

SILENT FEATURES OF ARCHS BUTTRESS CHECK DAM

- 1) Horizontal thrust of water is resisted by the arch action of the arches which uniformly transfer the load to the buttresses.
- 2) The buttresses are supported on the mat or a raft foundation. In soil (where the hard foundation is available in deeper strata in case of hard/rocky foundation the buttresses are supported on a spread footing).
- 3) To prevent the flow/seepage underneath the check dam, a cutoff wall with minimum reinforcement is provided at the upstream edge of the foundation. The cutoff wall also prevent the horizontal sliding of the check dam (it acts as key wall).
- 4) Minimum reinforcement is provided in the arch portion of the dam, because all joints in the arch portion are in compression. The permissible compressive strength in concrete is taken as $f_c = 40 \text{ kg/sqcm}$ or 400 tone/cm^2 .
- 5) The buttresses are designed as cantilever fixed at the base as well as at the junction of arch and buttresses, suitable reinforcement is worked out for the same.
- 6) Field boulders/broken stones are filled in the arch cavity and between buttresses, these boulders
 - (a) Add to the weight which consequently increase the stability of the check dam with complete raft below the buttresses.
 - (b) The boulders also provide a D/S smooth sloping spillway so that the energy is dissipated without much scouring at the D/S.
- 7) However an energy dissipating device in the form of stilling basin is provided at the D/S.along with a small toe wall at the D/S edge of the stilling basin.
- 8) The check dam is checked for
 - a) Stability against over turning the factor of safety against over turning is taken as $F.S > 2$.
 - b) Factor of safety against sliding should be $F.S > 1$.
- 9) The angle subtended by the arch at the center varies from 100° to 140° . the numerical value of this angle θ for minimum concrete is $\theta = 133^\circ 34' 00''$ ($\theta = 2.331$ radians) which is very economical.

DESIGN DETAILS OF MULTIPLE ARCH BUTTRESS DAM

HYDRALLIC PERTICULARS OF NALA

- 1) Lowest nala bed level.-
- 2) H.F.L of nala –
- 3) Crust level of the structure –
- 4) Normal /Maximum scour level of the foundation-
- 5) Linear water way of the nala-
- 6) Catchment area of the nala should be arrived by the Topo sheet or area velocity method-

BY RYE'S FORMULA

Discharge $Q=C (A)^{2/3}$

where $C =10(\text{constant})$

$A=$ Area in sq km

$Q=$ Discharge in cumec.

While calculating the foundation depth the normal scour depth

$$D=0.473(Q)^{1/3}$$

$$f^{1/3}$$

where $f=1.0(\text{constant})$

in case of loose foundation the maximum scour depth $D_1=1.50xD$ should be adopted.

The scour level of the foundation should be worked out from H.F.L = scour depth

- 1) Consider span of nala 22.00mt, let us take spacing of buttresses 4.25mt, provide 5 arch bays $5 \times 4.25=21.25$ mt which remains bay to bay
- 2) For design let us consider one bay of check dam C/C of buttresses
- 3) Design of spillage :
 $Q= 10/3 \times L \times H^{2/3}$ where L is length of spillage
H is the depth of spillage
- 4) Thickness of arch = $w h r / F_e$

