DROP SPILLWAY

Drop spillway is a weir structure. Flow passes through the weir opening, drops to an approximately level apron or stilling basin and then passes into the downstream channel. The different components (fig) of the drop spillway are: (1) head wall and head wall extension, (2) side walls, (3) wing walls, (4) apron and (5) Longitudinal and transverse sills

i) FUNCTIONAL USES:

a) Gully and ravine stabilization
b) Erosion control structures for stabilization of landslides and mined areas
c) Protection of fields, roads and hutments etc. from gullies
d) Grade control for stabilizing channels and waterways
e) Reservoir spillway where the total drop is relatively low
f) Control of irrigation water
g) Rain water harvesting

ii) ADAPTABILITY:

The drop spillway is an efficient structure for controlling low heads, normally up to 3meters.

iii) DESIGN OF DROP SPILLWAY:

a) Hydrologic design: The peak rate of runoff expected during the designed recurrence interval (RI) from the watershed can be computed using Rational formula as given below:

$$Q = \frac{CIA}{360} \qquad \text{.... (2.25)}$$

Where,

Q = Design peak rate of runoff, m^3/s,

C = Runoff coefficient,

I = Intensity of rainfall, mm/hr for the duration equal to time of concentration (Tc) of watershed and design RI, and

A = Area of the watershed, ha.

b) Hydraulic design: The discharge through a broad crested rectangular spillway is governed by the following formula:

$$Q = 1.711\, LH^{3/2} \qquad \text{.... (2.26)}$$

Taking into account the free board (f.b.) to be provided for the wave action, the above formula is modified as:

$$Q = \frac{1.711\, Lh^{3/2}}{(1.1 + 0.01\, F)} \quad \text{.... (2. 27)}$$

Where,

Q = Maximum discharge capacity of weir (including f.b.), m^3/s, L

= Crest length of weir, m,

H = Depth of flow over weir crest, m

h= Height of weir (including f.b.), m, and

F= Net drop from top of transverse sill to crest, m.

The peak discharge (Q) in Eq. 2.27 can be taken as the one calculated from Eq. 2.25. The net fall, F, is known from the survey of the site where the structure is to be located. Still Eq. 2.27 consists of two unknown variables L and h, hence the equation cannot be solved as such and requires hit and trial solution. To start with, one of the unknown values of L or h can be assumed based on nala/ gully cross section and computations are done as follows:

- Assume a suitable value of h such that h/F<0.5 (as h/F ratio increases, the tendency

To scour increases,this ratio should in no case exceed 0.75).

-Put this assumed value of 'h' in Eq. 2.27 and compute of 'L'.

- Check if L/h > 2. If not, assume another lower value of 'h' and compute corresponding

value of L as in step 2, till this condition is satisfied.

-See that the computed value of 'L' is appropriate with respect to width of the gully.

(c) Structural Design

After L, h and F have been decided by the hydraulic requirements, the dimensions of the components can be computed from the following empirical relations

E = Minimum length of head wall extension, m

= (3h + 0.6) or (1.5 F) whichever is greater **.... (2.28)**

L_B = Length of apron, m

= F (2.28 h/F + 0.52) **.... (2.29)**

S = Height of end sill, m = h/3 **.... (2.30)**

J =Height of wing wall and side wall at junction, m

= (2h) or [F + h + s - (L_B + 0.10)/ 2] **.... (2.31)**

$M = 2 (F + 1.33 h-j)$ **.... (2.32)**

$K = (L_B + 0.01) – M$ **.... (2.33)**

$S_h =$ Height of Longitudinal sill = h/4 **.... (2.34)**

$S_t =$ Height of transverse sill = h/3 **.... (2.35)**

d) Foundation design: Cutoff and toe walls are constructed below the ground level in foundation. Cutoff wall is constructed below the head wall to prevent seepage below the structure. Whereas, toe wall is extended below the front of apron to prevent undercutting. Scour formulae are adopted for the design of cutoff and toe walls as below:

