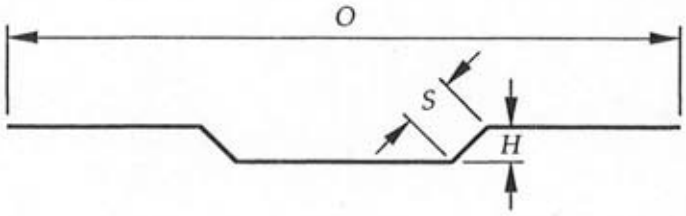
Estimating Appendix

Circle Data

Diameter	Circumference ft	Area sq ft	Diameter	Circumference ft	Area sq ft	Diameter	Circumference ft	Area sq ft
4"	1.0471	0.0873	2' - 4"	7.3303	4.2763	4' - 9"	14.9226	17.7205
4½"	1.1781	0.1104	2' - 5"	7.5923	4.5873	4' - 10"	15.1843	18.3481
5"	1.3091	0.1363	2' - 6"	7.8540	4.8900	4' - 11"	15.4463	18.9868
5½"	1.4398	0.1650	2' - 7"	8.1157	5.2414	5' - 0"	15.7080	19.6350
6"	1.5708	0.1963	2' - 8"	8.3777	5.5848	5' - 1"	15.9696	20.2953
6½"	1.7018	0.2304	2' - 9"	8.6394	5.9395	5' - 2"	16.2317	20.9666
7"	1.8325	0.2673	2' - 10"	8.9011	6.3052	5' - 3"	16.4933	21.6474
7½"	1.9635	0.3068	2' - 11"	9.1631	6.6818	5' - 4"	16.7550	22.3399
8"	2.0945	0.3490	3' - 0"	9.4250	7.0686	5' - 5"	17.0171	23.0448
8½"	2.2252	0.3942	3' - 1"	9.6865	7.4669	5' - 6"	17.2787	23.7582
9"	2.3562	0.4417	3' - 2"	9.9485	7.8766	5' - 7"	17.5404	24.4834
10"	2.6179	0.5454	3' - 3"	10.2102	8.2957	5' - 8"	17.8024	25.2203
11"	2.8799	0.6660	3' - 4"	10.4719	8.7267	5' - 9"	18.0641	25.9671
1' - 0"	3.1416	0.7854	3' - 5"	10.7339	9.1690	5' - 10"	18.3258	26.7250
1' - 1"	3.4033	0.9214	3' - 6"	10.9956	9.6211	5' - 11"	18.5879	27.4947
1' - 2"	3.6653	1.0689	3' - 7"	11.2573	10.0845	6' - 0"	18.8496	28.2743
1' - 3"	3.9270	1.2271	3' - 8"	11.5193	10.5588	6' - 3"	19.6349	30.6795
1' - 4"	4.1887	1.3961	3' - 9"	11.7810	11.0446	6' - 6"	20.4203	33.1830
1' - 5"	4.4507	1.5764	3' - 10"	12.0427	11.5413	6' - 9"	21.2057	35.7846
1' - 6"	4.7124	1.7671	3' - 11"	12.3047	12.0489	7' - 0"	21.9910	38.4845
1' - 7"	4.9741	1.9688	4' - 0"	12.5664	12.5664	7' - 3"	22.7765	41.2825
1' - 8"	5.2361	2.1818	4' - 1"	12.8281	13.0957	7' - 6"	23.5619	44.1786
1' - 9"	5.4978	2.4052	4' - 2"	13.0901	13.6364	7' - 9"	24.3473	47.1729
1' - 10"	5.7595	2.6399	4' - 3"	13.3518	14.1862	8' - 0"	25.1327	50.2654
1' - 11"	6.0215	2.8852	4' - 4"	13.6135	14.7485	8' - 3"	25.9181	53.4560
2' - 0"	6.2830	3.1416	4' - 5"	13.8755	15.3215	8' - 6"	26.7036	56.7452
2' - 1"	6.5449	3.4083	4' - 6"	14.1372	15.9043	8' - 9"	27.4889	60.1319
2' - 2"	6.8069	3.6876	4' - 7"	14.3989	16.4993	9' - 0"	28.2743	63.6173
2' - 3"	7.0686	3.9760	4' - 8"	14.6609	17.1053			

Slants and Increments for 45° Bar Bends



O = Overall Bar Dimension.
H = Height of Bend
S = Slant = 1.414 H to nearest ½ inch
I = Increment = $S - H$

Height H	Slant S	Increment for 2 Slants $2I$
2"	3"	2"
2½"	3½"	2"
3"	4"	2"
3½"	5"	3"
4"	5½"	3"
4½"	6½"	4"
5"	7"	4"
5½"	7½"	4"
6"	8½"	5"
6½"	9"	5"
7"	10"	6"
7½"	10½"	6"
8"	11½"	7"
8½"	1' - 0"	7"
9"	1 - ½"	7"
9½"	1' - 1½"	8"
10"	1' - 2"	8"
10½"	1' - 3"	9"
11"	1' - 3½"	9"
11½"	1' - 4"	9"
1' - 0"	1' - 5"	10"

Height H	Slant S	Increment for 2 Slants $2I$
1' - 1"	1' - 6½"	11"
1' - 2"	1' - 8"	1' - 0"
1' - 3"	1' - 9"	1' - 0"
1' - 4"	1' - 10½"	1' - 1"
1' - 5"	2' - 0"	1' - 2"
1' - 6"	2' - 1½"	1' - 3"
1' - 7"	2' - 3"	1' - 4"
1' - 8"	2' - 4"	1' - 4"
1' - 9"	2' - 5½"	1' - 5"
1' - 10"	2' - 7"	1' - 6"
1' - 11"	2' - 8½"	1' - 7"
2' - 0"	2' - 10"	1' - 8"
2' - 1"	2' - 11½"	1' - 9"
2' - 2"	3' - 1	1' - 10"
2' - 3"	3' - 2"	1' - 10"
2' - 4"	3' - 3½"	1' - 11"
2' - 5"	3' - 5"	2' - 0"
2' - 6"	3' - 6½"	2' - 1"
2' - 7"	3' - 8"	2' - 2"
2' - 8"	3' - 9"	2' - 2"
2' - 9"	3' - 10½"	2' - 3"
2' - 10"	4' - 0"	2' - 4"
2' - 11"	4' - 1½"	2' - 5"
3' - 0"	4' - 3"	2' - 6"

Height H	Slant S	Increment for 2 Slants $2I$
3' - 1"	4' - 4½"	2' - 7"
3' - 2"	4' - 5½"	2' - 7"
3' - 3"	4' - 7"	2' - 8"
3' - 4"	4' - 8½"	2' - 9"
3' - 5"	4' - 10"	2' - 10"
3' - 6"	4' - 11½"	2' - 11"
3' - 7"	5' - 1	3' - 0"
3' - 8"	5' - 2"	3' - 0"
3' - 9"	5' - 3½"	3' - 1"
3' - 10"	5' - 5"	3' - 2"
3' - 11"	5' - 6½"	3' - 3"
4' - 0"	5' - 8"	3' - 4"
4' - 1"	5' - 9½"	3' - 5"
4' - 2"	5' - 10½"	3' - 5"
4' - 3"	6' - 0"	3' - 6"
4' - 4"	6 - 1½"	3' - 7"
4' - 5"	6' - 3"	3' - 8"
4' - 6"	6' - 4½"	3' - 9"
4' - 7"	6' - 6"	3' - 10"
4' - 8"	6' - 7"	3' - 10"
4' - 9"	6' - 8½"	3' - 11"
4' - 10"	6' - 10"	4' - 0"
4' - 11"	6' - 11½"	4' - 1"
5' - 0"	7' - 1"	4' - 2"

Increment for 2 Slants — $2 \times (S - H)$
Length of Truss Bars — $O + 2I$
All Dimensions are out to out of bar.

