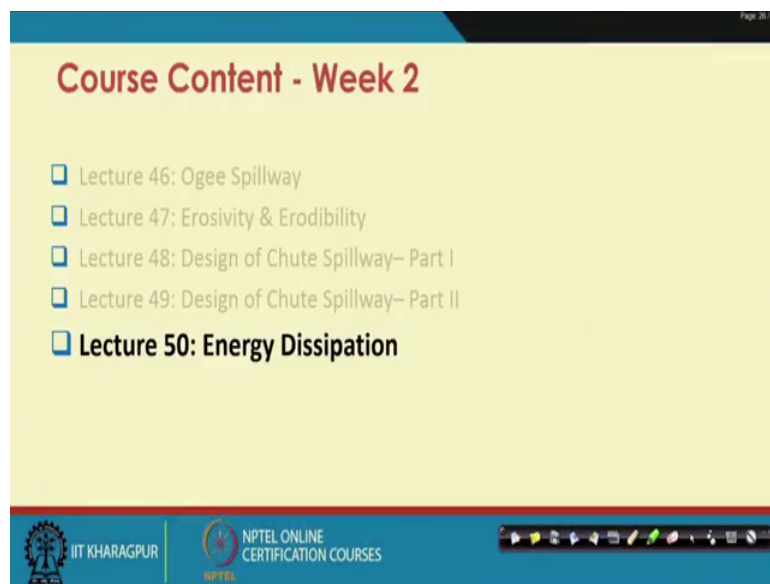


Soil and Water Conservation Engineering
Dr. Poulomi Ganguli
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Lecture – 50
Chute Spillway

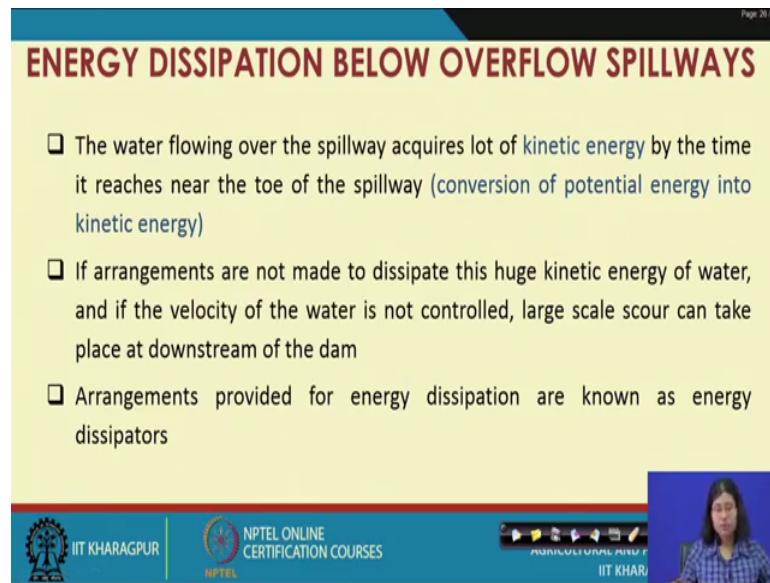
Hello this lecture is about the last component of the Chute Spillway Design that is the energy dissipation part. So, this is the last component the energy dissipation.

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So, first we went through the ogee spillway then the design principle of part one part two the last component is energy dissipation.

(Refer Slide Time: 00:39)



The slide is titled "ENERGY DISSIPATION BELOW OVERFLOW SPILLWAYS" in a red, bold font. It contains three bullet points, each preceded by a square icon with a checkmark. The first bullet point states that water flowing over a spillway acquires a lot of kinetic energy by the time it reaches the toe of the spillway, due to the conversion of potential energy into kinetic energy. The second bullet point explains that if arrangements are not made to dissipate this kinetic energy, and the water's velocity is not controlled, large-scale scour can occur downstream of the dam. The third bullet point notes that arrangements for energy dissipation are known as energy dissipators. In the bottom right corner, there is a small video inset showing a woman speaking. The slide footer includes the IIT Kharagpur logo, the NPTEL Online Certification Courses logo, and a navigation bar with icons for back, forward, and search, along with the text "IIT KHARAGPUR" and "NPTEL".

ENERGY DISSIPATION BELOW OVERFLOW SPILLWAYS

- ❑ The water flowing over the spillway acquires lot of kinetic energy by the time it reaches near the toe of the spillway (conversion of potential energy into kinetic energy)
- ❑ If arrangements are not made to dissipate this huge kinetic energy of water, and if the velocity of the water is not controlled, large scale scour can take place at downstream of the dam
- ❑ Arrangements provided for energy dissipation are known as energy dissipators

So, what is the energy dissipation of below the spillway? Since water is flowing over the spillway it requires lot of kinetic energy by the time it reaches near the toe of the spillway. That is since the water is flowing from the top so, conversion of potential energy is into the kinetic energy.

If the arrangements are not made to dissipate this huge kinetic energy of water and if the velocity of water is not controlled large scale squard or the erosion occurs at the point place at the downstream of the dam. So arrangements is to be provided for energy dissipation, which is widely known as energy dissipaters.

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ENERGY DISSIPATION

- In general kinetic energy of this super-critical flow can be dissipated in two ways:
 - ✓ By converting the super-critical flow into sub-critical flow by hydraulic jump
 - ✓ By directing the flow of water into air and then making it fall away from toe of the structure

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In general the kinetic energy of the super critical flow can be dissipated in two ways. So by converting the super critical flow into sub critical flow, by hydraulic jump or by directing the flow of water into air and then making it fall away from the toe of structure. So, these are the two ways in which we can dissipate the energy.

