Research Paper

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Reservoir Sedimentation – A Simple Analysis on Malampuzha Dam, Kerala

Engineering

KEYWORDS : Sedimentation, reservoir, trap effeciency, Siltation

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ABSTRACT

A reservoir to be fully effective in working, its storage capacity for which it is designed should not be depleted due to the accumulated sediments. Interest in sediments is increased nowadays because people are now aware of how rapidly sediments can accumulate in streams, ditches, culverts and reservoirs. The shortened economic life of these structures and the troubling the equipments in these reservoirs were felt by many researchers. Many are concerned about the decreased quality of their drinking water. The major cause of the dried reservoir is siltation which in turn reduces the storage capacity of the reservoirs. Studies reveals that, most of the reservoirs in India are lost their dead storage capacity which is meant to be reserved for the sediment dumping during the life time of the reservoirs. The objective of this paper is to discuss the sedimentation issues in general by touching its causes, impacts and useful controlling measures giving potential to the sedimentation issues in Malampuzha dam in a simple analysis for improving its present condition.

INTRODUCTION

Increase in population and demand for water for various purpose made us to construct dams and reservoirs all over the world since industrial revolution. They are designed to store runoff from all major and minor storm events. Unlike the ones constructed prior to the industrial revolution these major dams are designed not to fail, but these large dams trap sediment and do not allow the transportation of sediment to the downstream reaches. The majorities of the reservoirs created by these dams around the world are filling up with sediment and are losing its water storage capacity. This imbalance due to increase in demand for water and loss of storage in reservoirs as well as global warming are potential for major conflicts around the world [1]. When a river is silted behind a dam, the sediments it contains sink to the bottom of the reservoir. The proportion of a river's total sediment load captured by a dam called its trap efficiency approaches 100 per cent for many projects, especially those with large reservoirs. As the sediments accumulate in the reservoir, so the dam gradually loses its ability to store water for the purposes which it was built. Every reservoir loses storage due to sedimentation although the rate at which it happens varies widely. Sedimentation is still considered as a serious problem even after seventy years of research throughout the world. Every river carries certain amount of sediment load [2]. Silt studies done so far in major reservoirs in India shows that year by year the storage capacity of the reservoir is getting depleted alarmingly.

GLOBAL AND INDIAN SCENARIO

A small reservoir on an extremely muddy river will rapidly lose capacity but big reservoir on a very clear river may take centuries to lose an appreciable amount of storage and the rate of reservoir sedimentation depends mainly on the size of a reservoir relative to the amount of sediment flowing in to the reservoir. Large reservoirs in the US lose storage capacity at an average rate of around 0.2 per cent per year, with regional variations ranging from 0.5 per cent per year in the Pacific states to just 0.1 per cent in reservoirs in the northeast and major reservoirs in China lose capacity at an annual rate of 2.3 per cent [3]. Apart from rapidly filling their reservoirs, sediment filled rivers also cause other related problems for dam operations by affecting its components. The efficiency of a turbine is largely dependent upon the hydraulic properties of its blades, the erosion and cracking of the tips of turbine blades by water borne sand and silt considerably reduces their generating efficiency and can require expensive repairs. Globally there are about 25,500 storage reservoirs with the total storage volume of about 6,464BCM [4]. However sediments do not build up evenly along a horizontal plane, so that some live storage is lost long before the dead storage is filled. For example, at Tarbela Reservoir in Pakistan, 12 per cent of the live storage had been lost in 1992 after 18 years of operation, while 55 percent of the dead storage was still empty of sediment. In India, government statistics on eleven of the country's reservoirs with capacities greater than one cubic kilometre show that all are filling with sediment faster than expected, with increases over assumed rates ranging from 130 percent (Bhakra) to 1,650 percent (Nizamsagar in Andhra Pradesh). Even at early 90's to a World Bank paper on watershed development concluded that in India, erosion and reservoir sedimentation are not only severe and costly, but accelerating and presently it is still worst [5]. The following figures 1 & 2 shows a clear idea about the distribution of reservoir storage globally supplemented with reservoir storage loss also. It underlines the fact that this is going to be a major concern in the coming years globally.

