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DESIGN CRITERIA

Cast-in-place concrete pipe shall be used only if it is shown on approved plans, conforming with the following design criteria:

1. Prior to considering CIPP, a geotechnical investigation report shall be prepared and transmitted to the City at the time the drawings are initially submitted for review. The report shall be prepared by a registered civil engineer and shall contain, but not necessarily be limited to, the following information:

   a. Trench wall stability.

   b. Existence of groundwater.

   c. Existence of expansive soils, fills and rock.

   d. Acidity and sulfate content.

   e. Recommendation regarding the feasibility of constructing cast-in-place concrete pipe.

   CIPP shall not be installed under the following conditions.

   a. Soils with acidity pH of 6.0 or less.

   b. Loose sandy and cohesionless soil.

   c. Shallow location (less than 4-foot of cover) in expensive soil where the volume change would crack pipe. Some special treatment may be needed in expansive soil, depending on moisture content, Backfilling with expansive soil is not permitted.

   d. In fills or in rock.

   e. In areas where the groundwater is above the bottom of the pipe.

2. Earth cover between top of pipe and ground surface shall be at least 3 feet, measured from top of pipe,

3. For determining the maximum earth cover, use:

   a. Table “A”; when installation is in trench condition in an easement.

b. The Structural Calculation Form included in this guide; for installation within right-of-way for negative projection conditions and when the maximum cover in Table "A" is exceeded.

4. Pipes with cover of 15 feet or more shall be oversized by 12 inches.

5. Angular change in pipe alignment is not permitted. The following formula shall be used to determine minimum radii:

$$R = D/2$$

Where R = radius of curvature in feet,
D = nominal pipe size in inches.

6. Minimum pipe slope shall be 0.4 percent,

7. Concrete shall be Class 560-C-3500 (minimum). The modulus of rupture shall be at least 560 psi.

* 660 for different types of cement as indicated in Table "B"
** B may be used for pipes 48" or greater in size.

8. Fly ash may be substituted for cement, up to a maximum of 15% by weight for all concrete, Fly ash shall be in accordance with the standards of ASTM Designation C 618. When fly ash is used, water reducing agents meeting ASTM C 494 is permitted in amounts recommended by the supplier and approved by the City Engineer.

No other admixture shall be used in any cast-in-place concrete without written permission from the City Engineer.

9. The consistency of the concrete shall be such as to allow it to be worked in place without segregation. The concrete from the cast-in-place concrete A pipe shall have a slump of 2±1 inches.

10. Cast-in-place concrete pipe may be used only if the HGL is less than 5 feet above pipe's spring line, including the effects of water jumps.

11. An n-Value of 0.014 shall be used in Manning's Formula.

12. Up to 20 FPS velocity is permitted for normal design, 2-inch, thickened invert shall be specified on plans for velocities of over 20 FPS. No greater than 30 FPS velocity is permitted in cast-in-place pipes, Invert thickening shall be accomplished by overexcavating the trench 2 inches in depth and "shimming up" the pipe machine mandrel 2 inches higher.

GUIDELINES FOR STRUCTURAL ANALYSIS

a. After classifying the conduit installation condition (trench/negative projecting), enter the required data and perform calculations for Steps No. 1, 2 and 3, Then determine the Total Load per linear foot of conduit.

b. Use the Total Load in the moment and thrust equations in Steps 4 and 5 to detemine their respective values for use in Step No, 6, a condensed equation for determining the extreme fiber stress.

c. Step No. 7, for 3500 psi concrete establishes the Safety Factor based on extreme fiber stress for the concrete design to be used. A minimum Safety Factor of 2 to 1 must be achieved.

d. Where results show a Safety Factor of less than 2:1, the designer should consider the following:

   1. Increasing the thickness of the soffit and invert (t).

   2. Increasing the concrete compressive strength (f_cl).

TABLE A

MAXIMUM HEIGHT OF COVER OVER PIPE

Diameter (in)	Max Cover (ft)
24	50
27	50
30	50
33	50
36	45
42	40
48	35
54	30
60	25
66	20
75	16
78	13
84	10
96	8

TABLE B

GUIDE FOR SULFATE RESISTING CONCRETE PIPE[2]

Water-Soluble Sulfate in Soil Sample[1] (Percent)	Sulfate in Water Sample[2] (Parts per Million)	Type of Cement	Cement Content
0-0.200	0-2000	II	6 Sacks
0.20-1.50	2000-15000	V II	6 Sacks 7 Sacks
Over 1.50	Over 15000	V	7 Sacks

Notes: 1. Reported as SO_4.
2. Recommended measures for type and amount of cement based on analysis of sulfate content in soil and water.