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HYDRAULIC JUMP FORMATION

- Hydraulic jump can form in a horizontal rectangular channel, when the following relation is satisfied between the pre-jump depth (y_1) and post-jump depth (y_2):

$$y_2 = -\frac{y_1}{2} + \sqrt{\frac{y_1^2}{4} + \frac{2q^2}{gy_1}}$$

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So, hydraulic jump formation so, hydraulic jump can form in a horizontal rectangular channel when the following relation is satisfied between pre jump and a post jump depth. So, pre jump is y_1 and the post jump depth is y_2 . So, all of you know that hydraulic

jump can be created and then we can get conjugate depth equation. So, this is the basic form of equation to be used for y_2 and y_1 .

(Refer Slide Time: 02:32)

HYDRAULIC JUMP FORMATION

□ For a given discharge intensity over a spillway, the depth y_1 is equal to $\frac{q}{V_1}$; and V_1 is determined by the drop V_1 , being equal to $\sqrt{2gH_1}$

The diagram illustrates a dam spillway with a hydraulic jump. The total energy line is shown as a dashed line that drops at the spillway and then jumps at the hydraulic jump. The dam height is labeled H_1 . The height of the water surface above the dam is H_1 . The height of the water surface above the spillway is H_2 . The length of the jump is L . A handwritten note on the right says $\frac{q}{\sqrt{2gH_1}}$.

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So, for a given discharge intensity over the spillway and at a depth of y_1 so, this is the first conjugate depth y_1 is equal to q by V_1 . So, this is the discharge this is the total energy line this is H_1 the gradient and H_1 the discharge is a y_1 is the ratio of the critical discharge divided by V_1 .

And V_1 is determined by the drop V_1 and equal to root under $2gH_1$. So, the entire equation comes out to be q upon $\sqrt{2gH_1}$ the H_1 is the height and total energy line height of the total energy line from the dam bottom to this point.

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HYDRAULIC JUMP FORMATION

- ❑ For a given discharge intensity and given height of spillway, y_1 and y_2 are fixed
- ❑ Availability of a depth equal to y_2 in the channel on the downstream depends on the tail water level, which depends on the hydraulic dimensions and slope of the river channel below
- ❑ If a graph is plotted between **q and tail water depth**, the curve obtained is known as **Tail Water Curve (T. W. C)**
- ❑ If a curve is plotted on the same graph, **between q and y_2** , the curve is known as the **Jump Height Curve (J. H. C)** or y_2 curve

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For a given discharge intensity and given height of the spillway generally y_1 and y_2 are fixed. Availability of depth equal to y_2 in the channel on the downstream depends on the tailwater level which depends on the hydraulic dimension and the slope of the river channel. If a graph is plotted between discharge and tail water depth a curve is obtained this curve is called sorry; this curve is called a tailwater Curve.

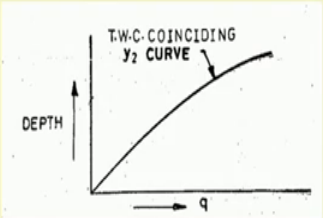
The graph between discharge critical discharge and tailwater depth like if a curve is drawn this is called tailwater curve and if a graph is plotted in the same graph between q and conjugate depth y_2 , the curve is known as jump water height curve so, this is called T W C and this is called J H C or the y_2 curve. So, these are two different curve which is related to hydraulic jump formation.

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HYDRAULIC JUMP FORMATION

□ There are five possibilities

a) T. W. C coinciding with y_2 curve at all discharges



The graph plots DEPTH on the vertical axis and discharge q on the horizontal axis. A single solid curve starts from the origin and curves upwards to the right. An arrow points to this curve with the label 'T.W.C. COINCIDING y_2 CURVE'.

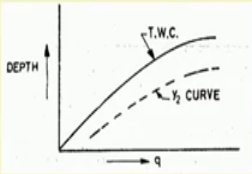
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So, there are five possibility in this case. So, the T W C or the tailwater curve when coinciding with y_2 curve or the J H C curve so, this looks as a on the same point. So, this one is coinciding with this where T W C is coinciding with J H C this depth and this is the critical discharge.

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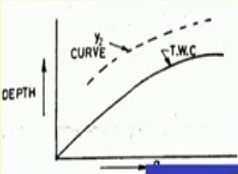
HYDRAULIC JUMP FORMATION

b) T. W. C lying above y_2 curve at all discharges



The graph plots DEPTH on the vertical axis and discharge q on the horizontal axis. Two curves start from the origin and curve upwards to the right. The upper curve is solid and labeled 'T.W.C.', and the lower curve is dashed and labeled ' y_2 CURVE'.

c) T. W. C lying below y_2 curve at all discharges



The graph plots DEPTH on the vertical axis and discharge q on the horizontal axis. Two curves start from the origin and curve upwards to the right. The lower curve is solid and labeled 'T.W.C.', and the upper curve is dashed and labeled ' y_2 CURVE'.

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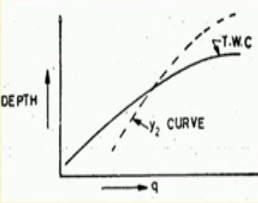
And the second possibility is when T W C is laying above the y_2 curve. So, this is T W C curve this is y_2 curve and a third possibility can be if T W C is lying below the y_2

curve at all the discharges. So, first one is T W C is above this and the second one is just reverse the situation.