Sectional Areas of Welded Wire Fabric from Wire Reinforcement Institute Manual of Standard Practice 1979

Wire Size Number		Nominal Diameter Inches	Nominal Weight Lbs./Lin. Ft.	A_s – Square Inches Per Linear Foot Center to Center Spacing						
Smooth	Deformed			2"	3"	4"	6"	8"	10"	12"
W20	D20	0.505	0.680	1.200	0.800	0.600	0.400	0.300	0.240	0.200
W18	D18	0.479	0.612	1.080	0.720	0.540	0.360	0.270	0.216	0.180
W16	D16	0.451	0.544	0.960	0.640	0.480	0.320	0.240	0.192	0.160
W14	D14	0.422	0.476	0.840	0.560	0.420	0.280	0.210	0.168	0.140
W12	D12	0.391	0.408	0.720	0.480	0.360	0.240	0.180	0.144	0.120
W11	D11	0.374	0.374	0.660	0.440	0.330	0.220	0.165	0.132	0.110
W10.5	—	0.366	0.357	0.630	0.420	0.315	0.210	0.157	0.126	0.105
W10	D10	0.357	0.340	0.600	0.400	0.300	0.200	0.150	0.120	0.100
W9.5	—	0.348	0.323	0.570	0.380	0.285	0.190	0.142	0.114	0.095
W9	D9	0.338	0.306	0.540	0.360	0.270	0.180	0.135	0.108	0.090
W8.5	—	0.329	0.289	0.510	0.340	0.255	0.170	0.127	0.102	0.085
W8	D8	0.319	0.272	0.480	0.320	0.240	0.160	0.120	0.096	0.080
W7.5	—	0.309	0.255	0.450	0.300	0.225	0.150	0.112	0.090	0.075
W7	D7	0.299	0.238	0.420	0.280	0.210	0.140	0.105	0.084	0.070
W6.5	—	0.288	0.221	0.390	0.260	0.195	0.130	0.097	0.078	0.065
W6	D6	0.276	0.204	0.360	0.240	0.180	0.120	0.090	0.072	0.060
W5.5	—	0.265	0.187	0.330	0.220	0.165	0.110	0.082	0.066	0.055
W5	D5	0.252	0.170	0.300	0.200	0.150	0.100	0.075	0.060	0.050
W4.5	—	0.239	0.153	0.270	0.180	0.135	0.090	0.067	0.054	0.045
W4	D4	0.226	0.136	0.240	0.160	0.120	0.080	0.060	0.048	0.040
W3.5	—	0.211	0.119	0.210	0.140	0.105	0.070	0.052	0.042	0.035
W3	—	0.195	0.102	0.180	0.120	0.090	0.060	0.045	0.036	0.030
W2.9	—	0.192	0.098	0.174	0.116	0.087	0.058	0.043	0.035	0.029
W2.5	—	0.178	0.085	0.150	0.100	0.075	0.050	0.037	0.030	0.025
W2	—	0.160	0.068	0.120	0.080	0.060	0.040	0.030	0.024	0.020
W1.4	—	0.134	0.049	0.084	0.056	0.042	0.028	0.021	0.017	0.014

Single Bar Splices

Bar Size No. 3 thru No. 11 – Lap Splice

Bar Size	Lap Splice Length			
	Uncoated		Epoxy Coated	
3	1'-5"	45d Laps	1'-8"	54dLaps
4	1'-11"		2'-3"	
5	2'-4"		2'-10"	
6	2'-10"		3'-5"	
7	3'-3"		3'-11"	
8	3'-9"		4'-6"	
9	5'-8"	60d Laps	6'-9"	72d Laps
10	6'-4"		7'-7"	
11	7'-1"		8'-6"	

Bar Size No. 14 thru No. 18

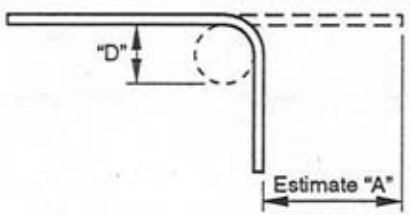
Splice by welding or mechanical butt splices. Lap splices are not permitted.

Bundled Bar Splice – Lengths

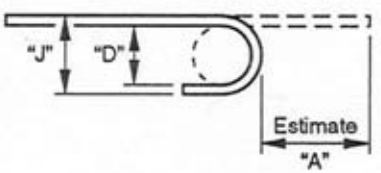
2 bar bundles – Same splice lengths as for single bars.
3 bar bundles – 1.2 times lap length single bar splice.
4 bar bundles – 1.33 times lap length single bar splice.

Reinforcing Bar Data – Grade 60 (ACI 318-89)

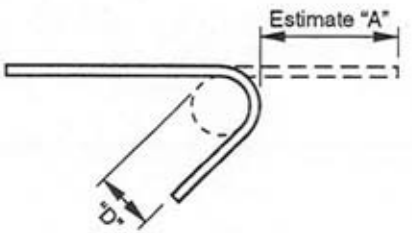
Physical Properties						Hook Dimensions						
						Standard				Stirrups and Ties		
Bar Size	Weight Lbs/Ft	Nominal Diameter Inches	Approximate Diameter Outside Deformation Inches	Area Sq. In.	Perim. Inches	"D"	90°	180°		"D"	90°	135°
							"A"	"J"	"A"		"A"	"A"
3	0.376	0.375	0.44	0.11	1.178	2 ¼"	6"	3"	5"	1 ½"	4"	4"
4	0.668	0.500	0.56	0.20	1.571	3"	8"	4"	6"	2"	4 ½"	4 ½"
5	1.043	0.625	0.69	0.31	1.963	3 ¾"	10"	5"	7"	2 ½"	6"	5 ½"
6	1.502	0.750	0.88	0.44	2.356	4 ½"	1'-0"	6"	8"	4 ½"	1'- 0"	8"
7	2.044	0.875	1.00	0.60	2.749	5 ¼"	1'- 2"	7"	10"	5 ¼"	1'- 2"	9"
8	2.670	1.000	1.13	0.79	3.142	6"	1'- 4"	8"	11"	6"	1'- 4"	10 ½"
9	3.400	1.128	1.25	1.00	3.544	9 ½"	1'- 7"	11 ¾"	1'- 3"	—	—	—
10	4.303	1.270	1.44	1.27	3.990	10 ¾"	1'-10"	1'- 1¼"	1'- 5"	—	—	—
11	5.313	1.410	1.63	1.56	4.430	12"	2'- 0"	1'- 2 ¾"	1'- 7"	—	—	—
14	7.650	1.693	1.88	2.25	5.320	1'- 6 ¼"	2'- 7"	1'- 9 ¾"	2'- 3"	—	—	—
18	13.60	2.257	2.50	4.00	7.090	2'- 0"	3'- 5"	2'- 4½"	3'-0"	—	—	—



90° Standard/90° Stirrup and Tie



180° Standard



135° Tie Hook

Board Feet Measure

Nominal Size in Inches	Board Feet Per Lineal Foot of Piece
2 × 2	0.33
2 × 3	0.50
2 × 4	0.67
2 × 6	1.00
2 × 8	1.33
2 × 10	1.67
2 × 12	2.00
2 × 14	2.33
3 × 3	0.75
3 × 4	1.00
3 × 6	1.50
3 × 8	2.00
3 × 10	2.50
3 × 12	3.00
3 × 14	3.50
3 × 16	4.00
4 × 4	1.33
4 × 6	2.00
4 × 8	2.67
4 × 10	3.33
4 × 12	4.00
4 × 14	4.67
4 × 16	5.33
6 × 6	3.00
6 × 8	4.00
6 × 10	5.00
6 × 12	6.00
6 × 14	7.00
6 × 16	8.00
6 × 18	9.00
6 × 20	10.00

Nominal Size in Inches	Board Feet Per Lineal Foot of Piece
8 × 8	5.33
8 × 10	6.67
8 × 12	8.00
8 × 14	9.33
8 × 16	10.67
8 × 18	12.00
8 × 20	13.33
8 × 22	14.67
8 × 24	16.00
10 × 10	8.33
10 × 12	10.00
10 × 14	11.67
10 × 16	13.33
10 × 18	15.00
10 × 20	16.67
10 × 22	18.33
12 × 12	12.00
12 × 14	14.00
12 × 16	16.00
12 × 18	18.00
12 × 20	20.00
12 × 22	22.00
12 × 24	24.00

Form Number	Form Name
DS-D-0001	Historical Cost Record
DS-D-0015	Pile Summary
DS-D-0016	Bridge General Plan Estimate or Planning Estimate
DS-D-0017	Miscellaneous General Plan Estimate or Planning Estimate
DS-D-0019	Structure Quantity and Marginal Estimate
DS-D-0019A	Marginal Estimate – Miscellaneous Structure Other Than Bridge
DS-D-0019B	Marginal Estimate – Miscellaneous Structure Other Than Bridge (EQ Retrofit)
DS-D-0019SUP	Marginal Estimate – Miscellaneous Structure Other Than Bridge
DS-D-0022	Summary – Structure Excavation and Structure Backfill
DS-D-0050	Concrete Summary
DS-D-0067	Bar Reinforcing Summary
DS-D-0100	Pile Quantity Calculations
DS-D-0110	Reinforcing Steel Quantities
DS-D-0153	Sound Wall Summary
DS-D-0154	Summary – Miscellaneous Metal – Bridge and Restrainer

STATE OF CALIFORNIA • DEPARTMENT OF TRANSPORTATION

HISTORICAL COST RECORD

DS-D-0001 (REV. 4/93)

DISTRICT	COUNTY	ROUTE	EXPENDITURE AUTHORIZATION	ALL PRICES x $1,000	UPDATE = Price Change Only	REVISION = Design Change, Explain on back (Revision Usually Includes Price Update)

STRUCTURE \ DATE												
PROJECT STRUCTURE TOTAL												
COST INDEX												

DS 90 0003

O = Initial Shotgun Estimate By Others P = Planning Estimate G = General Plan M = Marginal (Plans Complete) B = Final (Specs Complete)

STATE OF CALIFORNIA • DEPARTMENT OF TRANSPORTATION

PILE SUMMARY

DS-D-0015 (REV. 4/93)

Estimating Section to forward to RE Pending File

STRUCTURE			BRIDGE NO	CALCULATED BY
DISTRICT	COUNTY	ROUTE	EA	CHECKED BY

LOCATION	LENGTH		NUMBER	
	ESTIMATE	CHECK	ESTIMATE	CHECK
TOTALS	LF	LF	EA	EA

DS 93 0006

STATE OF CALIFORNIA • DEPARTMENT OF TRANSPORTATION

BRIDGE GENERAL PLAN ESTIMATE ☐ OR PLANNING ESTIMATE ☐

DS-D-0016 (REV. 5/93)

