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Dams and damming

Jay C. Cullings

DAMS AND DAMMING,

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Dams and Damming

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Jay Cullings.

Dams in general may be divided into the three distinctive titles of Coffer Dams, Weirs, and Reservoir dams

Coffer Dams are devices for for the exclusion of water from areas upon which are to be constructed foundations for buildings &c.

The most simple as well as the most usual form consists of two rows of piles driven around the area to be enclosed. one within the other and about four feet apart, this distance is regulated by the depth of water and strength of frame The piles are connected by stringers or wale pieces which are notched and bolted to the piles. The string pieces of the inner row are placed on the side of the piles toward the side to be enclosed and those on the outer toward the water These stringers are placed about two ft. above the level of the water.

Cross pieces of square timber connect the two rows of piles upon which they are notched and bolted to the stringers. These serve both to prevent the piles from spreading and as floor beams for the floor that supports the machinery used in construction.

On opposite sides to the wale pieces are placed interior stringer pieces which serve as guides and supports to the sheeting piles.

When the water is more than ten ft deep there should be other string pieces bolted to the piles interior sides to the top and bottom to give additional strength to the sheeting or to give the dam a greater strength by a frame work which occupies the enclosed area. Some times it becomes necessary to resort to both measures.

Against the interior stringers serving as guides are driven the sheeting piles; Ribbons are spiked on the interior of the sheeting piles, through them to the inner ties.

A puddling of clay is now rammed in between the sheeting, and the water pumped from the enclosed area.

The stability of this structure depends upon the space filled with puddling between the two rows of sheeting piles, the specific gravity of the puddling and the strength of the frame.

It is required to find the stability of a coffer in a depth of water of 10 ft. The depth of puddling 12 ft. Width between rows of sheeting 4 ft.

The moment of the puddling, held to form by the frame, about the lower inner edge, considering a unit length, is 120 x 12 x 4 x 2 = 1152 Wt. of a cu ft of clay = 120 lbs

The wt of the water into its lever arm of 1/3 the depth of water is

62.5 x 10 x 10 x 1/2 x 3 1/3 = 10416

Hence the clay held to place by the frame would be stable without the additional strength of frame, since the moment of the clay exceeds that of the water by 1104 lbs and will only require the frame to hold it firmly to place. Then if we find the dimensions of the pieces required to perform this duty the stability of the dam is determined.

The weight to be supported by each linear foot of the dam is given by taking the weight of a prism of clay the upper side of which is of which is horizontal the side toward the interior of dam is inclined to the vertical at an angle of 1/2 φ = 1/2 the angle of repose of clay = 8° and the other which coincides with the pile, is vertical and equal to 12 ft. ∴

log tan 8° + log 12 + log 12 = 1.30205 = volume of the prism and

1.30205 + log 120 = 3.38306 = log 2414.27 = the wt of prism to be supported

A pile in this frame is in the condition of a beam fixed at one end, supported at the other and loaded at the point of support. The load is transmitted to the stringers by the upper end of the sheeting piles and then to the cross pieces which have to sustain the [illegible] weight by the shearing strength of the notches.

We have then to find the weight transmitted by the sheeting piles to the cross pieces. To do this we consider a unit width of the sheeting as a beam fixed at one end, supported at the other and loaded at 1/3 its dist. length from the top. To find the strain upon the point of support at the top of the sheeting piles, [illegible] this stress by R_1. $R_1 + R_2 = 1214$. R_2 being that at the bottom and $\frac{R_1}{R_2} = \frac{8}{4}$ $\therefore R_1 = 2R_2 = 818$ lbs pressure to the linear foot on the stringer.

Now if we place the cross pieces at 4 ft apart each notch must have longitudinal shearing strength of 3232 lbs.

If heavy machinery is to be used in construction and other loads are to be supported upon the top of the dam the piles will act as pillars, and cross pieces as beams and must be made large enough to support the maximum load as well as to give additional strength to the dam.

Weirs. When a dam discharges the waste water over its top it is called a weir.

In many small dams the water flows over the whole length of the dam at certain times and the whole must be built to withstand the pressure and the action of water in falling over.

Many devices are resorted to for getting a head of water in shallow streams, such as a dam formed by simply piling in boulders as well as other crude devices, but more often a systematic and economical method is adopted as log dams, frame dams, stone dams etc.

Log Dams are made use of in situations where the head of water required is small, stream is narrow and depth of water not great.

In situations where timber is plenty a log dam is made with the least expenditure of money and labour.