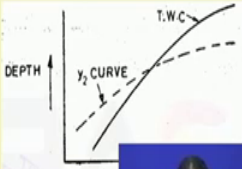
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HYDRAULIC JUMP FORMATION

d) T. W. C lying above y_2 curve at smaller discharges and lying below y_2 curve at large discharges



e) T. W. C lying below y_2 curve at smaller discharges and lying above y_2 curve at larger discharges



The slide contains two graphs. The top graph shows a dashed line labeled 'T.W.C.' and a solid line labeled 'y2 CURVE'. The y-axis is 'DEPTH' and the x-axis is 'q'. The T.W.C. curve starts above the y2 curve at low q and crosses below it at high q. The bottom graph shows the same two curves, but the T.W.C. curve starts below the y2 curve at low q and crosses above it at high q.

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There is a fourth condition when the T W C is lying above the y_2 curve at a smaller discharge and laying below the y_2 curve at a large discharge. The condition where both are intersecting y_2 curve is below and T W C to curve is in the next stage it is above.


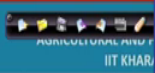


And the fifth condition is just reverse of this situation where T W C curve lying below y_2 curve at smaller discharge and lying above the y_2 curve at a large discharge. So, these are the five different possibility that a hydraulic jump can generate a huge amount of energy.

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ENERGY DISSIPATORS

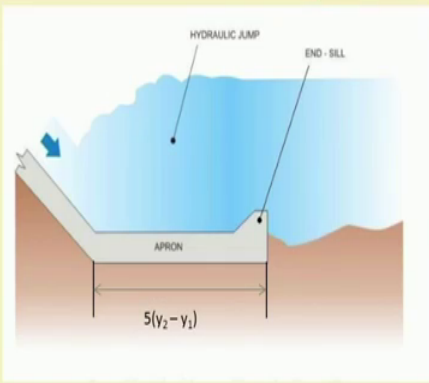
Case (a): When T. W. C coincides with y_2 curve at all discharges

- ❑ This is the most ideal condition for the jump formation
- ❑ The hydraulic jump will form at the toe of the spillway at all discharges
- ❑ In such case, a simple concrete apron of length $5(y_2 - y_1)$ is generally sufficient to provide protection in the region of hydraulic jump


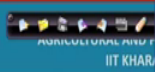




So, how to dissipate this energy? So, we will first go for case one when both the graphs are coinciding when T W C coincides with y_2 curve at all discharges. This is the most ideal condition for the jump formation the hydraulic jump will form at the toe of the spillway at all discharges. And in such case a simple concrete apron of length 5 times y_2 minus y_1 is generally sufficient to provide protection in the region of hydraulic jump. So, this concrete length is if you provide concrete length this is the simple solution for this.

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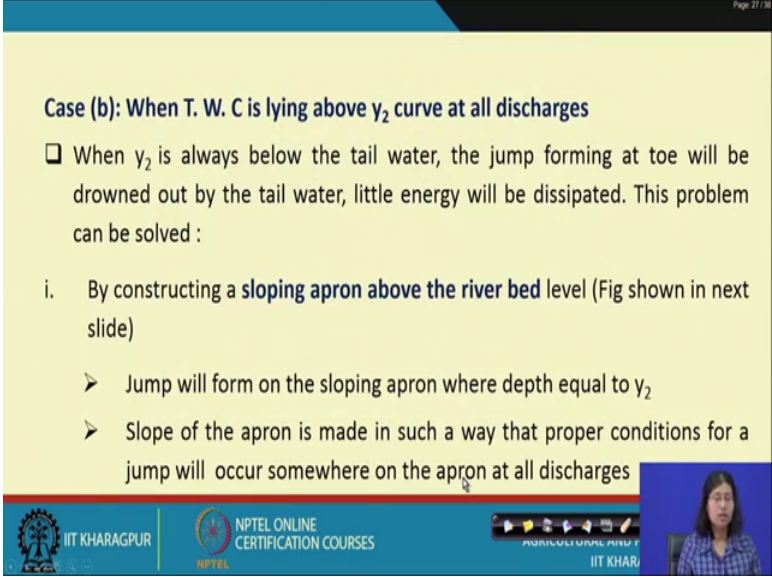


Simple horizontal apron



So, this is the condition here there is a formation of hydraulic jump and you provide a simple horizontal apron in this case and this is sill end still here.

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Case (b): When T. W. C is lying above y_2 curve at all discharges

❑ When y_2 is always below the tail water, the jump forming at toe will be drowned out by the tail water, little energy will be dissipated. This problem can be solved :

i. By constructing a **sloping apron above the river bed level** (Fig shown in next slide)

