DESIGN OF BELL-MOUTH SPILLWAY AT BARVI DAM

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Abstract - *Design of Bell-Mouth Spillway has special features, because the hydraulic behavior of this structure is strongly related to boundary topography crest diameter, curve or bend downstream, spillway profile and the funnel dimension towards the outlet section. In the case of Barvi Dam which is located on Barvi River near Badlapur in Thane district which has flooding nature mostly. So to overcome this condition, a solution adopted by foreign countries to stop the flowing water a Bell Mouth Spillway is widely used. The objective of this investigation is to study the flow conditions in Bell Mouth Spillway in order to develop design information. In this project we design spillway on the basis of determination of flow pattern, control condition, model capacity and inlet outlet data correspondence to dam site. The major effort of this investigation was to determine experimentally the flow conditions associated with incipient sealing in the horizontal leg of the spillway.*

Keywords**:-**Bell-mouth spillway, investigation,crest, model capacity, topography

1. INTRODUCTION

Spillway is a hydraulic structure which is used to divert overflow water from upstream to downstream side and prevent the overflow condition in reservoir.

i. BELL-MOUTH SPILLWAY

Bell-mouth is a funnel shaped structure by which water enter through entire perimeter. Bell-mouth is an uncontrolled spillway which can be controlled by providing mechanical gates. E.g. Morning Glory spillway, Plug hole .

ii. COMPONENTS OF BELL-MOUTH SPILLWAY

1) Crest
2) Mechanical gate/ Overflow piers
3) Transition tube
4) Vertical shaft
5) Circular bottom bend
6) Tunnel/Conduit

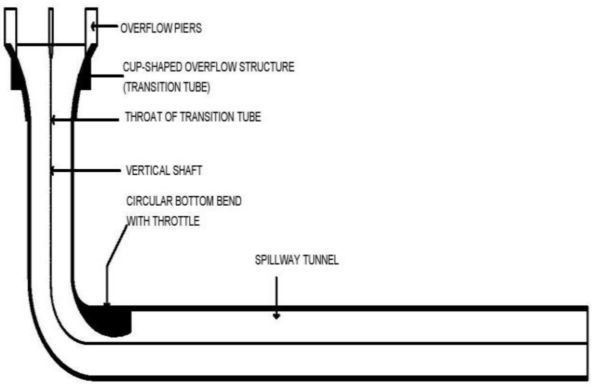

Fig No1: Cross section of bell-mouth

2. NEED OF PROJECT

- To create head for a turbine.
- To control the flood situation.
- Use the overflow water for the benefit for a city as shown below

1) For irrigation.
2) For Industrial use.
3) For domestic purpose.

Due to completion of 3rd stage of Barvi dam flood situation is developed. Due to this reason people residing there need to migrate.

3. METHODOLOGY

Year	Annual Rainfall
2016	2437
2015	1841
2014	2840
2013	3798
2012	2431

Table No1: Rainfall data

3.1 Calculation of design flood

Catchment Area = 166.08 km^2

From Inglis Formula,

Approximate Discharge,

$$Q = \frac{124A}{\sqrt{A+10.4}}$$

$$= \mathbf{1550.21} \frac{m^3}{sec}$$

1) Design Flood = 3118 cumec

& coefficient of Discharge, C_d=0.2

2) R.L. of Foundation Level = 48.78 m

R.L. of Spillway Crest = 68.6 m

Total Height of Dam = 76.22 m

Therefore, Height of Shaft = 68.6 – 48.78

H = 19.82 m

Assuming or constructing two No. of bell mouth spillway

For one bell mouth,

Discharge = $\frac{Q}{2} = \frac{3118}{2}$ = **1559 cumecs**

3.2 To find Diameter of Shaft

$$Q = \frac{2}{3} C_d \sqrt{2g}\, \pi D H^{\frac{3}{2}}$$

$$1559 = \frac{2}{3} \times 0.2 * \sqrt{2 * 9.81} * \pi * D$$

D = 9.52 = 10m

Check for Diameter/Radius:-

$$Q = \frac{2}{3} C_d \sqrt{2g}\, \pi D H^{\frac{3}{2}}$$

Where, Ha is the difference between the water surface and the elevation under consideration. Assuming losses to account for contraction, friction, etc. as 10% of the head