$$Y_c = 0.788 r = 1.82$$

$$CG = 1.82 - 0.91 + 1.20 = 2.11 \text{ mtr}$$

$$r_1 = 2.385 \text{ mtr (outer dia)}$$

$$Y' = 0.25 r_2 + 1.20 = 1.78 \text{ mtr}$$

$$r_2 = 2.235 \text{ mtr (inner dia)}$$

$$r_1 = 2.31 \text{ center}$$

$$\theta = 133^\circ 34' = 2.331 \text{ radians}$$

$$\sin \theta/2 = 0.919$$

$$\cos \theta/2 = 0.3942$$

$$\text{outer } D = 4.77 \text{ mtr}$$

$$\text{inner } d = 4.47 \text{ mtr}$$

$$\text{Center} = 4.62 \text{ mtr}$$

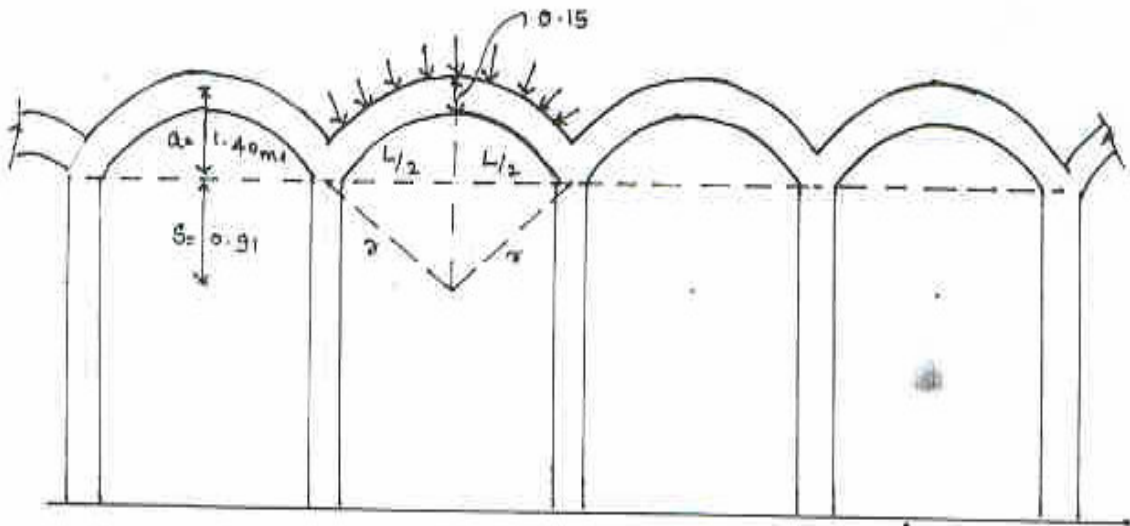
$$t = 0.15 \text{ mtr}$$

$$L/2 = r \sin \theta/2$$

$$L = 2r \sin \theta/2$$

$$= 2 \times 2.31 \times 0.919 = 4.2456$$

$$= 4.25 \text{ mtr}$$



$$t = whr/fc = 1 \times 2 \times 2.31/400 = 0.0115 \text{ mtr} \text{ or } 11.55 \text{ mtr} \text{ or say } 1.1 \text{ cm}$$

provide 15 cm of arch

$$\therefore fc = 40 \text{ kg/cm}^2 = 400 \text{ tn/m}^2$$

$$s = r \cos \theta/2 = 2.31 \times 0.3942 = 0.91 \text{ mtr}$$

$$a = r - s = 2.31 - 0.91 = 1.40 \text{ mtr}$$

$$L_{\text{arch}} = r \theta = 2.31 \times 2.331 = 5.38 \text{ mtr}$$

$$\text{Area of segment} = 0.803 \times (r_2)^2 = 0.803 \times 2.235^2 = 4.011 \text{ m}^2$$

Taking wt of stone boulders=2.08tn/m³

Cg of segmental area from B=1.20+0.25 x r₂=1758mtr

Uplift pressure at on arch A₁ of circular area=0.803(r₁)²=0.803x(2.385)²=4.56m²

A₂of base of the footing (base width of thefooting=0.45m)=0.45x1.20=0.54m²

Average stress at the circular segments=2x0.834/2=1.417tn/m²

CG of the Y circular =1.20+0.25r₁=1.20+0.25x2.385=1.796mtr.

$$\sum M_{-ve} = \sum M_w = 43.76 \text{tn}$$

$$\sum M_{-ve} = \sum M_{pv} = 17.42 \text{tn}$$

$$\text{F.S against overtiring} = \frac{\sum M_{-ve}}{\sum M_{ve}} = 43.76/17.42 = 2.51 > 2.00 \text{(Hence safe)}$$

Case II

Without boulder in the circular portion and no slab below the circular segment.

