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DEPARTMENT OF AGRICULTURAL ENGINEERING

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Factors Affecting the Sedimentation of Reservoirs

Sedimentation is the process of letting suspended material settled by gravity. Suspended material may be particles, such as clay or silts, originally present in the source water. Sedimentation occurs due to the decrease in velocity of the water to a point below which the particles will no longer remain in suspension. When the velocity no longer supports the transport of the particles, gravity will remove them from the flow. Several factors affect the sedimentation of reservoirs. Some of the more common types of factors to be considered are:

1. **Slope of Stream:** The deposition of the sediment takes place in the bottom portion, of the reservoir which are constructed on a stream having steep slope and longer reach whereas, deposition of the sediment takes place in higher elevation of the reservoir which are constructed on the stream with flat slope.

2. **Reservoir Length:** The distribution of sediment in the reservoir is affected greatly by its length. It has been observed that the large size sediment is deposited in the lower portion of the reservoir for a shorter length and the smaller size sediment is deposited at the higher elevation of the reservoir for longer length.

3. **Reservoir Constriction:** If there is constriction in the reservoir, the deposition of the sediment takes place in the upper portion comparatively in large proportion. The sediment deposition pattern is flatter in the constricted portion but it does not follow the natural slope of the stream.

4. **Size of Sediment:** The size and type of particles have a significant effect on the sedimentation. Because of their density, sand or silt can be removed very easily. The velocity of the water-flow in stream is slowed down as soon as they enter into the reservoir, and most of the gravel and grit settle down by simple gravitational forces.

5. **Capacity Inflow:** The capacity inflow is one of the most important factors which play a great role in the distribution pattern of sediment in the reservoir. A small reservoir in a large size river passes most of the finer particles along the inflow very quickly into the storage area, they do not get the time to settle down in the reservoir but they are disposed off downstream. In case of large reservoirs, the water for a long time resulting into complete deposition of suspended sediments.

6. **Vegetal Growth:** vegetal growth on the upstream part of the reservoir and in nearby areas helps in trapping the sediments and thus affecting the entry of silts in large amount into the reservoir.

7. **Reservoir Operation:** The reservoir operation technique greatly affects the pattern of sediment deposition. The reservoir may be operated for single purpose and for multipurpose both. Single purpose reservoir operations are generally performed relatively at constant level and as such the primary patterns of sediment deposition is not much affected. But in case of multipurpose reservoirs, the operation is conducted within a wide range of elevations to fulfill the various demands, throughout the year. It causes significant variations in the primary sediment distribution pattern, because it flushes down some deposited sediments from live storage of the reservoir at higher elevation due to seasonal reduction in the reservoir water level.

8. **Inflow Patterns of the Stream:** A stream, in which flood occurs during the early part of the monsoon, the amount of sediment reaching the reservoir being more tends to settle down in the reservoir. But when major flood occurs during the later part of the monsoon period, a reverse trend is obtained.

9. **Sediment Load in River Flow:** The amount of sediment load carried by the river flow varies greatly both in quantity and quality, depending on the watershed characteristics with regard to the land use as well as the climatic conditions. In addition, trapping of sediment is a function of retention period, which is reduced with the age of reservoir. The sedimentation pattern in the reservoir is greatly affected by these variations.

10. **Shape of Reservoirs:** The shape of a reservoir also plays a key role in sediment distribution pattern. For example in a reservoir of regular shape, the suspended sediment tends to deposit uniformly over the bed along the direction of flow, with decreasing depth away from the dam. But there would be a large variation in the depth of sediment deposition at the bottom, if the shape of reservoir is irregular.

11. **Outlets:** If the outlet of the reservoir has adequate capacity and is located at lower elevation then the density current tends to pass out very rapidly. As a result the deposited sediment mixed in the density current near the dam of the reservoir is removed.

12. **Sediment-reservoir Volume Ratio:** If the inflow volume of water and sediment is large compared to the reservoir volume, water cannot be retained in the reservoir for a longer period. In that case deposition of the percentage of inflow sediment will be much less as the retention period is low.

Rate of Reservoir Sedimentation- Sediment Delivery Ratio, Trap Efficiency

Rate of reservoir sedimentation depends not only on the volume of reservoir inflow into the reservoir but also on the trap efficiency.