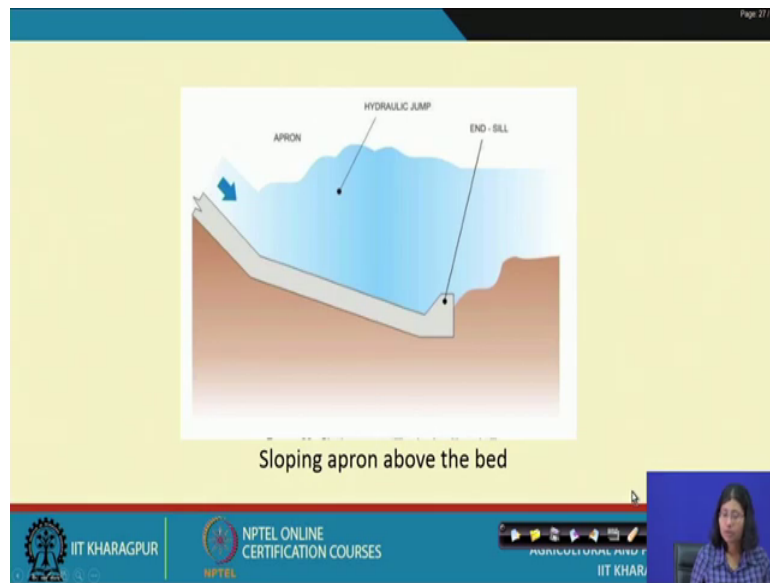
- Jump will form on the sloping apron where depth equal to y_2
- Slope of the apron is made in such a way that proper conditions for a jump will occur somewhere on the apron at all discharges

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Now, coming to case two when the T W C is lying above the y_2 curve at all discharges when y_2 is always below the tail water, the jump forming at the toe will be drowned out by the tailwater and in this case what happened a little energy will be dissipated. This problem by is can be solved by two or three ways. So, first will go by constructing sloping apron above the river bed; this will going to show in the next slide.

So, Jump will form fall on the sloping apron where depth equals to y_2 second Slope of the apron is made in such a way that the proper condition for a jump will occur somewhere on the apron at all discharges.

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So, this is a sloping apron is provided above the bed. So, like this and this is the end sill and this is the hydraulic jump this is the apron is going like this and is slope.

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Case (b): When T. W. C is lying above y_2 curve at all discharges

ii. By providing a **roller bucket** type energy dissipator

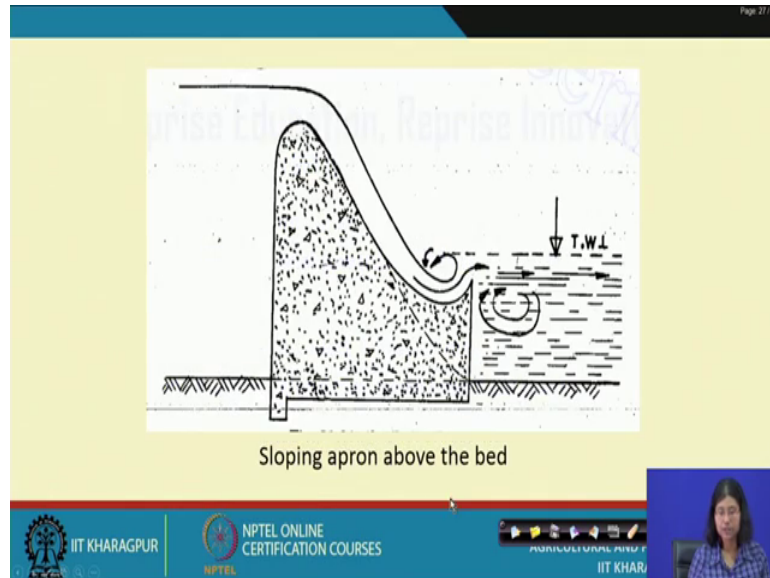
- Roller which is formed downstream of the bucket, tends to move the scoured bed material towards the dam, thus, preventing serious scour at toe of the dam
- Sometimes, the scoured material may enter the bucket under the action of u/s roller, and may cause severe abrasion
- A **dentated bucket lip** may, therefore, have to be provided so as to permit removal of material caught in bucket

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Now, the second way to solve this by and we are continuing the same case when T W C is lying above the y_2 at all discharges the case two second solution is to provided roller bucket type energy dissipator. Roller which is formed downstream of the bucket tends to move the scoured bed material towards the dam thus preventing the serious scour at a toe of the dam. Sometimes, the scoured material may enter the bucket under the action of

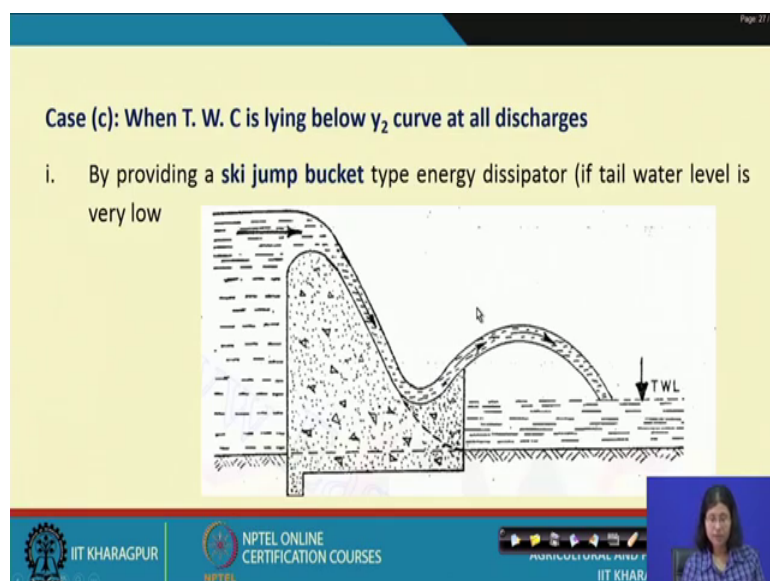
upstream roller and may cause severe abrasion. So, what we can do in that case a dentated bucket lip may therefore, have to be provided so, as to permit removal of material caught inside the bucket.

