Debris Control for Culverts and Bridges

An Online Continuing Education Course for Engineers

Course Number: C-7005

Credit: 7 Hours / 7 PDH / 7 CPD

Debris Control for Culverts and Bridges

LIST OF SYMBOLS

A	=	Cross sectional area of flow, m^2 (ft^2)
A_B	=	Net area of the bridge opening, m^2 (ft^2)
A_{bu}	=	Net area of the bridge opening at the upstream face of the bridge, m^2 (ft^2)
A_{bd}	=	Net area of the bridge opening at the downstream face of the bridge, m^2 (ft^2)
A_c	=	Unobstructed cross-sectional flow area in the contracted section, m^2 (ft^2)
A_d	=	Cross-sectional flow area blocked by debris in the contracted bridge section, m^2 (ft^2)
A_D	=	Area of wetted debris based on the upstream water surface elevation projected normal to the flow direction, m^2 (ft^2)
A_{hd}	=	Area of the vertically projected, submerged portion of the debris accumulation below the downstream water surface, m^2 (ft^2)
A_{hu}	=	Area of the vertically projected, submerged portion of the debris accumulation below the upstream water surface, m^2 (ft^2)
A_o, A_i	=	Outlet and inlet storm drain cross-sectional areas, m^2 (ft^2)
A_o	=	Orifice area, m^2 (ft^2)
A_{rack}	=	Area of debris rack, m^2 (ft^2)
B	=	Blockage ratio
C	=	Expansion and contraction loss coefficients
C_g	=	Discharge coefficient for sluice gate type of pressure flow
C_d	=	Discharge coefficient for fully submerged pressure flow
C_D	=	Drag coefficient
C_w	=	Discharge coefficient for weir flow
DB_{EL}	=	Bottom elevation of the debris accumulation, m (ft)
D	=	Culvert diameter, m (ft)
DHW	=	Design high water elevation, m (ft)
D_o	=	Outlet pipe diameter, m (ft)
D_{50}	=	Mean riprap size, m (ft)
E_t	=	Total energy, m (ft)
F	=	Total segment force on the bridge structure, N (lbs)
F_D	=	Drag force, N (lbs)
F_{DEL}	=	Elevation of drag force on the bridge structure, m (ft)
F_{DST}	=	Station of drag force on the bridge structure, m (ft)
F_{EL}	=	Elevation of total segment force on the bridge structure, m (ft)
F_f	=	External force due to friction, N (lbs)
F_h	=	Total hydrostatic force on the bridge structure, N (lbs)
F_{hd}	=	Hydrostatic force on downstream side of the bridge structure, N (lbs)
F_{hEL}	=	Elevation of hydrostatic force on the bridge structure, m (ft)
F_{hu}	=	Hydrostatic force on upstream side of the bridge structure, N (lbs)
F_{hST}	=	Station of hydrostatic force on the bridge structure, m (ft)
Fr	=	Froude number
F_{ST}	=	Station of total force on the bridge structure, m (ft)
g	=	Acceleration due to gravity, 9.81 m/s^2 (32.2 ft/s^2)
h	=	Vertical distance from water surface to center of gravity of flow area, m (ft)

