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Section I

Design of Reinforced Concrete Pipe

I-1 Standard Installations

The methods to be used for design of reinforced concrete pipe are the Indirect Design and Direct Design methods. The D-Load Tables that appear on 1982 Ver. Manual pages S-38 through S-64 are based on conservative principles using Marston-Spangler formulas developed in the 1930s. These tables may be used for reference and design should be based on the methods that appear in this update.

Indirect design method, using D-Loads, is a widely used empirical method for selecting and specifying pipes. The specified D-Load for a pipe is the minimum test load where cracks no more than 0.01 inch in width are generated in a three-edge bearing test. D-Load for pipes is calculated through employing an empirical procedure that relates the three-edge bearing test loads to the actual required performance of the pipe in the installed field condition. The variables in the D-Load procedure are: total vertical loads acting on the pipe, installation conditions, pipe diameter, and depth of cover. Pipes with 0.01 inch cracks do not automatically indicate the structural integrity of the pipe is compromised. However, it is prudent to verify the performance of these pipes.

Direct design method follows the principles of strength of material and reinforced concrete design. The designer needs to determine all the internal forces and stresses and perform the design in accordance to the design formulas prescribe in the subsequence Subsections. Due to the complexity of the initial structure analysis and the cumbersome design procedure that follows, Direct design methods should only be considered when the pipe is greater than 72 inches and the required D-Load is greater than 2000.

In general, embankment condition with Standard Installation Type 3 should be assumed for the design of pipes. It is preferred that pipes less than 72 inches in diameter be designed using Indirect method. For larger diameter pipe, Direct design might be more appropriate.

The Indirect and Direct design methods prescribed within this Section, are based on Section 16, Soil-Reinforced Concrete Structure Interaction Systems, of Caltrans Bridge Design Specifications, April 2000 (1996 AASHTO with Interims and Revisions by Caltrans).

Standard Pipe Installations are presented in Los Angeles County Department of Public Works, Standard Plan 3080-3*;* these figures define soil areas and critical dimensions. Soil types, minimum compaction requirements, and minimum bedding thicknesses for Standard Pipe Installation.

I-2 Design

Design shall conform to applicable sections of this manual except as provided otherwise in this Section. For design loads, see Subsection I-3; for Standard Installations, see Subsection I-1. Live loads W_L, Fluid weight W_f shall be included as part of the total load W_T, and shall be distributed through the earth cover as specified in Subsection I-3.3. Other methods for determining total load and pressure distribution may be used, if they are based on successful design practices or tests that reflect the appropriate design conditions.

I-3 Loads

I-3.1 Earth Loads and Pressure Distribution

I-3.1.1 Earth Loads and Pressure Distribution

The effects of soil-structure interaction shall be taken into account and shall be based on the design earth cover, side fill compaction, and bedding characteristics of the pipe soil installations.

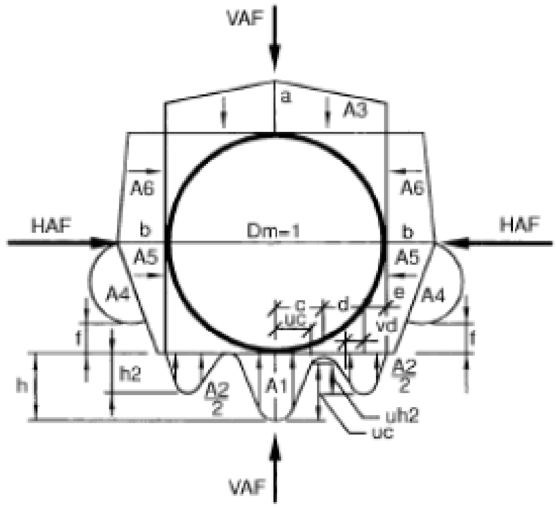

Figure I-1

Table I-1

Installation Type	VAF	HAF	Al	A2	A3	A4	A5	A6	a	b	c	e	f	u	v
1	1.35	0.45	0.62	0.73	1.35	0.19	0.08	0.18	1.40	0.40	0.18	0.08	0.05	0.80	0.80
2	1.40	0.40	0.85	0.55	1.40	0.15	0.08	0.17	1.45	0.40	0.19	0.10	0.05	0.82	0.70
3	1.40	0.37	1.05	0.35	1.40	0.10	0.10	0.17	1.45	0.36	0.20	0.12	0.05	0.85	0.60

Notes:

1. VAF and HAF are vertical and horizontal arching factors. These coefficients represent nondimensional total vertical and horizontal loads on the pipe, respectively. The actual total vertical and horizontal loads are (VAF) X (PL) and (HAF) X (PL), respectively, where PL is the prism load.
2. Coefficients Al through A6 represent the integration of nondimensional vertical and horizontal components of soil pressure under the indicated portions of the component pressure diagrams (i.e., the area under the component pressure diagrams). The pressures are assumed to vary either parabolically or linearly, as shown with the nondimensional magnitudes at governing points represented by h_1. h_2, uh_1, vh_1, a, and b. Nondimensional horizontal and vertical dimensions of component pressure regions are defined by c, d, e, uc, vd, and f coefficients.
3. d is calculated as (0.5 c-e)
   h_1 is calculated as (1.5Al)/(c) (I + u)
   h_2 is calculated as (1.5A2)/[(d) (1 + v) + (2e)].

I-3.1.2 Standard Installations

For the Standard Installations given in Subsection I-2, the earth load, W_E, may be determined by multiplying the prism load (weight of the column of earth) over the pipes outside diameter by the soil-structure interaction factor, Fe, for the specified installation type.

W_E= F_e w B_c H.

w= unit weight of soil, lbs per cubic foot.

B_c= out-to-out horizontal span of pipe, or box, foot.

H = height of fill above top of pipe, foot.

Standard Installations for both embankments and trenches shall be designed for positive projection, embankment loading conditions where Fe =VAF given, in Figure I-1 and Table I-1, for each type of Standard Installation.

For Standard Installations, the earth pressure distribution shall be the Heger pressure distribution shown in Figure I-1 for each type of Standard Installation.

The unit weight of soil used to calculate earth load shall be the estimated unit weight for the soils specified for the pipe-soil installation and shall not be less than 110 lbs/cu. ft. (120 lbs/ cu. ft. for pipe designed by the indirect method).