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So, in the next slide I am going to show the structure. So, like this a bucket kind of arrangements is to be provided and is a sloping apron above the bed here is there is a formation of whirlpool and this bucket kind of arrangement here.

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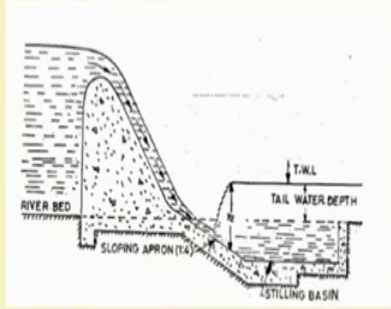
Now, when the T W C is lying below y_2 curve at all discharges. So, here case this is the case three. So, by providing a ski jump bucket energy dissipator if tail water level is very low so, if provided a ski jump kind of bucket here.

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Case (c): When T. W. C is lying below y_2 curve at all discharges (contd ..)

ii. By providing a sloping apron below the river bed



The diagram shows a cross-section of a dam. On the left is the river bed. The dam structure includes a sloping apron (labeled 'SLOPING APRON (1:4)') that extends into the river. Below the apron is a stilling basin (labeled 'STILLING BASIN'). The tail water level (T.W.L.) and tail water depth are indicated on the right side of the stilling basin.

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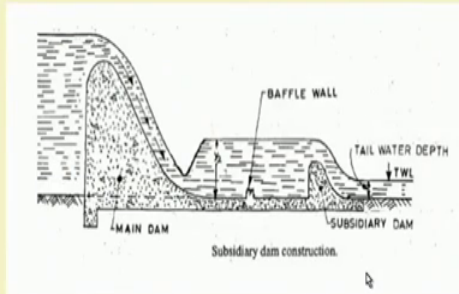
The second way to solve this is by providing a sloping apron below the river bed. So, the same case three is continuing that is when T W C is laying below the y_2 curve at all discharges. So, a sloping apron is provided below the river bed here.

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Case (c): When T. W. C is lying below y_2 curve at all discharges (contd..)

iii. Construction of a subsidiary dam below the main dam



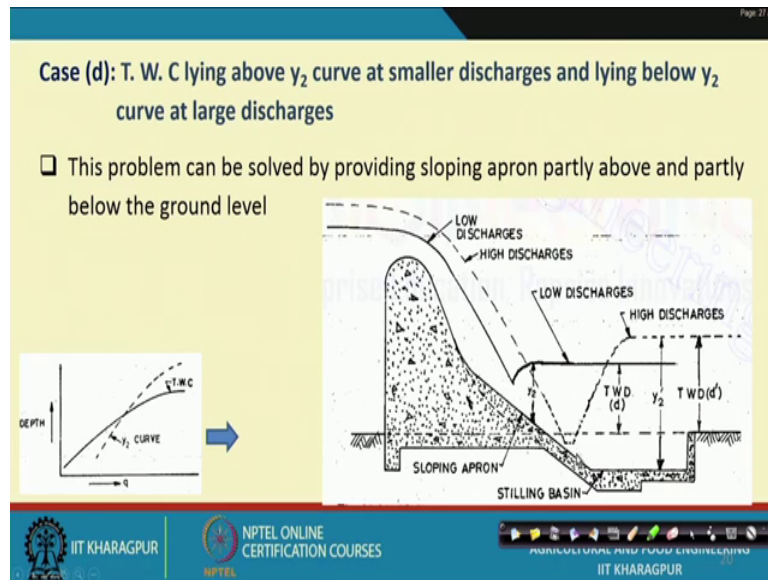
The diagram shows a cross-section of a dam with a subsidiary dam. The main dam is on the left. A baffle wall is located between the main dam and the subsidiary dam. The subsidiary dam is on the right. The tail water level (T.W.L.) and tail water depth are indicated on the right side of the subsidiary dam.

Subsidiary dam construction.

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Now, the third way to solve this construction of a subsidiary dam below the main dam is subsidiary dam is to be constructed and that can take care of this energy dissipation problem so, subsidiary dam is here.

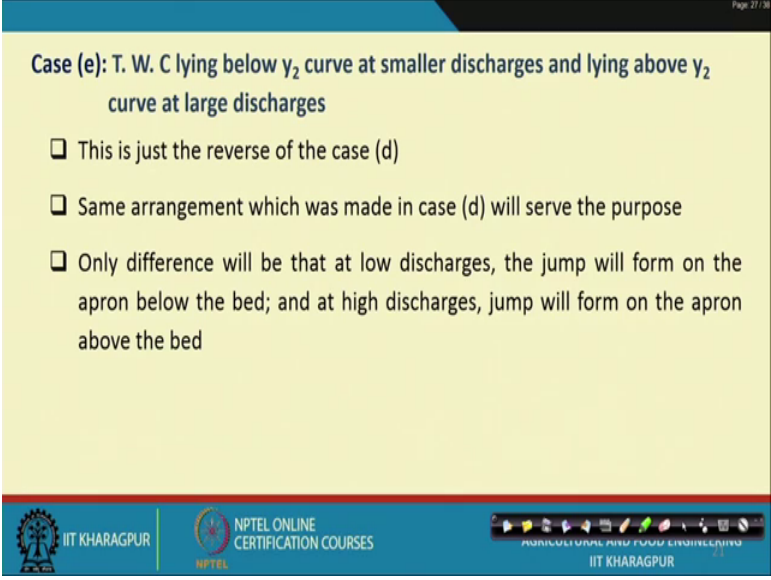
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Now, we are see the case four when the T W C curve as the y_2 curve and both are coinciding and a T W C is lying about the y_2 curve at small discharges and lying below the y_2 curve at all large discharges. So, this problem can be solved by providing a sloping apron partly above and partly below the ground level.