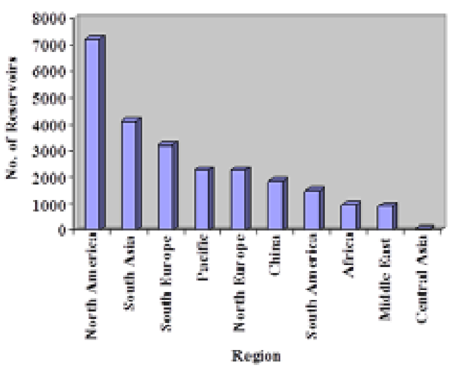

Figure.1, Distribution of Storage Reservoirs, Worldwide

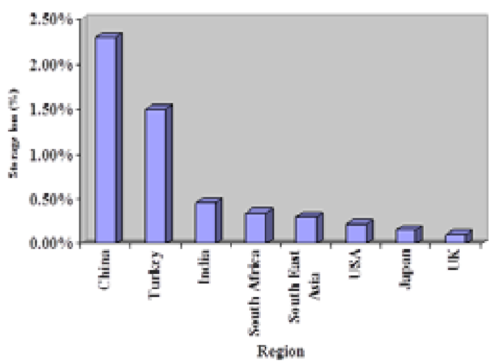

Figure.2, Reservoir Storage loss, Worldwide

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LITERATURE REVIEW

Experimental studies on reservoir sedimentation was carried out by many researchers a few from 1971 are highlighted. Using a laboratory flume, investigation has been made on the degradation of the bed profile caused by cutting off completely the sediment supply upstream, and aggradations caused by supplying sediment upstream in excess of the carrying capacity of the flow. When the incoming sediment exceeds the transport capacity of a channel, it deposits at the upstream reach with a resulting increase in slope and decrease in depth. [6] Documented bed degradation, bed coarsening and bank erosion just downstream of dams because of the release of water that has excess stream power as a result of low sediments loads. Increased frequency and intensity of extreme events may increase sediment production and downstream transportation. It is understood that extreme rain events control erosion and sediment transportation across the globe concluded by [7]. Problems caused by reservoir sedimentation in China are described, including elevated groundwater levels, entry of sediments into hydropower turbines; and loss of beneficial storage. [8] Describes in detail the Mechanism of Sedimentation, problems of sedimentation, Factors affecting sedimentations, possible controlling measures etc. [9] Studied the time rate of delta development in Upper Indrāvati Hydro Electric Project of India. [10] Studied that many reservoirs store almost the entire sediment load supplied by the drainage basin. The problem still persists all over the world and particularly in India.

SEDIMENT TRANSPORT MECHANISM

The Sediments generated in the uplands of the catchment reaches the streams and rivers wherein sediment transport takes place with flowing water as carrier. Sediment transport refers to the mechanisms by which sediment is moved downstream by flowing water either in suspension or by rolling , sliding along the river bottom or by bouncing along the bed called siltation. It is the transitional stage between bed load and suspended load and it is usually considered as the part of bed load. It is turbulence in water which is responsible for suspended load, while the shear stress developed by flowing water on the channel bed account for bed load. The sediment which moves as suspended load in one section may be moving as bed load in some other section. The transport of sediment continues in the downstream direction until the flow is no longer able to carry the sediment and at that time sediment deposition occurs. Generally it happens at the entrance to reservoirs where the depth of flow is decelerated due to impounding water by the dam structure. The interaction of the particles within a sediment laden stream leads to the formation of sediment waves or bars known as ripples. And these have a long and flat upstream slope and a steep downstream slope. The character of the ripple changes as the mean velocity is increased. When the velocity is increased, higher than that just to move the bed consisting of fine sand of less than 2mm dia, saw tooth type ripples are formed shown in figure 3. As the velocity is further increased ripples are super imposed upon them (figure 4) but at higher velocity ripples give place to periodic irregularities called Dunes. Dunes are more rounded and larger than ripples and may be formed in sediments of any grain size. Such ripples and dunes have short crested waves. A further increase in the velocity erases the dune formation in to a flat bed. A further higher velocity generates formations of sand waves associated with surfaces waves. The transportation of sediment in a stream is of vital importance in the planning of storage reservoirs.

Silt studies have revealed that coarse silt is deposited at the head of the reservoir building upper delta below full reservoir level thus encroaching on the live capacity. A part of the medium silt builds up deposit above the coarse silt delta and river reach upstream to enable the river to take up a slope of 0.55m/km. After this slope is established the medium silts deposit closely in advance of the coarse silt delta and is reworked, as the reservoir is depleted, in to the dead storage to form a lower delta. These deposits above dead storage are assumed to take a comparatively flatter slope (0.20m/Km). Once the delta reaches the dam, the entire medium silt is assumed to pass through the irrigation and penstock outlets.