h_f	=	Friction loss, m (ft)
h_v	=	Velocity head, m (ft)
H	=	Increase in water surface elevation from the downstream side to the upstream side of the bridge, m (ft)
H	=	The difference in the upstream energy gradient elevation and the downstream water surface elevation, m (ft)
H	=	Height of debris-control structure, m (ft)
h_{cu}	=	Vertical distance from the upstream water surface to the centroid of area A_{hu}, m (ft)
h_{cd}	=	Vertical distance from the downstream water surface to the centroid of area A_{hd}, m (ft)
HGL_i	=	Hydraulic grade line elevation at the inflow pipe, m (ft)
HGL_o	=	Hydraulic grade line elevation relative to the outlet pipe invert, m (ft)
h_L	=	Energy head loss, m (ft)
H_w	=	Difference between the upstream energy and the road crest, m (ft)
INV	=	Inlet invert elevation, m (ft)
K	=	Conveyance, m^3/s (ft^3/s)
K	=	Yarnell's pier shape coefficient
K_c	=	Units conversion factor or coefficient
K_o	=	Expansion coefficient
L	=	Horizontal length of curve, flow length, length of basin at base length of pipe, or length of culvert, m (ft)
L_w	=	Effective length of the weir, m (ft)
n	=	Manning's roughness coefficient
P	=	Wetted perimeter, m (ft)
P	=	Hydrostatic pressure force, N (lbs)
Q	=	Flow, m^3/s (ft^3/s)
Q	=	Total discharge through the bridge opening, m^3/s (ft^3/s)
Q_w	=	Total discharge over the roadway approaches and the bridge, m^3/s (ft^3/s)
R	=	Hydraulic radius (flow area divided by the wetted perimeter), m (ft)
s	=	Spacing between the bars of a debris-control structure, m (ft)
S	=	Surface slope, m/m (ft/ft)
S_f	=	Friction slope, m/m (ft/ft)
S_L	=	Longitudinal slope, m/m (ft/ft)
S_o	=	Energy grade line slope, m/m (ft/ft)
SL	=	Main channel slope, m/km (ft/mi)
t	=	Bar thickness, m (ft)
T	=	Surface width of open channel flow, m (ft)
V	=	Mean velocity, m/s (ft/s)
V	=	Storage volume, m^3 (ft^3)
V_r	=	Reference velocity, m/s (ft/s)
V_2	=	Mean velocity for the cross-section at the downstream side of the bridge, m/s (ft/s)
V_3	=	Average flow velocity at the cross section immediately upstream of the bridge, m/s (ft/s)
y	=	Flow depth, m (ft)

y_r	=	Average flow depth corresponding with the reference velocity, m (ft)
Y_3	=	Hydraulic depth at the cross section immediately upstream of the bridge, m (ft)
w	=	Width of debris-control structure, m (ft)
W	=	Force due to weight of water in the direction of flow, N (lbs)
W_D	=	Width of debris accumulation defined by design log length, m (ft)
WS_{DS}	=	Water surface elevation downstream of the bridge, m (ft)
W_{min}	=	Minimum width of debris rack, m (ft)
WS_{US}	=	Water surface elevation upstream of the bridge, m (ft)
Z	=	Elevation above a given datum, m (ft)
z	=	Horizontal distance for side slope of trapezoidal channel, m (ft)
γ	=	Specific weight of water, 9810 N/m^3 (62.4 lb/ft^3) at 15.6 EC (60 EF)
γ_s	=	Specific weight of sediment particle, N/m^3 (lb/ft^3)
τ	=	Average shear stress, Pa (lb/ft^2)
ρ	=	Fluid density, kg/m^3 ($slugs/ft^3$)
ω	=	Ratio of velocity head to depth for the cross-section at the downstream side of the bridge
α	=	Obstructed area of the piers divided by the total unobstructed area for the cross section at the downstream side of the bridge
α	=	Apex angle for a culvert debris deflector, degrees

GLOSSARY

abutment: The structural support at either end of a bridge usually classified as spill-through or vertical.

aggradation: General and progressive buildup of the longitudinal profile of a channel bed due to sediment deposition.

alluvium: Unconsolidated material deposited by a stream in a channel, floodplain, alluvial fan, or delta.

average velocity: Velocity at a given cross section determined by dividing discharge by cross-sectional area.

backwater: The increase in water surface elevation relative to the elevation occurring under natural channel and floodplain conditions. It is induced by a bridge or other structure that obstructs or constricts the otherwise unobstructed flow of water in a channel.

backwater area: The low-lying lands adjacent to a stream that may become flooded due to backwater.

bank: The side slopes of a channel between which the flow is normally confined.

bank, left (right): The side of a channel as viewed in a downstream direction.