So, this is my case four and this is a combination of case one and case two. So, here it provide sloping apron partly above and the partly below the ground level. So, this way we can solve this kind of energy dissipation problem.

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Case (e): T. W. C lying below y_2 curve at smaller discharges and lying above y_2 curve at large discharges

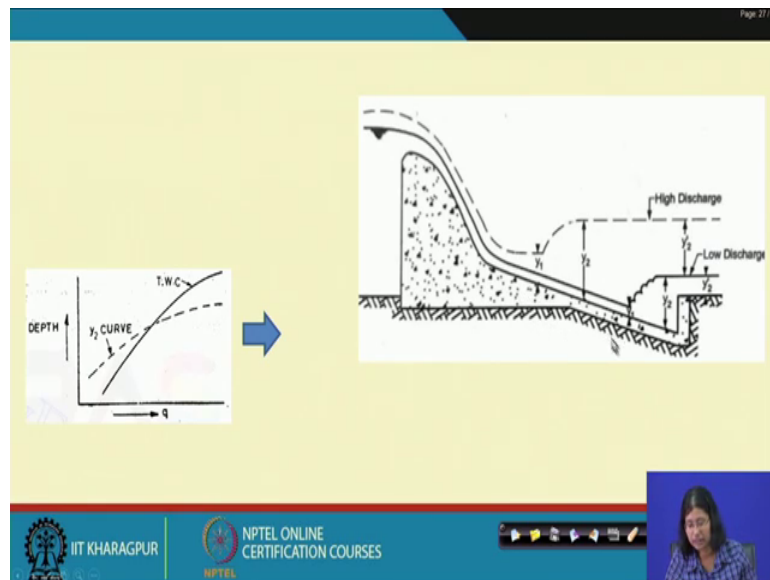
- This is just the reverse of the case (d)
- Same arrangement which was made in case (d) will serve the purpose
- Only difference will be that at low discharges, the jump will form on the apron below the bed; and at high discharges, jump will form on the apron above the bed

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And now that last case the last case is when this also the case when T W C and y_2 curve both are intersecting where the case is just opposite of case four, that is a T W C is lying below the y_2 curve at smaller discharges and lying above the y_2 curve at large discharges.

So, here the arrangement will be same; the same arrangement which was made in case d will serve the purpose, only difference will be that at low discharges, the jump will form on the apron below the bed; and at high discharges, the jump will form the apron above the bed.

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So, this is the case five just that is a rivers of case four and this is the jump here is forming above the bed below the bed and at high discharge the jump will form on the apron above the bed, the last case. So, these are the five ways we can solve the energy dissipation problem.

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ENERGY DISSIPATION BELOW OTHER TYPES OF SPILLWAYS

- A chute or a shaft or a side channel spillway generally discharges at a point away from the dam
- Hence, the protection is required only for the spillway, as the danger to the main dam is not there
- A **hydraulic stilling basin** is generally sufficient, and may be provided at the discharging point of the spillway
- If sound rocks are available, a **Ski jump bucket** may be provided at low cost

Now, coming to energy dissipation below other type of spillway so, if the spillway are some other type how we can solve this energy dissipation problem. So, first a chute or a shaft or a side channel spill way general discharges at a point away from the dam. Hence

the protection is required only for the spillway as the danger to the main dam is not here. So, in this case a hydraulic stilling basin generally sufficient and may be provided at discharge point of the spillway. So, hydraulic spill stilling basin is sufficient to solve this kind of problem; however, if there is a rocks are available, in that case a ski jump bucket may be provided which is at a low cost ok.

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STILLING BASIN USING HYDRAULIC JUMP AS ENERGY DISSIPATOR

- Hydraulic jump formation depends considerably upon the Froude number of the incoming flow (F_1)
- The pre-jump depth (y_1) and post-jump depth (y_2) are governed by:

$$\frac{y_2}{y_1} = \frac{1}{2} \left[\sqrt{1 + 8F_1^2} - 1 \right]$$

Where $F_1 = \frac{V_1}{\sqrt{g y_1}}$

- If the incoming Froude number F_1 is higher, greater energy dissipation can take place






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So, and stilling now the design now hydraulic jump formation depends considerably upon the Froude number of the incoming flow. So, the pre jump depth and post jump depth or the conjugate depth are given by this formula. So, this is a Froude number here and the Froude number is the ratio between V_1 up on root $g y_1$ this two depth. If the incoming Froude number F_1 is higher the greater energy dissipation can take place.

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□ The approximate percentage loss of energy for various values of F_1

F_1	% loss of energy
2.5	17
4.5	45
9.0	70
14.0	80
20.0	85



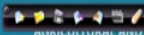




So, here we have given the range of Froude number and corresponding percentage of energy loss. So, from Froude number range from 2.5 to 20 so, 2.5 is the Froude number is low in number on 17 percent loss of energy happen; however, if it is 20 around 85 percent losses can happen.

