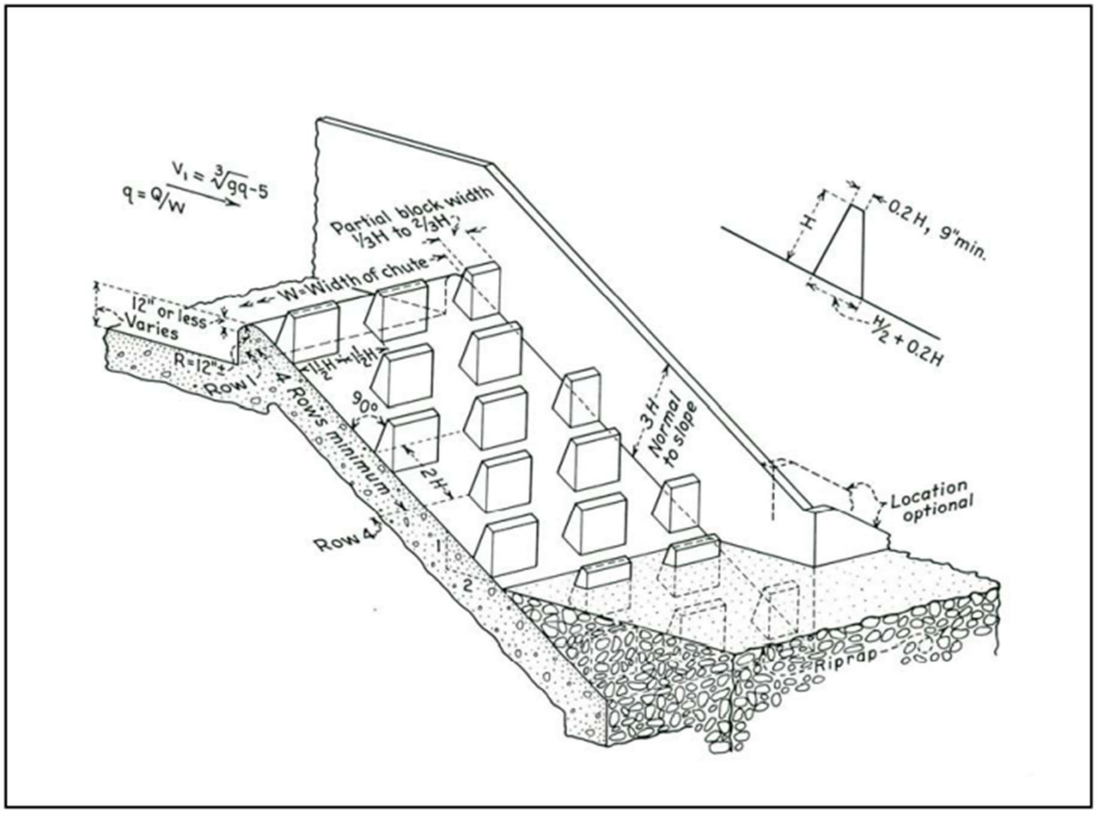
Energy dissipation in canal

The velocity of flow can be decreased significantly by applying number of baffles at the bottom of the culvert as suggested by USBR TYPE IX BAFFLED APRON. This method is very popular in energy dissipation in the drainage canal in highway. Peterka (1978) has described the design process for a baffled apron that makes the use of roughness elements on the floor of a box culvert or chute as given in the following figure.



The limitation of the design is as follows

1. Culvert/chite slopes of no greater than 50% (1:2) and no less than 25% (1:4).
2. Unit discharge less than or equal to 5.6 m3/s.
3. Approach velocity less than critical velocity (Froude number prior to drop less than 1).

The baffled apron is not a device intended to slow excessive aproach velocity, but to prevent excessive acceleration during the vertical drop. According to Peterka (1978), the recommended approach velocity is 1.5 m/s less than critical velocity. Velocities near or above critical velocity tend to cause the flow to be thrown into the air after striking the first row of baffles and jumping past the first two or three baffle rows. This is of particular concern for relatively short aprons. One strategy for reducing the approach velocity is providing a recessed approach prior to the entrance of the apron.

Another key design element is the selection of the baffle dimensions (height, width, and spacing). Based on model testing and prototype observations by Peterka, baffle height, H, should be about 0.8 times the critical depth, yc. The height may be increased as high as 0.9yc, but should not be less than 0.8yc.

The size of baffles, their spacing are given in above figure.

Required input data:

Q = Design discharge

D = Depth of Culvert

B = Width of culvert

Approach Channel:

n= Manning's roughness constant

S_0=longitunal slope

Box/Chute:

n= Manning's roughness constant

S_0= longitunal slope

Design steps

1. Compute normal flow conditions in the culvert/chute to determine if the discharge conditions at the outlet require mitigation.

Since the culvert has been used for incoming of flow to the box culvert

$$Q = \frac{1}{n} A R^{\frac{2}{3}} S_0^{\frac{1}{2}}$$

Using hit and trial determine normal flow depth yn at the entrance. In excel, use Goal-seek for hit and trial.

Calculate velocity using Manning's equation using yn.

$$v_n = \frac{1}{n} R^{\frac{2}{3}} S_0^{\frac{1}{2}}$$

If vn>3 then the energy dissipation requires.