TABLE C

THRUST AND MOMENT COEFFICIENTS

LOADING	HORIZONTAL THRUST AT INVERT	MOMENT AT INVERT
1. Vertical earth load Uniform distributed load top and bottom, $\phi = 90°$	0	$+0.250wR^2 = +0.125PR$
2. Horizontal earth pressure Uniform side load, $\phi = 65°$	+0.994wR=+0.662H.L.	$-0.224wR^2 = -0.158H.L.R$
3. Weight of pipe	+0.500wR=+0.080Wp	$+1.50wR^2 = +0.239RWp$
4. Reaction due to weight of pipe Uniform load on bottom, $\phi = 90°$	-0.106wR=-0.053Wp	$-0.337wR^2 = +0.169RWp$
5. Net moment and thrust due to weight of pipe (3 + 4)	+0.027Wp	+0.070RWp
6. Weight of water	$-0.125wR^2 = -0.398Ww$	$+0.750wR^3 = +0.239RWw$
7. Reaction due to weight of water Uniform load on bottom, $\phi = 90°$	-0.106wR=-0.053Ww	$-0.337wR^2 = -0.169RWw$
8. Net moment and thrust due to weight of water	-0.451Ww	+0.070RWw
9. Hydrostatic pressure head	-62.5Hr	0

R = radius to center of shell
r = radius to inside of shell
w = unit loading
P = earth load + live load in lb./ft

H.L. = horizontal load in lb./ft = 0.333P
H = Pressure head above top of pope
Ww = total weight of water in lb./ft
Wp = total weight of pipe in lb./ft

Fiber stress at invert

Maximum fiber stress at the invert is computed from the formula

$$f = \frac{6M}{t^2} - \frac{T}{12t}$$

Where
f = stress in extreme fiber in lb. per sq. inch
M = moment at invert in ft. lb. per foot of pipe
T = thrust (direct stress) at invert in lb. per foot of pipe
T = thickenss of pipe shell in inches

TABLE D

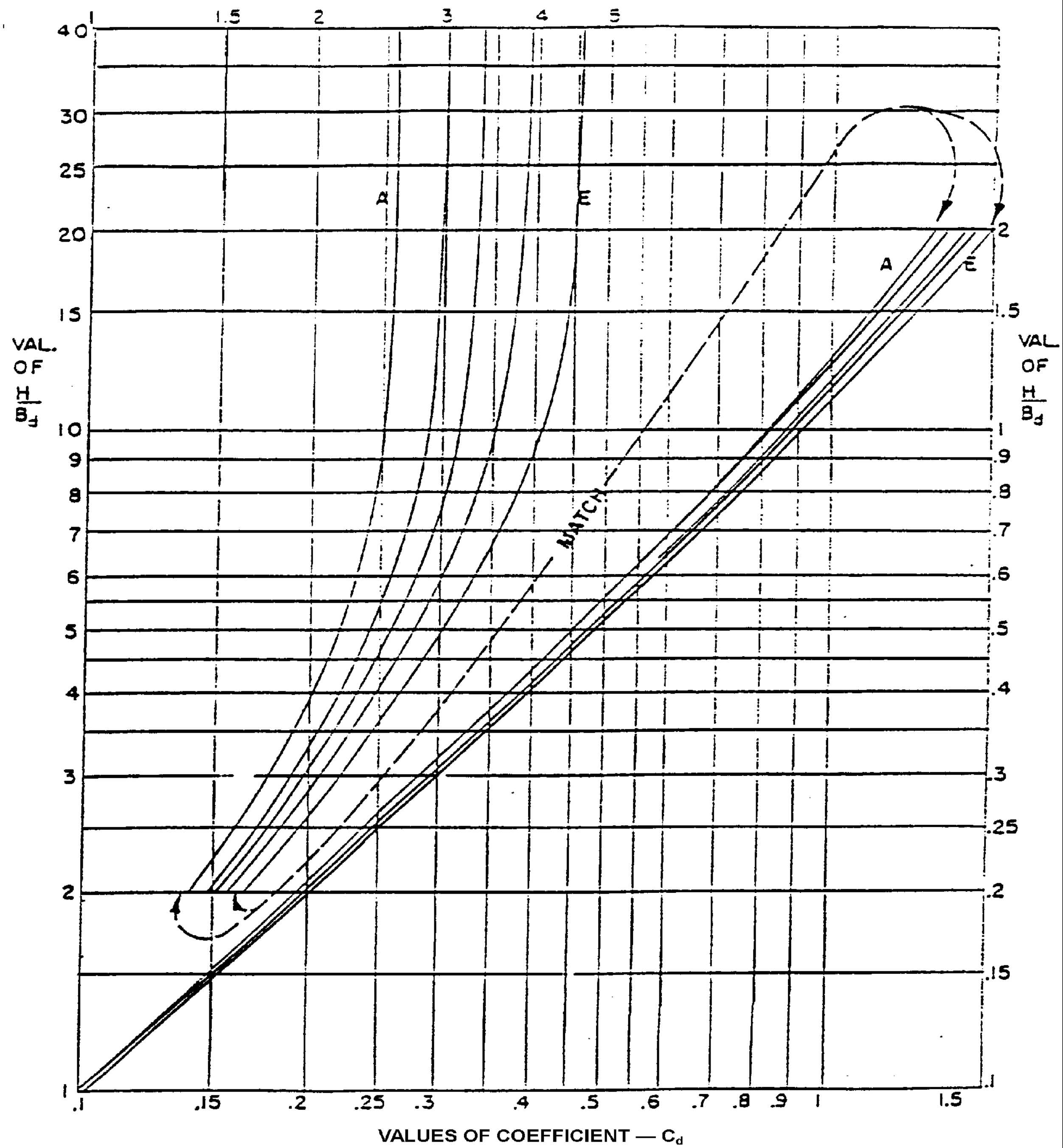
M = MOMENT CALCULATION
(At Invert)