A very economical form is that in which the trees are felled and the branches lopped then placed in a layer on the bed of the stream, with the tops up stream, and clay rammed in between them. After this has been done another should be started laying the butts several feet back of the first and more clay put in them. Back of these the dam proper is framed and laid in tiers with sticks of timber placed between and clay filled in between. These tiers should be laid so that the plane of the butts shall be in the form of an arc of a circle. The first layers with their projecting butts form protection to the foundation of the dam, from the eroding action of the water.

In each bank is built a crib filled with clay to protect the ends of the dam.

It is required to build a dam across a stream in which the greatest probable depth of water, after the erection of the dam is 10 ft. Height of dam is 6 ft.

The length of logs at the bed joint is given by the following formulae

$$z^2 = \frac{w' x^3 \sec^2 j}{6n(q-q')wh} - 2\,\frac{w x^2 (\frac{q}{2}+\frac{1}{4})\tan j}{2n(q-q')wh}\, z$$

In which z = the length of logs. w = weight of 1 cu ft of water. j the angle that the inner face makes with the vertical $\therefore \sec j = \frac{z}{x}$ and $\tan j = \frac{h}{\sqrt{z^2 - x^2}}$ in which h is the height of the dam, x the depth of the joint below the surface of the water. q = the ratio of the centre of resistance from the middle point of z which may be taken as ¼. q' = the ratio of the distance of the point where a line drawn vertically from the centre of gravity would cut the line z, from the middle point of z to the whole length t. which is 1/6. w is the weight of 1 cu ft of the material used in construction and n a numerical factor depending upon the figure of section which for a triangle is 1/2 making the substitutions in the above formulae there obtains the following result

$$z^2 = \frac{62.6 \times 1000 \times \frac{z^2}{36}}{6 \times \frac{1}{2}(\frac{1}{4}-\frac{1}{6})70\times 6} - \frac{62.6 \times 100(\frac{1}{2}+\frac{1}{4})\frac{6}{\sqrt{z^2-10}}}{\frac{1}{2}(\frac{1}{4}-\frac{1}{6})70\times 6} z$$

whence $z = 12$ ft

In building a dam of this sort logs of much greater length are usualy at hand and may as well be used their full length as to be cut of, the logs in each layer being of the same length a slight batter is given to the down stream face

If the above conditions are complied with the dam will be stable at all its points, provided the one at the bed joint is stable. and for it to be stable the following condition must be complied with

$$\frac{W'}{2nw\frac{z}{k}+w'\tan j} \leq \tan f$$

In which f = the angle of repose of the material at the foundation which for clay is about 18¼° and the tan f about .33⅓ making the substitutions in the preceding formulae

$\frac{62.5}{70\frac{12}{10}+62.5\times.90496} = .44$ which is greater than the tan φ hence we must increase the length the length, suppose we increase the length of foundation by means of projecting tiers to 40 ft for the value of the equation about .19 which would give the entire structure stability on a bed of clay.

Frame Dams. The application of frame dams is coming into quite general use in river improvements and this application has produced a form of dam peculiarly adapted to its use. This class of dams will be considered further on.

An example of a simple frame dam of wood is the following. It consists of a series of triangular frames resting upon sills lying across the stream in a direction perpendicular to its axis, and which rest upon short blocks of wood. These frames are covered by means of ties or floor beams which support a sheeting of boards. To prevent leakage these may either be tongued and grooved or battened and then pitched or any other common method which is convenient.

The frames consist of a beam or sill laid from one of the lower sills across to the other in a direction parallel to the axis of the stream, an inclined beam which is supported at the up stream end by the sill at the down stream end by an inclined strut which runs up from the down stream end of the sill perpendicular to the end of the inclined frame, and at the centre of pressure of the water by another inclined strut perpendicular to the frame.

The dam is anchored to place by the down stream sills projecting into a crib of logs in either bank and filled with clay and stone and the up-stream sill resting against the side of the crib, also by iron rods which pass through sills of frame and down into holes drilled into rocks in the bed of the stream secured by having the lower end split and an iron wedge started in the cleft, which when the rod is driven home spreads the rod to fit the drill hole.

That this dam should have the strongest form and to distribute the pressure on it more equally it should be built in, then, the shape of a portion of a polygon or convex up stream, in this form the

Sills would be chords of a circle cut from an arch having for their abutments the cribs in the flanges.

It is required to find the dimensions of the pieces of a dam, where the maximum depth of water shall not exceed 12 ft, height of dam 8 ft. length of oblique beam 21 ft

To find the stress upon the oblique beam and consequent dimensions, we have to consider a beam with three supports one at each end and one at an intermediate point, the centre of pressure of the water, under an uniform load and a constantly increasing load from the top downward.