I-3.1.3 Nonstandard Installations

When nonstandard installations are used, the earth load on the structure shall be the prism load (PL). The unit weight of soil shall be 140 lbs/cu. ft. Pressure distribution shall be determined by an appropriate soil-structure interaction analysis. See Figure I-5 for suggested pressure distributions.

I-3.2 Pipe Fluid Weight

The weight of fluid, W_f in the pipe shall be considered in design based on a fluid weight of 62.4 lbs/ft^3, unless otherwise specified. For Standard Installations, the fluid weight shall be supported by vertical earth pressure that is assumed to have the same distribution over the lower part of the pipe as given in Figure I-1 for earth load.

I-3.3 Live loads

I-3.3.1 Highway Loads

Pipe conduits shall be designed for one HS20-44 truck per lane except where passing beneath railroad tracks. The wheel loads shall be distributed through the fill to the top of the pipe as follows:

Transverse (with reference to truck) spread of wheels = 1.67+1.75F

Longitudinal (with reference to truck) spread of wheels = 0.83+1.75F

Where F = depth of fill over top of conduit in feet.

1. Truck loads on pipe conduits for covers of 8 feet and less are as follows:

TABLE OF VERTICAL LIVE LOADS

Cover "F" Feet	Wheel Load Kips	L.L. Pressure PSF
1	16.0	2357 *
2	32.0	967
3	32.0	530
4	32.0	322
5	48.0	245
6	48.0	193
7	48.0	156
8	48.0	129
9	48.0	108
10	48.0	92

These values include the effect of overlapping wheel loads and also the effect of impact: 30% for F = 1', 20% for F = 2', and 10% for F = 3'.

* Wheel loads do not overlap.

2. For covers exceeding 8 feet, the effect of truck live loads shall be assumed to be negligible.

I-3.3.2 Railroad Loading

Conduits passing under railroads shall be designed in accordance with the requirements of the particular railroad. In general, the minimum design loads are as follows:

Railroad	Cooper Loading
Burlington and Santa Fe	E 80
Southern Pacific	E 72
Union Pacific	E 72

Cooper E 65 loading may be used for industrial spur and connecting tracks under the jurisdiction of Union Pacific Railroad Company.

Values from the chart "Vertical Railroad Loads on Top Slab of Box Conduit" (1982 Ver. Manual page S-10) may be used in determining vertical railroad loads on pipe.

I-3.4 Other External Loads

Vertical loads due to existing or proposed structures, such as buildings, abutments, etc., shall be considered in the design.

I-4 Concrete Cover for Reinforcement

The minimum concrete cover for reinforcement in precast concrete pipe shall be 1 inch in pipe having a wall thickness of 2 1/2 inches or greater and 3/4 inch in pipe having a wall thickness of less than 2 1/2 inches.

Ordinarily, it is not necessary to call out steel clearances on D-Load pipe. However, where velocities are between 20 fps and 30 fps, the concrete cover on the inside face of the pipe must be increased 1/2 inch. Where velocities are in excess of 30 fps, the cover on the inside face of the pipe must be increased 1 inch. Velocities in excess of 40 fps shall not be used without prior District approval. If the pipe carries debris or abrasive materials, an additional 1/2 inch of concrete cover on the inside is required. If the pipe is subject to the action of seawater or harmful groundwater, an additional 1/2 inch of cover on the inside or outside face is required. Pipes subject to harmful industrial wastes may require additional cover. These increases are accumulative. The amount of additional cover needed and the locations of the pipes affected shall be noted in the Special Provisions Section of the detailed specifications.

I-5 Minimum Cover

For unpaved areas and under flexible pavements, the minimum fill cover over reinforced concrete pipes shall be 2 feet. It is undesirable to install mainline reinforced concrete pipe where the earth cover or flexible pavement is less than 2 feet. If this is absolutely necessary, the project plans shall provide for concrete Distribution Slab. This applies to all pipe sizes.

I-6 Design Methods

The structural design requirements of installed precast reinforced concrete circular pipe for both standard and nonstandard installations may be determined by either the **Indirect** or **Direct Method**. Elliptical pipe in nonstandard installations may be designed by either the indirect or direct method. Elliptical pipe in standard installations and arch pipe regardless of installation type shall be designed by the indirect method.

I-6.1 Indirect Design Method Based on Pipe Strength and Load-Carrying Capacity

$$D_{0.01} = ß \left[\frac{W_E + W_F}{B_{fe}} + \frac{W_L}{B_{fLL}} \right] \frac{1.3}{S_i}$$

$D_{0.01}$ = D-load of the pipe (three-edge-bearing test load expressed in pounds per linear foot per foot of diameter) to produce a 0.01-inch crack.

1. For pipes designed to be under pressure flow condition, D-load as calculated above shall be modified by multiplying a hydraulic factor of 1.30.

2. For Type 1 installations, D-load as calculated above shall be modified by multiplying an installation factor of 1.10.

ß = Factor provided by the Technical Review Committee to ensure cracking will not occur on pipes.

D_{ult}= Ultimate D-load shall be the Ultimate D-load Factor times $D_{0.01}$, see Figure I-2.

W_E= earth load on the pipe as determined according to Subsection I-3.1.

W_F= fluid load in the pipe as determined according to Subsection I-3.2.

W_L= live load on the pipe as determined according to Subsection I-3.3.

B_{fe}= earth load bedding factor.

B_{fLL}= live load bedding factor.

S_i= internal diameter or horizontal span of the pipe in inches.

