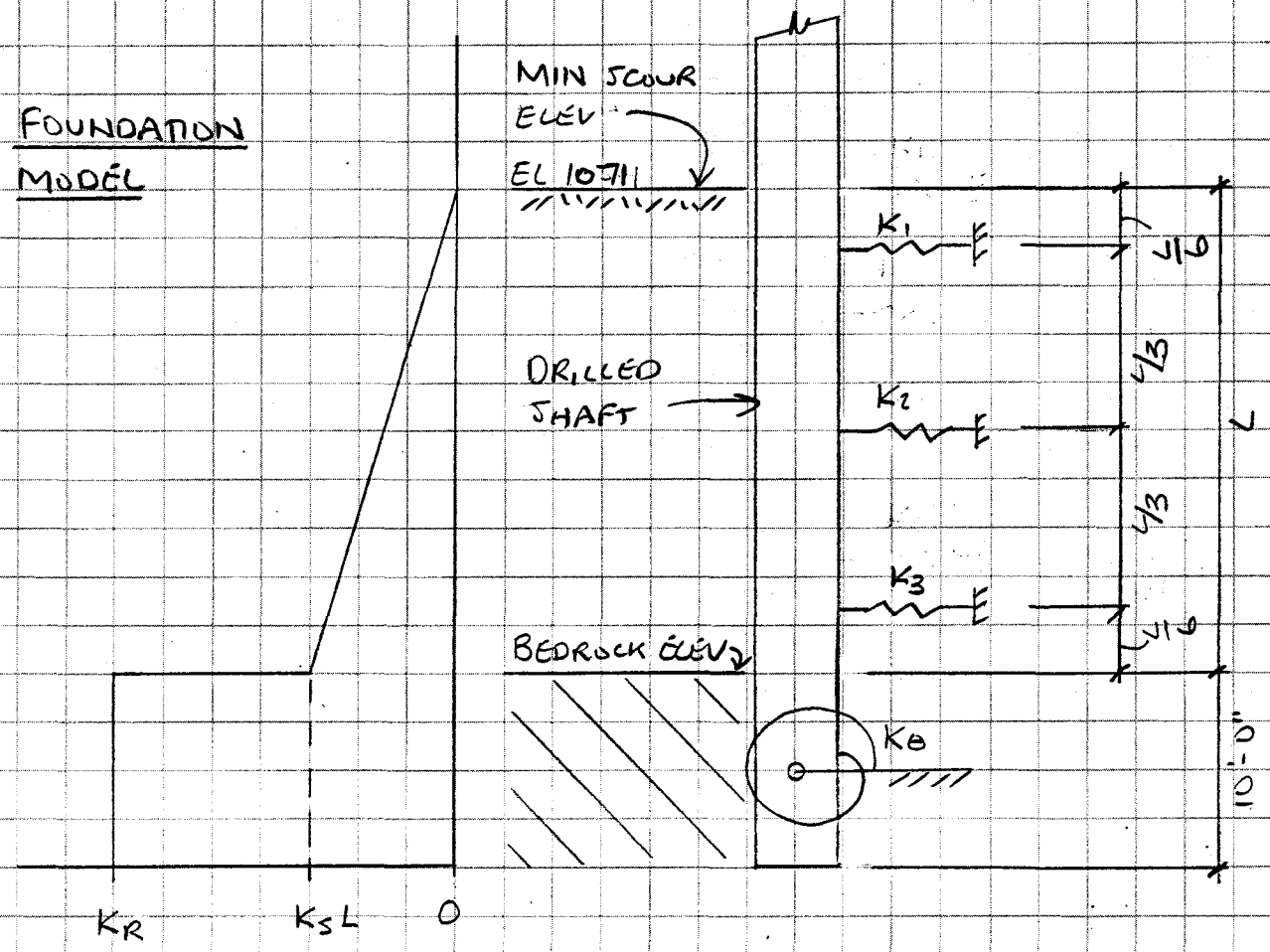
SHEET NO. 115 OF

DATE 9-89

COMPUTATIONS FOR PIER CAPS & COLUMNS

BY RCS CHKD PBB

FOUNDATION MODEL



LATERAL MODULUS OF SUBGRADE

BEDROCK

PER FOUNDATION REPORT: $K_R = (6.5)(1780\ \text{KSF/ft}) = 11{,}570\ \text{KLF/ft}$

SOIL

PER TELECON WITH STEVE HAIRE @ THOMAS-HARTIG (SEE FOLLOWING SHT.)

$$K_S = (6.5)\left(1.49\ \frac{\text{LB}}{\text{in}^4}\right)\left(\frac{20736\ \text{in}^4}{\text{Ft}^4}\right)\left(\frac{1}{1000}\right)$$