STRUCTURE	BR. NO.		RCVD. BY		ESTIMATING GROUP	
TYPE	DIST.	CO.	RTE.	P.M.	IN	
					OUT	

LENGTH _____ × WIDTH _____ = AREA _____ SQ FT

DESIGN SECTION _____ QUANTITIES BY _____ DATE _____ ESTIMATE NO. _____

PROJECT INCLUDES _____ STRUCTURE(S) QUANTITITES CHCKD. BY _____ DATE _____ PRICED BY _____

AND $ _____ ROADWORK CHARGE UNIT AND EA _____ COST INDEX _____

	CONTRACT ITEMS	UNIT	QUANTITY	PRICE	AMOUNT
1	TEMPORARY RAILING (TYPE)	LF			
2	REMOVE CONCRETE	CY			
3	STRUCTURE EXCAVATION (BRIDGE)	CY			
4	STRUCTURE EXCAVATION (TYPE D)	CY			
5	STRUCTURE BACKFILL (BRIDGE)	CY			
6	PERVIOUS BACKFILL MATERIAL	CY			
7	CIDH CONCRETE PILING	LF			
8	FURNISH PILING	LF			
9	DRIVE PILING	EA			
10	PC/PS CONCRETE GIRDERS (FEET)	EA			
11	ERECT PC/PS CONCRETE GRIDERS	EA			
12	STRUCTURAL CONCRETE BRIDGE	CY			
13	STRUCTURAL CONCRETE BRIDGE FOOTING	CY			
14	STRUCTURAL CONCRETE APPROACH SLAB (TYPE)	CY			
15	BAR REINFORCING STEEL (BRIDGE)	LBS			
16	PRESTRESSING STEEL	LBS			
17	STRUCTURAL STEEL (INCL PAINT)	LBS			
18	SLOPE PAVING	CY			
19	JOINT SEAL (TYPE)	LF			
20	JOINT SEAL ASSEMBLY (MR =)	LF			
21	CONCRETE BARRIER (TYPE)	LF			
22					
23					
24					

SUBTOTAL	$
MOBILIZATION (%)	
SUBTOTAL STRUCTURE ITEMS	$
CONTINGENCIES (%)	
BRIDGE TOTAL (/SQ FT)	$
BRIDGE REMOVAL (CONTINGS INCL)	
WORK BY RAILROAD OR UTILITY FORCES	
GRAND TOTAL	$
FOR BUDGET PURPOSES – USE	$

ROUTING

1. DESIGN SECTION _____
2. DESIGN A SUPERVISOR
3. DESIGN B SUPERVISOR
4. PLANNING

_____

_____

_____

COMMENTS _____

ESTIMATING – LAST

DS 90 0043

STATE OF CALIFORNIA • DEPARTMENT OF TRANSPORTATION

MISCELLANEOUS GENERAL PLAN ESTIMATE ☐ OR PLANNING ESTIMATE ☐

DS-D-0017 (REV. 5/93)

STRUCTURE	BR. NO.		RCVD. BY		ESTIMATING GROUP	
TYPE	DIST.	CO.	RTE.	P.M.	IN	
					OUT	

LENGTH _____ × WIDTH _____ = AREA _____ SQ FT

DESIGN SECTION _____ QUANTITIES BY _____ DATE _____ ESTIMATE NO. _____

PROJECT INCLUDES _____ STRUCTURE(S) QUANTITITES CHCKD. BY _____ DATE _____ PRICED BY _____

AND $ _____ ROADWORK CHARGE UNIT AND EA _____ COST INDEX _____

	CONTRACT ITEMS	UNIT	QUANTITY	PRICE	AMOUNT
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					

SUBTOTAL	$
MOBILIZATION (%)	
SUBTOTAL STRUCTURE ITEMS	$
CONTINGENCIES (%)	
BRIDGE TOTAL (/SQ FT)	$
BRIDGE REMOVAL (CONTINGS INCL)	
WORK BY RAILROAD OR UTILITY FORCES	
GRAND TOTAL	$
FOR BUDGET PURPOSES – USE	$

ROUTING

1. DESIGN SECTION _____
2. DESIGN A SUPERVISOR
3. DESIGN B SUPERVISOR
4. PLANNING

_____

_____

_____

COMMENTS _____

ESTIMATING – LAST

DS 93 0044

STATE OF CALIFORNIA • DEPARTMENT OF TRANSPORTATION

STRUCTURAL QUANTITY AND MARGINAL ESTIMATE

DS-D-0019 (REV. 5/93)

CHARGE	EXP. AUTH.	BR. NO.	BRIDGE NAME	TYPE	DISTRICT	COUNTY	ROUTE	POST MILE	LENGTH	WIDTH	DEPTH	LL

LONG SPAN	SPANS	SKEW	DESIGN SECT.	REC'D IN ESTIMATES BY	DATE	QUANTITIES BY	DATE	CHECKED BY	DATE	REVISED BY	DATE

CODE	CONTRACT ITEMS	UNIT	SUPERSTRUCTURE QUANTITY	SUPERSTRUCTURE CHECK	SUPERSTRUCTURE USE	SUBSTRUCTURE QUANTITY	SUBSTRUCTURE CHECK	SUBSTRUCTURE USE	OTHER ELEMENTS – DESCRIBE QUANTITY	OTHER ELEMENTS – DESCRIBE CHECK	OTHER ELEMENTS – DESCRIBE USE	TOTALS USE	PRICE	AMOUNT
	TEMPORARY RAILING (TYPE)	LF												
	REMOVE CONCRETE	CY												
	BRIDGE REMOVAL													
	STRUCTURE EXCAVATION (BRIDGE)	CY												
	STRUCTURE EXCAVATION (TYPE D)	CY												
	STRUCTURE BACKFILL (BRIDGE)	CY												
	PREVIOUS BACKFILL MATERIAL	CY												
	CIDH CONCRETE PILING	LF												
	FURNISH PILING	LF												
	DRIVE PILES	EA												
	FURNISH PILING	LF												
	DRIVE PILES	EA												
	FURNISH PRECAST PREST CONCRETE GIRDER	EA												
	FURNISH PRECAST CONCRETE GIRDER	EA												
	ERECT PRECAST PREST CONCRETE GIRDER	EA												
	ERECT PRECAST CONCRETE GIRDER	EA												
	STRUCTURAL CONCRETE BRIDGE FOOTING	CY												
	STRUCTURAL CONCRETE BRIDGE	CY												
	BAR REINFORCING STEEL (BRIDGE)	LBS												
	PRESTRESSING STEEL	LBS												
	STRUCTURAL STEEL	LBS												
	MISCELLANEOUS METAL (BRIDGE)	LBS												
	MISCELLANEOUS METAL (RESTRAINER)	LBS												
	DECK SEAL	SQ FT												
	SLOPE PAVING	CY												
	PERMEABLE MATERIAL	CY												
	8" PSP	LF												
	8" CSP	LF												
	METAL RAILING (TYPE)	LF												
	WATERSTOP	LF												
	JOINT SEAL (MR =) 2" MAXIMUM	LF												
	JOINT SEAL ASSEMBLY (MR =) > 2"	LF												
	CONCRETE BARRIER (TYPE)	LF												
													SUBTOTAL	$

QUANTITY PER GIRDER				
LENGTH OF PRECAST PRESTRESS GIRDER				
CUBIC YARDS F.O.C.				
POUNDS BAR REINFORCING				
POUNDS PRESTRESSING STEEL				
NUMBER OF GIRDERS				

MARGINAL ESTIMATE BY			
DATE			
COST INDEX			

MOBILIZATION	
SUBTOTAL CONTRACT ITEMS	
CONTINGENCIES	
TOTAL	$
FOR BUDGET PURPOSES — USE	$

DS-M-0002

STATE OF CALIFORNIA • DEPARTMENT OF TRANSPORTATION

MARGINAL ESTIMATE – MISCELLANEOUS STRUCTURE OTHER THAN BRIDGE

DS-D-0019A (REV. 5/93)

STRUCTURE	BR. NO.	CHARGE	EA	DESIGN SECT.