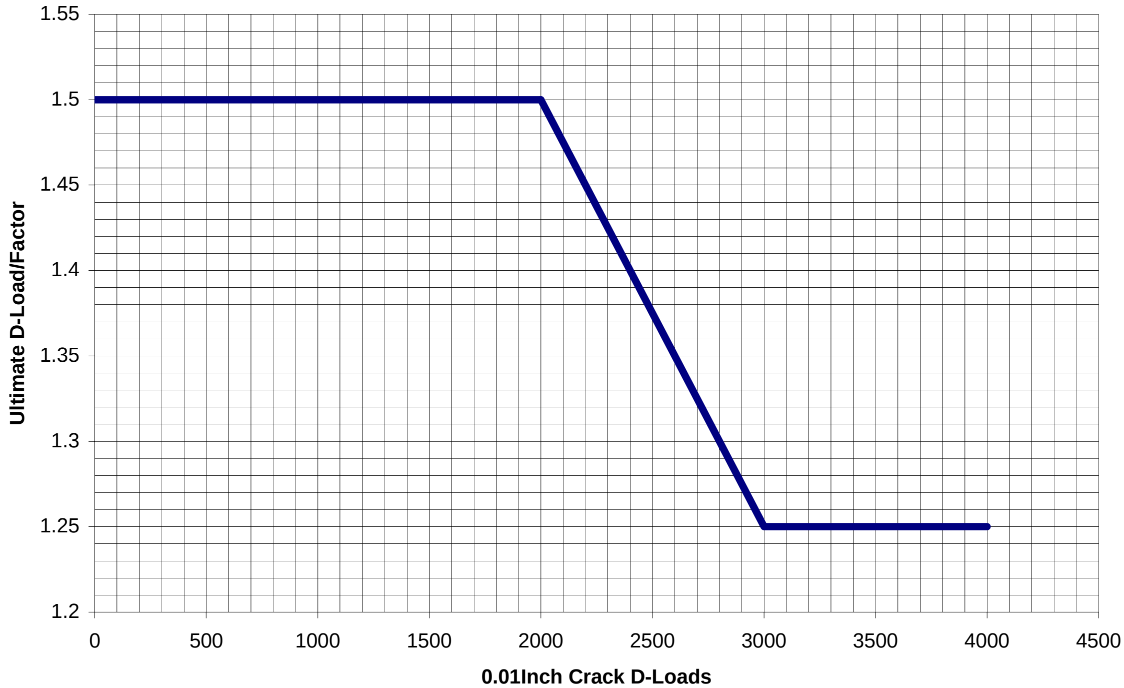

Figure I-2 Ultimate Pipe D-Loads Versus 0.01 Inch Crack D-Loads

D-Loads shall be specified on project drawings as follows:

(Values on Table I-5 have been rounded off to the values listed.)

36-inch diameter and under – to next highest 250 of calculated value.

39 - to 60-inch diameter – to next highest 100 of calculated value.

63 - to 108-inch diameter – to next highest 50 of calculated value.

The minimum D-Load specified shall be 800-D for pipes designed per the Indirect Design Method. For pipes with an inside diameter of 72 inches and larger, the D-Load from the three-edge-bearing test and its associated internal pipe stresses may not reflect the actual radial soil pressure experienced by the pipe in the installed condition. Therefore, for these large diameter pipes, Direct Design Method may be used in lieu of Indirect Design Method.

I-6.1.1 Bedding Factor

The bedding factor is the ratio of the supporting strength of buried pipe to the strength of the pipe determined in the three-edge-bearing test. The supporting strength of buried pipe depends on the type of Standard Installation. See Figures Standard Plan 3080-3 for circular pipe and Figures I-3 and I-4 for other arch and elliptical shapes.

1-6.1.1.1 Earth Load Bedding Factor for Circular Pipe

Table I-2 Bedding Factors B_{fe}, for Circular Pipe

Standard Installations			
Pipe Diameter,	Type 1	Type 2	Type 3
12	4.4	3.2	2.5
24	4.2	3.0	2.4
36	4.0	2.9	2.3
72	3.8	2.8	2.2
144	3.6	2.8	2.2

Note:

1. For pipe diameters other than listed, embankment condition bedding factors B_{fe} can be obtained by interpolation.

2. Bedding factors are based on soils being placed with minimum compaction specified for each Standard Installation.

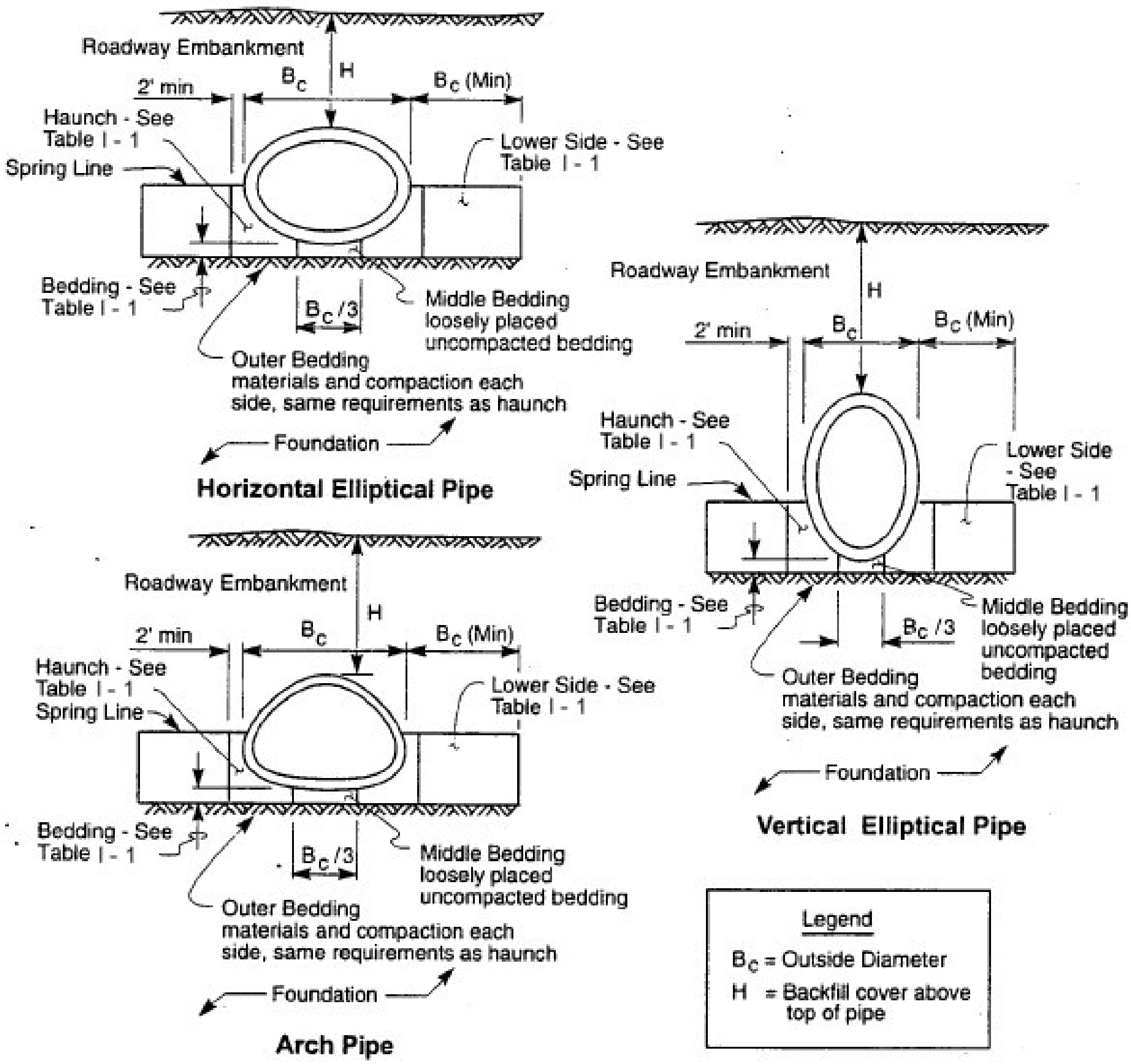

Figure I-3 Embankment Beddings, Miscellaneous Shapes

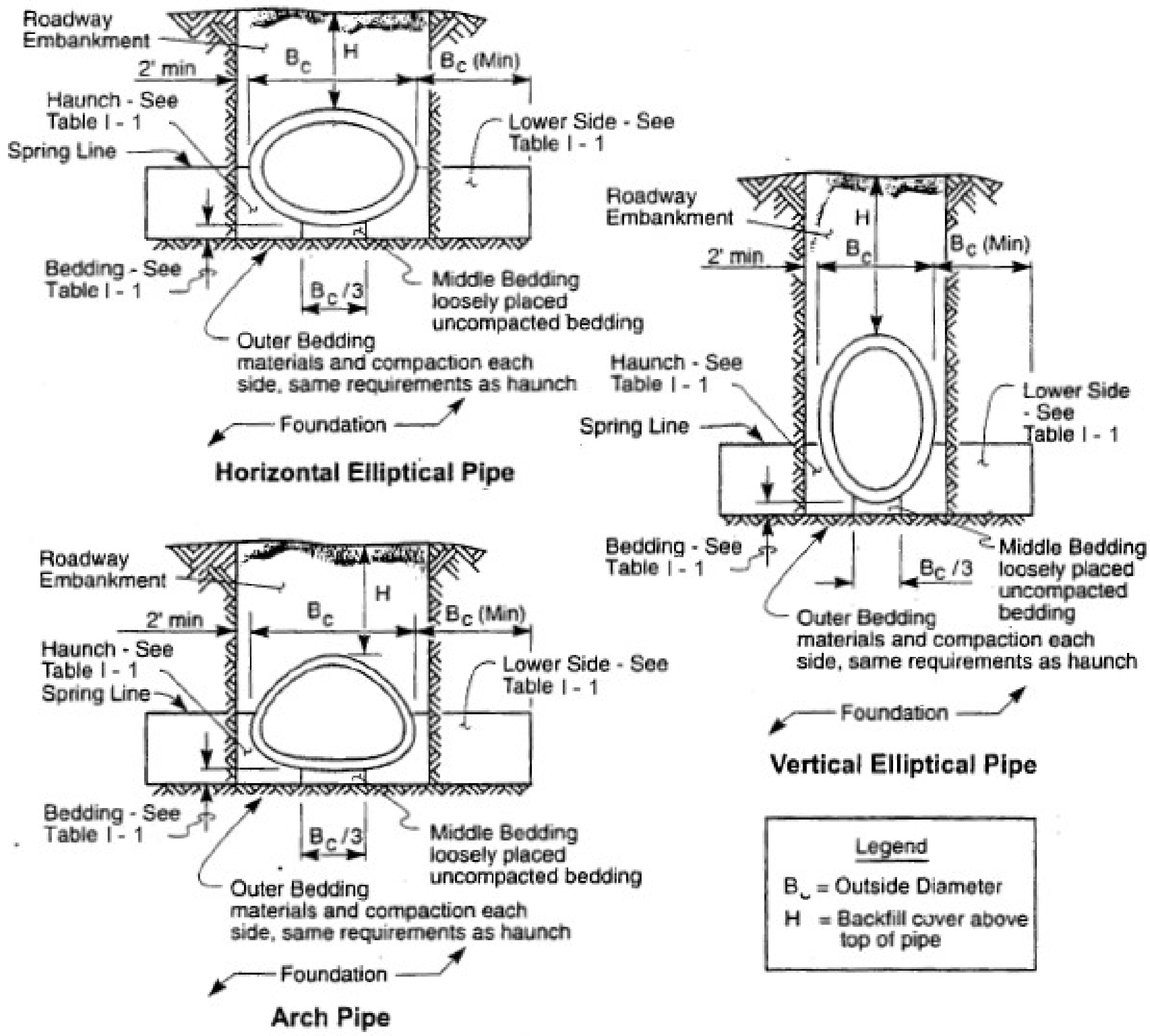

Figure I-4 Trench Beddings, Miscellaneous Shapes

I-6.1.1.2 Earth Load Bedding Factor for Arch and Elliptical Pipe

The bedding factor for installations of arch and elliptical pipe, Figures I-5 and I-6, is:

$$B_{fe} = \frac{C_A}{C_N - xq}$$

Values for C_A and C_N are listed in Table I-3.

C_A = a constant corresponding to the shape of the pipe;
C_N = a parameter which is a function of the distribution of the vertical load and vertical reaction;
x = a parameter which is a function of the area of the vertical projection of the pipe over which lateral pressure is effective;
q = ratio of the total lateral pressure to the total vertical fill load. Design values for C_A, C_N, and x are found in Table I-3. The value of q is determined by the following equations:
Arch and Horizontal Elliptical Pipe:

$$q = 0.23\frac{p}{F_e}\left(1 + 0.35p\frac{B_c}{H}\right)$$

Vertical Elliptical Pipe:

$$q = 0.48\frac{p}{F_e}\left(1 + 0.73p\frac{B_c}{H}\right)$$

p = projection ratio, ration of the vertical distance between the outside top of the pipe and the ground or bedding surface to the outside vertical height of the pipe.