$$= 201\ \text{KLF/ft/ft}$$

$K_1 = K_S \frac{L}{6} \cdot \frac{L}{3} = K_S L^2/18 = 11.2\,L^2$ K/ft

$K_2 = K_S \frac{L}{2} \cdot \frac{L}{3} = K_S L^2/6 = 33.5\,L^2$ K/ft

$K_3 = K_S \frac{5L}{6} \cdot \frac{L}{3} = 5 K_S L^2/18 = 55.8\,L^2$ K/ft

K_θ -- SEE SHT 27

SVERDRUP

JOB 50106 SALT RIVER BRIDGE

COMPUTATIONS FOR PIER CAPS & COLUMNS

SHEET NO. 117 OF

DATE 9-89

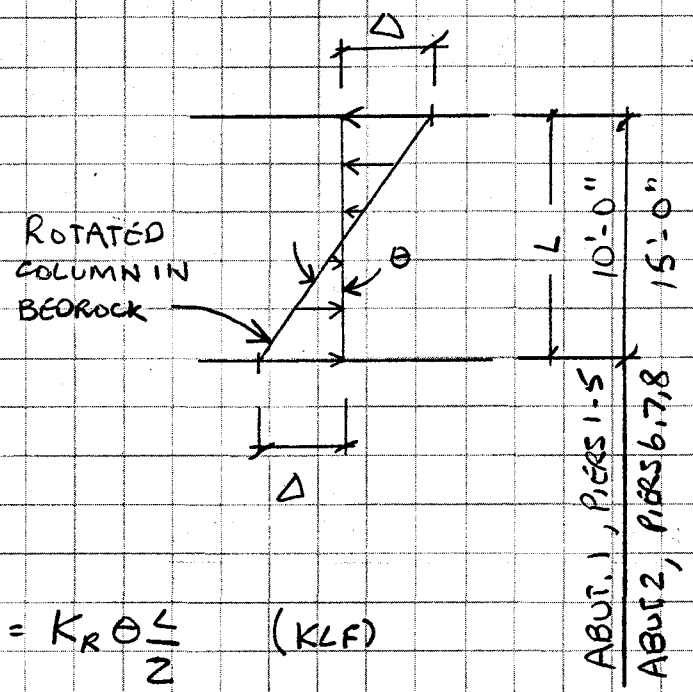
BY RCS CHKD PBB

PIER	SCOUR ELEV	BEDROCK ELEV	DIST. "L"	K_1	K_2	K_3
ABUT 1	1071	1012	59	39990	116,610	194,240
1	1071	1020	51	29,130	87,135	145,135
2	1071	1021	50	28,000	83,750	139,500
3	1071	1023	48	25,805	77,185	128,565
4	1071	1034	37	15,335	45,860	79,390
5	1071	1038	33	12,195	36,480	60,765
6	1071	1045	26	7,570	22,645	37,720
7	1071	1045	26	7,570	22,645	37,720
8	1071	1052	19	4,045	12,095	20,145
ABUT 2	1071	1063	8	715	2,145	3,570

SOIL SPRING CONSTANTS

K IN UNITS OF K/ft

ROTATIONAL SPRING



ASSUMING A RIGID COLUMN,

$$\Delta = \theta \frac{L}{2}$$

MAX SOIL FORCE $q = K_R \Delta = K_R \theta \frac{L}{2}$ (KLF)

MOMENT $M = \left(\frac{1}{2} q \frac{L}{2}\right)\left(\frac{2L}{3}\right) = \frac{qL^2}{6}$

FORCE LEVER ARM

$$M = \left(K_R \theta \frac{L}{2}\right)\frac{L^2}{6} = \frac{K_R \theta L^3}{12}$$

ROTATIONAL SPRING CONSTANT $K_\theta = \frac{M}{\theta} = \frac{K_R L^3}{12}$

resistance of rock socket

$K_\theta = (11{,}570 \text{ KLF/Ft})\left(\frac{10^3 \text{ Ft}^3}{12}\right) = 964{,}170 \frac{\text{'K}}{\text{RAD}} = 16{,}830$ 'K/DEGREE (10' EMBEDMENT)

$K_\theta = (11{,}570 \text{ KLF/Ft})\left(\frac{15^3 \text{ Ft}^3}{12}\right) = 3{,}254{,}000 \frac{\text{'K}}{\text{RAD}} = 56{,}790$ 'K/DEGREE (15' EMBEDMENT)