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Types of jumps for different ranges of Froude numbers:

- When $F_1 < 2.5$, the jump is weak and energy loss is low**
 - No blocks or other devices are provided in this range
- When F_1 lies between 2.5 to 4.5, the jump is trouble-some and oscillating which gives rise to heavy waves on the surface**
 - Wave suppressors may be needed in this range
 - The length of the jump may be taken as $5(y_2 - y_1)$



Now, coming to types of jump for different ranges and their Froude number: when F_1 is less than 2.5, the jump is weak and energy loss is low. So, no blocks or other devices are provided in this range. So, we are basically safe in this range; however, when F_1 lies

between 2.5 to 4.5 the jump not troublesome and oscillating and which gives rise heavy waves on the surface. So, in that case wave suppressor maybe needed in this range and the length of the jump may be taken as a difference between y_2 minus y_1 and 5 times of this difference.

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The slide is titled "Types of jumps for different ranges of Froude numbers:". It contains two main points, iii and iv, each with a sub-point. Point iii states that when F_1 is between 4.5 and 9.0, the jump is steady and its length is approximately $6y_2$. It notes that for large spillways, this requires long and expensive stilling basins, and that auxiliary devices can be used to stabilize the flow and shorten the basins. Point iv states that when F_1 is 9.0 or larger, the jump is strong and rough/choppy, and a bucket-type energy dissipator is preferred over a hydraulic jump type. The slide footer includes the IIT Kharagpur logo, NPTEL Online Certification Courses logo, and a small video feed of a presenter.

Types of jumps for different ranges of Froude numbers:

iii. When F_1 lies between 4.5 and 9.0, the jump is steady. The length of the jump is almost constant and equal to $6y_2$

- Hence for large spillways, where y_2 may be quite high, very long expensive stilling basins may be required
- Some auxiliary devices may also be introduced for further stabilizing the flow and to reduce the length of the basins

iv. When $F_1 = 9.0$ and larger, it is a strong jump. But the jump is likely to be rough and choppy

- Bucket type energy dissipator is preferred to a stilling basin of hydraulic jump type

When F_1 lies between 4.5 and 9 the jump is steady. The length of the jump is almost constant and equal to 6 of y_2 . Hence for large spillways, where y_2 may be quiet high very long expensive stilling basin may be required.

Some auxiliary devices may also be introduced for further stabilizing the flow and to reduce the length of the basin. When F_1 is 9 and larger it is a strong jump, but the jump is likely to be rough and choppy bucket type energy dissipater is preferred in this case and of this hydraulic jump type.

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STANDARD STILLING BASINS

- ❑ Various types of stilling basins have been generalized for use on different types of works, various agencies
- ❑ Design of these basins have been developed on the basis of long experience and on model studies
- ❑ These basins are not simple concrete aprons but are generally provided with **auxiliary devices**
- ❑ These devices can help in dissipating energy of flow by offering resistance to flow and may stabilize the flow in shorter length of basin
- ❑ In general, a **stilling basin** may be defined, as a structure in which the **energy dissipating action is confined**

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Now, the kind of stilling basin; so, various kind of stilling basins have been generalized for use on different types of work and various agencies. So design of this basin have been developed on the basis of long experience and model studies. So, these basins are not simple concrete apron, but generally provided with an auxiliary devices this device can help in dissipating energy of flow by offering resistance to flow and may stabilize the floor in shorter length of the basin.

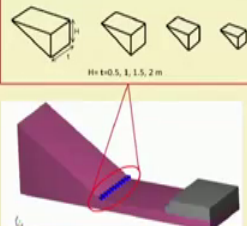
So, in general a stilling basin may be defined as a structure in which the energy dissipation action is confined. So, stilling basin is a kind of structure in which energy dissipation can be taken place.

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AUXILIARY DEVICES

Chute Blocks:

- ❑ Chute blocks are a kind of serrated device and provided at the entrance of the stilling basin
- ❑ Incoming jet of water is furrowed and partly lifted from the floor, producing a shorter length of jump what would have been without them
- ❑ They also help in stabilizing the flow and thus improve the jump performance



$H = 0.5, 1, 1.5, 2 \text{ m}$

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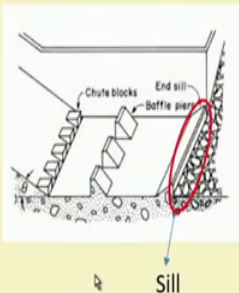
So, this kind of auxiliary devices are designed for energy dissipation. So, one of them is chute blocks. So, chute blocks are a kind of serrated device and provided at the entrance of the stilling basins. So, you can see this point here at the entrance of the stilling basin this small small chute blocks are provided. So, incoming jet of water is followed and partly lifted from the floor a producing a shorter length of the jump and which would be produce here and they also help in stabilizing the flow and then they can improve the jump performance in presence of this small small blocks.

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AUXILIARY DEVICES

Sills and Dentated Sills:

- ❑ Sill or dentated sill is generally provided at the end of the stilling basin
- ❑ Dentated sill diffuses the residual portion the high velocity jet reaching the end of the basin
- ❑ They help in dissipating residual energy and to reduce the length of the jump or the basin



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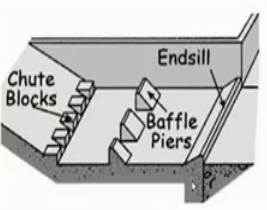
Now, the other way of is to provide sill and dentated sills here sill or dentated sill is generally provided at the end of the stilling basin. So, dentated sill diffuses the residual portion of the high velocity jet reaching at the end of the basin. They help in dissipating residual energy and to reduce the length of the jump or the basin. So, these are the stilling basin here.