2. Verify that the approach flow conditions are acceptable.

Calculate normal depth of the approach culvert using Manning's Equation same as Step 1 and then flow velocity at approach culvert.

Calculate critical velocity using the formulas

$$q_s = \frac{Q}{B}$$

Where ba is width of approach culvert

And critical velocity

$$V_c = (q_s g)^{\frac{1}{3}}$$

Where g is acceleration due to gravity.

If V_c > V_n (approach velocity) and the unit discharge is less than 5.6 /s/m, the baffled apron is applicable

3. Compute the discharge velocity

$$V_d = \frac{1}{3} * V_c$$

If V_d <3 m3/s then application of this method valids

4. Size the baffle height, spacing, and other design features.

$$y_d = \frac{q_s}{V_c}$$

$$H = 0.8 y_d$$

Baffle height =	*H*
Baffle width =	*1.5H*
Baffle spacing (Horizontal) =	*1.5H*
Vertical drop between baffle rows	*0.89H*
Spacing (measured along apron) =	*2H*
Minimum side wall height =	*3H*
No of rows of baffles	*nr*

The outgoing velocity from the culvert is V_d

Design of Energy dissipation structure(USBR Type IX Baffle Apron)

Project Name: Date: 2/3/2023
Structure:
Prepared by: Checked by: Approved by:

Input

Design discharge		*Q*	2.8	m^3/s
Vertical drop of canal		*h*	8	m
Type of Energy dissipation		USBR Type IX		
Structure		Approach Culvert	Culvert	
Provision		Yes		
Longitudinal slope	*S*	100	3	*1V:H*
Manning's constant	*n*	0.02	0.013	
Width	*B*	1.2	1.2	m

This method works for Q<5.6 m3/s Slope <50% and >25% and approach velocity less than critical velocity

Calculation

Normal depth of Culvert	*yn*	0.19	m
Velocity of flow at culvert	*vn*	12.24	m/s
Requirement of EDS		Yes	
Normal depth of Approach Culvert	*yac*	0.92	m
Velocity of Approach Culvert	*vac*	2.54	m/s
Critical velocity at approach culvert	*vacc*	2.84	m/s
Provision of baffle aproan		Applicable	
Discharge velocity of culvert	*vd*	0.95	m/s
Application of USBR Type IX		Yes	
Cricitical depth at culvert		0.82	m
Sizes of structures			
Baffle height =	*H*	0.66	m
Baffle width =	*1.5H*	0.99	m
Baffle spacing (Horizontal) =	*1.5H*	0.99	m
Vertical drop between baffle rows	*0.89H*	0.59	m
Spacing (measured along apron) =	*2H*	1.31	m
Minimum side wall height =	*3H*	1.97	m
No of rows of baffles	*nr*	13.00	
Length of apron =		17.09	m
Outlet velocity =		0.95	m/s

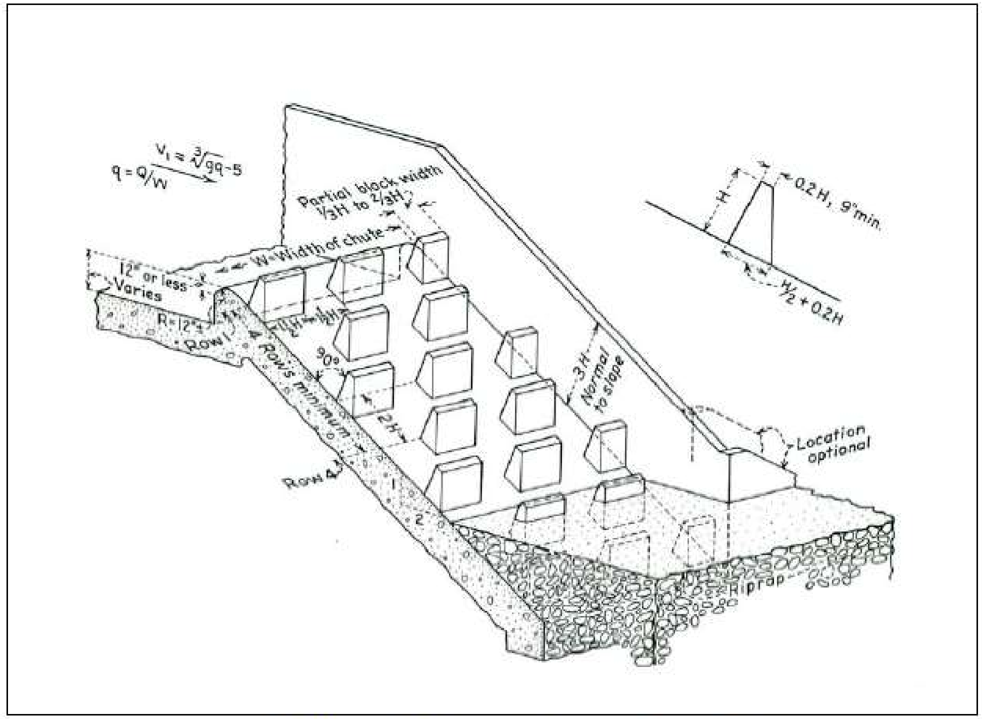


Figure 7.9 USBR Type IX Baffled Apron (Peterka, 1978)