SVERDRUP

JOB 50106 SALT RIVER BRIDGE

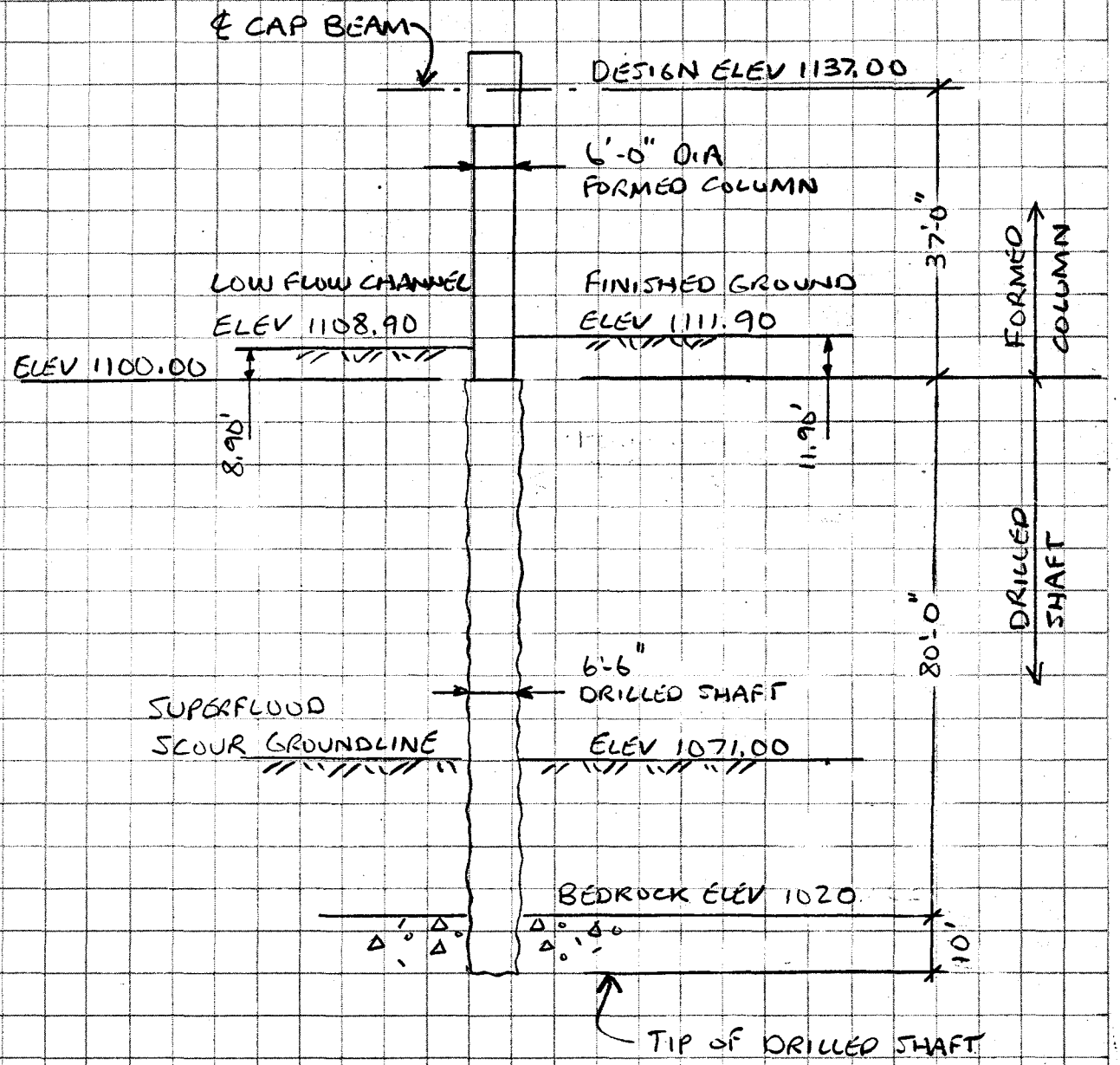
COMPUTATIONS FOR PIER CAPS & COLUMNS

SHEET NO. 140 OF

DATE 6-89

BY RCS CHKD PBB

COLUMN DIMENSIONS FOR INPUT TO PROGRAM P7038



ELEVATION AT PIER 1

SVERDRUP

JOB 50106 SALT RIVER BRIDGE

COMPUTATIONS FOR COLUMNS & SHAFTS

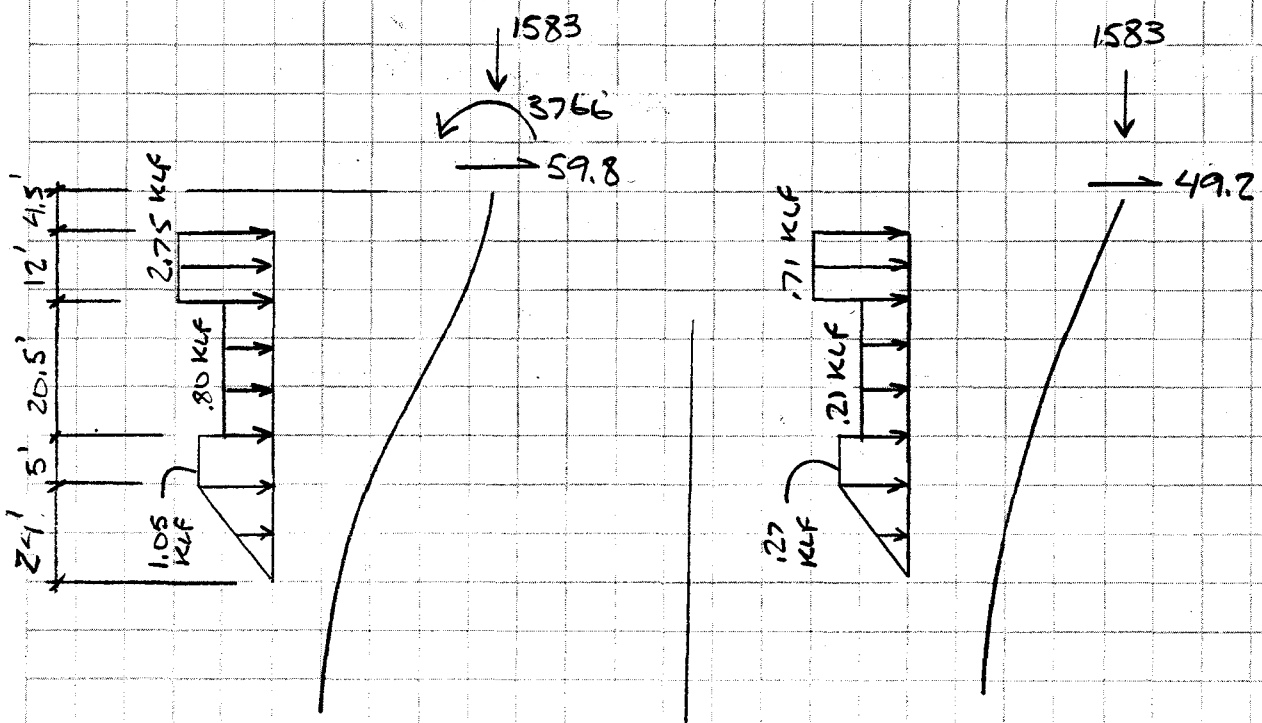
SHEET NO. 141 OF

DATE 5-91

BY RCS CHKD PBB

APPLIED FORCES FOR P7038 INPUT

PIER 1 IS THE PROTOTYPE FOR ALL FIXED PIERS
CRITICAL LOAD COMBINATION IS
AASHTO GROUP 2 (BASED ON FORCES @ JOINT 19 FROM COMPUTER OUTPUT)



