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Various Remedial Measures for Dam Siltation

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Abstract: Siltation, the gradual accumulation of fine sediments, poses a significant threat to water quality, ecological balance, and sustainable resource management. This paper explores the various remedial measures and strategies aimed at mitigating the adverse impacts of siltation on reservoirs created by the construction of dams, particularly earthen dams. A range of remedial measures and management strategies are discussed. These include physical interventions, such as sediment removal techniques, sediment traps, and erosion control measures, as well as biological methods like the use of vegetation to stabilize riverbanks and improve sediment retention. Furthermore, we examine the role of sustainable land use practices, watershed management, and legislative policies in preventing and managing siltation. Through the implementation of these remedial measures, we can contribute to the preservation of our natural environment and improve the overall well-being of society.

I. INTRODUCTION

In the water resource management, reservoirs, created by dams play an important role by storing the water in flood season, which is later put to use for irrigation or other uses. However, siltation is a common problem in earthen dams and it impacts dams by reducing useful storage, affecting the benefit/cost ratio calculated for the dam, and sometimes increases flooding hazards on the dam and for the downstream. While the growing population is demanding additions in the water reserve, the current siltation trend is continuously decreasing the reservoir capacity. On a worldwide basis, the replacement cost of the capacity annually lost to siltation is estimated to be around \$6 billion (Adamoet *al.*). Though siltation may not be an immediate problem for many of the dams with large reservoir, however, within decades, it can reduce their storage capacities.

To address siltation problems in earthen dams, various remedial measures can be implemented which are listed below:

A. Regular Maintenance

Routine inspections and maintenance of the dam are crucial to identify siltation issues early. Regular removal of silt deposits can prevent significant problems. The accumulated sediment can be periodically dredged or desilted during desilting operations, the frequency of which depends on the rate of siltation and the reservoir's capacity. The rate of siltation and consequent reduction in storage capacity can be assessed by the periodical capacity surveys of reservoirs. It is also necessary to arrive at a realistic siltation index for planning of future reservoir projects.

B. Vegetative Cover

Promote vegetative cover in the upstream watershed and on the dam's slopes to reduce soil erosion and the inflow of sediments into the reservoir. A combination of fast establishing species and species that will persist into the future is often needed for soil stabilisation in the upstream or adjoining areas of the reservoirs or dams. Deep rooted plants promote soil stabilisation. Moreover, native legumes ass nitrogen and promote plant growth thereby help in reducing erosion, which indirectly contribute to siltation problem. For planting and promoting natural succession, a variety of methods may be employed including hydro-seeding, broadcast seeding tree planting etc.

C. Sediment Basins

Sediment basins are specialized structures designed to capture and settle out sediments from runoff water before it enters a reservoir or other water body, such as an earthen dam. They play a crucial role in controlling siltation in earthen dams by reducing the inflow of sediment-laden water, thus preserving the dam's storage capacity and maintaining its long-term functionality. Sediment basins not only reduce siltation, but also help in maintaining the water quality of reservoir, which is essential for the downstream users and maintaining the ecological balance of reservoir.

D. Check Dams

Check dams are small to medium-sized, low-level structures constructed across natural drainages, gullies, or streams to manage and control the flow of water. Typically made of various materials, (including rocks, logs, concrete blocks, gabions and earthworks), check dams play an important role in highly erodible catchments for trapping sediment (Quinonero *et al.*, 2016) with various million units built worldwide (Verstraeten & Poesen, 2000). Check dams can also give an idea about the amount of silt contributed by a particular area

E. Silt Curtains

Silt curtain is a temporary sediment barrier installed parallel to the bank of a stream or lake. It is mainly used during construction activities along the banks of streams or reservoirs. They are available with visible floating tops and a weight pocket on the bottom for a tight fit. The permeable body fabric allows water to flow while preventing fine particles from escaping. They are designed for still or slow moving water and thus reduce environmental impact.

F. Soil Conservation Measures

Apart from adopting the various measures at the reservoir point to prevent siltation, various soil conservation practices can be implemented in the upstream watershed, such as reforestation, terracing, and erosion control structures to reduce soil erosion. The choice of these methods depends upon the soil characteristics, topography, slope etc.

G. Erosion Control

The sediment can be contributed by dam body as well, owing to its poorly compacted soil on the upstream or downstream slope. Such erosion phenomenon can be eradicated by controlling erosion on the dam's slopes and spillway areas by using appropriate vegetation, erosion control blankets, or riprap.

H. Sediment Removal Structures

Install sediment removal structures, such as sediment pipes or outlets at different levels within the dam, to allow periodic removal of sediments without significantly lowering the reservoir level. Dredging is also a large civil works endeavour, which not only involves excavating the silt but also the safe relocation of the excavated silt at a place from where there is no risk of its return into the waterway or reservoir.

I. Proper Land Use Planning

Findings by various researchers suggest that the extinction of evergreen forests and a significant change in land-use from range grasses and forest to agriculture generic and residential type results in surface runoff, sediment yield, and flow alteration and alteration in the evapotranspiration. These changes negatively impact the watershed runoff. The urbanization process (an anthropogenic factor) is a major cause of global LULC (Land use land cover change), which often leaves irremediable consequences on the environment. Hence work should be done with local authorities and landowners to promote sustainable land use practices in the watershed to minimize soil erosion. Various modelling techniques can be used as well to assess the impact of LULC changes.

J. Watershed Management

This involves a comprehensive watershed management plan to address the root causes of siltation, including land use, agriculture, mining and industrial activities.

K. Education and Outreach

Awareness among the local community and stakeholders need to be raised about the importance of preventing siltation and involve them in the conservation efforts. This would help to stop the siltation problem at the root cause to a larger extent.

L. Research and Monitoring

Continuous monitoring of sedimentation rates, water quality, and the effectiveness of implemented measures is also required to encourage the research in this area and adapt new techniques as needed.

M. Dam Modification

If any of the (or combination of) above remedial measures does not work effectively, consider modifying the dam design to include features that promote sediment settlement and easy removal, such as sediment sluices or sediment bypass systems.

It's essential to customize these remedial measures to the specific conditions and requirements of the dam and its watershed. Additionally, regulatory agencies, dam owners, and local communities should collaborate to implement and maintain these measures effectively.

II. CONCLUSION

Siltation poses a significant risk to dam safety and water resource management, as it can lead to reduced storage capacity, compromised water quality, and increased operational and maintenance costs. The remedial measures for siltation in earthen dams are crucial for maintaining the integrity and functionality of these vital structures. In short, addressing siltation in earthen dams requires a combination of proactive preventative measures and responsive remediation strategies. The key to success lies in a comprehensive and adaptive approach that considers the unique characteristics of each dam and its watershed. By implementing these measures, we can ensure the continued safety, functionality, and environmental sustainability of earthen dams, thus safeguarding the vital role they play in water resource management and society at large.

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