$$R = 0.275 \frac{Q^{\frac{1}{2}}}{Hd^{\frac{1}{4}}}$$

$$R = 0.275 * \frac{1559^{\frac{1}{2}}}{19.82^{\frac{1}{4}}}$$

R = 5.15m

Therefore, D =10.3m

Diameter of shaft = 10.3m

3.3 Calculate the crest discharge Q:

$$Q = C_o(2\pi R_s) H_o^{\frac{3}{2}}$$

Where,

C_o= Coefficient of circular crest

R_s= Radius of crest circle

H_o= Total head over the solid crest

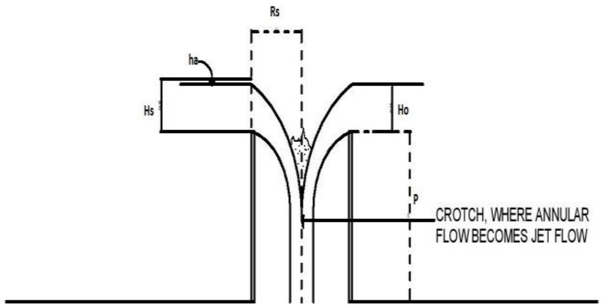

Fig No 2: crest profile

We have, Distance from the cross section in question to the crest,

H_s = 72.6 – 68.2 = 4 m

To Find:- H_o

Assuming Y_s= 0.4 m

Therefore, $H_o = H_s - Y_s$ = 3.6 m

3.4 To Find COEFFICIENT OF DISCHARGE (Co)

1) $\frac{H_O}{H_S} = \frac{3.6}{5.15}$

= 0.7

Ho/R (range)	PROFILE
<= 0.45	FREE FLOW
0.45 < X <1	PARTLY SUBMERGED
>=1	FULLY SUBMERGED

TABLE NO 2: Nappe profile

So, Ho/R is between 0.45 and 1

Therefore weir is partly submerged.