Normal scour depth (NSD) = $0.473 (Q/f)^{1/3}$ **.... (2.36)**

Where, f = silt factor (1 to 1.2)

Maximum scour depth (MSD) = 1.5 x NSD **.... (2.37)**

The height of the cut-off and toe walls may be taken equal to MSD in Eq. 2.37.

e) Apron thickness: Thickness of the apron in plain concrete may be kept from 20 to 30 cm for over fall height (F) varying from 0.5 to 3.0 m. For masonry and gabion constructions, the same may be increased by 1.5 and 2 times, respectively.

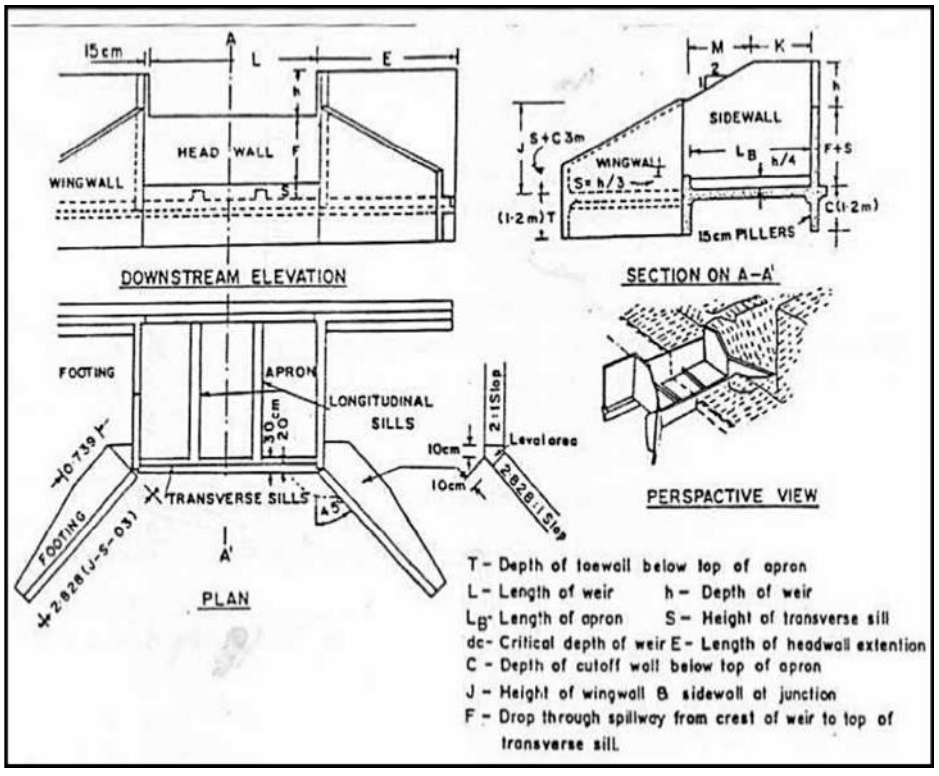

Figure: Nomenclature and symbols of drop spillway

f) Wall thickness: Top widths and minimum base widths of headwall, side wall, wing wall and headwall extension for different wall heights for different constructions can be determined using the formulae presented in Table.2.8

Table 2-8: Formulae for determination of base widths of different walls of a drop spillway in different constructions

Type of construction	Minimum top Width (m)	Walls	
		Head Wall	Side Wall
Plain concrete	0.25	0.67 (F-0.4) + 0.25	0.55 (F-0.45) + 0.25
Masonry	0.45 (head wall)	0.67 (F-0.67) + 0.45	0.55 (F-0.55) + 0.30
	0.30 (other walls)		
Gabion	0.75	0.67 (F-1.12) + 0.75	0.55 (F-1.40) + 0.75
F = height of wall from top of the crest to the bottom of apron.			

