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Design Data Sheet
Minimum Cover Depths of Corrugated Steel Pipes Subjected to Tracked Construction Vehicles

Purpose

Construction loads frequently exceed the service loads that buried structures were designed to carry. Corrugated steel pipes can generally support the use of heavy construction equipment but require the loads from the construction vehicles to be distributed through compacted ground until the forces from the vehicles can be safely carried by the pipe. This document demonstrates a methodology to compute the minimum cover required for tracked construction equipment and proposes tables based on that methodology.

Design Methodology

A method of predicting the plastic moment demand induced on a buried pipe from wheel loads was developed by Dr. J. M. Duncan. That methodology incorporates factors such as axle loads, soil stiffness, span and depth of cover to predict the plastic moment demand acting on a buried flexible pipe. The methodology proposed for computing the moment demand on a pipe from a tracked load translates the loading from the tracked vehicle to an equivalent axle load. That equivalent axle load is then utilized in the Duncan methodology to predict the resulting moment demand.

Calculating Required Plastic Moment for CSP Under Tracked Loading

The design methodology involves relating a track load to an equivalent wheel load system to determine if the plastic moment of a given pipe is enough to support the proposed vehicle.

1.) Calculate the live load area (A_{LL}) from the tracked vehicle load at depth H.

$$H_{int\text{-}t} = \frac{s_w - w_t - 0.06*D}{LLDF}$$ REF: AASHTO 3.6.1.2.6b-1

Where: $H_{int\text{-}t}$ = depth of track interaction
s_w = track spacing
w_t = track width
D = diameter of pipe
LLDF = live load design factor

**If $H_{int\text{-}t} > H$, number of interacting wheels is one (n=1)*

$$l_w = l_t + LLDF * H$$ REF: AASHTO 3.6.1.2.6b-5

Where: l_w = wheel length
l_t = track length
H = height of cover

$$w_w = w_t + LLDF * H$$ REF: AASHTO 3.6.1.2.6b-2

Where: w_w = wheel width

$$A_{LL} = l_w * w_w$$ REF: AASHTO 3.6.1.2.6a-1

Where: A_{LL} = area of live load

2.) Calculate the live load area for the typical HL-93 wheeled vehicle at depth H.
(AASHTO HL-93 truck dimensions s_w = 6', s_a = 14', w_t = 20", l_t = 10")

$$H_{int\text{-}t} = \frac{s_w - w_t - 0.06D}{LLDF}$$ REF: AASHTO 3.6.1.2.6b-1

Where: $H_{int\text{-}t}$ = depth of wheel interaction transverse to span

$$H_{int\text{-}p} = \frac{s_a - l_t}{LLDF}$$ REF: AASHTO 3.6.1.2.6b-4

Where: $H_{int\text{-}p}$ = depth of wheel interaction parallel to span

s_a = axel spacing

**If $H_{int\text{-}t} > H$ and $H_{int\text{-}p} > H$, number of interacting wheels is one (n=1)*

3.) Determine the equivalent wheeled axle load (P_{eq}) by using the two equations below to create a simplified equation, where:

$$P_{eq} = \frac{2*P_2*P_{L_1}}{P_{L_2}}$$ REF: AASHTO 3.6.1.2.6B-7

$$P_L = \frac{P*(1 + \frac{IM}{100})*n}{A_{LL}}$$ REF: AASHTO 3.6.1.2.6B-7

The simplified equation is shown below:

$$P_{eq} = \frac{2*P_1*n_1*A_{LL_2}}{A_{LL_1}*n_2}$$

4.) Calculate the required plastic moment (M_p) by the Duncan method to evaluate the adequacy of the pipe under P_{eq}.

$$K_3 = \frac{AL^*d^*F_p}{c}$$

Where: AL = axle load for the design vehicle ($AL=P_{eq}$)
d = corrugation depth [ft.]
F_p = factor of safety (1.3 for $0<H/S \leq 0.1$, 1.0 for $H/S > 0.2$)
c = coefficient based on backfill percent (69 for 90%, 115 for 95%)

$$M_p = K_3 * (\frac{S}{H})^2$$

Where: M_p = plastic moment

5.) After the plastic moment exerted on the pipe is calculated, it is compared with the published table on the next page from the NCSPA design manual titled "NCSPA Design Manual Table 8.6. "Plastic Moments for Corrugated Steel Pipe"" to ensure that it has enough strength to prevent failure.

