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Government of Madras

Public Works DEPARTMENT

G.O. No. 2751 (9) Press

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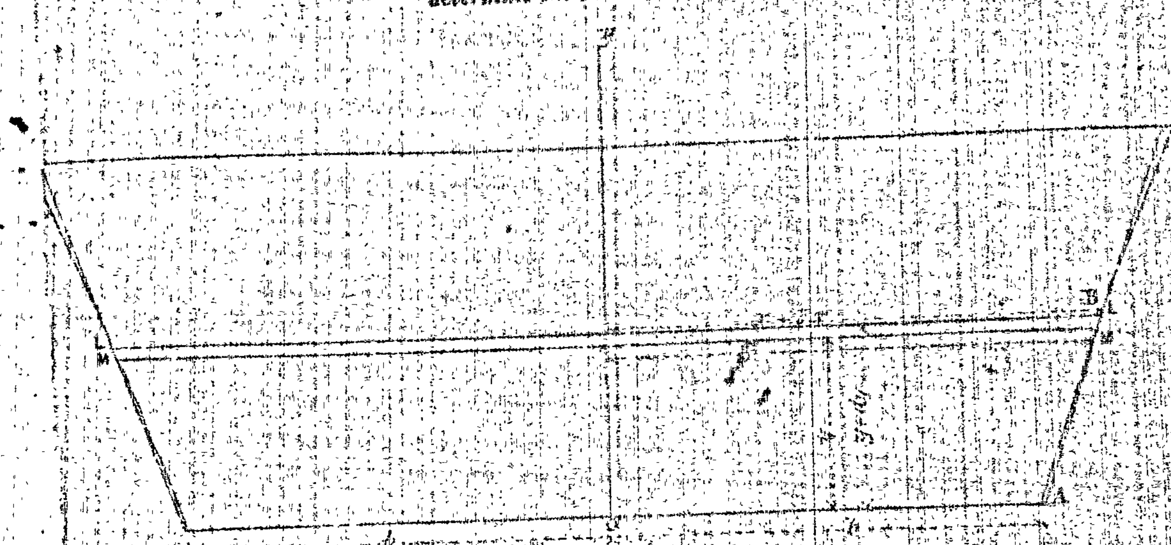
Proceedings of the Madras Government, Public Works Department, 22nd September 1875.

No. 533. Read the following Circular from the Government of India, Public Works Department (Civil Works—Irrigation), to the Governments of Madras, Bombay, Bengal, the North-Western Provinces, and the Punjab, in the Public Works Department, General and Irrigation Branches; the Chief Commissioners of Oudh, Central Provinces, British Burmah, Mysore and Coorg, and Assam; the Resident at Hyderabad; the Agents of the Governor-General for Central India and Rajpootana, dated Simla, 27th August 1875, Nos. 288-305 I.:—

The undersigned is directed to forward, for information, the accompanying formulæ for determining the form of a weir, when the water in a channel maintains a uniform shape up to the crest of an overfall for variable heads.

(Signed) G. T. SKIPWITH, Captain, R.E.,
Asst. Secy. to the Govt. of India.

If the water in a channel maintains a uniform slope up to the crest of an overfall for variable heads, to determine the form of the weir.



Let B = bottom width of canal.
" y = depth of water in the same.
" [illegible] = " on crest of weir.
" 1·5 = ratio of side slopes.
" i = slope of bed.
" C_c = co-efficient of discharge for canal.
" C_d = " " weir.

" $k = \frac{C_c^2 i}{2g}$, g being gravity.
" m = hydraulic mean depth.
" h = height due to velocity of approach.

Then $m = \frac{By + 1{\cdot}5\, y^2}{B + 3{\cdot}605 \ldots}$ ... ... (1)

[illegible] differential co-efficient of h. m. depth... (2)

And $\underset{c}{D} = (By + 1{\cdot}5\,y^2)\,\underset{c}{C}\sqrt{i\,m}$ = canal discharge per second.

$$= \sqrt{2g}\,(By + 1{\cdot}5\,y^2)\sqrt{k\,m} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

Let Fig. I be a section of the weir parallel to the crest;

„ b = half bottom width determined in the sequel;

Let (x^1, y^1) = co-ordinates of M, M^1, points in the perimeter with reference to rectangular axes $(o\,x, o\,y)$;

And $(x^1 + dx^1)$; $(y^1 + dy^1)$ = co-ordinates of $L\,L^1$, adjacent points to these;

Area of strip $L\,M^1 = 2x^1dy^1$, $L\,L^1$ being horizontal.

