UNIT – 5

CONCEPT:-

Spillways are structures constructed to provide safe release of flood waters from a dam to a downstream area - normally the river on which the dam has been constructed.

Every reservoir has a certain capacity to store water. If the reservoir is full and flood waters enter the same, the reservoir level will go up and may eventually result in overtopping of the dam. To avoid this situation, the flood has to be passed to the downstream and this is done by providing a spillway which draws water from the top of the reservoir. A spillway can be a part of the dam or separate from it.

Spillways can be controlled or uncontrolled. A controlled spillway is provided with gates which can be raised or lowered. Controlled spillways have certain advantages as will be clear from the discussion that follows.

When a reservoir is full, its water level will be the same as the crest level of the spillway. This is the normal reservoir level. If a flood enters the reservoir at this time, the water level will start going up and simultaneously water will start flowing out through the spillway. The rise in water level in the reservoir will continue for some time and so will the discharge over the spillway. After reaching a maximum, the reservoir level will come down and eventually come back to the normal reservoir level. The top of the dam will have to be higher than the maximum reservoir level corresponding to the design flood for the spillway, while the effective storage available is only upto the normal reservoir level. The storage available between the maximum reservoir level and the normal reservoir level is called the surcharge storage and is only a temporary storage in uncontrolled spillways. Thus for a given height of the dam, part of the storage – the surcharge storage– is not being utilised. In a controlled spillway, water can be stored even above the spillway crest level by keeping the gates closed. The gates can be opened when a flood has to be passed. Thus controlled spillways allow more storage for the same height of the dam.

Many parameters need consideration in designing a spillway. These include the inflow design flood hydrograph, the type of spillway to be provided and its capacity, the hydraulic and structural design of various components and the energy dissipation downstream of the spillway. The topography, hydrology, hydraulics, geology and economic considerations all have a bearing on these decisions.

For a given inflow flood hydrograph, the maximum rise in the reservoir level depends on the discharge characteristics of the spillway crest and its size and can be obtained by flood routing. Trial with different sizes can then help in getting the optimum combination.

TYPES OF SPILLWAYS

There are different types of spillways that can be provided depending on the suitability of site and other parameters. Generally a spillway consists of a control structure, a conveyance channel and a terminal structure, but the former two may be combined in the same for certain types. The more common types are briefly described below.

Ogee Spillway

The Ogee spillway is generally provided in rigid dams and forms a part of the main dam itself if sufficient length is available. The crest of the spillway is shaped to confirm the lower nappe of a water sheet flowing over an aerated sharp crested weir. The profile has been studied extensively by the United States Bureau of Reclamation (USBR)

The profile to the right of the crest is given by

$$y/H_d = -k\ (x/H_D)^n$$

where the value of k and n depends on the slope of the upstream face of the spillway and is available in the form of curves, being 0.5 and 1.87 respectively for a vertical upstream face. H_D is the design head which is taken as 0.75 H_{max}, being maximum expected head over the spillway. The profile to the left of the crest is given by a double circle as shown in the figure. The values of the parameters defining these circles can also be read from curves given by USBR.

The profile given by theabove equation to the right is continued till a point at which the tangent to the curve has a slope equal to the slope of the downstream face of the dam. Thereafter it continues at the same slope and given a reverse curve near the bottom.

The discharge over an ogee crest is given by

$$Q = C\ L\ H^{3/2}$$

Where L is the effective length of the crest, H the head over the crest and C is a coefficient which depends- besides other factors – on the ratio of H to the design head H_D.

If the spillway is operated at heads less than the design head, the sheet of water will have a tendency to press against the spillway surface resulting in positive pressures over the surface and in reducing the value of C. At the design head, the pressures over the surface will be atmospheric and at larger heads, these will be below atmospheric i.e. negative. The negative pressures will result in increased value of C and thus are advantageous from the discharging capacity point of view. Large negative pressures could however cause stability problems. The operating head therefore is not allowed to exceed the design head by more than a certain amount. This can be ensured by designing the crest for a head which is about 75-80 % of the head expected for the design flood.

Chute (Trough) Spillway

In this type of spillway, the water, after flowing over a short crest or other kind of control structure, is carried by an open channel (called the “chute” or “trough”) to the downstream side of the river. The control structure is generally normal to the conveyance channel. The channel is constructed in excavation with stable side slopes and invariably lined. The flow through the channel is supercritical. The spillway can be provided close to the dam or at a suitable saddle away from the dam where site conditions permit.This type of spillway is ideally suited for embankment dams and for rigid dams in narrow valleys where the river bed immediately downstream of the dam is of erodible material.