Table I-3 Design Values of Parameter in Bedding Factor Equation

Pipe	Values of C_A	Type of Bedding	Values of C_N	Projection Ratio	Values of x
Horizontal		Type 2	0.630	0.9	0.421
Elliptical	1.337			0.7	0.369
And Arch		Type 3	0.763	0.5	0.268
				0.3	0.148
		Type 2	0.516	0.9	0.718
Vertical				0.7	0.639
Elliptical	1.021	Type 3	0.615	0.5	0.457
				0.3	0.238

I-6.1.1.3 Live Load Bedding Factor

The bedding factors for live load, W_L, for both Circular pipe and Arch and Elliptical pipe are given in Table I-4. If B_{fe} is less than B_{fLL}, use B_{fe} instead of B_{fLL} for the live load bedding factor.

Table I-4 Bedding Factors B_{fLL} for HS20 Live Loading

	Pipe Diameter, in.										
Fill Height, Ft	12	24	36	48	60	72	84	96	108	120	144
0.5	2.2	1.7	1.4	1.3	1.3	1.1	1.1	1.1	1.1	1.1	1.1
1.0	2.2	2.2	1.7	1.5	1.4	1.3	1.3	1.3	1.1	1.1	1.1
1.5	2.2	2.2	2.1	1.8	1.5	1.4	1.4	1.3	1.3	1.3	1.1
2.0	2.2	2.2	2.2	2.0	1.8	1.5	1.5	1.4	1.4	1.3	1.3
2.5	2.2	2.2	2.2	2.2	2.0	1.8	1.7	1.5	1.4	1.4	1.3
3.0	2.2	2.2	2.2	2.2	2.2	2.2	1.8	1.7	1.5	1.5	1.4
3.5	2.2	2.2	2.2	2.2	2.2	2.2	1.9	1.8	1.7	1.5	1.4
4.0	2.2	2.2	2.2	2.2	2.2	2.2	2.1	1.9	1.8	1.7	1.5
4.5	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.0	1.9	1.8	1.7
5.0	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.0	1.9	1.8
5.5	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.0	1.9
6.0	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.1	2.0
6.5	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2

I-6.2 Direct Design Method for Precast Reinforced Concrete Circular Pipe

I-6.2.1 General

The direct design method was accepted in 1993 by ASCE and is published in ASCE 93-15, Standard Practice for Direct Design of Buried Precast Concrete Pipe Using Standard Installation Direct Design (SIDD).

The pressure distribution on the pipe from applied loads and bedding reaction shall be determined from a soil-structure analysis or shall be a rational approximation. Acceptable pressure distribution diagrams are the Heger Pressure Distribution (see Figure I-1) for use with the Standard Installations; the Olander/Modified Olander Radial Pressure Distribution (see Figure I-5 (a) or the Paris/Manual Uniform Pressure Distribution (see Figure I-5 (b)).

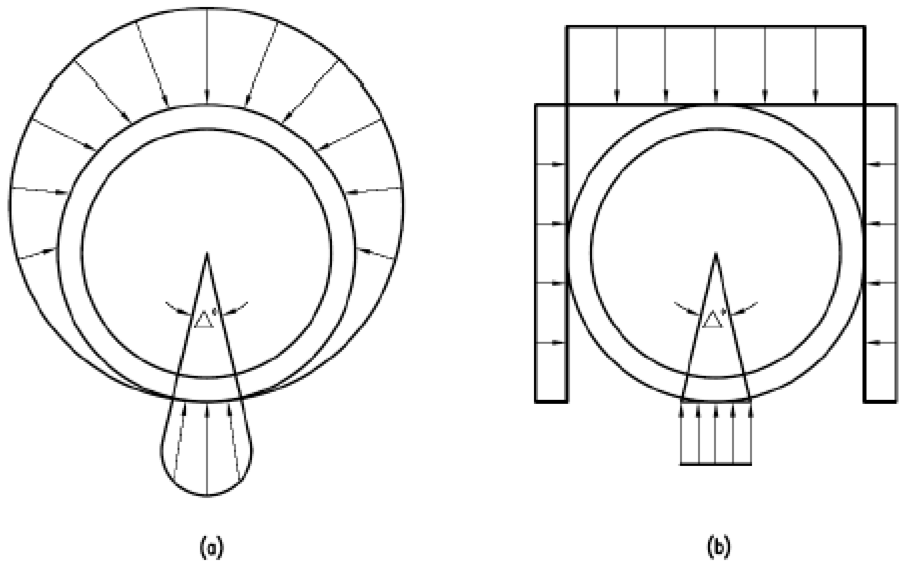

Figure I-5

Other methods for determining total load and pressure distribution may be used if based on successful design practice or tests that reflect the appropriate design condition.

I-6.2.2 Strength-Reduction Factors

Strength-reduction factors for load factor design of plant made reinforced concrete pipe may be taken as 1.0 for flexure (ϕ_f) and 0.9 for shear (ϕ_v) and radial tension (ϕ_r). For Type 1 installations, the strength-reduction factor shall be 0.9 for flexure and 0.82 for shear and radial tension.

I-6.2.3 Process and Material Factors

Process and material factors, F_{rp} for radial tension and F_{vp} for shear strength for load factor design of plant made reinforced concrete pipe are conservatively taken as 1.0. Higher values may be used if substantiated by appropriate test data approved by the Engineer.

I-6.2.4 Orientation Angle

When quadrant mats, stirrups and/or elliptical cages are used, the pipe installation requires a specific orientation. Designs shall be based on the possibility of a rotation misorientation during installation by an orientation angle of 10 degrees in either direction.

I-6.2.5 Reinforcement

I-6.2.5.1 Reinforcement for Flexural

$$A_s = \left(g\phi_f d - N_U - \sqrt{g\left(g\left(\phi_f d\right)^2 - N_U\left(2\phi_f d - h\right) - 2M_U\right)}\right)\frac{1}{f_y}$$

where g = 0.85 b f'_c
b = 12 in.
d= distance from compression face to centroid of tension reinforcement, in.
h= overall thickness of member (wall thickness), in.
N_u= factored axial thrust acting on cross section of width b, lbs/ft.
M_u= factored moment acting on cross section of width b, in-lbs/ft.