DISTRICT	COUNTY	ROUTE	POST MILE	TYPE	LENGTH	WIDTH

CODE	CONTRACT ITEMS	UNIT	QUANTITY	CHECK	USE	PRICE	AMOUNT

SUBTOTAL	$
MOBILIZATION %	
SUBTOTAL CONTRACT ITEMS	
SUPPLEMENTAL WORK	
CONTINGENCIES %	
TOTAL	$
FOR BUDGET PURPOSES USE	$

RECEIVED IN ESTIMATE SECTION BY	DATE
QUANTITIES BY	DATE
CHECKED BY	DATE
REVISED BY	DATE
MARGINAL ESTIMATE BY	DATE
COST INDEX	COMMENT

DS 50 0046

STATE OF CALIFORNIA • DEPARTMENT OF TRANSPORTATION

MARGINAL ESTIMATE – MISCELLANEOUS STRUCTURE OTHER THAN BRIDGE (EQ RETROFIT)

DS-D-0019B (REV. 5/93)

STRUCTURE				BR. NO.	CHARGE	EA	DESIGN SECT.
DISTRICT	COUNTY	ROUTE	POST MILE	TYPE		LENGTH	WIDTH

CODE	CONTRACT ITEMS	UNIT	QUANTITY	CHECK	USE	PRICE	AMOUNT
153530	Access Opening Deck	EA					
153531	Access Opening Soffit	EA					
157560	Bridge Removal (Portion)	CY					
19200	Structure Excavation	CY					
19300	Structure Backfill	CY					
49	Furnish Piling	LF					
49	Drive Pile	EA					
4906	CIDH Piling	LF					
500060	Tiedown Anchor (Pile)	EA					
51005	Structure Concrete	CY					
510051	Structure Concrete Bridge Footing	CY					
510502	Minor Concrete (Minor Structure)	CY					
510505	Diaphragm Bolster	EA					
511106	Drill and Bond Dowel	LF					
511125	Close Access Deck	EA					
51506	Core Concrete	LF					
520101	Bar Reinforcing Steel	LB					
540101	Asphalt Member Waterproof	Sq Ft					
550110	Column Casting	LB					
590115	Clean and Paint Structural Steel	Sq Ft					
750498	Misc. Metal (Restrainer Cable)	LB					
750499	Misc. Metal (Restrainer Rod)	LB					
750501	Miscellaneous Metal Bridge	LB					
750506	Miscellaneous Metal (Tie Rod)	LF					

SUBTOTAL	$
MOBILIZATION %	
SUBTOTAL CONTRACT ITEMS	
SUPPLEMENTAL WORK	
CONTINGENCIES %	
TOTAL	$
FOR BUDGET PURPOSES USE	$

RECEIVED IN ESTIMATE SECTION BY	DATE
QUANTITIES BY	DATE
CHECKED BY	DATE
REVISED BY	DATE
MARGINAL ESTIMATE BY	DATE
COST INDEX	COMMENT

DS 93 0048

STATE OF CALIFORNIA • DEPARTMENT OF TRANSPORTATION

MARGINAL ESTIMATE – MISCELLANEOUS STRUCTURE OTHER THAN BRIDGE

DS-D-0019SUP (REV. 5/93)

STRUCTURE				BR. NO.	CHARGE	EA	DESIGN SECT.
DISTRICT	COUNTY	ROUTE	POST MILE	TYPE		LENGTH	WIDTH

CODE	CONTRACT ITEMS	UNIT	QUANTITY	CHECK	USE	PRICE	AMOUNT
12900	Temporary Railing (Type)	LF					
153210	Remove Concrete	CY					
1920	Structure Excavation	CY					
193003	Structure Backfill	CY					
4906	CIDH Piling	LF					
49	Furnish Piling	LF					
49	Drive Piles	EA					
5100	Structure Concrete	CY					
510502	Minor Concrete (Minor Structure)	CY					
520102	Bar Reinforcing Steel	LB					
550102	Structural Steel (Including Paint)	LB					
682005	Previous Backfill Material	CY					
750501	Miscellaneous Metal Bridge	LB					
750506	Miscellaneous Metal (Restrainer)	LF					

SUBTOTAL	$
MOBILIZATION %	
SUBTOTAL CONTRACT ITEMS	
SUPPLEMENTAL WORK	
CONTINGENCIES %	
TOTAL	$
FOR BUDGET PURPOSES USE	$

RECEIVED IN ESTIMATE SECTION BY	DATE
QUANTITIES BY	DATE
CHECKED BY	DATE
REVISED BY	DATE
MARGINAL ESTIMATE BY	DATE
COST INDEX	COMMENT

DS 93 0047

STATE OF CALIFORNIA • DEPARTMENT OF TRANSPORTATION

SUMMARY – STRUCTURE EXCAVATION AND STRUCTURE BACKFILL

DS-D-0022 (REV. 4/93)

Estimating Section to forward to RE Pending File

STRUCTURE			BRIDGE NO	CALCULATED BY
DISTRICT	COUNTY	ROUTE	EA	CHECKED BY

LOCATION	STRUCTURE EXCAVATION		STRUCTURE BACKFILL		PERVIOUS BACKFILL MATERIAL	
	ESTIMATE	CHECK	ESTIMATE	CHECK	ESTIMATE	CHECK
TOTAL CY						

DS 10 0005

STATE OF CALIFORNIA • DEPARTMENT OF TRANSPORTATION

CONCRETE SUMMARY

DS-D-0050 (REV. 4/93)

Estimating Section to Forward to RE Pending File

STRUCTURE	BRIDGE NO	EA	DISTRICT	COUNTY	ROUTE	CALCULATED BY	CHECKED BY

SUPERSTRUCTURE	ESTIMATE	CHECK	SUBSTRUCTURE	ESTIMATE	CHECK	RETAINING WALLS	ESTIMATE	CHECK
Top Slab			Abutments					
Overhang								
Bottom Slab								
Bottom Slab Flares								
Girders - Interior								
Girders - Exterior			Wingwalls					
Girder Flares								
Fillets								
Closure Pour								
						TOTAL CY (RW)		
End Diaphragms			Columns – Piers					
						APPROACH SLABS	ESTIMATE	CHECK
Caps								
			NON-FOOTING TOTAL CY			TOTAL CY (APP SLABS)		
			Footings			BREAKDOWN BY CONCRETE TYPES		
Hinges							ESTIMATE	CHECK
						Struct Conc Bridge Footing		
						Struct Conc Bridge		
						Struct Conc Retaining Wall		
			FOOTING TOTAL CY			Struct Conc Approach		
TOTAL CY (SUPER)			TOTAL CY (SUB)			TOTAL CY		

DS 93 0023

STATE OF CALIFORNIA • DEPARTMENT OF TRANSPORTATION

BAR REINFORCING SUMMARY

DS-D-0067 (REV. 5/93)

Estimating Section to Forward to RE Pending File

STRUCTURE	BRIDGE NO	EA	DISTRICT	COUNTY	ROUTE	CALCULATED BY	CHECKED BY

BAR SIZE		SUPERSTRUCTURE		SUBSTRUCTURE		RETAINING WALL			
		ESTIMATE	CHECK	ESTIMATE	CHECK	ESTIMATE	CHECK	ESTIMATE	CHECK
3									
4									
5									
6									
7									
8									
9									
10									
11									
14									
18									
99	INT. DIAPHRAGM								
	RAIL								
	WALL								
	HINGE								
SUBTOTAL									
2% SPLICES									
TOTAL									

NOTES

DS 93 0024

STATE OF CALIFORNIA • DEPARTMENT OF TRANSPORTATION

PILE QUANTITY CALCULATIONS

DS-D-0100 (REV. 5/93)

SHEET ______ OF ______

STRUCTURE			BRIDGE NO.	CALCULATED BY	DATE
DISTRICT	COUNTY	ROUTE	POST MILE	ITEM	PILES

For piles battered 1:3, use 1.054 factor × vertical length = Battered Length

LOCATION	TOP ELEV.	TIP ELEV.	VERT. LENGTH	NO.	BATTER FACTOR	TOTAL LIN. FT.
			SHEET TOTALS	EA		LF

DS 93 0049

STATE OF CALIFORNIA • DEPARTMENT OF TRANSPORTATION

REINFORCING STEEL QUANTITIES

DS-D-0110 (REV. 5/93)

SHEET _____ OF _____

PROJECT	BRIDGE	NAME	DATE

ITEM	NUMBER OR WEIGHT/FT OF WALL	LENGTH TO 1/10 FOOT	TOTAL LENGTH – EACH SIZE									
			NO. 4	NO. 5	NO. 6	NO. 7	NO. 8	NO. 9	NO. 10	NO. 11	NO. 14	NO. 18
	TOTAL LENGTHS											
	WEIGHT PER FOOT		0.668	1.043	1.502	2.044	2.670	3.400	4.303	5.313	7.650	13.600
	TOTAL WEIGHT											

DS 80 0050

STATE OF CALIFORNIA • DEPARTMENT OF TRANSPORTATION

SOUND WALL SUMMARY

DS-D-0153 (NEW 6/93)

Submit to Estimating Section with Marginal Estimate

STRUCTURE OR SOUND WALL DESCRIPTION			BRIDGE OR SOUND WALL NO.	CALCULATED BY
DISTRICT	COUNTY	ROUTE	EA	CHECKED BY

ITEM	UNITS	ESTIMATE	CHECK	USE	PRICE	AMOUNT
Masonry Block	SF					
Minor Concrete:						
Trench	CY					
Cap	CY					
Footing (Spread)	CY					
CIDH Piling – 12"	LF					
CIDH Piling – 14"	LF					
CIDH Piling – 16"	LF					
					TOTAL COST	
					COST/SQ FT	

DS 93 0055

STATE OF CALIFORNIA • DEPARTMENT OF TRANSPORTATION

SUMMARY – MISCELLANEOUS METAL – BRIDGE AND RESTRAINER

DS-D-0154 (REV. 5/93)

Estimating Section to forward to RE Pending File

STRUCTURE			BRIDGE NO	CALCULATED BY
DISTRICT	COUNTY	ROUTE	EA	CHECKED BY

MISCELLANEOUS METAL – BRIDGE

ITEM	ESTIMATE	CHECK
Equalizing Bolts		
Frames and Grates		
Deck Drains		
TOTAL LBS		

MISCELLANEOUS METAL – RESTRAINER

ITEM	ESTIMATE	CHECK
Strand		
H.S. Rod		
TOTAL LBS		

DS 10 00/2

The following pages of *Bridge Design Aids*, Section 12, have been reviewed in February 1990 and found to be valid and appropriate for continued use:

Pages	*Date*	*Title*
12-30 thru 12-49	September 1986	Pile Shaft Design

These pages will be updated from time-to-time when significant changes in the technology occur.