Pipe Size I.D.	(1) Moment due to Vertical & Side Loads (in ft. lb.)	(2) Moment Due to Wt. Of Pipe & Water (in ft. lb.)
24	$+0.037 \times (W_e + W_1)$	+39
30	$+0.046 \times (W_e + W_1)$	+64
36	$+0.054 \times (W_e + W_1)$	+109
42	$+0.063 \times (W_e + W_1)$	+170
48	$+0.073 \times (W_e + W_1)$	+268
54	$+0.082 \times (W_e + W_1)$	+374
60	$+0.091 \times (W_e + W_1)$	+505
66	$+0.100 \times (W_e + W_1)$	+646
72	$+0.112 \times (W_e + W_1)$	+858
84	$+0.129 \times (W_e + W_1)$	+1119
96	$+0.145 \times (W_e + W_1)$	+2036

$M = (1)^{*} + (2)$

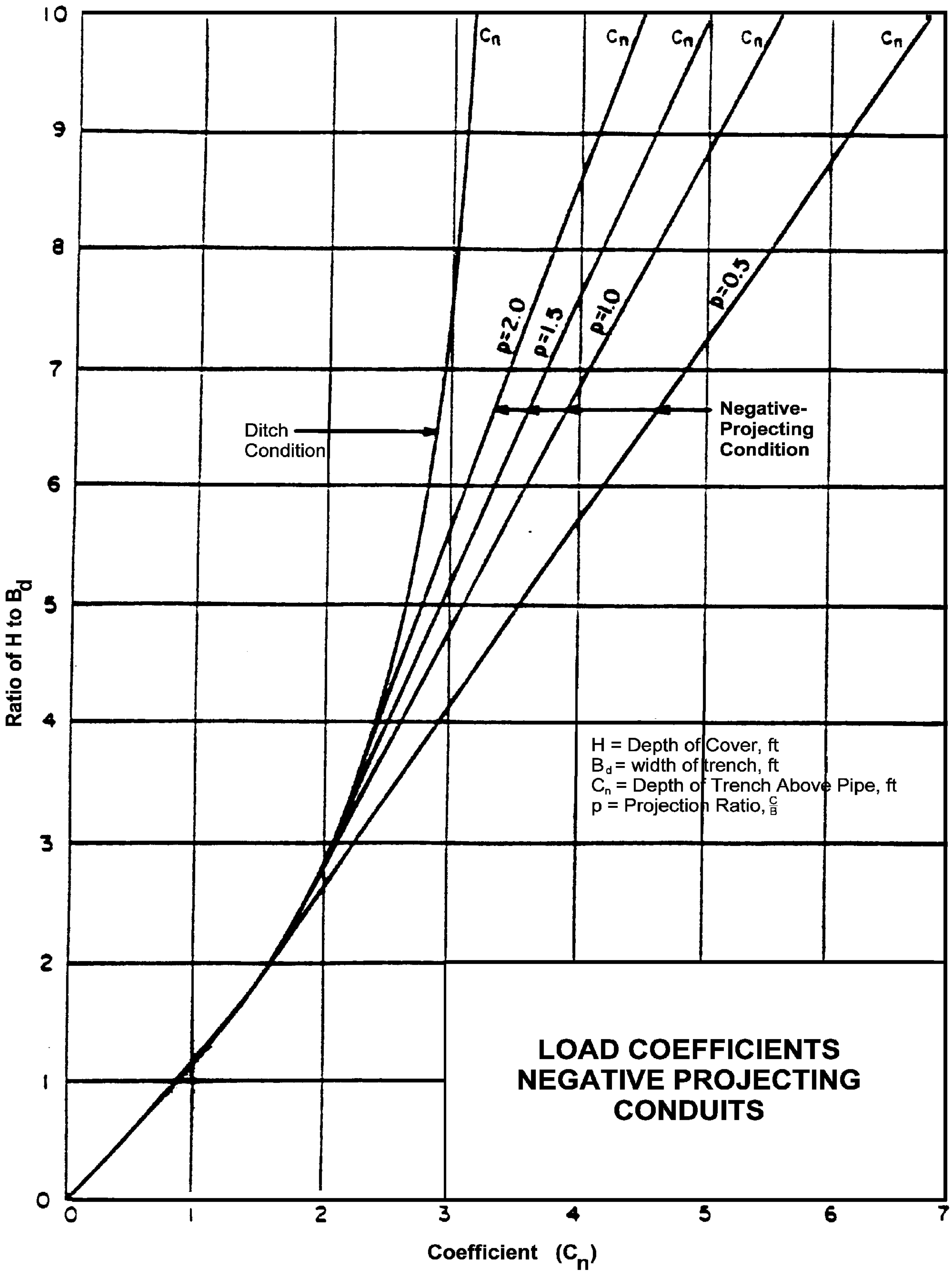
* Multiply (1) by 2.37 for S.D. located within right-of-way

Figure 1



A = C_d for K_u and $K_{u'}$ = .1924 for Granular Materials Without Cohesion
B = C_d for K_u and $K_{u'}$ = .165 Maximum for Sand and Gravel
C = C_d for K_u and $K_{u'}$ = .150 Maximum for Saturated Top Soil
D = C_d for K_u and $K_{u'}$ = .130 Ordinary Maximum for Clay
E = C_d for K_u and $K_{u'}$ = .110 Maximum for Saturated Clay

LOAD COEFFICIENTS FOR TRENCH CONDUITS



Ratio of H to Bd
Coefficient (Cn)
0
1
2
3
4
5
6
7
8
9
10
Cn
p=2.0
p=1.5
p=1.0
p=0.5
Ditch Condition
Negative-Projecting Condition
H = Depth of Cover, ft
Bd = width of trench, ft
Cn = Depth of Trench Above Pipe, ft
p = Projection Ratio, C/B
LOAD COEFFICIENTS
NEGATIVE PROJECTING
CONDUITS

TABLE E

T = THRUST CALCULATION
(At Invert)