Discharge „ $= 2\,C_d\,x^1\sqrt{2g\,(y+h-y^1)}\,dy^1$

Total discharge over weir when depth of water in the canal is y feet

$$= D_w = 2C_d\sqrt{2g}\int_o^y x^1\sqrt{y+k\,m-y^1}\,dy^1 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

= discharge of canal for the same depth.

Hence $2C_d\sqrt{2g}\int_o^y x^1\sqrt{y+k\,m-y^1}\,dy^1 = \sqrt{2g}\,(By + 1{\cdot}5\,y^2)\sqrt{k\,m} \quad \ldots \quad \ldots \quad (5)$

Suppose A, B, C, D a trace of the slope of a trapezoidal weir drawn from the same starting point A, and so as to intersect the desired curved trace in one or more points B, C, &c.

From A to B the discharge from the curved form continues to increase over that of the trapezoidal one, and beyond No. 1 crossing point to No. 2 the trapezoidal one continues to gain on the curved form; hence at the points where the trapezoidal section cuts the curved one, $D_w - D_T$ is either a maximum or minimum, D_T being the discharge from a trapezoidal section.

$$\therefore \frac{d}{dy^1}(D_w - D_T) = 0$$

or $$\frac{dD_T}{dy^1} = \frac{dD_w}{dy^1}$$; and as $D_w = D_c$,

$$\therefore \frac{dD_T}{dy^1} = \frac{dD_c}{dy^1} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (6)$$

If $t \equiv$ tangent of angle between A D, and the vertical in the case of a trapezoidal section we have—

$$x^1 = t\,y^1 + b. \quad \text{Substituting in the general equation (4)} \quad \ldots \quad \ldots \quad (7)$$

$$D_T = 2\,C_d\sqrt{2g}\int_o^{y^1}(t\,y^1 + b)\sqrt{y + k\,m - y^1}\,dy^1$$

$$= \left[t\left\{\frac{4}{15}\left(\sqrt[3]{y+k\,m} - \sqrt[3]{k\,m}\right) - \frac{2}{3}y\sqrt[3]{k\,m}\right\} + b\left\{\sqrt[3]{y+k\,m} - \sqrt[3]{k\,m}\right\}\right]2\,C_d\sqrt{2g}$$

$$\frac{dD_T}{dy} = \left[\left\{\frac{2}{3}(1+k\,m^1)\left(\sqrt[3]{y+k\,m} - \sqrt[3]{k\,m}\right) - k\,m^1\,y\sqrt{k\,m}\right\}t + b\left\{(1+k\,m^1)\sqrt{y+k\,m} - k\,m^1\sqrt{k\,m}\right\}\right]2\,C_d\sqrt{2g} \quad \ldots \quad \ldots \quad (8)$$

By equation (3), $\frac{dD_c}{dy} = \left\{(B+3\,y)\sqrt{k\,m} + (By + 1{\cdot}5\,y^2)\frac{m^1\sqrt{k}}{2\sqrt{m}}\right\}\sqrt{2g}$

$$= \left\{(B+3\,y)\sqrt{k\,m} + \tfrac{1}{2}(B+3{\cdot}6055\,y)\,m^1\sqrt{m\,k}\right\}\sqrt{2g} \quad \ldots \quad (9)$$

Hence by (6), (8) and (9)—

$$\left[\left\{\frac{2}{3}(1+km^1)\left(\sqrt[3]{y+km} - \sqrt[3]{km}\right) - km^1y\sqrt{km}\right\}t + b\left\{(1+km^1)\sqrt{y+kn} - km^1\sqrt{km}\right\}\right]2C_d$$

$$= (B+3\,y)\sqrt{k\,m} + \frac{B+3{\cdot}6055\,y}{2}\,m^1\sqrt{m\,k}.$$

Transposing—

$$t = \frac{(B+3y)\sqrt{k\,m} + \frac{1}{2}(B+3{\cdot}6055\,y)\,m^1\sqrt{m\,k} - b\left\{(1+k\,m^1)\sqrt{y+k\,m} - k\,m^1\sqrt{k\,m}\right\}2C_d}{2\,C_d\left\{\frac{2}{3}(1+k\,m^1)\left(\sqrt[3]{y+k\,m} - \sqrt[3]{k\,m}\right) - k\,m^1\,y\sqrt{k\,m}\right\}}$$

By (7) $t = \frac{x-b}{y}$;

$$\therefore x - b = y\,\frac{(B+3\,y)\sqrt{k\,m} + \frac{1}{2}(B+3{\cdot}6055\,y)\,m^1\sqrt{m\,k} - b\left\{(1+k\,m^1)\sqrt{y+k\,m} - k\,m^1\sqrt{k\,m}\right\}2C_d}{2C_d\left\{\frac{2}{3}(1+k\,m^1)\left(\sqrt{(y+k\,m)^3} - \sqrt{(k\,m)^3}\right) - k\,m^1\,y\sqrt{k\,m}\right\}}$$