TRANSVERSE SERVICE LOAD FORCES

LONGITUDINAL SERVICE LOAD FORCES

	Ax	Vy	Vz	My	Mz
DL	1413	6.6	0	0	364
W	102	53.2	49.2	0	2038
OT	-1	0	0	0	-12
SF	69	0	0	0	1376
	1583	59.8	49.2	0	3766

FROM STAAD OUTPUT

JOB NO. 50106 SALT RIVER BRIDGE

PROBLEM PIER 1 COLUMNS, TRANSVERSE LOADS -- FILE "COL1T"

5. - RESULTS

JOINT	X(FT)	DEFLECTION(FT)	SLOPE(RAD)	MOMENT(F-K)	SHEAR(KIP)	REACTION(KIP)
0	0.0000E+00	0.5307E+00		0.0000E+00		-0.2000E-10
			-0.2138E-02		0.5980E+02	
1	0.2017E+01	0.5264E+00		-0.3645E+04		0.1279E-09
			-0.2721E-02		0.5980E+02	
2	0.4034E+01	0.5209E+00		-0.3525E+04		-0.6375E-09
			-0.3284E-02		0.6257E+02	
3	0.6052E+01	0.5143E+00		-0.3398E+04		0.2735E-09
			-0.3828E-02		0.6812E+02	
4	0.8069E+01	0.5066E+00		-0.3261E+04		0.1478E-09
			-0.4349E-02		0.7367E+02	
5	0.1009E+02	0.4978E+00		-0.3112E+04		-0.3175E-09
			-0.4846E-02		0.7922E+02	
6	0.1210E+02	0.4880E+00		-0.2953E+04		-0.2364E-09
			-0.5318E-02		0.8476E+02	
7	0.1412E+02	0.4773E+00		-0.2781E+04		0.7210E-10
			-0.5763E-02		0.9031E+02	
8	0.1614E+02	0.4657E+00		-0.2599E+04		0.2082E-10
			-0.6179E-02		0.9389E+02	
9	0.1816E+02	0.4532E+00		-0.2410E+04		0.9579E-10
			-0.6564E-02		0.9551E+02	
10	0.2017E+02	0.4400E+00		-0.2217E+04		0.9677E-10
			-0.6918E-02		0.9712E+02	
11	0.2219E+02	0.4260E+00		-0.2021E+04		-0.2445E-09
			-0.7241E-02		0.9873E+02	
12	0.2421E+02	0.4114E+00		-0.1822E+04		0.2569E-09
			-0.7533E-02		0.1003E+03	
13	0.2622E+02	0.3962E+00		-0.1619E+04		0.3918E-09
			-0.7791E-02		0.1020E+03	
14	0.2824E+02	0.3805E+00		-0.1414E+04		0.1434E-09
			-0.8017E-02		0.1036E+03	
15	0.3026E+02	0.3643E+00		-0.1205E+04		0.3449E-09
			-0.8210E-02		0.1052E+03	
16	0.3228E+02	0.3478E+00		-0.9924E+03		0.3473E-10
			-0.8369E-02		0.1068E+03	
17	0.3429E+02	0.3309E+00		-0.7769E+03		0.7179E-09
			-0.8493E-02		0.1084E+03	
18	0.3631E+02	0.3138E+00		-0.5580E+03		0.1274E-08
			-0.8534E-02		0.1103E+03	
19	0.3833E+02	0.2965E+00		-0.3355E+03		-0.1541E-09
			-0.8579E-02		0.1124E+03	
20	0.4034E+02	0.2792E+00		-0.1086E+03		-0.4280E-10
			-0.8594E-02		0.1145E+03	
21	0.4236E+02	0.2619E+00		0.1225E+03		-0.2759E-09
			-0.8577E-02		0.1166E+03	
22	0.4438E+02	0.2446E+00		0.3578E+03		-0.8233E-10
			-0.8529E-02		0.1186E+03	
23	0.4640E+02	0.2274E+00		0.5971E+03		-0.2290E-09

SVERDRUP & PARCEL AND ASSOCIATES, INC. 08:37 JUN 28,'91

JOB NO. 50106 SALT RIVER BRIDGE

157

PROBLEM PIER 1 COLUMNS, TRANSVERSE LOADS -- FILE "COL1T"