Let a = the depth of the upper end of the beam below the surface of the water (4 ft) b = height of dam (8 ft), $2l$ = the length of the beam, $2l'$ the portion of the beam between the upper point of support and the one at center of pressure, $2l$ between bottom and centre of pressure Q' the point of support at the top, Q support at bottom and, P support a centre of pressure.

Letting $x \times w$ = the intensity of the uniformly increasing load, and $a w$ = the intensity of the uniformly distributed load, we shall have for the lengths of the pieces between the ends and the centre of presure.

$$2Z' = \frac{\int_0^{2c}(a+2x)\,w\,x\,dx}{\int_0^{2c}(a+2x)\,w\,dx} = \frac{2c}{3}\,\frac{a+2b}{a+b} = 10\tfrac{2}{3}$$

$$\therefore\ 2Z = 9\tfrac{1}{3}$$

We now have given $2Z' = 10\frac{2}{3}$, $2Z = 9\frac{1}{3}$, $2c = 20$, $a = 4$, $b = 8$ and $w' = 62\frac{1}{2}$ to find the weight upon Q', Q, and P.

$$Z^2Q + Z'^2Q' = \frac{Zw'}{8}(2d'Z'^3 - \tfrac{4}{5}Z'^4) + \frac{Zw'}{8}(2dZ^3 - \tfrac{4}{5}Z^4) \quad (1)$$

$$-\ Z^2Q + Z'ZQ' = \tfrac{1}{3}ZZ'(a'+2a)w' - \tfrac{1}{3}Z^3(a'+2b)w' \quad (2)$$

$$Z'^2Q' + Z'ZQ' = \frac{Zw'}{8}(2d'Z' - \tfrac{4}{5}Z'^4) + \frac{Zw'}{8}(2dZ^3 - \tfrac{4}{5}Z^4) \quad (3)$$

$$+\ \tfrac{1}{3}ZZ'(a'+2a)w' - \tfrac{1}{3}Z^3(a'+2b)w'$$

$$2cZ = b - a$$

$$a' = a + 2Z'Z$$

$$Zd' = a' - 2a$$

$$dZ = a + 2b.$$

$\log Z' = \log(\frac{16}{3}) = .726999$

" $Z =$ " $\frac{28}{6} = .669087$

" $\frac{1}{3} =$ 9.522876

" $a' = \frac{92}{15}$ − .787697

" $a =$ " $4 =$ .602060

" $b =$ " $8 =$ .903090

" $d' =$ " $(\frac{212}{5}) = 1.150246$

" $d =$ " $\frac{42}{3} = 1.141628$

" $\frac{4}{5} =$ 9.602660

" $Z'^2Q' = 1.453998 + \log Q' = \log(27.44\,Q')$

" $ZZ'Q' = 1.396086 +$ " $Q' =$ " $(24.889\,Q')$

" $\frac{1}{3}ZZ'a'w' = 1.706079 +$ " $w' =$ " $(50.884\,w')$

" $\frac{2}{3}ZZ'aw' = 1.821972 +$ " $w' =$ " $(66.39\,w')$

" $\frac{1}{3}Z^3a'w' = 2.317594 +$ " $w' =$ " $(207.77\,w')$

" $\frac{2}{3}Z^3bw' = 2.730017 +$ " $w' =$ " $(135.5\,w')$

$\log \frac{Zw'}{4} d' l'^3 = 3.821092 = \log 6623.6$

$\text{"} \frac{Zw'}{10} l'^4 = 2.603876 = \text{"} \; 401.68$

$\log \frac{Zw}{4} d l^3 = 3.648999 = \text{"} \; 4456.6$

$\text{"} \frac{Zw'}{10} l^4 = 2.398724 = \text{"} \; 250.45$

Substituting these values in the preceding formulae we shall have.

$$0.7.32\, Q' = (6623.6 - 401.68) + (4456.6 - 250.45) - (129856.25 + 8468.75) = 119943$$

$$Q' = -22937^{\#}$$

Now if the frames are placed 8 ft apart Q' becomes $18349^{\#}$ which substituted in eq (1) gives $Q = -15190^{\#}$ and these values in

$$P + Q + Q' = l(a'+b)w' + l'(a'+a)w' \quad (4)$$

$$P = -7007$$

Now if we make the frame uniform in cross section throughout its length as is usual, take moments at P we shall have the dimensions given by

$$18344 \times 10^{2}/3 = 1/6\, 1000\, b h^2$$

$$170722 = 1/6\, 1000\, b h^2$$

$$b h^2 = 1174\tfrac{1}{3}$$

Shall have to make the frame about 10" × 12"

The struts are given by the following formulae, For strut down stream

(1) $18349 = \dfrac{1000\, s}{1 + \frac{2}{125} \frac{l^2}{h^2}}$ in which s = section in sq in.

h = dimension in the direction of least resistance. l = length in inches, solving (1) we have the strut about 8" x 10" etc for the strut below the centre of pressure.