2) $\frac{P}{R_S} = \frac{19.82}{5.15}$

= 3.85

$\frac{P}{R_S} \geq 2$

Where, P = height of the crest shaft spillway from the bed

Therefore, , $\frac{P}{R_S} \geq 2$ & $\frac{H_S}{R_S} = 0.78$

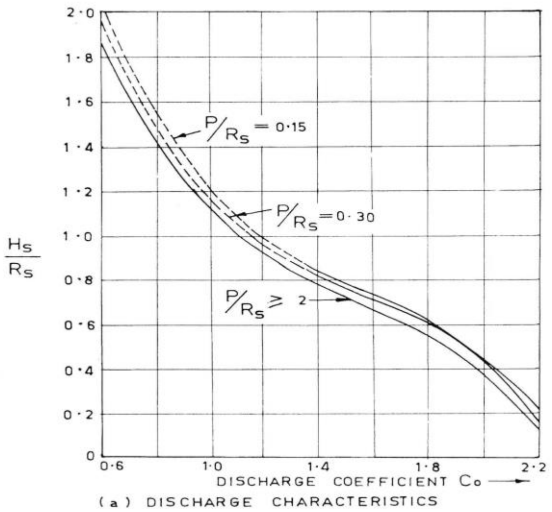

Fig No 3: Discharge characteristics based on Wagner

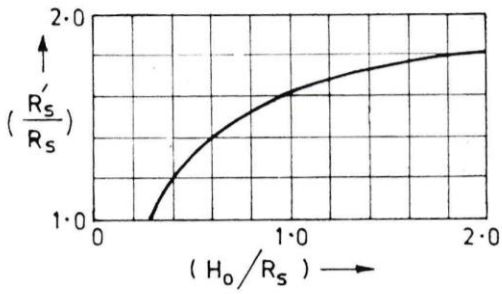

Fig No 4: Coefficient of discharge for heads other than design head

We get, Co=1.38

Therefore, Q = 1.38×2×π×5.15×$3.6^{\frac{3}{2}}$

Q = 305.01 cumecs

Therefore, Total discharge from two spillway = 2*Q
= 2*305.01

Q = 610.02 cumecs

3.5 Tunnel Design

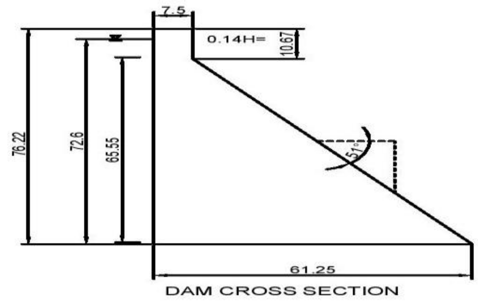

FIG NO 5: Barvi dam cross section

$$\theta = \tan^{-1}\frac{1}{0.82}$$

$$\theta = 50.65$$

$$\tan(50.65) = \frac{65.55}{X}$$

X = 53.75m

Therefore, total length = 61.25m
Length of dam in C/S = 61.25m

3.6 To find conduit diameter

We establish portal invert elevation or Rl of conduit placing = 48.78 $\cong 49m$ (assumed foundation level)

Case (1) The radius of the overflow crest may be any size, and sub atmospheric pressures along crest must be minimized:

$\emptyset = 5.6\ m$, R = 2.8 m

$$A = 0.75\pi r^2 = 0.75*\pi*2.8^2 = 18.47\ m^2$$

$$\text{Velocity} = = \frac{305.01}{18.47} = 16.51 \text{ m/s} = 54.17 \text{ feet/sec}$$

$$h_v = \frac{V^2}{64.4} = \frac{54.17^2}{64.4} = 45.56 \text{ feet}$$

$$\frac{d}{D} = 0.702$$

$$r = 0.2964*5.6*3.28 = =5.44$$

Submergence depth above crest cross section area of shaft,

$$\mathbf{S} = \left(\frac{Vn}{1.486 r^{\frac{2}{3}}}\right)^2 = \left(\frac{54.17*0.017}{1.486*5.44^{\frac{2}{3}}}\right)^2$$

$$\mathbf{= 0.04}$$

h_f = 0.063*61.25*3.28 **= 8.06 feet**

The invert elevation at the downstream portal of the conduit will then be equal to

(1) The elevation of the throat, plus
(2) The velocity head at the throat, minus
(3) The velocity head in the conduit flowing 75 percent full, minus
(4) The friction losses in the conduit, minus
(5) The depth of flow at the downstream portal.

The required portal invert elevation for this trial conduit diameter is approximately

$$\text{Required portal elevation} = 68.6*3.28 + \frac{1}{1.1}(72.6-68.6)*3.28-45.56-8.06-0.702*5.15*3.25$$
$$= 170.42 \text{ feet}$$
$$\cong \mathbf{51.96\ m}$$

Therefore , actual losses through the conduit be larger at invert elevation this diameter is correct

