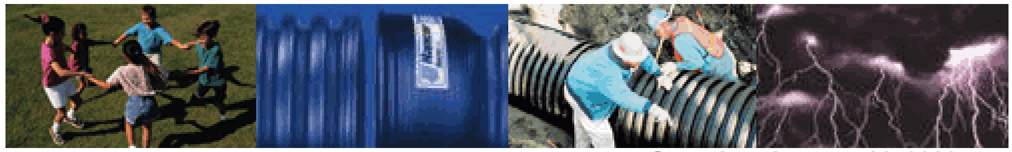
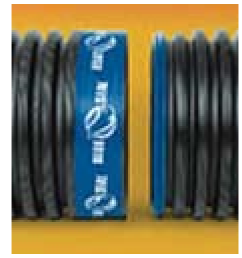


Saturday, January 11, 2003

Hancor Design Aids Section



2-3 DESIGN CRITERIA

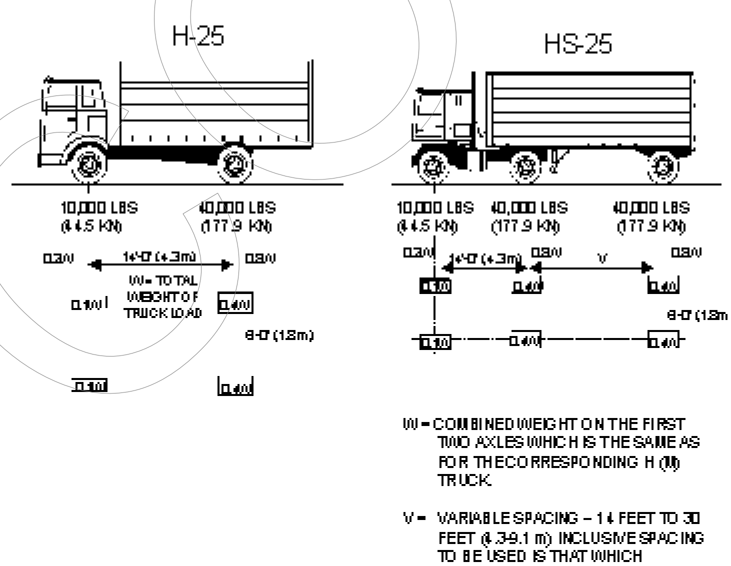
Loads

Loads are considered to be either a live load or a dead load. Live loads change in position or magnitude, whereas dead loads remain constant throughout the design life of the drainage system. The most commonly considered live loads in pipe applications are vehicular loads, usually from trucks, railroads, and aircraft. The soil load is often the sole dead load consideration, however forces from high groundwater and foundations are also types of dead loads and should be incorporated into the design when appropriate.

Live Loads

Vehicular loads are typically based on the AASHTO H-25 or HS-25 configuration, Figure 2-2, which represents a 25 ton (222 kN) semi-truck. Some specifiers use an H-20 or HS-20 load; the load distribution is the same as an H-25 or HS-25, but the resulting load is about 20% lower. Similarly in railroad applications, the standard load is represented by the Cooper E-80 configuration at 80,000 lbs/ft (1167 kN/m) of track.

Figure 2-2 – AASHTO H-25 Highway Load



Source: AASHTO Standard Specifications for Highway Bridges

In applications where the pipe is buried relatively shallow it can experience an additional force from the rolling motion of the vehicle. To account for this additional force, the stationary vehicular load is multiplied by an ‘impact factor.’ For highway loads, AASHTO establishes a range of impact factors from 1.3 at about one foot (0.3m) of cover to 1.1 at depths just under three feet (1 m). Impact has negligible influence at depths over three feet (1 m). Table 2-7 provides information about the resultant H-25 and E-80 vehicular forces at various cover heights with impact included in the shallow cover situations. Resultant loads for H-20 vehicles can be estimated by decreasing the values in Table 2-7 by 20%. These values are widely used throughout the industry, although values based on alternative computation methods can be substituted.

The intensity of the vehicular load decreases as the depth increases, however, the area over which the force acts increases. Table 2-7 lists the live load distribution width showing this relationship for an AASHTO H-25 or HS-25 load. This width is based on AASHTO information and assumes that the pipe is installed perpendicular to the direction of traffic. Other AASHTO H or HS loads would have identical live load distribution widths. If desired, alternative ways of calculating this value may be used.