Removing the common factor $y^{\frac{3}{2}}$ from numerator and denominator,

Desired equation is—

$$x - b = \frac{(B+3\,y)\sqrt{k\,n} + \frac{1}{2}(B+3{\cdot}6055\,y)\,m^1\sqrt{n\,k} - b\left\{(1+k\,m^1)\sqrt{1+kn} - km^1\sqrt{k\,n}\right\}2C_d}{2C_d\left\{\frac{2}{3}(1+km^1)\left(\sqrt{(1+kn)^3} - \sqrt{(k\,n)^3}\right) - km^1\sqrt{k\,n}\right\}} \quad (10)$$

Where $n = \frac{m}{y} = \frac{B+1{\cdot}5\,y}{B+3{\cdot}6055\,y}$

$$m = \frac{By + 1{\cdot}5\,y}{B+3{\cdot}6055\,y}$$

$$\frac{1}{m} = \frac{B^2 + 3\,By + 5{\cdot}4083\,y^2}{(B+3{\cdot}6055\,y)^2}$$

$$b = \frac{3\,B}{4\,C_d}\,\frac{\sqrt{k}}{\sqrt{(1+k)^3} - \sqrt{k^3}}$$

C_d = co-efficient of discharge for weir.

C_c = „ „ canal.

i = Sine of the angle which the bed makes with a horizontal plane = slope of bed.

$$k = \frac{C_c^2\,i}{2g}$$

The above (10) is a relation existing between the horizontal and vertical co-ordinates of any point in the sides of the required weir.

To determine the half breadths b, b put in (10) $x = b$, & $y = o$,

when there results $\frac{1}{2}B\sqrt{k} - b\left(\sqrt[3]{1+k} - \sqrt[3]{k}\right)2C_d = o$.

Bottom half width—

$$b = \frac{\sqrt{k}}{\sqrt{(1+k)^3} - \sqrt{k^3}}\,\frac{3\,B}{4\,C_d} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (11)$$

11) is also arrived at by equating D_T to D_o thus—

$$\left[\frac{4}{15}\left(\sqrt[\frac{5}{2}]{y+km}-\sqrt[\frac{5}{2}]{km}\right)-\frac{2}{3}y\sqrt[\frac{3}{2}]{km}\right]+\frac{2}{3}b\left(\sqrt[\frac{3}{2}]{y+km}-\sqrt[\frac{3}{2}]{km}\right)\Bigg]2C_d\sqrt{2g}$$
$$=\sqrt{2g}\,(By+1{\cdot}5\,y^2)\sqrt{km} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (12)$$

Dividing by $y^{\frac{5}{2}}$, there results—

$$\left[\frac{4}{15}y\left(\sqrt[\frac{5}{2}]{1+kn}-\sqrt[\frac{5}{2}]{kn}\right)-\frac{2}{3}y\sqrt[\frac{3}{2}]{kn}\right]+\frac{2}{3}b\left(\sqrt[\frac{3}{2}]{1+kn}-\sqrt[\frac{3}{2}]{kn}\right)\Bigg]2C_d\sqrt{2g}$$
$$=\sqrt{2g}\,(B+1{\cdot}5\,y)\sqrt{kn} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (13)$$

(12) and (13) are only true when the trapezoidal section of water on the crest is so small in depth that the sides are sensibly very short straight lines, and is more exactly true the less y is. Putting $y = o$ in (13) as before, we get—

$$\frac{2}{3}b\left(\sqrt[\frac{3}{2}]{1+k}-\sqrt[\frac{3}{2}]{k}\right)2C_d=B\sqrt{k}$$
$$\therefore b=\frac{\sqrt{k}}{\sqrt{(1+k)^3}-\sqrt{k^3}}\cdot\frac{3}{4}\frac{B}{C_d}$$

Example.

Fall at 10th mile Kotlah branch, Sirhind Canal.

$B = 50$, $k=\frac{1}{6250}$, $g = 32{\cdot}2$, and suppose $C_d = {\cdot}5$ and $C_o = 90$.