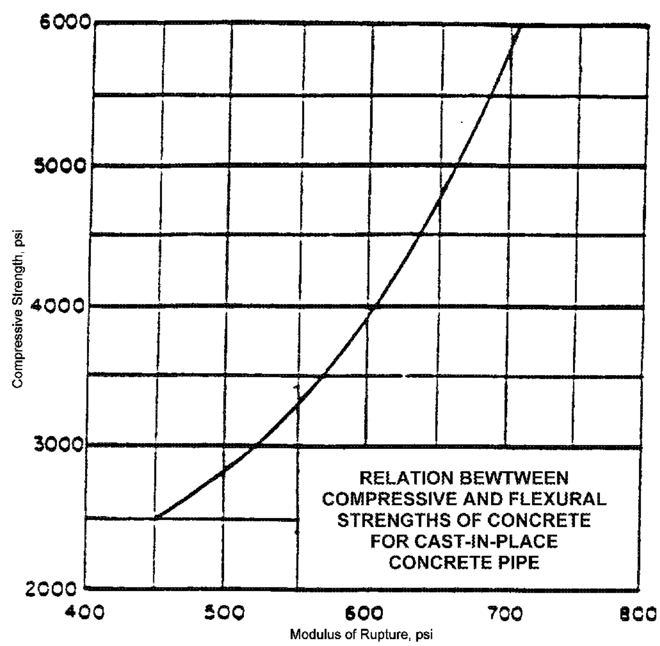
	(1)	(2)
Pipe Size I.D.	Thrust due to Vertical & Side Loads (in lb.)	Thrust Due to Wt. Of Pipe & Water (in lb.)
24	$+0.384 \times (W_e + W_1)$	-88
30	$+0.384 \times (W_e + W_1)$	-128
36	$+0.384 \times (W_e + W_1)$	-185
42	$+0.384 \times (W_e + W_1)$	-254
48	$+0.384 \times (W_e + W_1)$	-329
54	$+0.384 \times (W_e + W_1)$	-417
60	$+0.384 \times (W_e + W_1)$	-486
66	$+0.384 \times (W_e + W_1)$	-624
72	$+0.384 \times (W_e + W_1)$	-741
84	$+0.384 \times (W_e + W_1)$	-1008
96	$+0.384 \times (W_e + W_1)$	-1325

$T = (1)^{*} + (2)$

* Divide (1) by 2 for S.D. located within right-of-way

TABLE F

D	Min B_d	Min t	Max H	LIVE LOAD, Lbs/lin. Ft. Depth of cover, ft.							
(in)	(ft)	(in)	(ft)	3	4	5	6	7	8	9	10
24	2.62	3	50	1664	1048	681	498	380	312	267	236
27	2.87	3	50	1822	1148	746	545	416	342	293	258
30	3.12	3	50	1981	1248	811	593	452	371	318	281
33	3.42	3.5	50	2172	1368	889	650	496	407	349	308
36	3.71	3.5	45	2356	1484	965	705	538	441	378	334
42	4.29	4	40	2724	1716	1115	815	622	511	438	386
48	5.08	5	35	3226	2032	1321	965	737	605	518	457
54	5.75	5.5	30	3651	2300	1495	1093	834	684	587	518
60	6.33	6	25	4020	2532	1646	1203	918	753	646	570
66	6.83	6.5	20	4337	2732	1776	1298	990	813	691	615
72	7.42	7	16	4712	2968	1929	1410	1076	883	757	668
78	8	7.5	13	5080	3200	2080	1520	1160	952	816	720
84	8.58	8	10	5448	3432	2231	1630	1244	1021	875	772
96	9.75	9	8	6191	3900	2535	1853	1414	1160	995	878



CALCULATION SHEET

❑ Trench Condition

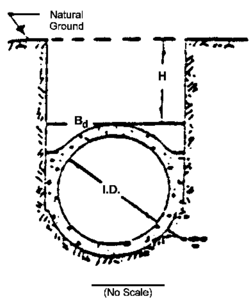
❑ Negative Projecting Condition

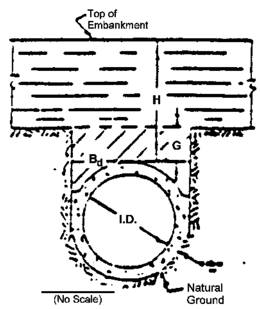
Date: ____________

By: ____________

Ckd: ____________

Data:





Pipe Size ________________ in.

H (cover) ________________ ft.

t (thickness) ________________ in.

w (soil wt) ________________ # / cu ft.

G (projection) ________________ ft.

Bd (tr. Weight)________________ft (Table F).

Cd or Cn ________________(Fig 1 or 2).

H/Bd (Ratio) ________________

G/Bd (Proj Ratio) ________________

Earth and Live Load Computation

(1) Earth Load, We = C·w·Bd (Marstan) = ______________________________ lb/l.f.

(2) Live Load, Wl = (Table F) = ______________________________ lb/l.f.

(3) Total Load, We + Wl = (1) + (2) = ______________________________ lb/l.f.