JOINT	X(FT)	DEFLECTION(FT)	SLOPE(RAD)	MOMENT(F-K)	SHEAR(KIP)	REACTION(KIP)
			-0.8448E-02		0.1203E+03	
24	0.4841E+02	0.2103E+00		0.8400E+03		0.1271E-09
			-0.8335E-02		0.1219E+03	
25	0.5043E+02	0.1935E+00		0.1086E+04		0.1041E-09
			-0.8189E-02		0.1233E+03	
26	0.5245E+02	0.1770E+00		0.1335E+04		-0.1703E-09
			-0.8009E-02		0.1246E+03	
27	0.5447E+02	0.1609E+00		0.1586E+04		0.3695E-10
			-0.7795E-02		0.1256E+03	
28	0.5648E+02	0.1451E+00		0.1840E+04		0.6410E-10
			-0.7548E-02		0.1265E+03	
29	0.5850E+02	0.1299E+00		0.2095E+04		-0.4386E-10
			-0.7265E-02		0.1272E+03	
30	0.6052E+02	0.1153E+00		0.2352E+04		0.8622E-10
			-0.6949E-02		0.1278E+03	
31	0.6253E+02	0.1012E+00		0.2610E+04		-0.6114E-10
			-0.6597E-02		0.1281E+03	
32	0.6455E+02	0.8793E-01		0.2868E+04		-0.6475E-10
			-0.6211E-02		0.1283E+03	
33	0.6657E+02	0.7540E-01		0.3127E+04		0.1592E-10
			-0.5790E-02		0.1283E+03	
34	0.6859E+02	0.6372E-01		0.3386E+04		-0.1981E+02
			-0.5333E-02		0.1085E+03	
35	0.7060E+02	0.5296E-01		0.3605E+04		-0.3326E+02
			-0.4848E-02		0.7521E+02	
36	0.7262E+02	0.4318E-01		0.3756E+04		-0.4085E+02
			-0.4342E-02		0.3436E+02	
37	0.7464E+02	0.3442E-01		0.3826E+04		-0.4368E+02
			-0.3827E-02		-0.9314E+01	
38	0.7666E+02	0.2670E-01		0.3807E+04		-0.4251E+02
			-0.3314E-02		-0.5183E+02	
39	0.7867E+02	0.2002E-01		0.3703E+04		-0.3825E+02
			-0.2815E-02		-0.9007E+02	
40	0.8069E+02	0.1434E-01		0.3521E+04		-0.3196E+02
			-0.2341E-02		-0.1220E+03	
41	0.8271E+02	0.9618E-02		0.3275E+04		-0.2450E+02
			-0.1900E-02		-0.1465E+03	
42	0.8472E+02	0.5786E-02		0.2979E+04		-0.1658E+02
			-0.1498E-02		-0.1631E+03	
43	0.8674E+02	0.2764E-02		0.2650E+04		-0.8800E+01
			-0.1141E-02		-0.1719E+03	
44	0.8876E+02	0.4615E-03		0.2303E+04		-0.1616E+01
			-0.8311E-03		-0.1735E+03	
45	0.9078E+02	-0.1215E-02		0.1953E+04		0.4643E+01
			-0.5680E-03		-0.1689E+03	
46	0.9279E+02	-0.2361E-02		0.1613E+04		0.9772E+01
			-0.3508E-03		-0.1591E+03	
47	0.9481E+02	-0.3068E-02		0.1292E+04		0.1368E+02

M max — Gen. rule — at approx. 1½ Dia. below gnd.

SVERDRUP & PARCEL AND ASSOCIATES, INC. 08:37 JUN 28,'91

158

JOB NO. 50106 SALT RIVER BRIDGE

PROBLEM PIER 1 COLUMNS, TRANSVERSE LOADS -- FILE "COLIT"

JOINT	X(FT)	DEFLECTION(FT)	SLOPE(RAD)	MOMENT(F-K)	SHEAR(KIP)	REACTION(KIP)
			-0.1768E-03		-0.1454E+03	
48	0.9683E+02	-0.3425E-02		0.9982E+03		0.1636E+02
			-0.4232E-04		-0.1291E+03	
49	0.9884E+02	-0.3510E-02		0.7378E+03		0.1788E+02
			0.5707E-04		-0.1112E+03	
50	0.1009E+03	-0.3395E-02		0.5135E+03		0.1838E+02
			0.1262E-03		-0.9282E+02	
51	0.1029E+03	-0.3141E-02		0.3262E+03		0.1800E+02
			0.1702E-03		-0.7482E+02	
52	0.1049E+03	-0.2797E-02		0.1753E+03		0.1692E+02
			0.1938E-03		-0.5790E+02	
53	0.1069E+03	-0.2406E-02		0.5850E+02		0.1532E+02
			0.2017E-03		-0.4258E+02	
54	0.1089E+03	-0.1999E-02		-0.2738E+02		0.1337E+02
			0.1980E-03		-0.2921E+02	
55	0.1109E+03	-0.1600E-02		-0.8630E+02		0.1121E+02
			0.1864E-03		-0.1800E+02	
56	0.1130E+03	-0.1224E-02		-0.1226E+03		0.8965E+01
			0.1698E-03		-0.9033E+01	
57	0.1150E+03	-0.8815E-03		-0.1408E+03		0.6736E+01
			0.1509E-03		-0.2297E+01	
58	0.1170E+03	-0.5771E-03		0.0000E+00		0.2297E+01

SVERDRUP & PARCEL AND ASSOCIATES, INC. 08:39 JUN 28,'91

168

JOB NO. 50106 SALT RIVER BRIDGE

PROBLEM PIER 1 COLUMNS, LONGITUDINAL LOADS -- FILE "COL1L"