(10) may be put in the form—

$$x=b+\frac{(B+3y)\sqrt{kn}+\left\{\frac{4}{3}(B+3{\cdot}6055\,y)+2C_d\,b\,k\right\}m^{\frac{1}{2}}\sqrt{nk}-2C_d\,b\,(1+km^2)\sqrt{1k+n}}{2C_d\left\{\frac{2}{3}(1+km^2)\left(\sqrt{(1+kn)^3}-\sqrt{(kn)^3}\right)-km^{\frac{1}{2}}\sqrt{kn}\right\}} \quad (14)$$

The curve and a trapezoidal section which nearly fulfils the conditions are shown in Fig. I, and the ordinates for these and four equivalent smaller ones in the following table :—

When (11) is substituted in (14), x is seen to vary inversely as C_d; so if it be determined to use some other constant, C instead of ·5, the corresponding ordinates will be exactly found by multiplying those in the following table by $\frac{\cdot5}{C}=\frac{1}{2C}$.

To find the direction of the curve at springing, differentiate x, and in the result put $y = o$; then tangent $i=\frac{dx}{dy_o}=$ ·307. See Fig. (2).

		One opening, true curve.	One opening, Trapezoidal.	Four openings, true curves.	Four openings, straight sides.	
	Y.					
2 x, the width of *one* opening	...	2 x	2 x	2 x	2 x	
	0	20·7097	20·7097	5·1774	5·1774	
	1′	21·2602	21·2506	5·3150	5·3376	
	2′	21·8704	21·9915	5·4698	5·4979	
	3′	22·5540	22·6324	5·6385	5·6581	
	4′	23·2733	23·2733	5·8183	5·8183	
	5′	24·0295	23·9141	6·0074	5·9785	
	6′	24·8162	24·5550	6·2040	6·1387	
	7′	25·6287	25·1959	6·4072	6·2990	
	8′	26·4631	25·8368	6·6158	6·4592	

A trapezoidal section approximately fulfiling the conditions will in general be best determined as follows :—By equation (14) calculate a sufficient number of points in the curve to allow of its being drawn. Then with the curve as a guide it will be possible by the eye to draw a line which will best serve all depths in proportion as they are likely to be practically used. This line may generally be drawn from the same springing point as the curve.

In the above example the line is drawn from the springing point of the curve, and passes through a point a little below where the surface of minimum supply cuts the curve.

For the higher discharges this trapezoidal in comparison with the curved area will appear to be scarcely sufficient; but it may be remarked about overfalls of this class in general that such is admissible, since the contraction in area of the higher layers is less than that of the lower ones, because the approaches of the former are more rounded off and easier than those of the latter.

Thus in practice it will be necessary to calculate by equation (14) the value of x when $y = o$, and when $y =$ the nearest whole number to the half depth of the maximum supply in the channel; a straight line drawn through the two points in the curve thus obtained may be produced as far as required, and will form one side of the trapezoidal notch.

No. 534. ORDER THEREON, 22nd September 1875, No. 2,751.

IRRIGATION, No. 50.

COMMUNICATED to the Chief Engineer for Irrigation and to the District Engineers, Godavery and Kistna.

(True Extract.)

(Signed) G. W. WALKER, Major-General, R.E.,
Secretary to Government.

To the Chief Engineer for Irrigation.
" District Engineer, Godavery.
" " Kistna.
" " Tanjore
" " Trichinopoly
" " Nellore

Exd. E. C. Shunker.

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GOVERNMENT OF INDIA.

PUBLIC WORKS DEPARTMENT.

CIVIL WORKS.

Irrigation.

To

THE GOVERNMENTS OF MADRAS, BOMBAY, BENGAL, THE NORTH-WESTERN PROVINCES, AND THE PUNJAB, IN THE PUBLIC WORKS DEPARTMENT, GENERAL AND IRRIGATION BRANCHES.

THE CHIEF COMMISSIONERS OF OUDH, THE CENTRAL PROVINCES, BRITISH BURMAH, MYSORE AND COORG, AND ASSAM.

THE RESIDENT AT HYDERABAD.

THE AGENTS OF THE GOVERNOR GENERAL FOR CENTRAL INDIA AND RAJPOOTANA.

Nos. 288-305 I.

Dated SIMLA, *August* 27, 1875.

Received Sept. 24—3

Forwards, for information, copy of formula for determining the form of a weir, when the water in a channel maintains a uniform slope up to the crest of an overfall, for movable heads.

Circ. of (1875) Subdrs.

PUBLIC WORKS.

To

Christopher Andrews

Dated

Filed

Ent.

22 Sept. 1875

Nos. 533-534

Formula for determining the form of a bevel Circular Metal Body, under forward Effort of —, when Vessel is Channel Mainsail Mizzen Stays of the Bed for reefed for heavily Reefs, Round Reefing Lugsail Storm Staysail Foresail and Trysail