Side Channel Spillway

Side channel spillways are located just upstream and to the side of the dam. The water after flowing over a crest enters a side channel which is nearly parallel to the crest. This is then carried by a chute to the downstream side. Sometimes a tunnel may be used instead of a chute. The crest is usually an ogee profile and generally straight in plan though shapes like "L" or "U" have also been sometimes used.

This type of spillway is specially suited in dams on narrow valleys where sufficient length for the spillway crest may not be available otherwise or when a large crest length is required to keep the rise in reservoir level low.

Shaft (Morning Glory or Gloryhole) Spillway

This type of spillway utilizes a crest circular in plan, the flow over which is carried by a vertical or sloping tunnel on to a horizontal tunnel nearly at the streambed level and eventually to the downstream side . The diversion tunnels constructed during the dam construction can be used as the horizontal conduit in many cases.The crest can be a standard crest or a flat crest. While the former has a larger discharge coefficient, the later requires smaller funnel diameter and hence economical if excavation has to be carried out. The standard crest conforms to the lower nappe of flow over a circular sharp crested weir. The ideal condition favouring this type of spillway is when there is a rock outcrop in the reservoir somewhat upstream of the dam.Problems frequently encountered in this type of spillway are vortex action, instability of flow and cavitation. Radial piers are generally used at the crest to suppress vortex formation.

Siphon Spillway

As the name indicates, this spillway works on the principle of a siphon. A hood provided over a conventional spillway forms a conduit. With the rise in reservoir level water starts flowing over the crest as in an ogee spillway. The flowing water however, entrains air and once all the air in the crest area is removed, siphon action starts. Under this condition, the discharge takes place at a much larger head. The spillway thus has a larger discharging capacity. The inlet end of the hood is generally kept below the reservoir level to prevent floating debris from entering the conduit. This may because the reservoir to be drawn down below the normal level before the siphon action breaks and therefore arrangement for depriming the siphon at the normal reservoir level is provided.

One of the important aspects of the siphon spillway is its priming and therefore priming devices such as a joggle or baby siphon are used to ensure early priming. Cracking of the hood can lead to depriming by allowing entry of air. The spillway is therefore provided in batteries so that the whole spillway does not get deprimed by the cracking of one portion of the hood. While this kind of spillway has a larger discharge for the same rise in reservoir level, it has problems of vibration and noise. Cavitation can also be a problem in some cases.

TERMINAL STRUCTURES – ENERGY DISSIPATION

The water flowing over a spillway loses a large amount of its potential energy. A good percentage of this is converted into kinetic energy and subsequently the flow at the toe of the spillway is a high velocity flow. If allowed as such to flow in the river, it is likely to cause considerable bed erosion and as such some sort of energy dissipation is required before allowing this flow into the river. Generally two major types of energy dissipating devices are used for spillways. These are the hydraulic jump type stilling basin and the bucket type energy dissipators.

Hydraulic Jump type Stilling Basins

As the name indicates, these basins employ the hydraulic jump as the energy dissipation mechanism. The characteristics of the jump- such as the length, efficiency in energy dissipation etc.- depend on the initial Froude number and the tailwater conditions. Appurtenances such as chute blocks, baffle blocks and end sill are also used to increase the efficiency as well as to decrease the length of the basin .A comprehensive study of this type of basins was carried out by the United States Bureau of Reclamation and certain types of basins have been recommended by them for various initial Froude numbers and inflow velocities. These basins- referred to as USBR Type II, Type III etc.- are suitable for different ranges of initial Froude numbers. The appurtenances to be used in each type are also specified. The dimensions of the basin as well as of the appurtenances to be employed in each case are given in the form of curves, which can be used to design the basin for a given set of conditions.

Bucket Type Energy Dissipators

These are used when the tailwater depth is either too low or too high for the formation of a hydraulic jump, rendering a jump type basin uneconomical. The bucket can be a ski-jump bucket or a roller bucket.

1. **Ski Jump Bucket**

   This type of bucket is used when the tailwater depth is quite low for the formation of a jump. The water leaves the bucket as an upturned jet (Fig.10.8) and strikes the river bed somewhat downstream of the spillway. During its trajectory, the jet splits into smaller jets and part of the energy is dissipated due to air friction. The bulk of the energy dissipation however takes place due to the impact of the jet on the water and river bed downstream. This also requires that the river bed be comprised of hard rock to withstand the impact of the jet.