Floyd L. Mellon

Guy D. Mancarti

TPJ:mkp

PILE SHAFT DESIGN

GENERAL

This pile shaft material (12-30 thru 12-49) replaces previously distributed literature concerning pile shaft design. The two design charts which estimate the depth to the point of effective fixity based on the Kocsis procedure, contained in the memorandum dated November 1984, have been replaced. These charts are no longer to be used.

After obtaining input from representatives of both design and research, new charts have been developed based on Professor Reeses research efforts. The new charts more accurately estimate the point of effective fixity.

The drilled shaft foundation is generally cheaper than other foundation types and permits the location of columns in tight locations with a minimum of disturbance to existing facilities. The use of this foundation is generally limited to areas where soil conditions permit economical excavation for the shaft and where ground water is not encountered. The presence of ground water does not prohibit the use of the drilled shaft, however the cost becomes considerably higher in this case. Lined and slurry displacement shafts require special considerations and should be cleared with the columns and piles committee.

The design problems involved with the use of the pile shaft are slightly different from those of ordinary pile and spread footing foundations. The pile shaft has a smaller lateral stiffness and therefore requires more refined foundation data at an earlier stage in the design process. This smaller lateral stiffness must also be considered in the design and analysis of the superstructure as well as the substructure components.

Engineering Geology Translab should be consulted where foundations are composed of rock or rock like material in order to determine weakness due to jointing and fracture planes.

The following memo describes the recommended procedure for the design and analysis of large diameter pile shafts. The procedure is divided into a number of distinct steps. It is a simplified method in which an equivalent column technique is used. An example problem is included. It is suggested that first-time users study the various steps before using the procedure.

Any comments or questions concerning pile shaft design should be directed to SASA 5-1439.

PILE SHAFT DESIGN PROCEDURE

1. Determine an equivalent column length using the rigorous or simplified procedure.

2.-4. Run the BDS, BENT, and STRUDL programs using the equivalent column lengths to determine column service loads to be used in programs YIELD and PILE. The superstructure may be designed using these listings.

5. Design the TOP of column reinforcement for all load groups I thru VII using the YIELD program and the equivalent column length.

6. Using the PILE program, determine the maximum service moments in the pile shaft for the components of group loads I thru VII. Detailed soil data from Engineering Geology is required for use of the PILE program.

7.-8. Using the YIELD program, determine the amount of vertical reinforcement required to resist the maximum moment in the pile shaft. The plastic moment capacity of the column and shaft is also determined at this time.

9. Using the PILE program, analyze the pile shaft for the plastic condition. The plastic moment, the associated axial load, and the assumed plastic shear are applied at the top of the column. The program is then run interactively by incrementing the shear until a plastic hinge forms in the pile shaft.

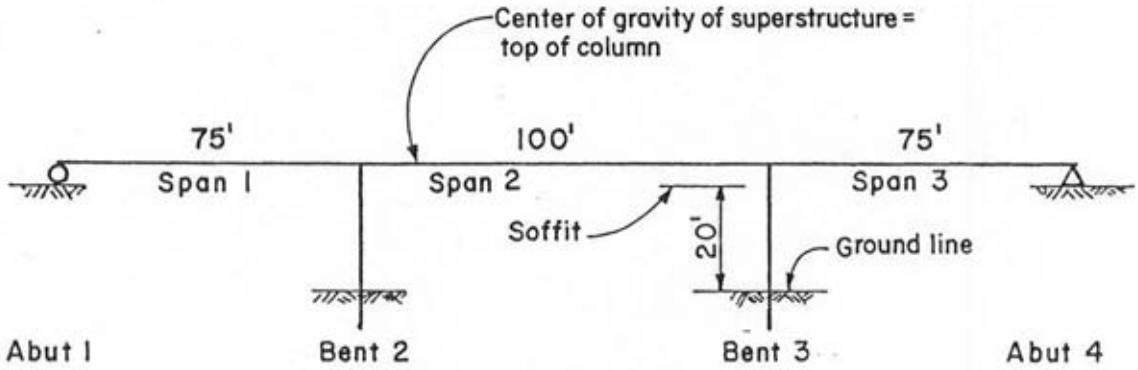
   The shear reinforcement is then designed for the lesser of the shears resulting from seismic plastic hinging or group loads I to VI and ARS unreduced seismic group load VII.

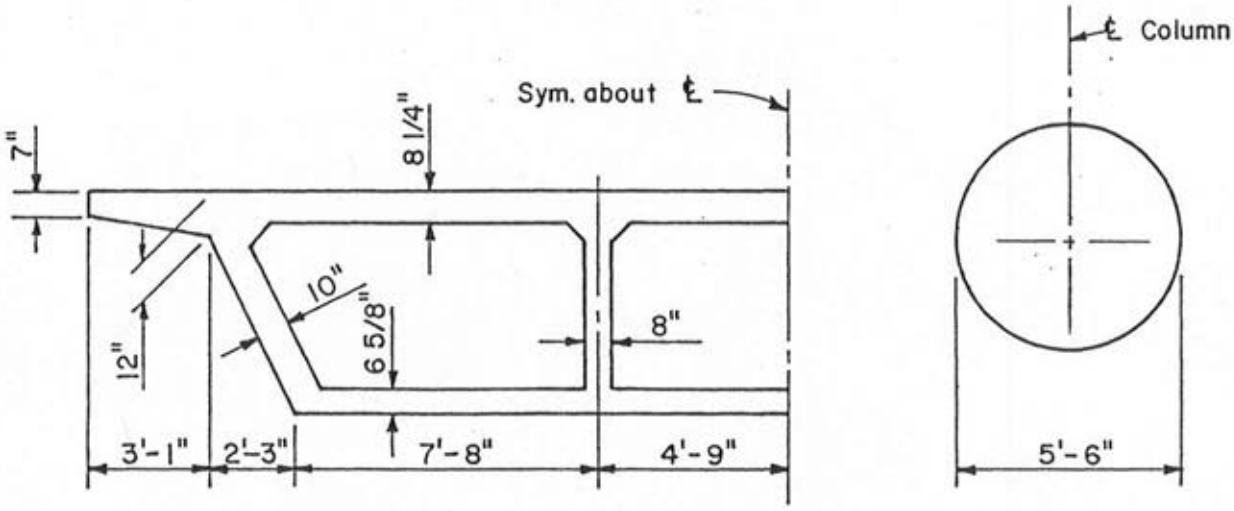
10. Perform a final check of the overall stability of the pile shaft using the PILE program.

Knowledge on the use of the PILE and YIELD programs in addition to BDS, BENT and STRUDL are required for successful application of this procedure.

PILE SHAFT DESIGN EXAMPLE PROBLEM

(Reference: Bridge Design Practice Manual 2-3)





COLUMN/SHAFT DATA:

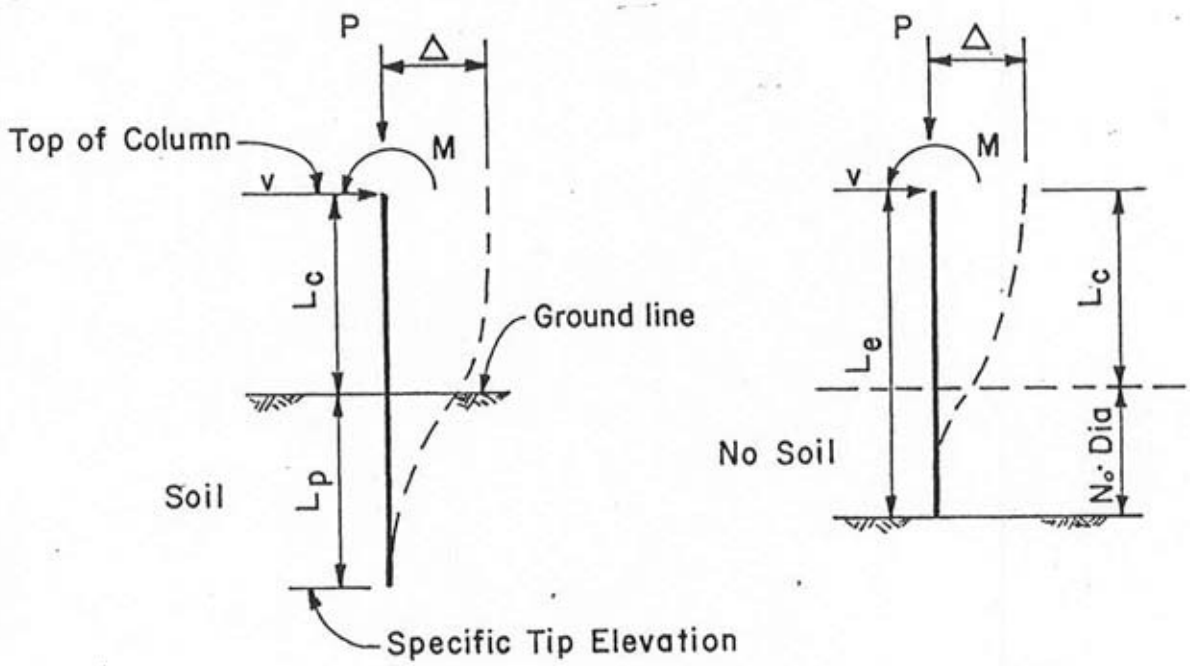
Dia = 5.5 Ft A = 23.8 Ft I = 44.9 Ft F'c = 3250 Psi
Lc = 20 Ft Lp = 60 Ft Ec = 468000 Ksf