$$\sum M_{-ve} = 43.76 - 29.32 = 14.44 - 2.53 = 11.91 \text{ tn}$$

$$\sum M_{-ve} = 17.42 - 11.60 = 5.82 \text{ tn}$$

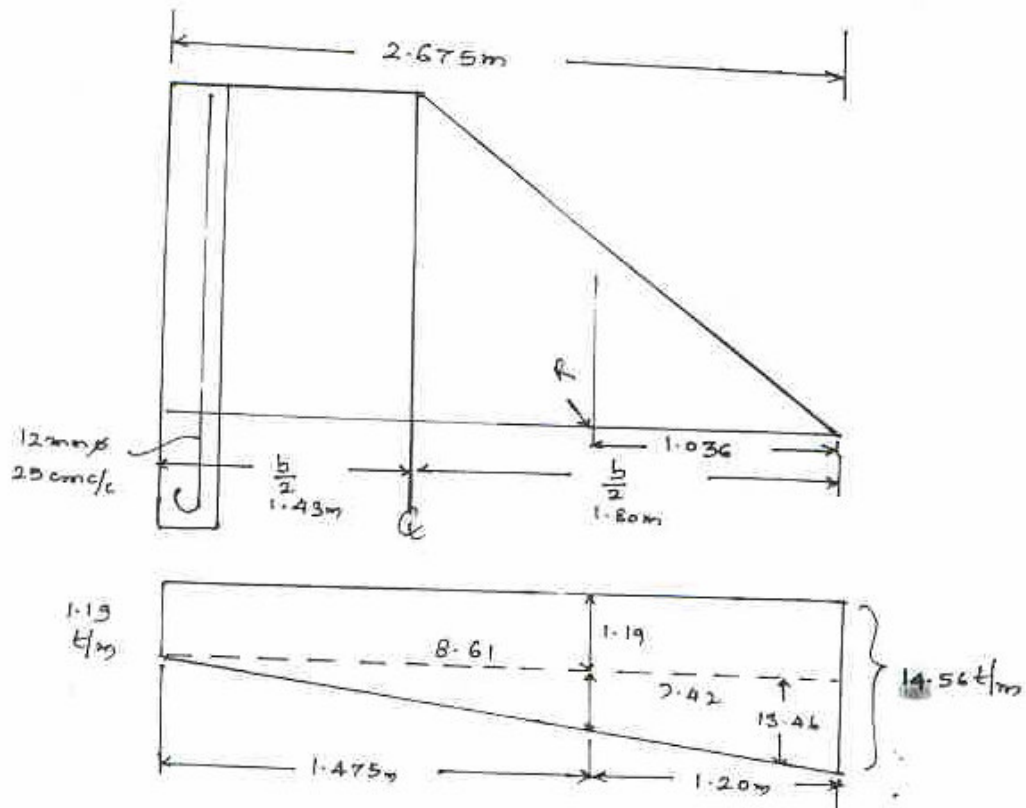
$$\text{F.S} = 14.44/5.82 = 2.04 > 2.00 \text{ (Hence safe)}$$

Pressure below foundation

For case I (with slab and boulders in circular areas)

$$x^- = (\sum M_{+ve} + \sum M_{-ve}) / \sum M_w = 43.76 - 17.42 / 17.43 = 1.51 \text{ mtr from the toe}$$

$$e = b / 2 - x^- = 2.675 / 2 - 1.51 = (-) 0.1725 \text{mtr}$$



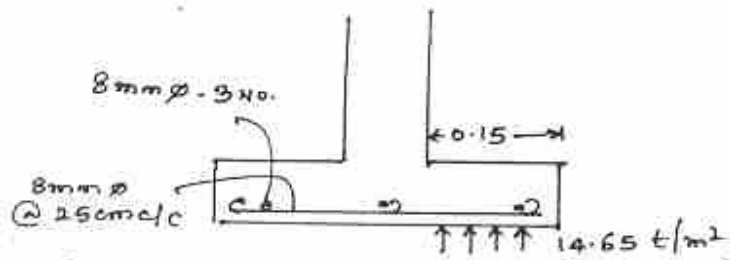
$$P_1 = \Sigma_w / d(1+6e/b) = 24.16 / 2.675 [1 \pm 6 \times (-) 0.1725 / 2.675] = 9.031 [1 \pm (-) 0.387]$$

$$= 9.031 \pm 3.494$$

$$P_1 = 9.031 - 3.494 = 5.537 \text{ tn} / \text{m}^2$$

$$P_2 = 9.031 + 3.494 = 12.525 \text{ tn} / \text{m}^2$$

DESIGN OF FOOTING



$P_1 = P_{\max} = 14.65 \text{ tn} / \text{m}^2 < \text{S.B.C of rock and crushing strength of concrete (300 tn/m}^2)$

Hence safe.