Required diameter of conduit or tunnel = 5.6 m

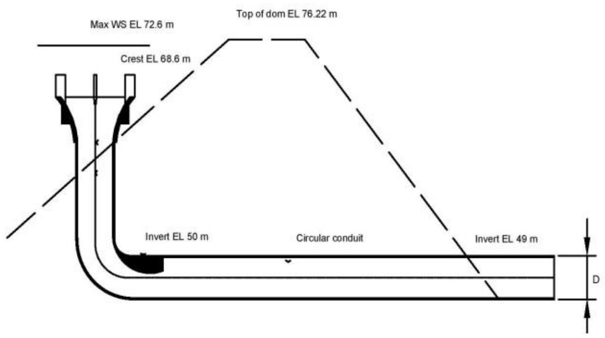

FIG No 6: Tunnel c/s

3.7 FORCES ACTING ON BELLMOUTH

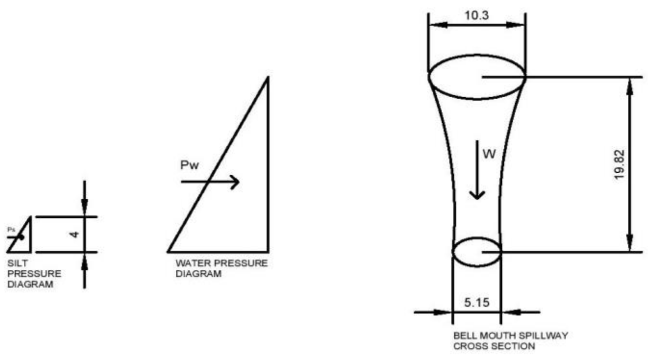

Fig No 6: Forces on shaft of bell-mouth

Table forces

1. **Water Pressure**

Table No 3: Water Pressure

Description	Force kN	Lever Arm	Moment
Water pressure	1926.84	6.61	12736.41

2. **Self Weight**

Table No 4: Self Weight

Description	Force kN	Lever Arm	Moment
Self Weight	30964.88	2.575	79734.57

3. **Silt Pressure**

Table No 5: Silt Pressure

Description	Force kN	Lever Arm	Moment
Silt Pressure	15.78	1.33	20.99

4. **Earthquake Pressure**

Table No 6: Earthquake Pressure

Description	Force kN	Lever Arm	Moment
Earthquake Pressure	246.76		2014.23

5. **Inertial Force due to earthquake**

Table No 7: Inertial force Due To earthquake

Description	Force kN	Lever Arm	Moment
Inertial Force due to earthquake	2786.84	2.575	7176.11

6. **Total Loads**

Table No 8: Load Combination

Description	Force kN	
	H	V
Water pressure	1926.84	
Self Weight		30964.88
Silt Pressure	15.78	

Earthquake Pressure	246.76	
Inertial Force due to earthquake	3715.79	-2786.84
TOTAL	5905.17	28178.04

Table No 9: Load Combination

Description	Moment (KNm)	
	Mr	Mo
Water pressure		12736.41
Self-Weight	79734.57	
Silt Pressure		20.99
Earthquake Pressure		2014.23
Inertial Force due to earthquake		7176.11 9568.16
TOTAL	79734.57	31515.95
	Ms=48218.62	

Where , H = horizontal force , V = vertical force

Mr =resisting moment, Mo= overturning moment

Stability check :-

FOS Overturning (F.S.) = $\frac{\Sigma M+}{\Sigma M-} = \frac{79734.57}{31515.95}$ = **2.53**

FOS Against Sliding (F.S.S.) = $\frac{\mu \Sigma V}{\Sigma H}$

$= \frac{0.55*28178.04}{5905.17}$

=2.62

Calculation of stresses

Normal stress

$\bar{x} = \frac{\Sigma M_s}{\Sigma V} = \frac{48218.62}{28178.04} = 1.71$ m

$e = \frac{b}{2} - \bar{x} = \frac{5.15}{2} - 1.71 = 0.865$m

$P_{n\,max/\,min} = \frac{\Sigma V}{b}(1 \pm \frac{\sigma e}{b})$

$= \frac{28178.04}{61.25}(1 \pm \frac{6*0.865}{61.25})$

P_{max} = **499.26** $\frac{kN}{m^2}$ $\quad P_{min}$ = **420.84** $\frac{kN}{m^2} > 0$