SOIL DATA: Sand Above The Water Table

Layer	Class	Unit Wt (Kcf)	Thickness (Ft)	Blow Count (Blows/Ft)	Friction Angle (Degrees)
1	Loose	.13	10	10	28
2	Dense	.14	50	45	40

Peak Rock acceleration = 0.3 G Depth of Alluvium = 70 Ft

1. Determine an equivalent column length. The equivalent length (Le) of a column/pile shaft member is defined as that length of column (Lc) plus pile shaft (Lp) which when fixed at the bottom will produce the same deflections at the top of the column for a given load as the actual column plus shaft surrounded by soil. The equivalent column has the same EI as the actual column. The analysis of the bridge supported by columns in the soil can be carried out if the columns of the bridge are adjusted to the equivalent length, thus eliminating the soil from the problem.



SIMPLIFIED METHOD

Often detailed soil information lags the bridge preliminary report and it is desired to proceed with the design. Therefore, a 'Simplified Method' may be used to determine the equivalent length. The designer must obtain the soils general classification (sand or clay) and the standard penetration index (N) or an estimate of the soils relative density (loose, compact, dense etc.).

Assume the top of the column is at the C.G. of the superstructure, (3 feet above the soffit).

Lc = 20' + 3' = 23'

The charts are based on a single layer of soil. For this example, assume a single layer of dense sand 55 feet thick and neglect the first 5 feet of loose sand.

Lc (Adjusted) = 23' + 5' = 28'

Enter Figure 1. on page 16 with the blow count (N=45) and determine the number of pile diameters (No=3) from the ground line to the point of effective fixity.

Le = Lc + (No x Dia) = 28' + (3 x 5.5') = 44.5' (use 45')

There are some sites where the 'Simplified Method' should not be used:

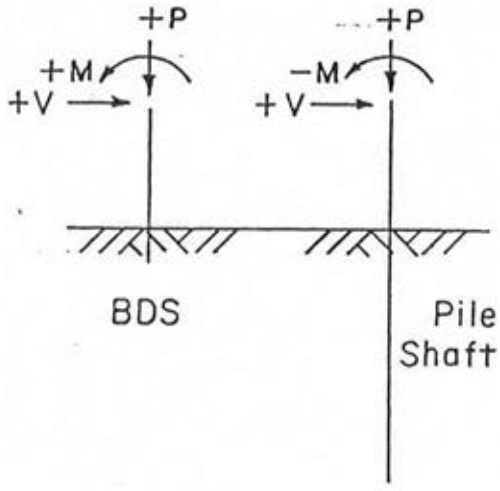
(1) Sites with large variations in soil stiffness with depth.
(2) Sites with soft intermediate layers.

For these cases, use the "Rigorous Method' to determine the equivalent length as described on page 12-45.

2. Run programs BDS and BENT (with or without sidesway) at the service level using the equivalent column length (Le). Determine the necessary service column loads to be used in programs YEILD and PILE at the TOP of the column. The shears at the top of the column are obtained by summing moments about the bottom of the column and dividing by the equivalent length. The moments at the bottom of the column are used only to obtain the shear forces and in no case are to be used to design the shaft.

BENT OUTPUT - TOP of Column Loads: (Service)

		:---- LL + IMPACT ----:		
		1	2	3
	DEAD LOAD	TRANS MY-MAX	LONG MX-MAX	AXIAL N-MAX
MY	0	1367	65	117
MX	-225	-80	-672	-108
N	1122	226	170	305
PMY		3944	2368	3944
PMX		-175	-933	-175
PN		459	276	459



BENT OUTPUT - Bottom of Column Loads: (Service)

	DEAD LOAD	:---- LL + IMPACT ----: 1 TRANS MY-MAX	2 LONG MX-MAX	3 AXIAL N-MAX
MY	0	1367	65	117
MX	112	40	337	54
N	1277	226	170	305
PMY		3944	2358	3944
PMX		88	468	88
PN		459	276	459

Calculated Top of Column Shear Forces: (Service)

	DEAD LOAD	:---- LL + IMPACT ----: 1 TRANS MY-MAX	2 LONG MX-MAX	3 AXIAL N-MAX
VX	0	0	0	0
VY	-7.5	-2.7	-22.4	-3.6
PVX	-	0	-	0
PVY	-	-5.8	-31.1	-5.8

Example calculation:

The shear is equal to the sum of the moments about the bottom of the column divided by the column length (Le):

(933 ft-k + 468 ft-k) / 45 = 31.1

3. Run STRUDL (or SEISAB) using the equivalent column length and obtain the unreduced elastic ARS seismic loads at the top of the column. The loads are RMS values and thus do not have a sign.

STRUDL OUTPUT - TOP of Column Loads: (Unreduced ARS)

	CASE I	CASE II
MY	3667	1100
MZ	5543	18475
N	41	138
VZ	193	58
VY	252	841

4. Determine Wind, WL, LF, CF, and T loads at the top of the column using STRUDL or hand procedures. Use the equivalent column length in these analyses. The loads at the bottom of the columns produced in the STRUDL analysis are fictitious and in no case are to be used to design the shaft.

STRUDL OUTPUT - TOP of Column Loads: (Service)

	Wind	WL	LF	CF-MY	TEMP
MY	175	14	0	0	0
MZ	289	107	86	0	420
N	2	1	1	0	1
VZ	10	2	0	0	0
VY	13	5	4	0	22

5. Using the YIELD program, design the top of the column for group loads I thru VII (moments and axial loads). Use the equivalent length as the column length and appropriate fixities. This will allow the correct moment magnification factors to be calculated.

YIELD INPUT - Top of Column Service Loads (Groups I - VII):

		:---- LL + IMPACT ----:							
		1	2	3					
	DEAD LOAD	TRANS MY-MAX	LONG MX-MAX	AXIAL N-MAX	WIND	WL	LF	CF	TEMP
MY	0	1367	65	117	175	14	0	0	0
MX	225	80	672	108	289	107	86	0	420
N	1122	226	170	305	2	1	1	0	1
PMY		3944	2368	3944					
PMX		175	933	175					
PN		459	276	459					

(ARS) UNREDUCED SEISMIC (Ductility Factor Z = 6)

	CASE 1	CASE 2
MY	3667	1100
MX	5543	18475
N	41	138

YIELD RESULTS:

Column Diameter = 5.5 ft.
Controlling Group Loading = IP Case 1
Percent Steel Required = 1.43
Total Area of Steel Required = 47.2 sq. in.
Number of bars Required = 37.2 @ 1.27 sq. in.

* Use 38 - #10 bars

6. Using the PILE program, apply the components of the group loads I to VII at the top of the column, and determine the corresponding maximum moments below the ground line in the shaft for each component. The moments and lateral loads are the moments and shears obtained from step 2. Case VII loads are reduced before input into program PILE. This is done to avoid excessive deflections which occur beyond the yield point. No axial loads are applied the because program YIELD considers slenderness by applying moment magnification factors. Obtain from the Engineering Geology and Technical Services Branch at Translab the soil classifications, thickness of soil layers, soil densities, pile shaft length (Lp based on maximum vertical loads) and the internal friction angles for a sand or the undrained shear strengths for a clay. Frequently the number of load cases can be reduced by inspection.

