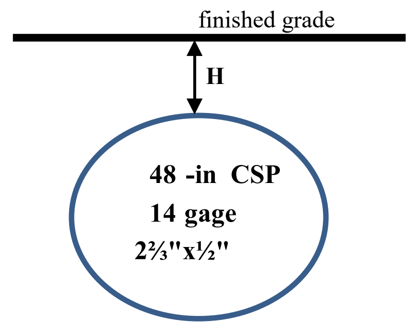
AASHTO LRFD Bridge Design Specifications

Cover Height Calculations by the National Corrugated Steel Pipe Association

Corrugated Steel Pipe



AASHTO Vehicle Loading

HL93 Truck	32 kips/axle
HL93 Tandem	25 kips/axle

Corrugation Section Properties

Thickness (in)	0.079
Area, A (in^2/ft)	0.968
Radius of Gyration, r (in)	0.1721
Moment of Inertia, I (in^4/in)	0.002392

Cover Height Investigated, H (ft) = 51.0

(1) Determine the factored vertical crown pressure for dead load, P_{FD}, and live load P_{FL} (ksf):

$$P_{FD} = \eta_{EV}\gamma_{EV}\,DL$$

η_{EV} (vertical earth pressure load modifier) = 1.05

γ_{EV} (vertical earth pressure load factor) = 1.95

$$P_{FL} = \eta_{LL}\gamma_{LL}P_L$$

The dynamic load allowance (IM) is a percentage increase in the live load to account for the rolling motion of the vehicle.

$$P_L = (m)(IM)(LL)$$

m (single-lane multiple presence factor) = 1.2

η_{LL} (LL load modifier) = 1.0

γ_{LL} (LL load factor) = 1.75

Geostatic Earth Pressure (i.e. dead load), DL (ksf) = γ_sH

H (ft) = 51.0 γ_s (soil density, kcf) = 0.120

DL = 6.12 ksf

Live Load for H = 51.0 ft

Where the depth of fill is greater than 1.0-ft the live load (LL) shall be distributed to the structure as wheel loads, uniformly distributed over a rectangular area with sides equal to the dimension of the tire contact area increased by the live load distribution factor (LLDF = 1.15). Compute the depth at which wheels on adjacent axles interact (Figure A), and the depth at which wheels on the same axle interact (Figure B). Wheel loads shall be added as appropriate and applied over the total interaction dimension for cover depths that exceed the interaction depth. Evaluate both the design truck and the design tandem to determine which configuration produces the maximum load.

ℓ_w = live load patch length at depth H (ft)

w_w = live load patch width at depth H (ft)

s_w = wheel spacing s_a = axle spacing

ℓ_t = tire patch length (in) w_t = tire patch width (in)

D_i = inside diameter or clear span of the culvert (in)

A_{LL} = live load distribution area at depth H (ft²) = $(\ell_w)(w_w)$

P = sum of all interacting wheel loads (kips)

$$H_{int\text{-}t} = \frac{s_w - w_t/12 - 0.06D_i/12}{LLDF}$$

wheel interaction depth transverse to culvert span (ft)

$$H_{int\text{-}p} = \frac{s_a - \ell_t/12}{LLDF}$$

axle interaction depth parallel to culvert span (ft)

For $H < H_{int\text{-}t}$ $\quad w_w = w_t/12 + LLDF(H) + 0.06D_i/12$

For $H \geq H_{int\text{-}t}$ $\quad w_w = w_t/12 + s_w + LLDF(H) + 0.06D_i/12$

For $H < H_{int\text{-}p}$ $\quad \ell_w = \ell_t/12 + LLDF(H)$

For $H \geq H_{int\text{-}p}$ $\quad \ell_w = \ell_t/12 + s_a + LLDF(H)$

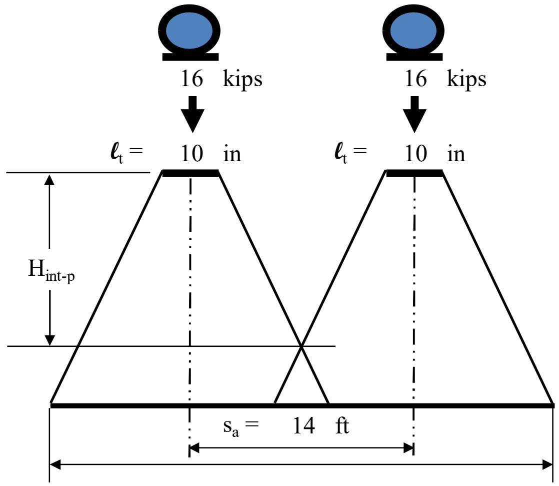


Fig A. Total Interaction Length ($H \geq H_{int\text{-}p}$)

HL93 Truck

$H_{int\text{-}p}$ =	11.45	ft
$H_{int\text{-}t}$ =	3.56	ft
ℓ_w =	73.48	ft
w_w =	66.56	ft
A_{LL} =	4890.81	ft²
P =	64	k
LL =	**0.01**	**ksf**