$70093 = 1000\,bh \therefore bh = 70.093$ or $b = 8$ $h = 9$ since the the pillar is short we may use 9"x8" timber.

To find the dimensions of the floor frames or ties upon which the covering rests and the manner of distributing them.

Suppose we place the ones at the bottom 1½ ft apart. Their dimensions are g amoved at as follows: 1st find the pressure of the water upon one which is $12 \times 8 \times 1\tfrac{1}{2} \times 62.5 = 9000$# which is divided equally between two frames.

Taking moments about one end

$4500 \times 4 = 18000$ hence the dimensions are given by

$18000 = \tfrac{1}{6}\,1000\,bh^2$

$\therefore$ Floor frames are 3" x 6

Now the load increases directly as the distance from the top, hence the distance between them may increase directly as distance from the bottom. We find that the distance between them at the top may be 4½ ft.

Then there should be 7 pieces 3x6 each placed 3/4 ft. higher up the frame than that preceding it.

Improvements of rivers for slack water navigation have produced a peculiar class of dams which are admirably adapted to the purpose which they serve

Many rivers are made navigable by damming and thus forming long pools deep enough for the draught of the boats to be used in their navigation

The boats are passed from one pool to another by means of locks This system is known by the title of lock and dam.

Fixed dams have been used for this purpose, but there is a great objection to these, in that, when the water in the stream is high enough for navigation without the aid of the lock and dam, that they are in the way of the free passage of boats up and down the stream

To overcome this difficulty, movable dams have been introduced There are two classes of these movable dams in general use

(1) Those which are manoeuvred by the aid of machinery and

(2) Those which are operated by the water itself.

Of the first class are the Poiree Trestle and Needle dam, The Chanoine wicket dam and the Boulé dam of trestles and sliding gates.

Of the second are the Bear trap dam, Desfontaines and the Girard dams.

The Poirée dam consists of a series of trapezoidal trestles, of iron, placed across the river parallel to its axis and about four feet apart. These are securely fastened to the bottom by means of an anchorage at each end of the lower portion. which is called the axis, and has at each end a journal which enters a journal box, which is anchored to the foundation.

The tops of the trestles are secured by connecting bars. The bars on the up-stream side are made stronger in order to support the upper ends of the needles. The up-stream member is called the stilt and stands almost vertical, the down stream one is more inclined and extends from the axis up to a level with the top of the up-stream member. and is connected with it by means of a cap. A diagonal member connects the top of the up stream member with the bottom of the down stream member.

The trestles revolve about the axis

in a direction perpendicular to the axis of the stream.

The needles are square wooden bars, which may be as much as fifteen feet long, they rest against the connecting bar at top and against a sill set in the foundation at the bottom

There are two manoeuvres of a needle dam, closing and opening.

The method of closing is as follows Suppose the dam to be entirely open with the trestles lying down. The tenders begin by grappeling for the trestle at the end of the series which is upper-most, with a long handled hook

The trestle may be raised by hand if not too heavy, but if it is the hook is fastened to a rope, by means of a ring in the end of the handle, and raised by a windlass, when the trestle is nearly up a man grapples it with a hand bar, with two clutches just the distance apart of two trestles when up. The trestle is held up by this bar until the second is raised when the connecting bar and planks are put in place, and the others raised in a similar manner.

When all of the trestles are raised to place and secured and secured the needles are put in place, one by one, from

from the top of the dam.

The objections to this dam are the number of pieces to be handled and then there frequently occur sudden rises in the water of rivers so that a dam of this description cannot be let down and thus from the same obstruction as a fixed dam.

The last objection has been overcome in the Belgian Meuse dam by letting the needle between two trestles all go at once by means of a jack post which is enclosed in an upright tube which extends up from the top of the up-stream member and acts as a post for the support of the bridge which is made of sheet iron, in sections of the width of the bridge and which are supported at one end on a trestle and at the other hinged to a bar on the top of the other trestle. The jack post is movable within the tube and is cut half way through by a notch near the lower end, about three inches long. There is also a corresponding notch in the tube. The jack post projects up above the bridge, terminating in a square end for the application of a wrench.