PILE INPUT - TOP of Column Component Loads (Groups I - VII):

LONGITUDINAL LOADS (Mx): (Service)

LOAD NO	AXIAL LOAD (k)	LATERAL LOAD (k)	MOMENT (k-ft)	LOAD COMPONENT
1	0.0	-7.5	225.00	DL
2	0.0	-2.7	80.00	IH-1
3	0.0	-22.4	672.00	IH-2
4	0.0	-3.6	108.00	IH-3
5	0.0	-5.8	175.00	IP-1,3
6	0.0	-31.1	933.00	IP-2
7	0.0	-13.0	289.00	W
8	0.0	-5.0	107.00	WL
9	0.0	-4.0	86.00	LF
10	0.0	-21.8	420.00	T
11	0.0	-42.1	924.00	VII-1 (reduced)
12	0.0	-140.2	3080.00	VII-2 (reduced)

LATERAL LOADS (My): (Service)

1	0.0	0.0	1367.00	IH-1
2	0.0	0.0	65.00	IH-2
3	0.0	0.0	117.00	IH-3
4	0.0	0.0	3944.00	IP-1,3
5	0.0	0.0	2358.00	IP-2
6	0.0	-10.0	175.00	W
7	0.0	-2.0	14.00	WL
8	0.0	-32.1	612.00	VII-1 (reduced)
9	0.0	-9.6	184.00	VII-2 (reduced)

PILE OUTPUT - Moments in Shaft below ground line:

LONGITUDINAL MOMENTS (Mx): (Service)

LOAD NO	MAX Mx MOMENT (k-ft)	LOAD COMPONENT
1	67	DL
2	15	IH-1
3	134	IH-2
4	22	IH-3
5	36	IP-1,3
6	187	IP-2
7	-161	W
8	-61	WL
9	-48	LF
10	-305	T
11	-490	VII-1 (reduced)
12	-1717	VII-2 (reduced)

LATERAL MOMENTS (My): (Service)

LOAD NO	MAX My MOMENT (k-ft)	LOAD COMPONENT
1	1370	IH-1
2	65	IH-2
3	117	IH-3
4	3940	IP-1,3
5	2370	IP-2
6	-159	W
7	-34	WL
8	-457	VII-1 (reduced)
9	-137	VII-2 (reduced)

7. Using the YIELD program, design the pile shaft below the ground line for group loads I - VII (moments and axial loads). To obtain the unreduced seismic moments for Group VII loads, multiply the reduced seismic moments in the pile shaft below the ground line, from step 6, by the ductility factor (Z). Use the equivalent column length and appropriate end fixities in the input.

YIELD INPUT - Service Loads in Shaft (Groups Loads I - VII):

		:---- LL + IMPACT ----:							
		1	2	3					
	DEAD LOAD	TRANS MY-MAX	LONG MX-MAX	AXIAL N-MAX	WIND	WL	LF	CF	TEMP
MY	0	1370	65	117	159	34	0	0	0
MX	67	15	134	22	161	61	48	0	305
N	1277	226	170	305	2	1	1	0	1
PMY		3940	2370	3940					
PMX		36	187	36					
PN		459	275	459					

UNREDUCED SEISMIC (Ductility Factor Z = 6)

	CASE 1	CASE 2
MY	2742	822
MX	2940	10302
N	41	138

YIELD RESULTS:

Column Diameter = 5.5 ft.
Controlling Group Loading = IP Case 1
Percent Steel Required = 1.25
Total Area of Steel Required = 42.75 sq. in.
Number of bars Required = 33.6 @ 1.27 sq. in.

* Use 38 - #10 bars (same as at top of column)

Top of column moments govern the design.

8. Run program YIELD in the check mode and determine the probable plastic moment and plastic shear at the top and bottom of the column. Assume the length of column is equal to the equivalent column length.

> Note: The plastic moment capacity of the shaft may be different than the plastic moment capacity of the top of the column (ie. different diameter, percent steel, or axial load).

<u>YIELD OUTPUT - Plastic Moment Capacity of Column/Pile Shaft</u>

Pp(top) = 1122 K
Mp(top) = 9699 K-Ft
Vp(top) = 436 K

Pp(bot) = 1277 K
Mp(bot) = 9921 K-Ft

9. Using program PILE, apply at the top of the column the associated probable plastic moment (Mp) and axial load (Pp) while incrementing the plastic shear until a second plastic hinge forms in the pile shaft.

a. If the plastic shear (Vp) is less than the unreduced elastic ARS (seismic) + dead load shear, design the shear reinforcement for the plastic shear (Vp).

c. If the plastic shear (Vp) is greater than the unreduced elastic ARS (seismic) + dead load shear, design the shear reinforcement for group loads I to VI and unreduced elastic group loads VII.

PILE INPUT/OUTPUT:

LOAD NO	TOP AXIAL P (k)	TOP SHEAR V (k)	TOP MOMENT M (k-ft)	MAX. M IN SHAFT (k-ft)	LOCATION FROM TOP (ft)
1	1122	-450	9699	5600	37
2	1122	-500	9699	7310	37
3	1122	-550	9699	8950	37
4	1122	-560	9699	9280	37
5	1122	-570	9699	9610	37
* 6	1122	-580	9699	9940	37
7	1122	-590	9699	10300	37
8	1122	-600	9699	10600	37

* The plastic hinge forms in the shaft.

Vp (580 K) < Vars (849 K)

Design the shear reinforcement for the plastic shear.

From YIELD in the CHECK mode:

Use #5 bars at max. pitch = 3 5/8 in.

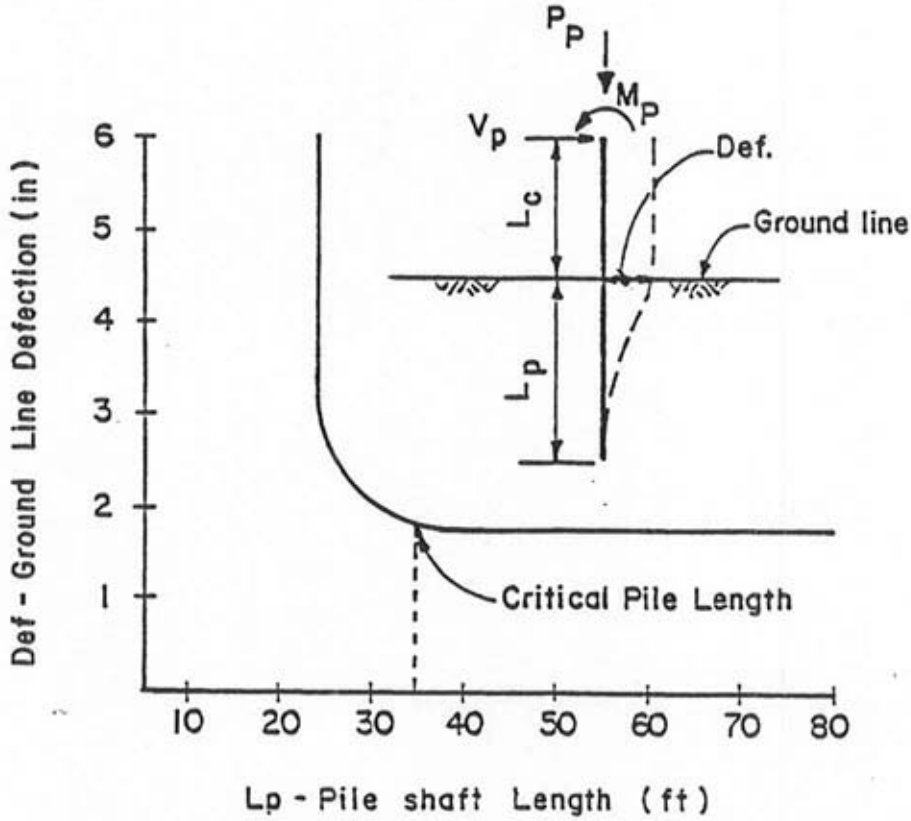
Shear Capacity of #5 bars = Vu (731 K) > Vp (580 K) OK

Note: The Pastic Hinge occured at 37 feet from the top of the column. The YIELD program calculated the plastic moment capacity of the shaft at 45 feet from the top of the column. In this example the decrease in plastic moment capacity due to a lower axial load at 37 feet as opposed to 45 feet is small and is ignored.

10. The pile shaft is considered stable when a substantial decrease in pile shaft length does not result in excessive deflection. The amount of reserve shaft length is an indication of the factor of safety against overturning. A stability ratio greater than 1.0 is mandatory. A good rule of thumb is; the greater the uncertainty of the soil, then the greater the stability ratio. A stability ratio below 1.5 is not recommended without reliable soil data.

P = 1122 K V = -580 K Mp = 9699 K-Ft

Column Length (Lc) = 23'



CRITICAL PILE LENGTH = 35 feet

STABILITY RATIO = 60/35 = 1.7

Pile Shaft Length (Lp) vs. Deflection (Def)
Graph 1.

RIGOROUS METHOD

This procedure should be used at the following sites:

(1) Sites with large variations in soil stiffness with depth.
(2) Sites with soft intermediate layers.

1. Obtain detailed soil information from Engineering Geology at Translab.

   SOIL DATA:

   Sand Above The Water Table

Layer	Class	Unit Wt (Kcf)	Thickness (Ft)	Friction Angle (Phi) (Degrees)
1	Loose	.13	10	28
2	Dense	.14	50	40

2. Apply approximate service level loads to the top of the column using the program PILE. Apply the shear and the moment as separate load cases to isolate them and their results. Note both the deflections and the rotations at the top of the column.