5. - RESULTS

JOINT	X(FT)	DEFLECTION(FT)	SLOPE(RAD)	MOMENT(F-K)	SHEAR(KIP)	REACTION(KIP)
0	0.0000E+00	0.8848E+00		0.0000E+00		0.7361E-10
			-0.1515E-01		0.4920E+02	
1	0.2017E+01	0.8543E+00		0.9938E+02		-0.1441E-09
			-0.1513E-01		0.4920E+02	
2	0.4034E+01	0.8237E+00		0.1988E+03		-0.8706E-09
			-0.1510E-01		0.4992E+02	
3	0.6052E+01	0.7933E+00		0.2996E+03		0.6468E-09
			-0.1505E-01		0.5135E+02	
4	0.8069E+01	0.7629E+00		0.4033E+03		0.6439E-10
			-0.1499E-01		0.5278E+02	
5	0.1009E+02	0.7327E+00		0.5099E+03		-0.3026E-09
			-0.1491E-01		0.5421E+02	
6	0.1210E+02	0.7026E+00		0.6194E+03		-0.5530E-09
			-0.1481E-01		0.5565E+02	
7	0.1412E+02	0.6727E+00		0.7318E+03		0.4063E-09
			-0.1469E-01		0.5708E+02	
8	0.1614E+02	0.6431E+00		0.8470E+03		-0.2074E-09
			-0.1456E-01		0.5801E+02	
9	0.1816E+02	0.6137E+00		0.9642E+03		0.1266E-09
			-0.1440E-01		0.5843E+02	
10	0.2017E+02	0.5847E+00		0.1082E+04		0.1723E-09
			-0.1423E-01		0.5885E+02	
11	0.2219E+02	0.5560E+00		0.1201E+04		-0.3833E-09
			-0.1404E-01		0.5928E+02	
12	0.2421E+02	0.5276E+00		0.1321E+04		0.3974E-09
			-0.1383E-01		0.5970E+02	
13	0.2622E+02	0.4997E+00		0.1441E+04		0.4409E-09
			-0.1360E-01		0.6012E+02	
14	0.2824E+02	0.4723E+00		0.1563E+04		0.1474E-09
			-0.1335E-01		0.6055E+02	
15	0.3026E+02	0.4454E+00		0.1685E+04		0.4285E-09
			-0.1308E-01		0.6097E+02	
16	0.3228E+02	0.4190E+00		0.1808E+04		0.1469E-09
			-0.1279E-01		0.6139E+02	
17	0.3429E+02	0.3932E+00		0.1932E+04		0.1005E-08
			-0.1248E-01		0.6182E+02	
18	0.3631E+02	0.3680E+00		0.2057E+04		0.1099E-08
			-0.1233E-01		0.6230E+02	
19	0.3833E+02	0.3432E+00		0.2183E+04		0.4701E-11
			-0.1204E-01		0.6285E+02	
20	0.4034E+02	0.3189E+00		0.2310E+04		-0.9064E-10
			-0.1172E-01		0.6339E+02	
21	0.4236E+02	0.2952E+00		0.2438E+04		-0.1376E-09
			-0.1140E-01		0.6394E+02	
22	0.4438E+02	0.2723E+00		0.2567E+04		-0.2490E-09
			-0.1105E-01		0.6444E+02	
23	0.4640E+02	0.2500E+00		0.2697E+04		-0.1819E-09

SVERDRUP & PARCEL AND ASSOCIATES, INC. 08:39 JUN 28,'91

169

JOB NO. 50106 SALT RIVER BRIDGE

PROBLEM PIER 1 COLUMNS, LONGITUDINAL LOADS -- FILE "COL1L"

JOINT	X(FT)	DEFLECTION(FT)	SLOPE(RAD)	MOMENT(F-K)	SHEAR(KIP)	REACTION(KIP)
			-0.1069E-01		0.6489E+02	
24	0.4841E+02	0.2284E+00		0.2828E+04		0.4990E-10
			-0.1031E-01		0.6530E+02	
25	0.5043E+02	0.2076E+00		0.2960E+04		0.1777E-09
			-0.9907E-02		0.6566E+02	
26	0.5245E+02	0.1876E+00		0.3092E+04		-0.1703E-09
			-0.9491E-02		0.6598E+02	
27	0.5447E+02	0.1685E+00		0.3225E+04		0.2404E-11
			-0.9056E-02		0.6625E+02	
28	0.5648E+02	0.1502E+00		0.3359E+04		0.7103E-10
			-0.8604E-02		0.6648E+02	
29	0.5850E+02	0.1329E+00		0.3493E+04		-0.9022E-11
			-0.8133E-02		0.6666E+02	
30	0.6052E+02	0.1165E+00		0.3628E+04		0.2345E-10
			-0.7644E-02		0.6680E+02	
31	0.6253E+02	0.1010E+00		0.3763E+04		-0.2811E-10
			-0.7138E-02		0.6689E+02	
32	0.6455E+02	0.8664E-01		0.3898E+04		-0.6931E-10
			-0.6613E-02		0.6693E+02	
33	0.6657E+02	0.7330E-01		0.4033E+04		0.4653E-10
			-0.6069E-02		0.6693E+02	
34	0.6859E+02	0.6106E-01		0.4168E+04		-0.1904E+02
			-0.5508E-02		0.4789E+02	
35	0.7060E+02	0.4995E-01		0.4264E+04		-0.3140E+02
			-0.4934E-02		0.1649E+02	
36	0.7262E+02	0.4000E-01		0.4298E+04		-0.3790E+02
			-0.4355E-02		-0.2141E+02	
37	0.7464E+02	0.3121E-01		0.4255E+04		-0.3971E+02
			-0.3781E-02		-0.6112E+02	
38	0.7666E+02	0.2358E-01		0.4131E+04		-0.3755E+02
			-0.3225E-02		-0.9867E+02	
39	0.7867E+02	0.1708E-01		0.3932E+04		-0.3263E+02
			-0.2695E-02		-0.1313E+03	
40	0.8069E+02	0.1164E-01		0.3668E+04		-0.2594E+02
			-0.2201E-02		-0.1572E+03	
41	0.8271E+02	0.7200E-02		0.3350E+04		-0.1834E+02
			-0.1750E-02		-0.1756E+03	
42	0.8472E+02	0.3669E-02		0.2996E+04		-0.1052E+02
			-0.1346E-02		-0.1861E+03	
43	0.8674E+02	0.9535E-03		0.2621E+04		-0.3036E+01
			-0.9933E-03		-0.1891E+03	
44	0.8876E+02	-0.1050E-02		0.2239E+04		0.3679E+01
			-0.6917E-03		-0.1854E+03	
45	0.9078E+02	-0.2446E-02		0.1865E+04		0.9345E+01
			-0.4404E-03		-0.1761E+03	
46	0.9279E+02	-0.3334E-02		0.1510E+04		0.1380E+02
			-0.2371E-03		-0.1623E+03	
47	0.9481E+02	-0.3812E-02		0.1183E+04		0.1699E+02