2. **Roller Bucket**

   This type of bucket is used when the tailwater depth is too large for the formation of a jump. The water entering the bucket forms a roller- called the bucket roller-within the bucket and another one – called the ground roller- just downstream of the bucket (Fig.10.9 a). While the former is anticlockwise, the latter moves in a clockwise direction. Energy dissipation takes place because of the interaction between the two rollers and the intermingling of the inflow with the same. The ground roller has a tendency to pile up loose material against the bucket lip and if some of this enters the bucket, it will keep moving with the bucket roller and can cause objectionable abrasion in the concrete surface. To avoid this, a slotted bucket is sometimes used instead of a solid bucket. The slotted bucket has teeth and gaps and leads to better flow conditions downstream, besides allowing any material that may enter the bucket to leave through the gaps.

SPILLWAY GATES

There are three major types of gates provided in spillways. These are :

1. **Vertical Lift Gates**
   These gates are made of steel plate and move in gate grooves provided in the supporting piers. They move vertically in their own plane and are operated from a hoist chamber, which has to be at a higher elevation than the raised position of the gates.
2. **Tainter Gates**
   Also called radial gates, these are segments of a cylinder made of steel plate and connected to a trunnion at the centre of the arc. The hoist chamber is suitably located and normally does not have to be as high as in case of vertical lift gates.
3. **Drum Gates**
   These are in the form of a floating drum which is hinged at the top and sits in a float chamber within the spillway crest. Rising of the gate is accomplished by allowing water under pressure into the float chamber, while for lowering the same another valve is used to empty the float chamber.

FOREBAY:

A **forebay** is an artificial pool of water in front of a larger body of water. The larger body of water may be natural or man-made.Forebays have a number of functions. They are used in flood control to act as a buffer during flooding or storm surges, impounding water and releasing in a controlled way into the larger waterbody. They may be used upstream of reservoirs to trap sediment and debris (sometimes called a sediment forebay in order to keep the reservoir clean. This may entail the use of a **forebay dam** or **pre-dam**. They may also be used upstream of lakes to prevent siltation. Some forebays are used simply to create a natural habitat for flora and fauna, to counterbalance the environmental impact of a dam or reservoir. Forebays vary greatly in size depending on their situation and purpose.

PENSTOCK

Penstocks for hydroelectric installations are normally equipped with a gate system and a surge tank. They can be a combination of many components such as anchor block, drain valve, air bleed valve, and support piers depending on the application.[1] Flow is regulated by turbine operation and is nil when turbines are not in service. Penstocks, particularly where used in polluted water systems, need to be maintained by hot water washing, manual cleaning, antifouling coatings, and desiccation.

The term is also used in irrigation dams to refer to the channels leading to and from high-pressure sluice gates.

Penstocks are also used in mine tailings dam construction. The penstock is usually situated fairly close to the center of the tailings dam and built up using penstock rings. These control the water level, letting the slimes settle out of the water. This water is then piped under the tailings dam back to the plant via a penstock pipeline.

Spillways	Spillways are structures constructed to provide safe release of flood waters from a dam to a downstream area normally the river on which the dam has been constructed.
A controlled spillway	A controlled spillway is provided with gates which can be raised or lowered.
Shaft Spillway	Shaft Spillway is water drops through a vertical shaft in the foundation material to a horizontal conduit that conveys the water past the dam. The shape is just like a funnel .
Side Channel Spillway	When the dam is not rigid and it is undesirable to pass flood water over the dam, this type of spillway is used is Side Channel Spillway
Siphon Spillways	When water rises over the FRL then water start spilling, It is designed by the principle of a siphon
Emergency Spillway	Extra spillways provided on a project in rare case of extreme floods(emergency)
Safety valve	This "safety valve" prevents water from spilling over the dam crest. It takes the form of a spillway a weir or sometimes a combination of both.

IMPORTANT QUESTIONS:-

1. a) Describe various types of hydel schemes .How do you assess the water potential of a hydel scheme.
   b) Enumerate principal components of a hydel scheme
2. a) Three turbo-generators each of capacity 10000 KW have been installed at a hydel power station. During a certain period of load, the load on the plant varies from 12000 kW to 26000 KW.Calculate (i)total installed capacity (ii) Load factor (iii)Plant factor (iv)Utilization factor
   b) Write any two functions of surge tank
3. a) Define a spillway? Give the design principles of Ogee spillway along with proper explanation
   b) Discuss the function of Surge tank
4. a) Explain Ogee spillway with sketches.
   b) Explain side channel spillway with sketches
   i) Forebay ii)Penstocks iii)Surge tank