Table 2-7 – Live Load Data for AASHTO H-25, HS-25 and Cooper E-80

	AASHTO H-25 or HS-25(1)		Cooper E-80(1)
Cover, ft. (m)	Live Load Transferred to Pipe, psi (N/mm^2)	Live Load Distribution Width, L_w in. (mm)	Live Load Transferred to Pipe, psi (N/mm^2)
1 (0.3)	15.63 (0.108)	31 (787)	N/R
2 (0.6)	6.95 (0.048)	52 (1321)	26.39 (0.1824)
3 (0.9)	5.21 (0.036)	73 (1854)	23.61 (0.1632)
4 (1.2)	3.48 (0.024)	94 (2388)	18.40 (0.1272)
5 (1.5)	2.18 (0.015)	115 (2921)	16.67 (0.1152)
6 (1.8)	1.74 (0.012)	136 (3454)	15.63 (0.1080)
7 (2.1)	1.53 (0.011)	157 (3988)	12.15 (0.0840)
8 (2.4)	0.86 (0.006)	178 (4521)	11.11 (0.0768)
10 (3.0)	Negligible	N/A	7.64 (0.0528)
12 (3.7)	Negligible	N/A	5.56 (0.0384)
14 (4.3)	negligible	N/A	4.17 (0.0288)
16 (4.9)	negligible	N/A	3.47 (0.0240)
18 (5.5)	negligible	N/A	2.78 (0.0192)
20 (6.1)	negligible	N/A	2.08 (0.0144)
22 (6.7)	negligible	N/A	1.91 (0.0132)
24 (7.3)	negligible	N/A	1.74 (0.0120)
26 (7.9)	negligible	N/A	1.39 (0.0096)
28 (8.5)	negligible	N/A	1.04 (0.0072)
30 (9.1)	negligible	N/A	0.69 (0.0048)
35 (10.7)	negligible	N/A	negligible

Notes:
1. Includes impact where required.
2. N/R indicates that the cover height is not recommended.
3. N/A indicates that the information is not applicable.
4. Information has been modified from Buried Pipe Design, Moser, McGraw-Hill, 1990, p. 34.

Loads from aircraft vary widely in magnitude and distribution. The aircraft manufacturer should be contacted for more specific information.

Some construction vehicles may pose a temporary, although severe, live load consideration. On the other hand, other construction vehicles may weigh substantially less than the design load. For very large loads, mounding additional cover over the pipe when necessary, then grading following construction may be warranted in situations where the pipe has little cover. Construction vehicles with loads lighter than the design load may be permitted over the pipe with less than the minimum recommended cover. Since many types of paving equipment are relatively light or have a well distributed load, pavement can usually be included as part of the minimum recommended cover. Construction loads are covered in additional detail in Section 6.

Dead Loads

The soil load is calculated in this design procedure using two different techniques, the soil column load (W_C) and the soil arch load (W_A). It is important to understand the differences between these two methods, as well as when to use the results from each of them.

Soil Column Load (W_C)

The soil column load is defined as the weight of the soil directly above the outside diameter of the pipe at the height of the pipe crown and must be used to determine deflection. The deflection equation was developed from empirical relationships based on the soil column load. In reality, the actual soil load is less than the calculated column load because the column is suspended, in part, by adjacent soil columns.

The soil column load is calculated as follows:

Equation 2-1

$$W_c = \frac{(H)(\gamma_s)(OD)}{144}$$

Where:

W_C = soil column load, lb/linear inch of pipe

H = burial depth, ft.

γ_S = soil density, pcf

OD = outside diameter of pipe, in. (Table 2-1 or 2-

Or, in metric units:
Equation 2-1(a)

Û $$W_c = 9.81 \times 10^{-6}(H)(\gamma_s)(OD)$$

Where:

W_C = soil column load, N/linearmm of pipe

H = burial depth, m

γ_S = soil density, kg/m^3

OD = outside diameter of pipe,mm (Table 2-1 or 2-2)

Soil Arch Load (W_A)

The soil arch load (W_A) more closely represents the actual soil load experienced by a pipe. The arch load calculation uses a vertical arching factor (VAF) to reduce the earth load in order to account for the support provided by adjacent soil columns. The soil arch load must be used to determine wall thrust.

The arch load is determined using the procedure described below.