M max at ~1 dia. below

JOB NO. 50106 SALT RIVER BRIDGE

PROBLEM PIER 1 COLUMNS, LONGITUDINAL LOADS -- FILE "COL1L"

JOINT	X(FT)	DEFLECTION(FT)	SLOPE(RAD)	MOMENT(F-K)	SHEAR(KIP)	REACTION(KIP)
			-0.7775E-04		-0.1453E+03	
48	0.9683E+02	-0.3969E-02		0.8895E+03		0.1896E+02
			0.4206E-04		-0.1264E+03	
49	0.9884E+02	-0.3884E-02		0.6346E+03		0.1979E+02
			0.1275E-03		-0.1066E+03	
50	0.1009E+03	-0.3627E-02		0.4196E+03		0.1963E+02
			0.1841E-03		-0.8693E+02	
51	0.1029E+03	-0.3256E-02		0.2443E+03		0.1866E+02
			0.2170E-03		-0.6827E+02	
52	0.1049E+03	-0.2818E-02		0.1066E+03		0.1705E+02
			0.2313E-03		-0.5122E+02	
53	0.1069E+03	-0.2351E-02		0.3230E+01		0.1497E+02
			0.2318E-03		-0.3624E+02	
54	0.1089E+03	-0.1884E-02		-0.6988E+02		0.1260E+02
			0.2223E-03		-0.2365E+02	
55	0.1109E+03	-0.1435E-02		-0.1176E+03		0.1006E+02
			0.2065E-03		-0.1359E+02	
56	0.1130E+03	-0.1019E-02		-0.1450E+03		0.7462E+01
			0.1870E-03		-0.6128E+01	
57	0.1150E+03	-0.6418E-03		-0.1574E+03		0.4904E+01
			0.1658E-03		-0.1223E+01	
58	0.1170E+03	-0.3074E-03		0.2494E-12		0.1223E+01

Sverdrup

JOB 50106 SALT RIVER BRIDGE

COMPUTATIONS FOR COLUMNS & DRILLED SHAFTS

SHEET NO. 171 OF

DATE 5-91

BY RCS CHKD PBB

DRILLED SHAFT
DESIGN MOMENTS

1. TRANSVERSE LOADS

INFLECTION POINT @ X ≈ 41 Ft
DEFLECTION = .26 Ft

MAX MOMENT = 3826 'K @ x = 74.6'
DEFLECTION = .03 Ft
AXIAL FORCE = 1583 + 37(4.24) + 37.6(4.98) = 1583^K + 344^K = 1927^K

$P\Delta$ = 1583(.26 - .03) + ½(344)(.26 - .03) = 404 'K

M_u = 1.3(3826 + 404) = 5499 'K

P_u = 1927(1.3)(.75) = 1879^K

2. LONGITUDINAL LOADS

DEFLECTION @ TOP = .88'

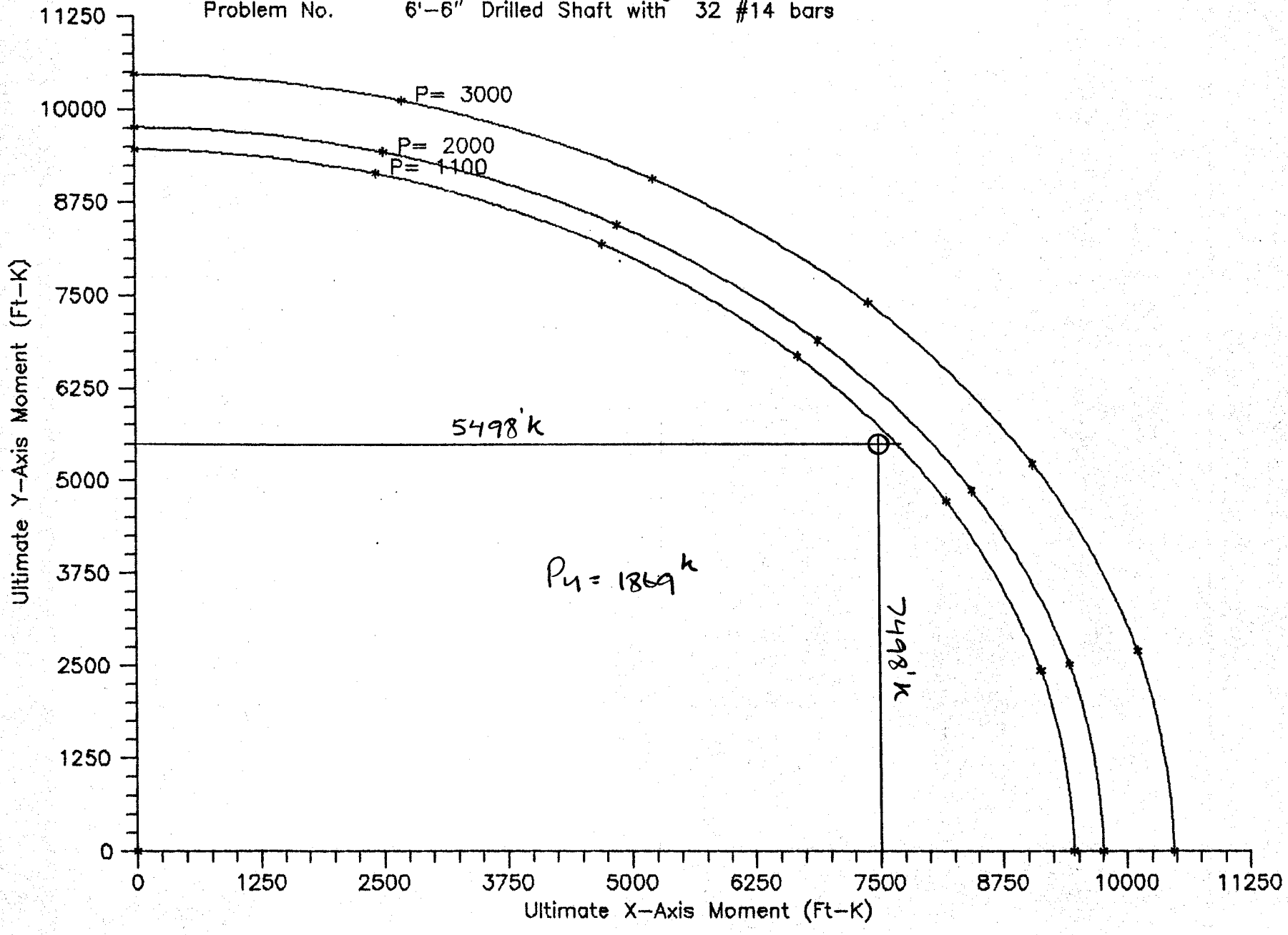
MAX MOMENT = 4298 'K @ X = 72.6' ≈ 74.6'
DEFLECTION = .04'
AXIAL FORCE = 1583 + 37(4.24) + 35.6(4.98) = 1583^K + 334^K
= 1917^K

