Culvert

Guoping Tang

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Abstract

Equations for culvert calculations.

1 Inlet Control Equations

1.1 Unsubmerged Inlet Control Equations

$\frac{Q}{AD^{0.5}} \leq 3.5$ (1.93 SI)

$$\frac{HW_i}{D} = \frac{H_c}{D} + K\left[\frac{K_u Q}{AD^{0.5}}\right]^M + K_s S \tag{1}$$

1.2 Submerged Inlet Control Equations

$\frac{Q}{AD^{0.5}} \geq 4.0$ (2.21 SI)

$$\frac{HW_i}{D} = c\left[\frac{K_u Q}{AD^{0.5}}\right]^2 + Y + K_s S \tag{2}$$

where

HW_i = Headwater depth above inlet control section invert, ft (m),

D = Interior height of culvert barrel, ft (m),

H_c = Specific head at critical depth ($d_c + v_c^2/2g$), ft (m),

Q = Discharge, ft^3/s (m^3/s),

A = Full cross sectional area of culvert barrel , $ft^2(m^2)$,

S = Culvert barrel slope, ft/ft (m/m),

K_u = unit conversion factor, 1 for English units (1.811 for SI), and

K_s = slope correction, -0.5 (mitered inlets 0.7).

$$H_c = d_c + \frac{v_c^2}{2g} = d_c + \frac{v_c^2}{2g} = d_c + \frac{D_{h,c}}{2} = d_c + \frac{A_c}{2T_c} \tag{3}$$

2 Outlet Control

For full flow conditions, energy balance equation is

$$HW_o + LS + \frac{V_u^2}{2g} = TW + \frac{V_d^2}{2g} + H_L \tag{4}$$

where

HW_o = Headwater depth above the entrance invert in outlet control, ft (m),

V_u = Approach velocity, ft/s (m/s),

TW_o = Tailwater depth above the outlet invert, ft (m),

V_d = Downstream velocity, ft/s (m/s),

H_L = Sum of all losses including entrance ($H_e = K_e \frac{V^2}{2g}$), friction ($H_f = \frac{K_u n^2 L}{R^1.33} \frac{V^2}{2g}$), exit ($\frac{V^2}{2g} - \frac{V_d^2}{2g}$), and other losses)$H_b$, H_j, ft (m),

K_u = unit conversion factor, 29 for English units (19.63 for SI),

L = Length of the culvert, ft (m), and

S = Culvert barrel slope, ft/ft (m/m),

In general, V_u and V_d are neglected

$$HW_o = \max(TW, \frac{d_c + D}{2}) + H_L - LS = \max(TW, \frac{d_c + D}{2}) - LS + \left(1 + K_e + \frac{K_u n^2 L}{R^1.33}\right) \frac{V^2}{2g} \tag{5}$$

with $V = Q/A$ where A is the full cross section area.

For unsubmerged outlet,