I-6.2.5.2 Minimum Reinforcement

For inside face of pipe:

$$A_{si} = \frac{b}{12}\left(S_i + h\right)^2 \frac{1}{f_y}$$ where b=12 in

For outside face of pipe:

$$A_{so} = 0.60\left(\frac{b}{12}\right)\left(S_i + h\right)^2 \frac{1}{f_y}$$ where b = 12 in

For elliptical reinforcement in circular pipe and for pipe with a 33-inch diameter and smaller with a single cage of reinforcement in the middle third of the pipe wall, reinforcement shall not be less than A_s, where:

$$A_{so} = 2\left(\frac{b}{12}\right)\left(S_i + h\right)^2 \frac{1}{f_y}$$ where b = 12 in

where:

h = wall thickness in inches

S_i = internal diameter of horizontal span of pipe in inches.

In no case shall the minimum reinforcement be less than 0.07 square inches per linear foot.

I-6.2.5.2 Maximum Flexural Reinforcement Without Stirrups

1-6.2.5.2.1 Limited by Radial Tension

$$A_{si\max} = \frac{b}{12}\left(16 r_s F_{rp}\sqrt{f_c^{'}}\left(\frac{\phi_r}{\phi_f}\right)F_{rt}\right)\frac{1}{F_y}$$

A_{simax} = maximum flexural reinforcement area without stirrups in^2/ft where b = 12 in.

F_{rt} = 1+0.00833(72-S_i)
For 12 in $\leq S_i \leq$ 72 in.

F_{rt} = $\dfrac{(144 - S_i)^2}{26{,}000} + 0.80$
For 72 in. $\leq S_i$ = 144 in.

F_{rt} = 0.8 for S_i > 144 in.

F_{rp} = 1.0 unless a higher value substantiated by test data is approved by the Engineer.
R_s = radius of the inside reinforcement in inches.

I-6.2.5.2.2 Limited by Concrete Compression

$$A_{si\max} = \left(\left[\frac{5.5\times10^4 g'\phi_f d}{87{,}000 + f_y}\right] - 0.75 N_U\right)\frac{1}{f_y}$$

where:

$$g' = b f_c^{'}\left(0.85 - 0.05\frac{(f_c^{'} - 4{,}000)}{1{,}000}\right)$$

g' =0.85 b f'_c and g'_{min} = 0.65 b f'_c

I-6.2.5.3 Crack Width Control (Service Load Design)

$$F_{cr} = \frac{B_1}{30{,}000\phi_f d A_s}\left[\frac{M_s + N_s\left(d - \frac{h}{2}\right)}{ij} - C_1 b h^2\sqrt{f_c^{'}}\right]$$

Cover for crack control analysis is assumed to be 1 inch over the tension reinforcement, even if it is greater or less than 1 inch. The crack control factor F_{cr} in equation above indicates the probability that a crack of a specified maximum width will occur.

When F_{cr}=1.0, the reinforcement area, A_s, will produce an average crack maximum width of 0.01 inch. For F_{cr} values less than 1.0, the probability of a 0.01-inch crack is reduced. For F_{cr} values greater than 1.0, the probability of a crack greater than 0.01 inch is increased.

Where:

F_{cr} =crack control factor
M_s =bending moment, service load
N_s =thrust (positive when compressive), service load

If the service load thrust, N_s, is tensile rather than compressive (this may occur in pipes subject to intermittent hydrostatic pressure), use the quantity ($1.1\ M_s - 0.6\ N_s d$) (with tensile N_s taken negative) in place of the quantity ($[M_s+N_s(d-h/2)]/ji$) in equation above.

J $\cong 0.74+0.1e/d$
J_{max} =0.9
i $= \dfrac{1}{1-\dfrac{jd}{e}}$
e $= \dfrac{M_s}{N_s} + d - \dfrac{h}{2}$, in
if e/d<1.15 crack control will not govern.
t_b =clear cover over reinforcement in inches
h =wall thickness of pipe in inches.
B_1 $= \sqrt[3]{\dfrac{t_b s_l}{2n}}$
Where:
s_l =spacing of circumferential reinforcement, in.
n =1, when tension reinforcement is a single layer.
n =2, when tension reinforcement is made of multiple layers.

C_1=Crack Control Coefficient

Type of Reinforcement	C_1
1. Smooth wire or plain bars	1.0
2. Welded smooth wire fabric, 8 in (200mm) maximum spacing of longitudinal	1.5
3. Welded deformed wire fabric, deformed wire, deformed bars, or any reinforcement with stirrups anchored thereto	1.9

Note: Higher values for C_1 may be used if substantiated by test data and approved by the Engineer.

I-6.2.5.4 Shear Strength

The area of reinforcement, A_s, determined in Subsection I-6.2.5.1 or I-6.2.5.3 must be checked for shear strength adequacy, so that the basic shear strength, V_b, is greater than the factored shear force, V_{uc}, at the critical section located where $M_{nu}/V_u d$=3.0.

$$V_b = b\phi_v d F_{vp} \sqrt{f_c^{'}}\left(1.1+63\rho\right)\left[\frac{F_d F_N}{F_e}\right]$$

where:

V_b =shear strength of section where $M_{nu}/V_u d$ =3.0

F_{vp} =1.0 unless a higher value substantiated by test data is approved by the Engineer

ρ =A_s/bd

ρ_{max} =0.02

$f^{'}_{c\,max}$ =7,000 psi

F_d =0.8+1.6/d

max F_d =1.3 for pipe with two cages, or a single elliptical cage

max F_d =1.4 for pipe through 36-inch diameter with a single circular cage

F_c $=1 \pm \dfrac{d}{2r}$

(+) tension on the inside of the pipe

(-) tension on the outside of the pipe

For compressive thrust (+N_u):

F_n $=1+ \dfrac{N_u}{2{,}000bh}$

where b=12 in.

For tensile thrust ($-N_u$):

F_n $=1+\dfrac{N_u}{500bh}$

where b=12 in.

M_{nu} $=M_u-N_u$

If V_b is less than V_{uc}, radial stirrups must be provided. See Subsection I-6.2.5.5.