The needles are supported by a bar, one of whose ends is hinged to a trestle and the other supported within the slot in the tube containing the jack post turned so that the slot in it is away from the one in the tube, and when turned by a wrench at top brings it around to correspond with that in the tube, thus leaving the bar without support and it swings around to the side of the trestle to which it is attached. The needles are prevented from being lost by a rope which passes through the handles and is fastened to the bridge.

The Chanoine Dam consists of a series of panels independent of each other, three or four feet wide, and separated from those along side by an interval of about four inches. The panels are of wood and rectangular in shape, they oscillate about the top of a frame called a horse, which revolves about an axle at the bottom in a direction parallel to the axis of the stream and is capable of swinging its top down to the foundation in a down stream direction but is checked in the up-stream direction by a sill fixed in the foundation. The top of the horse is held to place by a prop, the upper end being attached to the head of the horse, and the bottom rests against a shoulder or hurter. A panel, horse and prop comprise a wicket.

The axle of oscillation of the panel is placed at one half the length of the panel, in the pass, and those of the weirs at a little greater distance above the centre of pressure in

When the water rises so as to raise the centre of pressure above the point of support the panel is swung.

The wickets of the pass should never swing. The face of the panel makes an angle with the vertical of 20° and the top inclines away from the water. The horse and the prop incline toward the water at angles of 5° and 53° respectively.

The wicket is _up_ when the prop rests against the hurter, and the lower end of the panel rests against the sill. It is _swung_ when the foot of the panel is up so that the water passes above and below it and down when lying down upon the floor

The Boulé Dam is essentially the same as the Poirée except that in the place of needles are substituted sliding panels made of a number of planks laid horizontally and manoeuvred by a windlass. This form is not in general use

The Bear Trap Dam consists of two leaves having their axes of revolution in the floor. One is arrainged so as to fall up and the other down-stream. The one that falls up-stream has its axis down-stream and the other visa versa

When the dam is down the upper leaf projects over the lower. A bar of wood is placed near the top of the upper gate and fastened to the lower side so that when they are raised together the two gates shall cheak each others motion by the upper edge of the lower coming in contact with the timber on the upper.

An auxiliary gate is placed in front of the up-stream gate to aid in raising the dam by forming a temporary head of water.

A channel runs through the pier for the passage of water from the upper pool to the lower with a side passage leading under the gates. Each end is provided with valves.

When the dam is to be raised the lower valve is closed and the upper opened. The auxiliary, which is secured to the bed by an axle immed-iately in front of that of the upper gate. The upper end of this gate is held down to the bottom by a trigger, the trigger tripped by a trigger rod which extends up from the bottom to the surface of the water.

When the gate is loosened by the rod the end rises by its own bouyancy until it is caught by the current and raised to position thus forming a temporary dam. The water raising in the upper pool exerts a pressure upon the gates and raises them to position The gates remains up as long as the water is kept in the channel

To let the water out the upper valves are closed and lower ones opened

Resiovor walls are built for the purpose of storing up water for the use of cities, canals, manufactories, agriculture and to prevent the inundation of adjacent lands. Frequently dams are constructed so as to serve several of these duties by the erection of only one structure.

One of the most noteworthy of the modern dams is that on the river Furens near the town of St Etienne. The conditions imposed upon this dam was that the resivor should supply the town and factories with water and prevent the town from inundation.

To accomplish the first of these duties a subterranean channel was cut through the counterfort against which the wall rests the resivor end of which is stopped with masonry through this masonry pass two cast iron pipes 4 in in diameter, which are supplied with stop cocks and which carry the water to a bay from which the reserved water is conducted through an ~~covered~~ open channel to the bed of the river, Regulated by a regulator sluice. Through a covered channel also provided with a regulator sluice, from which it may be either by means of a pipe directly or by means of a small resivor, conducted to the St Etienne aqueduct

The second purpose which it was to serve was accomplished by gates at the head of the resivoir. One of which shuts off the water of the river from the resivoir and the other that of the waste. Just above the gates there is a scale which shows the depth of the water. When the water reaches the depth of 93 cu m in per second the town begins to be innundated. The resivoir is not allowed to fill to a depth exceeding 44.5 m when the discharge is below 92 cu m per sec. this is done by closing the gate between the river and resivoir, and opening that of the waste.