Moment, Thrust and Stress (Extreme Fiber) Computation

(4) Moment, M (Equation from Table D) = ______________________________ ft-lb

(5) Thrust, T (Equation from Table E) = ______________________________ lb

(6) Stress, $f = \frac{6M}{t^2} - \frac{T}{12t}$ = ______________________________ psi.

Safety Factor (Minimum = 2 to 1)

(7) For 3500 PSI Concrete = 560 psi**/(6) = ______________ to ______________

(8) For ____ PSI Concrete = ___ psi /(6) = ______________ to ______________

Notes: * Neglect live load when H ≥IO’

** Modulus of rupture form fig. 3

Denote the values of t and or f_c on the storm drain plans IF other than minimum is used

CAST-IN-PLACE CONCRETE PIPE GENERAL NOTES

1 . Construction materials and method shall conform to the latest edition of the “Standard Specification for Public Works Construction”, the City's Special Provisions and these plans.

2. Cast-in-place concrete pipe shall not be used unless it is shown as an alternate on the drawings approved by the City Engineer.

3. Cast-in-place pipe shall not be placed except in the presence of a City Inspector.

4. Trenching and backfilling shall be performed only in the presence of the soils engineer.

5. The minimum cover over the pipe shall be 3 feet, measured from top of pipe.

6. Cast-in-place pipe may be constructed only in ground capable or unsupported from the bottom of the trench to the top of the pipe without sloughing. The ground shall not contain trash, debris or bituminous materials. If rock is encountered, the rock shall be overexcavated to leave a 6-inch minimum compacted soils cushion between the rock and the bottom of the pipe, When expansive clays are encountered, they shall be thoroughly moistened by ponding to completely expand the soils, and the moisture maintained until the concrete is placed. Backfiling with expansive soils is not permitted. Cast-in-place shall not be installed in areas where groundwater is above the bottom of the pipe.

7. Backfilling of the pipe shall not bt done until the concrete has developed 80 percent of its design strength. No traffic (including construction equipment) shall be permitted on top of the pipe until the concrete has attained its design strength,

8. Water densification methods for backfilling the pipe will not be permitted. Mechanical compaction will be required. An 8-inch lift of loose backfill “shading” over the pipe will be permitted 24 hours after initial placement, provided the forms are still in place at the time of shading.

9. When engineer calls for thickening the soffit and/or the invert of the pipe, this shall be accomplished by the following manner:

   The soffit shall be increased by placing a blanket of concrete of the extra required thickness immediately following the pipe machine placement and beneath the polyethylene sheet. The invert thickening will be obtained by overexcavating the trench and “shimming-up” the pipe machine mandrel by the extra required thickness.

10. Concrete shall be Class 560-C-3500 (minimum) or as specified otherwise on the plans. Cement shall be Type II or V as specified by soils tests.
11. The consistency of the concrete shall be such as to allow it to be worked into place without segregation. The concrete for the cast-in-place concrete pipe shall have a slump of 2±l inches.

12. Fly ash, meeting ASTM C 618, may be used to substitute for cement (up to 15 percent of cement by weight). When fly ash is used, water reducing agents meeting ASTM Designation C 494 will be permitted in amounts recommended by the supplier and approved by the City Engineer.

    No other admixture shall be used in any class of concrete without written permission from the City Engineer.

13. The City Engineer may require drill holes at locations at intervals he may select to determine wall thickness of the pipe, and may require coring where needed to determine the concrete thickness and compressive strength,

14. 1-foot concrete backfill shall be placed over pipe when junction structure No. 2 (R.C.F.C.D.) is used.

15. At the end of all pours and the end of each working day, the Contractor shall install No. 4 dowels, 24 inches long, 12-inch centers around circumference of cast-in-place pipe.

REFERENCES

1. ACI Standard 346-70: Specifications for Cast-in-Place Nonreinforced Concrete Pipe, American Concrete Institute, Detroit.

2. Cast-in-Place Concrete Pipe Design and Construction Standards for Subdivision, R.C.F.C.D., 1984.

3. Design Manual - 1971 Edition by No-Joint Nonreinforced Concrete Pipe Company.

4. Design Manual: Channel Hydraulics and Structures, O.C.F.C.D., July 1972.

5. Foundation Engineering Handbook, Hsai-Yang Fang Phd., Van Nostrant Reinhold Company, New York 1975.

6. Highway Design Manual, 4th Edition, Caltrans.

7. Lynch Manual: Cast-in-Place Concrete Pipe Process.