Table 2-9: Thickness of walls (m) of a drop spillway constructed in stone or brick masonry

Description	Head wall	Side wall
Minimum top width, m	**0.45**	**0.30**
Wall height (m)	**Recommended base widths**	
0.5	0.45	0.30
1.0	0.67	0.55
2.0	1.33	0.10
2.5	1.67	1.37
3.0	2.00	1.65

Example:

Design a drop spillway to be constructed in a gully having width of 5 m and the outlet of a watershed having an area of 58 ha. The net drop is 2.0 m. Take the rainfall intensity for duration equal to time of concentration of the watershed and design return period of 25 years as 120 mm/hr. The coefficient of runoff for the watershed is 0.3.

Solution:

1. Hydrologic design

The design peak runoff rate (m3/s) for the watershed from Rational formula is given as (Eq. 2.25):

$$Q = CIA/360 \quad \textbf{... (2.25)}$$

= (0.3 x 120 x 58)/360 = 5.8cum/s

2. Hydraulic design

The maximum discharge capacity of the rectangular weir is given by (Eq. 2.27):

$$Q = \frac{1.711\, Lh^{3/2}}{(1.1 + 0.01\, F)}$$

$$5.8 = \frac{1.711\, Lh^{3/2}}{(1.1 + 0.01 \times 2)} \quad (F = 2.0 \text{ m})$$

Therefore, $Lh^{3/2} = \frac{5.8 \times 1.12}{1.711} = 3.796$

To find suitable values of 'L' and 'h'

i) Assume L = 4.0 m (since width of gully is 5.0 m)

ii) Putting the above value

h3/2 = 3.796/4.0 = 0.949

h = (0.949)2/3 = 0.965 or say 1.0 m

iii) Test: L/h = 4.0/1.0 = 4.0 > 2 (O.K.), h/F = 1.0/2.0 = 0.5 < 0.5 (O.K.)

Hence, the designed hydraulic dimensions of the spillway are: Crest length (L) = 4.0 m

Weir depth (h) = 1.0 m

3. Structural design

The dimensions of the components of the structure (Fig. 2.35) are determined as below (using Eqs. 2.28 -2.37):

(i) Minimum head wall extension,

E = (3h + 0.6) or 1.5F, whichever is greater E = 3 x 1 + 0.6 = 3.6 m or 1.5 x 2.0 = 3.0 m Hence, E = 3.6 m

(ii) Length of apron or basin, $L_B = F\,(2.28\, h/F + 0.52)$

= 2 (2.28 x 1 + 0.52) = 3.32 m 2

(iii) Height of end sill, S = h/3 = 1/3 = 0.33 m

(iv) Height of wing wall and side wall at junction

J = 2h or [F + h + s – (LB + 0.10)/2]

= 2 x 1 or [2 + 1 + 0.33 – (3.32 + 0.10)/2]

= 2.0 or 1.62

Adopt J = 2.0 m

(v) M = 2 (F + 1.33 h-j) = 2 (2 + 1.33 x 1-2) = 2.66 m

(vi) K = (LB + 0.1) – M

= (3.32 + 0.1) – 2.66 = 0.76 m

(vii) Depth of foundation

Normal scour depth (NSD) = $0.473 (Q/f)^{1/3}$

= $0.473 \times (5.8/1.2)^{1/3}$ = 0.80 (taking f = 1.2)

Maximum scour depth (MSD) = 1.5 x NSD

= 1.5 x 0.80 = 1.2 m

Therefore, depth of foundation = 1.2 m

Apron thickness: For an over fall of 2.0 m, the apron thickness in concrete construction is 0.30 m if the structure is constructed in masonry or gabion, the same may be increased by 1.5 and 2.0 times respectively.

Wall thickness: The thickness of different walls of the structure (masonry construction) is given below:

Description	**Thickness of walls (m)**	
	Top width	**Bottom width**
Head wall	0.45	1.33
Side wall	0.30	1.10
Wing wall and head wall extension	0.30	0.80