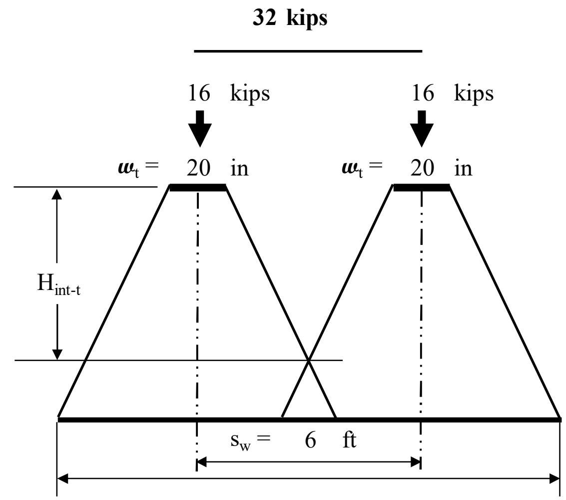


Fig B. Total Interaction Width ($H \geq H_{int\text{-}t}$)

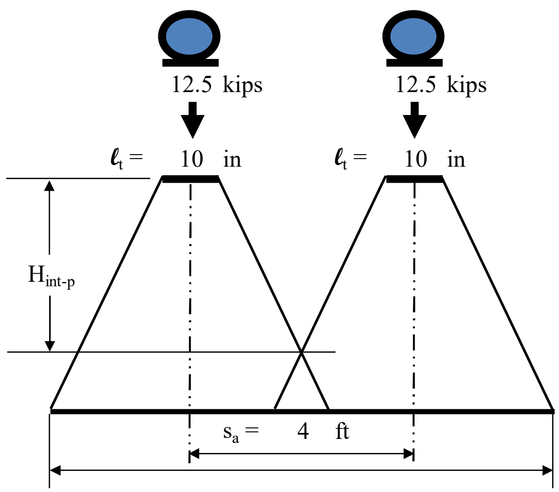


Fig A. Total Interaction Length ($H \geq H_{int\text{-}p}$)

HL93 Tandem

$H_{int\text{-}p}$ =	2.75	ft
$H_{int\text{-}t}$ =	3.56	ft
ℓ_w =	63.48	ft
w_w =	66.56	ft
A_{LL} =	4225.24	ft²
P =	50	k
LL =	**0.01**	**ksf**

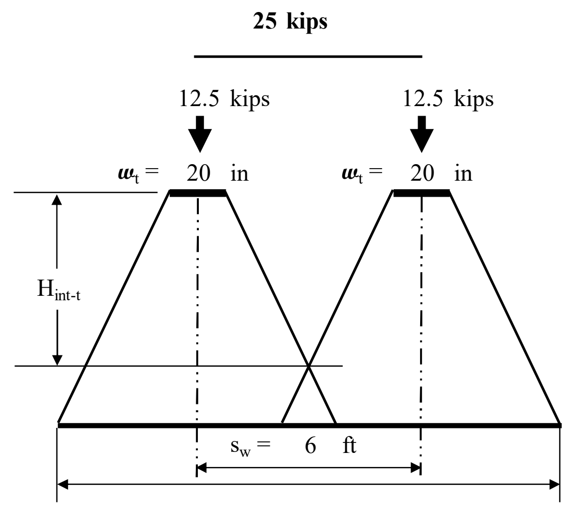


Fig B. Total Interaction Width ($H \geq H_{int\text{-}t}$)

Dynamic Load Allowance, IM = 33(1.0 - 0.125H) ≥ 0% **IM = 0.00 %** **IM factor = 1.00**

$P_L = (m)(IM)(LL_{max}) =$ 0.02 **$P_{FD} = \eta_{EV}\gamma_{EV}DL =$ 12.53** **$P_{FL} = \eta_{LL}\gamma_{LL}P_L =$ 0.03**

(2) Determine factored thrust per unit length of wall, T_L (kpf) = $P_{FD}S/2 + P_{FL}C_LF_1/2$

S, span of pipe (ft) = 4.0

T_L = 25.12 kpf

$F_1 = 0.75S/\ell_w \geq F_{min}$	$F_1 = 1.00$	C_L, width of culvert on which live load is applied parallel to the span (ft)
$F_{min} = 15/12S \geq 1$	$F_{min} = 1.00$	ℓ_w, live load patch length at depth H
$C_L = \ell_w \leq S$	$C_L = 4.00$	ℓ_w = ### ft

(3) Determine Critical Buckling Stress, f_{cr} (ksi)

(a) If $S < (r/k)(24E_m/F_u)^{1/2}$, then $f_{cr} = F_u - (F_ukS/r)^2/48E_m$

(b) If $S > (r/k)(24E_m/F_u)^{1/2}$, then $f_{cr} = 12E_m/(kS/r)^2$

E_m (ksi) =	29,000	r, radius of gyration (in) =	0.1721
F_y (ksi) =	33	k (soil stiffness factor) =	0.22
F_u (ksi) =	45	S, pipe arch span (in) =	48

$S < (r/k)(24E_m/F_u)^{1/2}$ = 97.2874

Therefore use equation (a) above

f_{cr} = 39.52 ksi

(4) Determine the Factored Axial Resistance to Buckling R_n (kpf) **$R_n = \phi_wF_yA$**

If the critical buckling stress is less than the actual yield stress then the resistance to buckling must be calculated using f_{cr} in place of F_y.

F_y (ksi) = 33

A = wall area (in^2/ft) = 0.968

$\phi_w = 1.0$

The actual yield strength is less than the critical buckling stress therefore use F_y (ksi) = 33.00

R_n = 31.94 kpf greater than T_L, therefore OK

(5) Check Flexibility Factor, FF (in/kip) **$FF = S^2/E_mI$**

E_m (ksi) =	29,000	S, pipe arch span (in) =	48
I (in^4/in) =	0.002392	FF max allowed (in/kip) =	43.00
		Embankment/Trench	

FF actual (in/kip) = 33.21

The actual FF is less than the maximum allowed, therefore OK