Trap Efficiency

There are a large number of reservoirs in the world which have been built for different purposes like water supply, irrigation, and flood control or for controlling downstream water quality. The reduced flow velocity in these water storage structures causes sedimentation of the transported particles. For most of the storage structures this is a drawback as their retention capacity decreases due to sedimentation processes. Sediment volumes in small ponds can be used to reconstruct sediment yield values and to study the spatial variation in sediment yield over large areas. Especially, in developing countries, this technique can be very helpful in establishing large data sets on sediment delivery as often no resources are available for expensive monitoring programmes. However, when such studies are undertaken, one has to take into account the efficiency of the pond in trapping sediments which is known as the *trap efficiency*. This trap efficiency is dependent on the characteristics of the inflowing sediment and the retention time of the water in the pond, which in turn are controlled by pond geometry and runoff characteristics. Trap efficiency (*TE*) is the portion of the incoming sediment that is deposited, or trapped, in a reservoir or pond.

$$TE = \frac{S_{inflow} - S_{outflow}}{S_{inflow}} = \frac{S_{settled}}{S_{inflow}} \qquad (22.4)$$

where, = the sediment mass entering a reservoir (= the sediment yield or delivery); = the sediment mass leaving the reservoir with the out flowing water; = the sediment mass deposited within the reservoir. To obtain data on *TE* for selected reservoirs or ponds, one can use the following methods:

1. Reservoir survey with suspended-load measurements downstream,
2. Reservoir survey with suspended-load measurements upstream, and
3. Suspended-load measurements up and downstream.

Sediment Delivery Ratio

It is the ratio between the yield of sediment at the measuring site and the gross erosion in the catchment.

$$S_{DR} = \frac{S_D}{S_G} \qquad (22.5)$$

where, S_{DR} = the sediment delivery ratio; S_D = the sediment amount delivered to downstream at a particular gauging site; and S_G = the total sediment generated over the land surface catchment to the gauging point.

Reservoir Sedimentation Control

In order to increase the life of reservoirs, it is very essential to control the problem of sedimentation *i.e.* deposition of sediment in the reservoir. Various control measures which are adopted to control the reservoir sedimentation can be classified into the following two types:

1. Pre Constructive Measures
2. Post Constructive Measures

1. Pre Constructive Measure: It refers to those measures which are adopted before and during the execution work of the reservoir construction. These measures can be enumerated as follows:

a) Selection of Dam Site: The amount of sediment reaching the reservoir from a catchment area depends upon the soil erosion caused by water. If the catchment area is less susceptible to erosion, then less silts are charged into the stream flow. As a result reservoir silting will be less.

b) Design Capacity of Reservoir: The design capacity of reservoir plays a significant role in the reservoir sedimentation. When the storage capacity is less than the volume of stream flow coming into the reservoir, then a large volume of water will be out from the reservoir quickly. This result in deposition of much less sediment in the reservoir compared to when the reservoir capacity-inflow ratio is high.

c) Construction of Check Dam: Check dams play a key role in controlling the inflow of sediment into the reservoir. The check dams are constructed across the stream/river to trap the major portion of sediment load. These dams trap large amount of coarser sediments.

d) Installation of Vegetative Screen: Vegetative screen is a vegetative cover through which flood water passes, before entering into the reservoir. The control of sediment entry into a reservoir by use of vegetative screen is based on the principle that vegetations trap large amount of sediments by reducing the flow velocity and filtering the soil particles from the flood water. It is one of the best and cheapest methods of silt control.

e) Construction of Sluice Gate under the Dam: There must a provision for installation of sluice gate at the base of the reservoir dam to remove the silted water from the reservoir. The sediment concentration is more at the bottom of the reservoir. Therefore, sluice gates (silt excluder) should be located at the lower portion of the dam. This method is not much suitable as the flow of water tends to develop a channel behind the sluice from where water flow takes place and as a result most of the silts do not get flushed as they remain undisturbed. It is very essential that the release of sediment from the reservoir through the sluice gate must be simultaneously supported by mechanical loosening and scouring of the neighbouring sediments to increase its effectiveness. However, since this method has structural problem it is not widely used.

f) Reservoir Operation: The sediment delivery rate increases with the rate of volume of discharge, which depends on the demand of water of the command area. The amount of sediment trapped by the reservoir for a given drainage area, increases with the increase in its capacity. The sedimentation rate decreases with more rigorous use of the reservoir. The ratio of the reservoir capacity and the size of the drainage basin is one of the most important factors which govern the annual rate of sediment accumulation in the reservoir.

g) Erosion Control: The erosion is a main source of sediment yield. To control sedimentation problem of reservoirs, the control of erosion is most essential. The erosion control measures include all those measures which are effective in preventing or delaying the movement of sediment laden flow from the origin.

2. Post Constructive Measure: Post constructive measures are undertaken during the operation of the reservoir. It includes the following methods.

a) Removal of Flood Water: It is well known that the sediment content is more in the stream water during initial stage of the flood. Therefore, this phase of flood water is not advised to be collected into the reservoir.

b) Stirring of Sediment: It is generally performed by using a mechanical stirrer. Due to this, the deposited sediment is scoured and disturbed in the water, which is flushed outside through the sluice gates.

c) Removal of Silt Deposits: The deposited sediments in the reservoir are also removed by excavation, dredging and sluicing with hydraulic or mechanical agitators. Dredging method is the most expensive method among all and is not economically feasible for all water storage works.

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