First, the geostatic load is calculated by determining the weight of soil directly above the outside diameter of the pipe plus a small triangular load extending just beyond the outside diameter. The equation for the geostatic load, P_{sp}, is shown in Equation 2-2 and 2-2(a).

Equation 2-2

$$P_{sp} = \frac{(\gamma_s)\left(H + 0.11\frac{OD}{12}\right)}{144}$$

Where:

P_{sp} = geostatic load, psi

H = burial depth, ft.

γ_S = unit weight of soil, pcf

OD = outside diameter of pipe, in. (Table 2-1 or 2-

Or, in metric units:
Equation 2-2(a)

Û $$P_{sp} = (9.81)(\gamma_s)\left[H + 1.1x10^{-4}(OD)\right]$$

Where:

P_{sp} = geostatic load, N/m^2

H = burial depth, m

γ_S = unit weight of soil, kg/m^3

OD = outside diameter of pipe,mm (Table 2-1 or 2-2)

Next, the vertical arching factor (VAF) must be determined. This factor accounts for the support provided by adjacent soil columns by reducing the geostatic load. The vertical arching factor is computed as shown in Equation 2-3 or 2-3(a).

Equation 2-3

$$VAF = 0.76 - 0.71\left(\frac{S_h - 1.17}{S_h + 2.92}\right)$$

Where:

VAF = vertical arching factor, unitless
S_h = hoop stiffness factor;
= $\phi_s M_S R / (E A)$
ϕ_s = capacity modification factor for soil, 0.9
M_S = secant constrained soil modulus, psi (Table 2-4)
R = effective radius of pipe, in.
= ID/2+c
ID = inside diameter of pipe, in. (Table 2-1 or 2-2)
c = distance from inside diameter to neutral axis, in. (Table 2-1 or 2-2)
E = modulus of elasticity of polyethylene
= 110,000 psi for short term conditions
= 22,000 psi for long term conditions
A = section area, in^2/in (Table 2-1 or Table 2-2)

Or, in metric units:
Equation 2-3(a)

$$VAF = 0.76 - 0.71\left(\frac{S_h - 1.17}{S_h + 2.92}\right)$$

Where:

VAF = vertical arching factor, unitless
S_h = hoop stiffness factor;
= $\phi_s M_S R / (E A)$
ϕ_s = capacity modification factor for soil, 0.9
M_S = secant constrained soil modulus, kPa (Table 2-4)
R = effective radius of pipe,mm
= ID/2+c
ID = inside diameter of pipe,mm (Table 2-1 or 2-2)
c = distance from inside diameter to neutral axis,mm (Table 2-1 or 2-2)
E = modulus of elasticity of polyethylene
= 758,500 kPa for short term conditions
= 151,700 kPa for long term conditions
A = section area,mm^2/mm (Table 2-1 or 2-2)

After the geostatic load, P_{sp}, and the VAF have been determined the soil arch load can be found as shown in Equation 2-4 or 2-4(a).

Equation 2-4

$$W_A = (P_{sp})(VAF)$$

Where:

W_A = soil arch load, psi

P_{sp} = geostatic load, psi

VAF = vertical arching factor, unitless

Or, in metric units:
Equation 2-4(a)

Û $$W_A = (P_{sp})(VAF)$$

Where:

W_A = soil arch load, N/m^2

P_{sp} = geostatic load, N/m^2

VAF = vertical arching factor

Hydrostatic Loads

The pressure of groundwater must also be accounted for only if present at or above the pipe springline. Equations 2-5 and 2-5(a) provide the method to calculate hydrostatic pressure.

Equation 2-5

$$P_w = \frac{\gamma_w (H_g)}{144}$$

Where:

P_W = hydrostatic pressure at springline of pipe, psi

γ_w = unit weight of water, 62.4 pcf

H_g = height of groundwater above springline of pipe, ft.

Or, in metric units:
Equation 2-5(a)

Û $$P_w = (9.81)(\gamma_w)(H_g)$$

Where:

P_W = hydrostatic pressure at springline of pipe, N/m^2

γ_w = unit weight of water, 1000 kg/m^3

H_g = height of groundwater above springline of pipe, m

Foundation Loads

Some pipe installations are beneath or near foundations. This load contribution must be added to the soil column load before proceeding with the design process. Soil mechanics textbooks include procedures to determine the effect of foundation loads some distance away from the point of application.