I-6.2.5.5 Radial Stirrups

I-6.2.5.5.1 Radial Tension Stirrups

$$A_{vr}=\frac{1.1s_v\left(M_u-0.45N_u\phi_r d\right)}{f_v r_s \phi_r d}$$

where:

A_{vr} =required area of stirrup reinforcement for radial tension

s_v =circumferential spacing of stirrups ($s_{v\,max}=0.75\phi_v d$)

f_v =maximum allowable strength of stirrup material ($f_{max}=f_y$, or anchorage strength whichever is less)

I-6.2.5.5.2 Shear Stirrups

$$A_{vs}=\frac{1.1s_v}{f_{vs}\phi_r d}\left[V_u F_c-V_c\right]$$

where:

A_{vs} =required area of stirrups for shear reinforcement

V_u =factored shear force as section

V_c $=\dfrac{4V_b}{\dfrac{M_{nu}}{V_u d}+1}$

$V_{c\,max}$ $=2\phi_v bd\sqrt{f_c'}$

$S_{v\,max}$ $=0.75f_v d$

$F_{v\,max}$ $=f_y$ or anchorage strength, whichever is less

A conservative approximation of the total required stirrup area is:

$A_v=A_{vs}+A_{vr}$

I-6.2.5.5.3 Stirrup reinforcement Anchorage

I-6.2.5.5.3.1 Radial Tension Stirrup Anchorage

When stirrups are used to resist radial tension, they shall be anchored around each circumferential of the inside cage to develop the design strength of the stirrup, and they shall also be anchored around the outside cage, or embedded sufficiently in the compression side to develop the design strength of the stirrup.

I-6.2.5.5.3.2 Shear Stirrup Anchorage

When stirrups are not required for radial tension but required for shear, their longitudinal spacing shall be such that they are anchored around each or every other tension circumferential. Such spacings shall not exceed 6 inches (150 mm).

I-6.2.5.5.3.3 Stirrup Embedment

Stirrups intended to resist forces in the invert and crown regions shall be anchored sufficiently in the opposite side of the pipe wall to develop the design strength of the stirrup.

I-6.3 Development of Quadrant Mat Reinforcement

I-6.3.1 When the quadrant mat reinforcement is used, the area of the continuous main cages shall be no less than 25 percent of the area required at the point of maximum moment.

I-6.3.2 In lieu of I-6.3.1, a more detailed analysis may be made.

I-6.3.2.1 For quadrant mat reinforcement consisting of welded smooth wire fabric, the outermost longitudinals on each end of the circumferentials shall be embedded: (a) past the point where the quadrant reinforcement is no longer required by the orientation angle plus the greater of 12 circumferential wire diameters or percent of the wall thickness of the pipe, and (b) past the point of maximum flexural stress by the orientation angle plus the development length, L_d.

$$L_d = 0.27 \frac{A_{wr} f_y}{s\sqrt{f_c^{'}}}$$

but not less than:

$L_d = s_l + 1$

The mat shall contain no less than two longitudinals at a distance 1-inch greater than that determined by the orientation angle from either side of the point requiring the maximum flexural reinforcement.

The point of embedment of the outermost longitudinals of the mat shall be at least a distance determined by the orientation angle past the point where the continuing reinforcement is no less than the double area required for flexure.

I-6.3.2.2 For quadrant mat reinforcement consisting of deformed bars, deformed wire, or welded wire fabric (a) circumferentials shall extend past the point where they are no longer required by the orientation angle plus the greater of 12 wire diameters or percent of the wall thickness of the pipe. (b) The circumferentials shall extend on either side of the point of maximum flexural stress not less than the orientation angle plus the development length L_d required by equation below and (c) they shall extend at least a distance determined by the orientation angle past the point where the continuing reinforcement is no less than double the area required by flexure.

$$L_d = \frac{0.03 d_b f_y A_{wr}}{A_{wa}\sqrt{f_c^{'}}}$$

but not less than:

$$L_d = 0.015\, d_b \frac{f_y}{\sqrt{f_c^{'}}}$$

I-7 D-Load Tables for Design of Reinforced Concrete Pipe

D-Load Tables I-6 to I-8 for Design of Reinforced Concrete Pipe, may be used to determine D-Loads for pipes if the loading conditions shown correspond to those of the pipe to be designed. It should be noted that in State Highways: (1) The minimum D-Load is 1,000.

In calculating D-Loads, the design unit soil weight shall ordinarily be taken as 120 pcf, except where soil analysis and judgment indicate earth loads should be increased. Therefore, D-Loads should normally be taken from Table I-7. However, on all projects, the soil report should be carefully analyzed and the applicable standard drawing used. Where unusual conditions exist that are not covered by the standard drawings, calculations must be submitted.

Pipe designs based on the maximum amount of earth fill plus live load are not always the critical loading condition; the minimum amount of fill plus live load may be the control. This occurs most frequently with catch basin connector pipes, especially connector pipes for catch basins in series.

I-8 Pipe to be Jacked

Refer to Section G2, Section G2-16, Box Conduits to be jacked.

The minimum length of the jacking pit is one pipe length plus 10 feet.

The design of pipe to be jacked shall be based on superimposed loads and not upon loads which may be placed upon the pipe as a result of jacking operations. Any increase in pipe strength required in order to withstand jacking loads shall be the responsibility of the Contractor.

In general, the jacking of pipe conduits should not be specified where the cover is less than 6 feet, or under railroads where the cover is less than the greater of 6 feet or 1/2 the outside diameter of the conduit.

I-9 Rubber Gasket Joint Pipe

Rubber gasket joint pipe should be used when:

1. The pipe conduit is under substantial pressure head. Amount of head is a function of depth of cover, type of backfill, etc.

2. Pipe conduits, which outlet to pump stations, are placed in sandy soil, and there is a possibility of sand infiltrating into the pipe through the joints.

3. There is a possibility of the pipe conduit deflecting due to settlement, as in the case of future freeway fill being placed over the pipe, and installations with varying cover or varying subgrade conditions. An elastomeric sealant may also be considered in this case.

It is requested that the District be consulted prior to the start of detailed design if the hydraulic grade line is 10 feet or more above the soffit or finish grade.

Where rubber gasket joint bell and spigot pipe is specified, the pipe shall be reinforced per the County of Los Angeles Department of Public Works Standard Plans 3096-1.