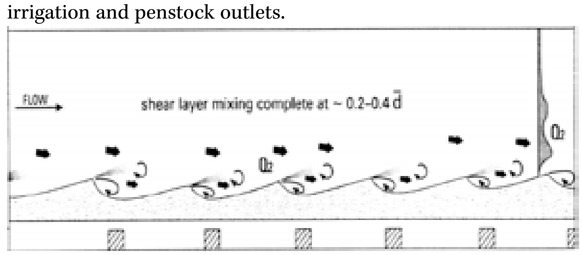

Figure.3, Saw Toothed Ripples

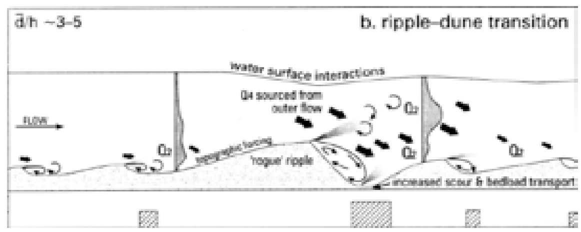

Figure.4, Ripple – Dune Transition

Conversion of reservoirs that are subject to sediment accumulation into sustainable resources which generate long-term benefits requires fundamental changes in the way they are designed and operated. It requires that the concept of a reservoir life limited by sedimentation be replaced by a concept of managing both water and sediment to sustain reservoir function and to alleviate sediment issues the following methods viz., Reduce sediment inflow, Sediment removal/dredging, Sediment placement, Sediment routing etc are widely used.

MALAMPUZHA DAM – AN INSIGHT

The river Malampuzha originates from the hills of north Palakkad bordering the Coimbatore district of the state of Tamil Nadu. The river is one of the tributaries of the river Kalpathipuzha that joins the river Bharathapuzha, the second longest river in the state of Kerala. The Malampuzha dam is constructed at about 4.5 km upstream of the falls about 8 km from the Palakkad town. An average rainfall of 1800mm is recorded from the command area of the Malampuzha irrigation project and about 75% of the annual rainfall is received during south west monsoon that sets in the last week of May and continue up to September. The reservoir formed by the Malampuzha Dam is 23.13 square kilometers in area and is the second largest reservoir in Kerala after the Idukki reservoir. The construction of Malampuzha dam started in the year 1949 and was completed in the year 1955 which is also used for power generation. The total catchments area is 145 square kilometers, while the reservoir has a capacity of 8000 square meters of water and it is the largest irrigation project in Kerala. The canal systems serve to irrigate farm land while the reservoir provides drinking water to Palakkad and surrounding villages. (Fig 8). The reservoir covering 2200 Ha is located between 76° 29' and 76° 42' E and 10° 48' and 10° 55' N. The masonry dam harnessing the Malampuzha River forms a reservoir with a full storage capacity of 236.69 Mm^3. It is designed with 367.54 Cumecs flood discharge capacity, 147 Ha drainage area, and 20553 Ha irrigable command area catered by the left and the right bank canals. The right bank canal (RBC) is 32 km long with a capacity of 4.25 Cumecs, while the left bank canal (LBC) is 27 km long with 21.23 Cumecs capacity [11]. The RBC traverses an area of rough undulating terrain and therefore the irrigable land served by it is relatively less As per the detailed project report (DPR) of the project, the dam was initially

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designed for 127.43 Mm^3 capacities with an ayacut area of about 16187 Ha [12]. The basic data of the dam is shown in Table 1 below. Periodic sample from the river are taken at various discharges and the suspended sediment concentration is measured. A sediment rating curve is prepared which is a plot of sediment concentration against the discharge and is used for approximate estimation of suspended sediment load (Refer Figure.6). The concentration of the suspended sediment not only changes from point to point in a cross section, but also fluctuates momentarily at any fixed point.

TABLE.1, FACTS AND OTHER HYDROLOGICAL DETAILS OF MALAMPUZHA DAM.

S.No	Description	Details
01.	River Basin	Bharathapuzha
02.	Dammed Tributary	Malampuzha
03.	Catchment Area	147.63Km^2
04.	Reservoir Capacity	236.69 Mm^3
05.	Water spread at FRL	23.13 Km^2
06.	Dam Height	115.06 m
07.	Length	2069 m
08.	Level of Siltation(KERI)	12.% or 27.12 mm^3
09.	Dead Storage	2.4Mm^3