$P\Delta$ = 1583(.88 - .04) + ½(334)(.88 - .04) = 1470 'K

M_u = 1.3(4298 + 1470) = 7498 'K

P_u = 1.3(.75)(1917) = 1869^K

Job No. 50106 SR 153 Salt River Bridge File 32BARS78
Problem No. 6'-6" Drilled Shaft with 32 #14 bars



CHK'D: PBB

179

SVERDRUP

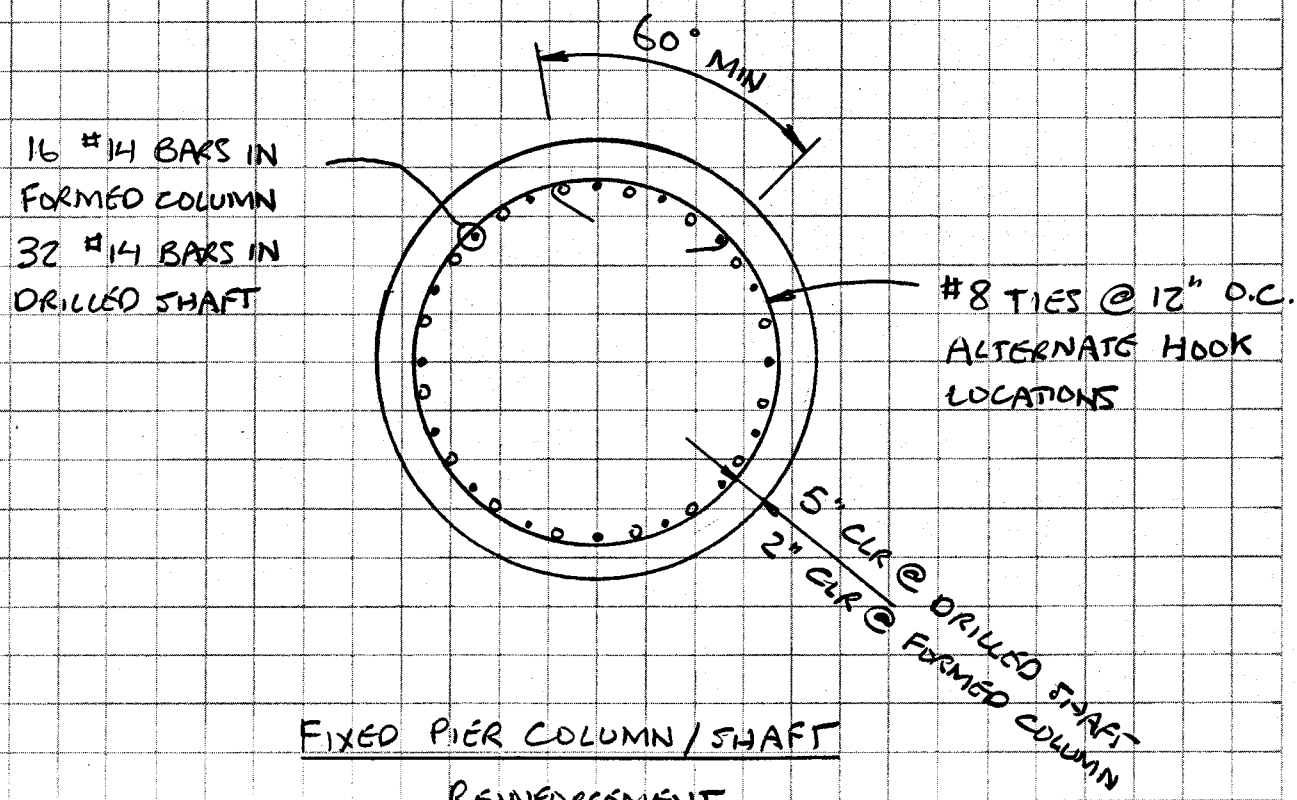
JOB 50106 SALT RIVER BRIDGE

COMPUTATIONS FOR COLUMNS & SHAFTS

SHEET NO. 182 OF

DATE 7-91

BY RCS CHKD PBB



FIXED PIER COLUMN / SHAFT REINFORCEMENT

• DENOTES CONTINUOUS BAR

∘ DENOTES BAR DISCONTINUED AT ELEV. 1100.00