Where pressure pipe is specified the plan shall include, where applicable, a detail for a pressure joint where pipe is joined to cast-in-place structures, such as manhole bases, transition structures, etc.

I-10 Pressure Test

A pressure test is required when the pipe conduit is under a substantial head. It is requested that the District be consulted when the pressure is greater than 1.5 times the depth of cover.

I-11 General Notes

The following note shall appear on all project drawings where concrete pipe is specified:

> Design of the pipe shown hereon is based on the assumption the pipe will be installed in accordance with Type 3 Standard Installation as shown on Standard Plan 3080-3 unless otherwise shown.

Table I-5

Required D-Load for Reinforced Concrete Pipe Per Standard Installation Type 3

Design Soil Density = 120 pcf

Pipe	Depth of cover																														Pipe
Size	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**Size**
12	2250	1250	800	800	800	1000	1000	1250	1250	1500	1500	1500	1750	1750	2000	2000	2250	2250	2500	2500	2500	2750	2750	3000	3000	3250	3250	3500	3500	3750	**12**
15	2000	1250	800	800	800	1000	1000	1250	1250	1500	1500	1500	1750	1750	2000	2000	2250	2250	2250	2500	2500	2750	2750	3000	3000	3250	3250	3500	3500	3500	**15**
18	2000	1000	800	800	800	1000	1000	1250	1250	1250	1500	1500	1750	1750	2000	2000	2250	2250	2250	2500	2500	2750	2750	3000	3000	3250	3250	3250	3500	3500	**18**
21	2000	1000	800	800	800	1000	1000	1250	1250	1500	1500	1500	1750	1750	2000	2000	2250	2250	2250	2500	2500	2750	2750	3000	3000	3250	3250	3250	3500	3500	**21**
24	2000	1000	800	800	1000	1000	1000	1250	1250	1500	1500	1500	1750	1750	2000	2000	2250	2250	2250	2500	2500	2750	2750	3000	3000	3250	3250	3500	3500	3500	**24**
27	2250	1000	800	800	1000	1000	1000	1250	1250	1500	1500	1500	1750	1750	2000	2000	2250	2250	2500	2500	2500	2750	2750	3000	3000	3250	3250	3500	3500	3500	**27**
30	2250	1250	800	800	1000	1000	1000	1250	1250	1500	1500	1500	1750	1750	2000	2000	2250	2250	2500	2500	2500	2750	2750	3000	3000	3250	3250	3500	3500	3750	**30**
33	2500	1250	1000	800	1000	1000	1000	1250	1250	1500	1500	1750	1750	1750	2000	2000	2250	2250	2500	2500	2750	2750	2750	3000	3000	3250	3250	3500	3500	3750	**33**
36	2500	1250	1000	800	1000	1000	1250	1250	1250	1500	1500	1750	1750	1750	2000	2000	2250	2250	2500	2500	2750	2750	3000	3000	3000	3250	3250	3500	3500	3750	**36**
42	2200	1100	900	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2200	2300	2400	2500	2600	2700	2800	3000	3100	3200	3300	3400	3500	3600	**42**
48	2000	1200	900	900	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2100	2200	2300	2400	2500	2600	2700	2900	3000	3100	3200	3300	3400	3600	3700	**48**
54	1900	1200	900	900	900	1000	1100	1200	1300	1400	1500	1600	1700	1900	2000	2100	2200	2300	2400	2500	2700	2800	2900	3000	3100	3200	3300	3500	3600	3700	**54**
60	1800	1300	900	900	1000	1000	1100	1200	1300	1400	1500	1700	1800	1900	2000	2100	2200	2300	2400	2600	2700	2800	2900	3000	3100	3300	3400	3500	3600	3700	**60**
66	1750	1350	900	900	950	1050	1100	1200	1300	1450	1550	1650	1750	1850	2000	2100	2200	2350	2450	2550	2700	2800	2900	3050	3150	3250	3400	3500	3600	3750	**66**
72	1700	1450	950	900	950	1050	1150	1250	1350	1450	1550	1650	1800	1900	2000	2150	2250	2350	2450	2600	2700	2850	2950	3050	3200	3300	3400	3550	3650	3750	**72**
78	1600	1450	1000	900	1000	1050	1150	1250	1350	1450	1550	1700	1800	1900	2000	2150	2250	2350	2500	2600	2700	2850	2950	3050	3200	3300	3400	3550	3650	3750	**78**
84	1500	1450	1050	950	1000	1050	1150	1250	1350	1450	1600	1700	1800	1900	2050	2150	2250	2400	2500	2600	2750	2850	2950	3100	3200	3300	3450	3550	3650	3800	**84**
90	1400	1500	1100	1000	1000	1100	1200	1300	1400	1500	1600	1700	1850	1950	2050	2150	2300	2400	2500	2650	2750	2850	3000	3100	3200	3350	3450	3550	3700	3800	**90**
96	1400	1500	1100	1000	1000	1100	1200	1300	1400	1500	1600	1700	1850	1950	2050	2150	2300	2400	2500	2650	2750	2850	3000	3100	3200	3350	3450	3550	3700	3800	**96**
102	1450	1500	1150	1000	1050	1100	1200	1300	1400	1500	1600	1750	1850	1950	2050	2200	2300	2400	2550	2650	2750	2900	3000	3100	3250	3350	3450	3600	3700	3800	**102**
108	1450	1450	1200	1050	1050	1150	1200	1300	1400	1550	1650	1750	1850	1950	2100	2200	2300	2450	2550	2650	2800	2900	3000	3100	3250	3350	3450	3600	3700	3850	**108**

Data:

Live Load: **H20-S16-44 Truck**

LOS ANGELES COUNTY
DEPARTMENT OF PUBLIC WORKS

D-LOAD TABLE I-5 FOR
DESIGN OF REINFORCED
CONCRETE PIPE

SUBMITTED
BY
DATE

RECOMMENDED
BY
ASSISTANT DEPUTY DIRECTOR DATE

APPROVED DONALD L. WOLFE, DIRECTOR OF PUBLIC WORKS
BY
DEPUTY DIRECTOR DATE

SCALE | DATE | DRAWING NUMBER S-

DRAFTER RL | DESIGNER RL | CHECKER