bankfull discharge: Discharge that, on the average, fills a channel to the point of overflow.

bar: An elongated deposit of alluvium within a channel, not permanently vegetated.

bed: The bottom of a channel bounded by banks.

bed load: Sediment that is transported in a stream by rolling, sliding, or skipping along the bed or very close to it; considered to be within the bed layer.

bed material: Material found on the bed of a stream (May be transported as bed load or in suspension).

boulder: A rock whose diameter is greater than 250 mm.

bridge opening: The cross sectional area beneath a bridge that is available for conveyance of water.

bridge waterway: The area of a bridge opening available for flow, as measured below a specified stage and normal to the principal direction of flow.

channel: The bed and banks that confine the surface flow of a stream.

channelization: Straightening or deepening of a natural channel by artificial cutoffs, grading, flow-control measures, or diversion of flow into a man-made channel.

clay: A particle whose diameter is in the range of 0.00024 to 0.004 mm. cobble: A rock whose diameter is in the range of 64 to 250 mm.

constriction: A natural or artificial control section, such as a bridge crossing, channel reach or dam, with limited flow capacity in which the upstream water surface elevation is related to discharge.

contraction: The effect of a natural or man-made channel constriction on flow streamlines.

countermeasure: A measure intended to prevent, delay or reduce the severity of stream or river problems.

contraction scour: Contraction scour, in a natural channel or at a bridge crossing, involves the removal of material from the bed and banks across all or most of the channel width. This component of scour results from a contraction of the flow area at the bridge which causes an increase in velocity and shear stress on the bed at the bridge. The contraction can be caused by the bridge or from a natural narrowing of the stream channel.

cross section: A section normal to the trend of a channel or flow.

culvert: A drainage conduit that conveys flow from one side of an embankment to the other.

dam jam: A type of debris jam that extends entirely across the channel as a result of the debris length being approximately equal to the channel width.

debris: Floating or submerged material, such as logs, vegetation, or trash, transported by a stream.

debris accumulation: The collection of debris material on a fixed object.

debris cribs: Open crib-type structures placed vertically over the culvert inlet in log- cabin fashion to prevent inflow of coarse bedload and light floating debris.

debris dams and basins: Structures placed across well-defined channels to form basins that impede the streamflow and provide storage space for deposits of detritus and debris.
debris deflectors: Structures placed at the culvert inlet to deflect the major portion of the debris away from the culvert entrance.

debris fins: Walls built in the stream channel upstream of a culvert or bridge. Their purpose is to align debris, such as logs, with the axis of the culvert or bridge so that the debris will move through the culvert or bridge opening.

debris jam: Accumulation of floating or neutrally buoyant debris material formed around large, whole trees that may be anchored to the bed or banks at one or both ends, once in the stream system.

debris racks: Structures placed across the stream channel to collect the debris before it reaches the culvert entrance. Debris racks are usually vertical and at right angles to the streamflow, but they may be skewed with the flow or inclined with the vertical.

debris risers: A closed-type structure placed directly over the culvert inlet to cause deposition of lowing debris and fine detritus before it reaches the culvert inlet.

deflector jam: A type of debris jam that redirects the flows to one or both of the banks. These types of jams usually occur when the channel width is slightly greater than the average tree height.

degradation (bed): A general and ... the channel bed due to erosion over a ...

design log le... nt and insufficiently strong throug... their length. This length does not repr... ershed upstream of the site.

detritus: Non-... . Fine detritus is a fairly uniform ... g debris, tending to deposit upon d... vel or rock fragments.

dike: An imper... or containment of overbank flow. ... evee in that it extends for a much shor... ater during floods.

dike (groin, spur... hat is designed to: (a) reduce the str... ouraging sediment deposition along ... y from the streambank (impe...

drift: Alternative t... through a river.

eddy current: A v... of a fluid flowing contrary to the main current, such as the rotational water movement that occurs when the main flow becomes separated from the bank.