$\therefore safe$

Principle Stress, $\sigma = p_{n\,sec\,\emptyset^2} = 499.26*\sec(40)^2$

= 850.78

Shear stress, $\tau = P_{n\,\tan\emptyset} = 499.26*\tan(40)$

= 41.93 $\frac{kN}{m^2}$

3.8 Losses in shaft and tunnel/conduit

1. Friction loss in shaft and in the tunnel

$$SL = L\left(\frac{n^2}{R_H^{\frac{4}{3}}}\right)\left(\frac{Q^2}{A^2}\right)$$

N = Manning's constant = 0.017

Q = 305.01 cumecs

$A = \pi R^2 = \pi*5.15^2$

$R_H = 5.15$m

$L = 19.82 + 61.25 = 81.07$m

$SL = 81.07 *n\left(\frac{0.017^2}{5.15^{\frac{4}{3}}}\right) * \left(\frac{305.01^2}{83.32^2}\right)$

= 0.035 m

2. Entrance loss

$= 0.05 \frac{Q^2}{2gA^2}$

$= \frac{0.05*305.01^2}{2*9.81*83.32^2}$ = **0.034 m**

3. Losses at bend

$$\left(0.13 + 1.8\frac{r^{\frac{7}{2}}}{P}\right)\left(\frac{Q^2}{2gA^2}\right)$$

P = Radius of bend = 2.8m

R = Radius of shaft = 5.15 m

$(0.13+1.8*\frac{5.15^{\frac{7}{2}}}{2.8})(\frac{305.01^2}{2*9.81*(\pi*2.575^2)^2})$

= 12.12 m

4. Exit loss

$$0.2\left(1 - \left(\frac{A}{A_1}\right)^n\right)\left(\frac{Q^2}{2gA^2}\right)$$

A = cross section of tunnel

A_1 = wetted area at the tunnel exit

$= 0.2\,[1-(\frac{0.75*\pi*R^2}{\pi*R^2})] * (\frac{305.01^2}{2*9.81*(\pi*2.8^2)^2})$

= 0.39m

Total loss of head from tunnel and shaft

= 12.12+0.39+0.034+0.035
= 12.579m

4 RESULTS AND CONCLUSION

Table No 10: Design parameter

PARAMETER	VALUE
Total design flood	3118 cumec
Height of shaft (H)	19.82 m
No of bellmouth spillway	2 nos
Diameter of shaft	10.3 m
Bottom diameter of shaft	5.15 m
Condition of bellmouth spillway	Partly submerged
Discharge from one bellmouth spillway	305.01 cumec
Combined discharge of two bellmouth spillway	610.02 cumec
Length of Tunnel/conduit	61.25 m
Invert elevation of conduit/Tunnel	48.76 ~49 m
Diameter of conduit/Tunnel	5.6 m
Total loss of head through tunnel and shaft	12.579 m

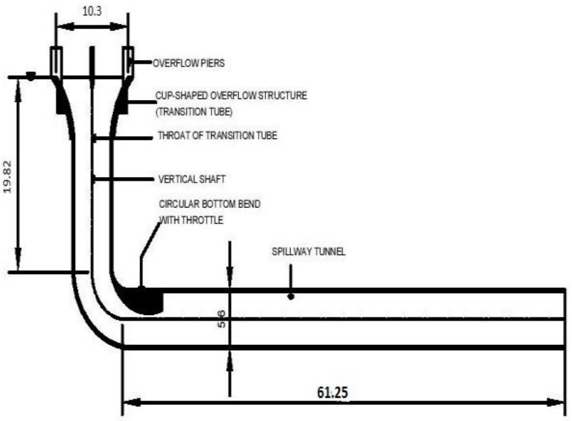

Fig No 6: Design C/S of Bellmouth

4. CONCLUSION

1. Flood situation of barvi dam and surrounding region can be controlled by constructing bellmouth spillway.
2. Hydroelectricity can be generated by installing the turbines through cannels.
3. Excess water can be used for agriculture and industrial purpose.

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