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AUXILIARY DEVICES

Baffle Piers:

- ❑ They are the blocks placed within the basin, across the basin floor
- ❑ They help in breaking the flow and dissipate energy mostly by impact
- ❑ These baffle piers, sometimes called friction blocks, are very useful in small structures
- ❑ These baffle piers are not suitable for large works



The diagram illustrates the components of a stilling basin. It shows a perspective view of the basin floor and walls. At the downstream end, there is a vertical wall labeled 'Endsill'. Along the sloped floor, there are several rectangular blocks labeled 'Chute Blocks'. Further upstream, there are several vertical rectangular structures labeled 'Baffle Piers'.

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The third way is to provide the baffle piers. So, baffle piers are like this is the end sill and this is the chute blocks and now you have the baffle piers. So, they are the small blocks placed within the basin and across the basin floor. So, they help in breaking the floor and dissipate the energy impact mostly by the impact. So, this baffle piers sometimes also called as friction blocks, are very useful for the small structure; however, for large structure these are not suitable.

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U. S. B. R BASINS

U. S. B. R. stilling basin II:

- ❑ This is recommended for use on large structures, such as dam spillways, large canal structures etc
- ❑ These are used when the incoming Froude number (F_1) is more than 4.5

The diagram illustrates the cross-section of a U.S.B.R. stilling basin II. It features a series of Chute blocks on the left side, leading to a Dentated wall on the right. The water depth at the inlet is y_1 and at the outlet is y_2 . The slope of the basin floor is 2:1. The distance between the chute blocks is $s_1 = y_1$ and $s_2 = 0.15y_2$. The width of the chute blocks is $w_1 = y_1$ and $w_2 = 0.15y_2$. The height of the chute blocks is $h_1 = y_1$ and $h_2 = 0.2y_2$. The total length of the basin is L . The bottom of the basin is set at a level that provides 5% more water depth than y_2 .

Now, another way is U S B R silling stilling basin two. So, this is the stilling basin two structure; this is recommended for use on the large structures such as dam spillway and large canal structure. These are used when the incoming Froude number is more than 4.5. So, a large structure these are the basic device to we use.

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Relation between basin length and the Froude number F_1

F_1	Length of the basin
4	$3.6 y_2$
6	$4.0 y_2$
8	$4.2 y_2$
10 or more	$4.3 y_2$

- ❑ An economy in the length of the basin up to about 35% ($4.3 y_2$ in place of $6 y_2$) is thus obtained by auxiliary devices
- ❑ The floor of the basin should be set at such a level as to provide 5% more water depth than y_2

Now the relation between basin length and the Froude number; so, if the Froude number is 4 so, the length of the basin is to be kept as 3.6 times of y_2 then at a two interval if it is 6 then 4 times y_2 , 8 4.2 times y_2 , 10 or more 4.3 times y_2 .

An economy in the length of the basin up to about 35 percent so, $4.23 y^2$ in place of $6 y^2$ is thus obtained by this auxiliary devices. The floor of the basin should be set at such a level as to provide 5 percent more water depth than y^2 . So, if you remember the design we did we kept as 5 percent more of y^2 in the water depth in earlier slides.

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U. S. B. R BASINS

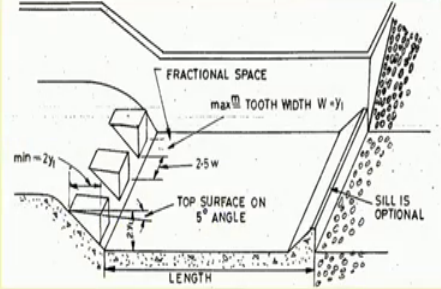
U. S. B. R. stilling basin IV:

- It is used for Froude number varying from 2.5 to 4.5, which is generally occurs in canal weirs, canal falls, diversion dams, etc.
- This basin is applicable only to rectangular cross sections
- Since oscillating waves are generated in this range of Froude number, they are tried to be controlled at source by providing large chute blocks

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So, U S B R stilling basin four; it is used for Froude number varying from 2.5 to 4.5, which is generally occurs in canal weirs, canal falls, diversion dam, etc. So, this basin is applicable only to rectangular cross section. Since oscillating waves are generated in this range of Froude number, they are tried to control at a source by providing large chute blocks.

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The diagram illustrates the design of a U.S.B.R. stilling basin. It shows a cross-section of the basin with a sloped top surface at a 5-degree angle. Key features include: 'FRACTIONAL SPACE' between the teeth, 'max TOOTH WIDTH $W = y_1$ ', 'min = $2y_1$ ', '2-5 w' spacing, 'TOP SURFACE ON 5° ANGLE', and 'SILL IS OPTIONAL'. The 'LENGTH' of the basin is also indicated.

- ❑ The floor of the basin may be set at such a level so as to provide 5 to 10% more water depth than the theoretical y_1
- ❑ The length of the basin is generally kept equal to $5(y_2 - y_1)$

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So, this is U S B R stilling basin four here. So, this is the top surface of the 5 degree angle. So, length of the basin and sill is optimum optional and floor of the basin must be set in such a way that level provide 5 to 10 percent more water depth and its theoretical y_1 value. So, the floor is to be kept in such a way it can provide 5 to 10 percent more water depth and the length of the basin is generally kept as the 5 times the difference between y_2 and y_1 the conjugate depth and the pre jump depth, so,

Thank you.