   PILE INPUT/OUTPUT:

LOAD NO	APPLIED SHEAR V (k)	APPLIED MOMENT M (k-ft)	DEFLECTIONS (in)	ROTATIONS (rad)
1	100		1.5353	0.00439
2		500	0.2635	0.00102

3. Solve for the equivalent length using the following equations. These four equations should result in approximately equal lengths. Average the results to determine the equivalent length.

$$L(Dv) = \left|\frac{3DvEI}{V}\right|^{1/3} \qquad L(Rv) = \left|\frac{2RvEI}{V}\right|^{1/2}$$

$$L(Dm) = \left|\frac{2DmEI}{M}\right|^{1/2} \qquad L(Rm) = \left|\frac{RmEI}{M}\right|$$

Dv = Top of column deflection due to applied shear (V).
Dm = Top of column deflection due to applied moment (M).
Rv = Top of column rotation due to applied shear (V).
Rm = Top of column rotation due to applied moment (M).

$$L(Dv) = \left|\frac{3*(1.5353/12)*468000*44.9}{100}\right|^{1/3} = 43.2 \text{ ft}$$

$$L(Rv) = \left|\frac{2*(0.00439)*468000*44.9}{100}\right|^{1/2} = 43.0 \text{ ft}$$

$$L(Dm) = \left|\frac{2*(0.2635/12)*468000*44.9}{500}\right|^{1/2} = 43.0 \text{ ft}$$

$$L(Rm) = \left|\frac{(0.00102)*468000*44.9}{500}\right| = 42.9 \text{ ft}$$

Le = (43.2 + 43.0 + 43.0 + 42.9) / 4 = 43.0 Ft

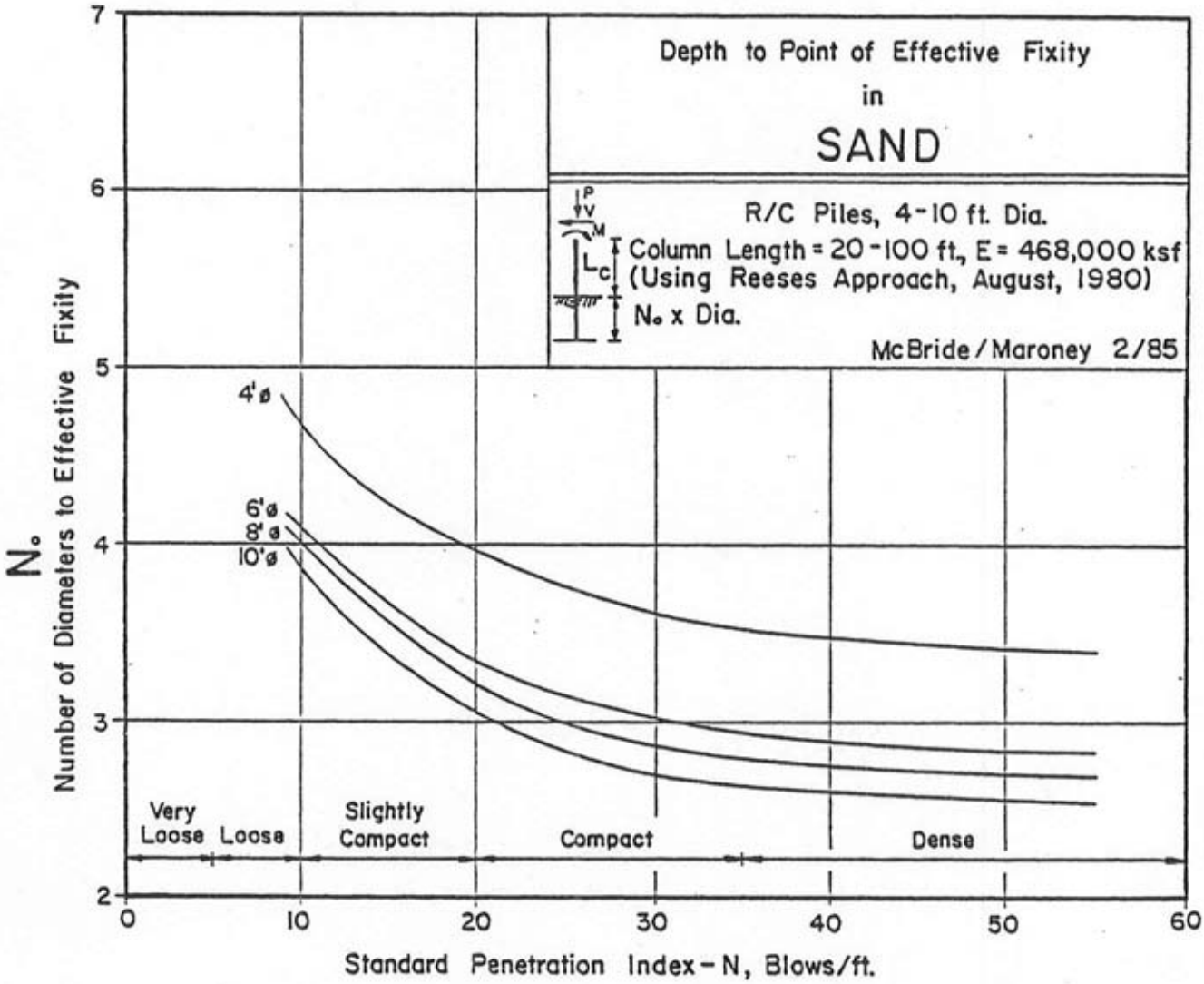
Note: 'Simplified' procedure gave an Le = 45.0 Ft.

Two observations should be noted with this example.

(1) Equivalent column lengths are used to design the superstructure and substructure. It is conservative to assume a longer equivalent column length for the design of the superstructure. However, this will produce unconservative top of column loads.

(2) A more accurate equivalent column length is produced with the additional effort displayed above, but for normal conditions the additional accuracy is not worth the required additional time and effort.

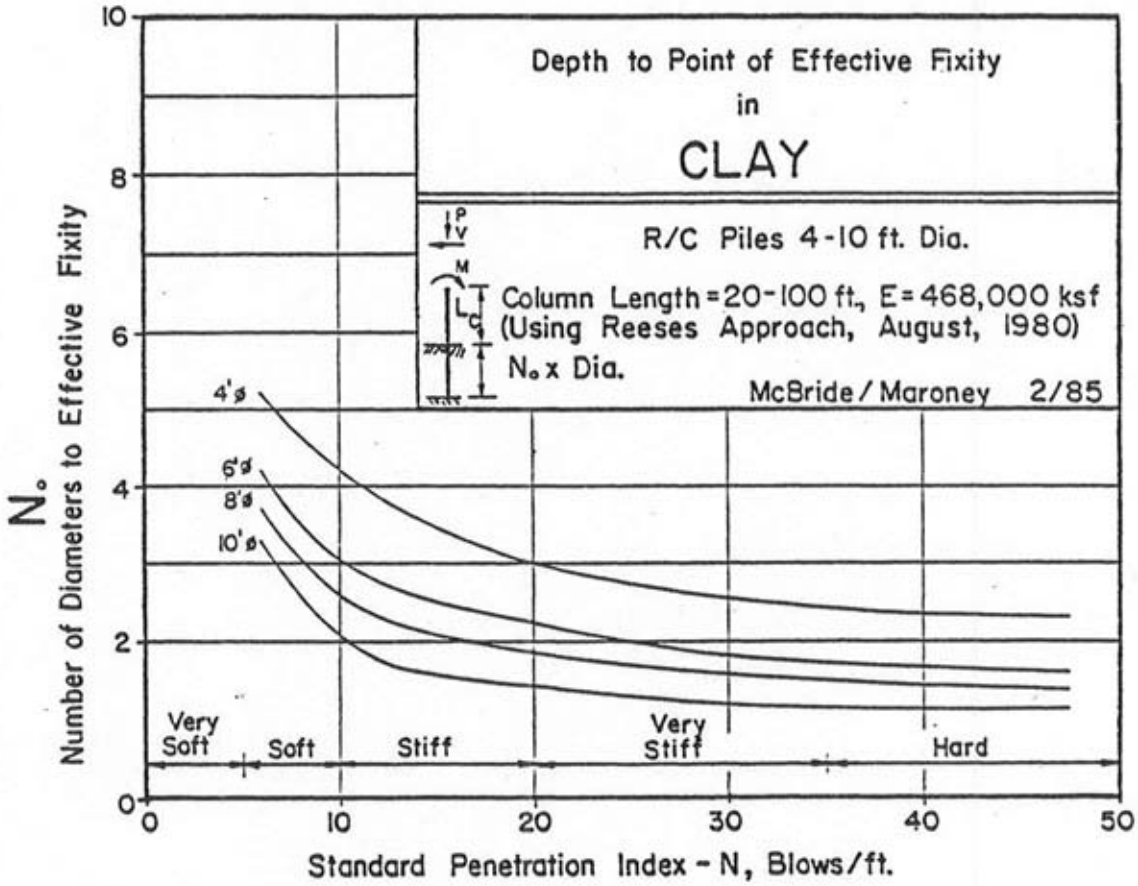
With the equivalent column modeling technique the bridge superstructure design, substructure design and the detailed geotechnical report may be completed simultaneously. Since the pile shaft design is dependent on the detailed soil information, the initial assumptions should be compared to the soil information included in the final geotechnical report.



0-28	28-30	30-36	36-41	Approximate ø in degrees

Depth to Point of Effective Fixity in Sand

Figure 1.



0-.5	.5-1	1-2	2-4	4-6 Shear Strength, ksf

Depth to Point of Effective Fixity in Clay

Figure 2.