$M \text{ at f ax} = (0.15 \times 1) (14.65) \times 0.15 / 2$

$M_t = 0.165 \text{ t m} = 1.65 \times 10^6 \text{ N mm}$

$M = Qbd^2 = 0.87 \times 1 \times d^2 = 0.165$

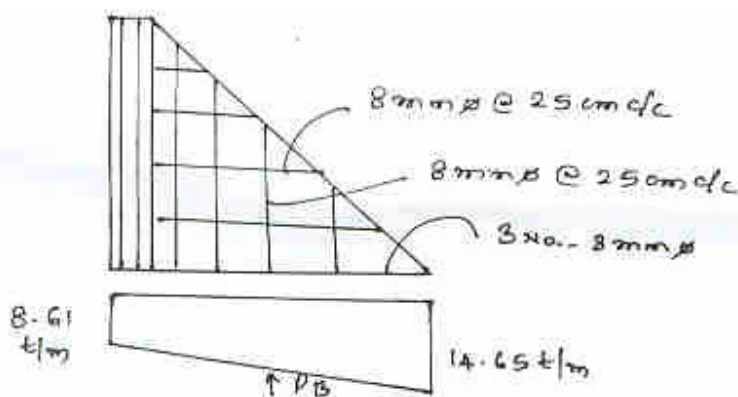
$Q = 0.874$

$D = \sqrt{M/Qxb} = \sqrt{1.65 \times 10^6 / 0.874 \times 10^3} = 43.67 \text{ mm} = 4.3 \text{ cm} < 15 \text{ cm}$

$A_{st} = M / \sigma_{st} \times j \times d = 1.65 \times 10^6 / 140 \times 0.87 \times 70 = 193.52 \text{ mm}^2$

$A_{\phi} = \pi / 4 \times (8)^2 = 50.26 \text{ mm}^2$

$s = 1000 \times 50.26 / 193.52 = 259 \text{ mm} = 25 \text{ cm C/C.}$



$P_b = (8.61 + 14.65) / 2 \times 0.45 \times 1.20 = 6.28 \text{ t m}$

$M_b = 6.28 \times 0.60 = 3.76 \text{ tn m} = 37.6 \times 10^6 \text{ kNm}$

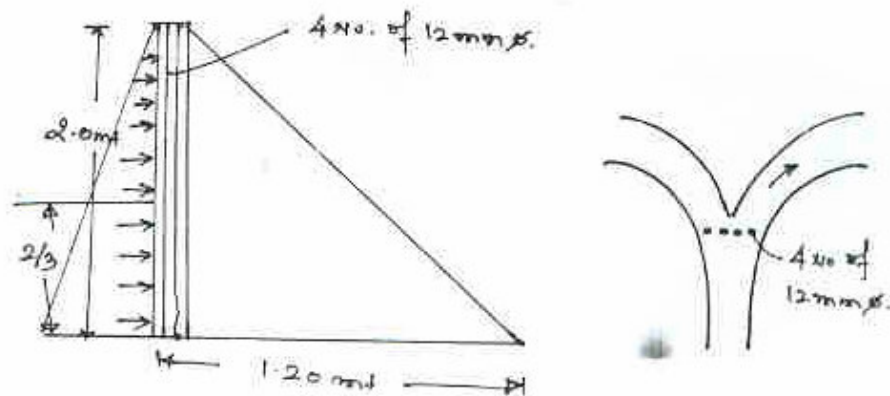
$$R = 0.874, j = 0.865$$

$$d = \sqrt{M/bxR} = \sqrt{37.6 \times 10^6 / 150 \times 0.874} = 536.118 \text{ mm} = 53.61 \text{ cm}$$

Provided 200cm (Hence safe)

$$A_{st} = M/\sigma_{st} \times j \times d = 37.6 \times 10^6 / 140 \times 0.865 \times 2000 = 155.29 \text{ mm}^2$$

Using 8mm ϕ , $A_{\phi} = 50.26$ Nos = $155.24/50.26 = 3.08$ Nos or say 3 Nos .



$$M_t = \frac{1}{2}(8.78) \times 2 \times 8.44 = 8.44 \times 8.44 = 5.62 \text{ tn} = 56.20 \times 10^6 \text{ kNmm}$$

$$D = \sqrt{56.20 \times 10^6 / 150 \times 0.874} = 654.73 \text{ mm} = 65.47 \text{ cm} < 120 \text{ cm (Safe)}$$

$$A_{st} = 56.20 \times 10^6 / 140 \times 0.865 \times 1200 = 386.73 \text{ mm}^2$$

$$A_{\phi} 8 \text{mm } \phi \text{ nos} = 386.73 / 50.26 = 7.69 = 8 \text{ bars of } 8 \text{ mm } \phi$$

$$A_{\phi} 12 \text{mm } \phi \text{ nos} = 386.73 / 113.10 = 3.41 = 4 \text{ bars of } 12 \text{ mm } \phi$$