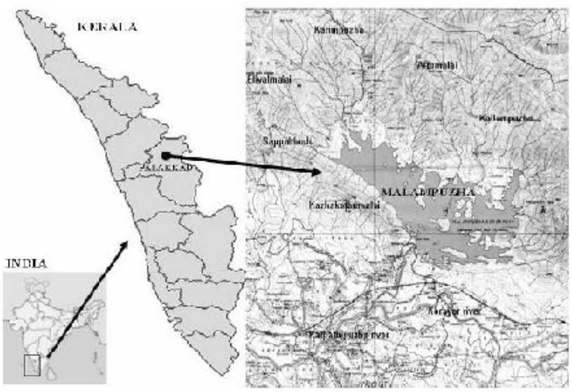

Figure.5, Location Sketch of Malampuzha Dam

Instantaneous or average concentration at a point or the average concentration in a vertical a suitable sampler has to be selected according to the requirement. The presence of the sampler and the process should not disturb the flow of the sediment in the medium from which the sample is drawn. The sampler can be vertical pipe, instantaneous vertical, instantaneous horizontal, bottle, integrating, pumping.

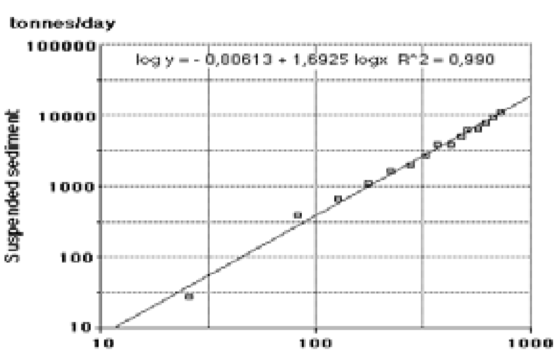

Figure.6, Suspended Sediment Load Vs Inflow

The methods used in locating vertical sampling stations have varied with different investigations as, Single vertical at mid-stream, Single vertical at deep point, vertical at 0.25, 0.5, and 0.7 width, Vertical at 1/6, 1/2, and 5/6 width and four or more vertically equally spaced across the stream. Usually the selection of these different positions of the vertical and the number has been decided more by urgency of the work as well as by the accuracy required. In this study the sampling locations were chosen as Single vertical at mid-stream, Single vertical at deep point, vertical at 0.25, 0.5 and 0.7 width. The concentration is found to be more in the deepest vertical and in the middle of the stream. Since the section is not too asymmetrical, variation in the vertical distribution of the sediments has been taken in to account.

Sediment load calculation was done using the universally accepted relation.

Meyer-Peter and Muller, $\Phi = 8(\theta - \theta cr)3/2$ ....(I)

Nielsen, $\Phi = 12\ \theta\ 1/2(\theta - \theta cr)$ ...... (II)

Where, θ = Shield's parameter, θcr = Critical Shield's parameter and Φ = Dimensionless transport number.

RESULTS AND DISCUSSION

Problems due to soil erosion and sediment deposition are worldwide problems and not restricted to one particular area, but it is essential to thoroughly understand and solve these problems in a practical way without affecting the reservoir for the betterment of the stakeholders of that region [13]. Malampuzha is one of the typical manmade reservoirs in Kerala, which confined by a characteristic humid tropical stream web on the Western side of the Western Ghats of Peninsular India. It is noted that the erosional energy of rainfall in this area is quite high. Soil erosion in this area is found out to be 532T/ha/year. The total land surface of the basin considered for the study is 147.63KM^2 and this area yields to a total annual sediment of 66900 T/year. Technology developed for sediment management could be transported by expanding these sediment management activities to the reservoir like Malampuzha.

CONCLUSION

Soil erosion is a complex dynamic process and it produces exposed subsurface where the soil has been detached and deposited in low-lying areas of the landscape or in water bodies downstream in a process known as sedimentation. Soil erosion and sedimentation are concurring environmental processes with varied negative and positive impacts. The negative impacts include the removal of nutrient rich topsoil in upland areas and subsequent reduction of agricultural productivity in those areas and at the same time if deposited in Lake or River bed than enhance the nutrients enrichment and reduce the storage volumes. The accelerated soil erosion has irreversibly converted vast tracts of land into infertile surface over the country. Siltation of reservoirs can also have a number of other impacts, including increased evaporation losses, increased backwater flooding and also could damage the power house turbines. While it is not possible to totally avoid or stop sedimentation, the way to reduce this is to do Catchment Area Treatment (CAT). CAT applies various techniques like plantation, gully plugging, check dams, etc in the degraded portions of the catchments to reduce the silt coming into the reservoirs. Through programs like soil conservation and similar methods are already in practice. It seems to b a difficult task to control erosion over vast tracts of lands by soil conservation practices alone. The problem of reservoir sedimentation can be brought under control by construction of upstream sediment traps and by evolving, effective procedures for sediment routing and sediment removal from existing reservoirs.

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