Plastic Moment Strengths "M_p" of Corrugated Steel Pipe (k-ft/ft)

Wall Thickness (in)	2-2/3 x 1/2	3 x 1 / 5 x 1	6 x 2	15 x 5-½**	16 x 6**
0.064	0.39	0.79			
0.079	0.49	0.99			
0.109/0.111*	0.69	1.40	2.66		
0.138/0.140*	0.90	1.82	3.44	14.43	
0.168/0.170*	1.11	2.24	4.22	17.66	18.46
0.188			4.73	19.75	
0.197					21.70
0.218			5.54	23.07	
0.236					26.34
0.249			6.36	26.39	
0.276					30.78
0.280			7.18	29.72	
0.315					35.00

Notes:
* Where two thicknesses are provided, the first is for pipe and the second for structural plate
** M_p Values for 15 x 5-½ and 16 x 6 corrugation are based on a yield strength (F_y) of 44 ksi

NCSPA Design Manual Table 8.6. "Plastic Moments for Corrugated Steel Pipe"

Design Tables for Maximum Track Pressures for CSP

Based on this method, the following tables have been developed to allow for quick reference for tracked loading conditions. For a given diameter of pipe, the tables can be used to determine minimum cover needed for the various tracked loading conditions shown.

For more TechNotes and other resources scan the QR code.

Maximum Allowable Tracked Vehicle Loads for Corrugated Steel Pipe

Maximum Track Pressure (PSI)					
Dia. (Inches)	Minimum Cover (Ft)	Track Width (Inches)			
		12	18	24	30
12 - 42	1.0	29	22	18	17
	1.5	58	41	34	30
	2.0	95	65	51	44
	2.5	138	91	70	59
	3.0	189	120	91	75
	4.0	321	195	143	115
48 - 66	1.0	10.6	8.0	6.9	6.2
	1.5	24	17	14.0	12.2
	2.0	39	26	21	18
	2.5	56	37	28	24
	3.0	77	49	37	30
	4.0	132	80	59	47
72 - 102	1.0	3.2	2.5	2.1	1.9
	1.5	8.8	6.2	5.0	4.4
	2.0	16	11.1	8.8	7.5
	2.5	24	15.0	12.0	10.1
	3.0	32	20	15	12.9
	4.0	56	34	25	20
108 - 120	1.0	2.8	2.1	1.7	1.6
	1.5	6.9	4.9	3.9	3.4
	2.0	14.8	10.1	8.0	6.7
	2.5	21	14.2	10.9	9.1
	3.0	29	18	14.1	11.6
	4.0	51	31	22	18
126 - 144	1.0	2.8	2.1	1.7	1.5
	1.5	6.0	4.3	3.5	3.0
	2.0	12.0	8.0	6.4	5.4
	2.5	21	14.0	10.6	8.9
	3.0	29	18	13.9	11.4
	4.0	50	30	22	18

Maximum Allowable Tracked Vehicle Loads for Spiral Rib Corrugated Steel Pipe

Maximum Track Pressure (PSI)					
Dia. (Inches)	Minimum Cover (Ft)	Track Width (Inches)			
		12	18	24	30
18 - 54	1.0	6.9	5.3	4.5	4.1
	1.5	13.9	10.1	8.3	7.3
	2.0	23	15	12.5	10.7
	2.5	33	22	17	14.4
	3.0	45	29	22	18
	4.0	78	47	34	28
60 - 66	1.0	5.6	4.1	3.5	3.2
	1.5	12.0	8.6	7.2	6.2
	2.0	19	13.6	10.8	9.3
	2.5	29	19	14.8	12.4
	3.0	39	25	19	15.0
	4.0	68	41	30	24
72 - 84	1.0	4.2	3.1	2.7	2.4
	1.5	11.6	8.0	6.6	5.8
	2.0	18	12.6	10.0	8.5
	2.5	27	17	13.8	11.5
	3.0	37	23	17	14.7
	4.0	63	38	28	22
90 - 102	1.0	3.2	2.7	2.2	2.0
	1.5	9.3	6.6	5.4	4.7
	2.0	17	11.9	9.4	8.0
	2.5	25	16	13.0	10.8
	3.0	34	22	16	13.8
	4.0	60	36	26	21

Notes:

1. Values in this table represent the maximum ground pressure permitted when performing reasonable work over the pipes, using the manufacturer's published equipment specifications.
2. Cover levels shown are for acceptable compacted backfill materials as described in the CSP installation guides and specifications. Care should be taken to maintain adequate cover depth during construction activities.
3. Tracked dozers don't exhibit the same variability in pressures under their tracks as other pieces of construction equipment. Therefore, the maximum track pressures shown above can be increased by a multiplier of 2.5 when applied to tracked dozers.
4. The track widths shown above are for single tracks. If your equipment has different track widths, use the width that most closely corresponds to your equipment or extrapolate from the widths shown.