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An Overview on Desilter Devices

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Abstract—*Desilter devices have been used from more than century for removal of sediments from canals and reservoir which are used for power generation and irrigation purpose. This paper focused on the principle involved behind working of these desilter devices and their optimum location of installation for efficient working. Desilter devices extract harmful sediments which are coming from intake sites which if not extracted will reduce carrying capacity of canal by deposition and will damage mechanical instrument of power project considerably. In river and canals different type of desilter devices are used like settling basin , silt extractor , tunnel type silt ejector , vortex tube ejector and vortex settling basin. These devices increases life of irrigation structure and decreases maintenance cost of power generating equipments.*

Keywords*: silt excluder, silt ejector, settling basin, vortex tube*

1. INTRODUCTION

One of the most significant points in design of intake, is providing condition for passing on the maximum flow incoming water into the intake, and also is minimizing rate of sediment access. Generally sedimentation incoming to the intake and channel is associated with various troubles which is always related to bend and intake location on the river. For this reason many different methods have been utilized for defending intake structure and canals from this injurious sediment. In general practice intake is protected from this problem by increasing end sill height, providing some wall at Bed of Intakes, and by using submersible vane to check sediment bed to turn out inlet. There are different types of extracting devices, which are used to control entry of the sediment in to the canal. These are tunnel type, vortex tube, settling basins, and vortex chamber type (Kothayri et al. 1994; Ranga Raju et al. 1999; Garde and RangaRaju 2000). The today's world wide yearly loss of storage capacity due to sedimentation is already higher than the increase of capacity by the construction of new reservoirs for irrigation, drinking water and hydropower; due to which improvement of these desilter devices become rising topic for hydraulic engineers.

Garde and Pande (1976) used some of the concepts on sediment transport of uniform sediments to outline a method for design of sediment excluders, which facilitates the choice of the various parameters involved and at the same time ensures proper functioning of the excluder. Blench (1952) said that vertex tube is very useful for Giant channel with capacity more than 280 cms. Ahmad (1962) offered to use the vortex tube in the flow strand. He concluded that vortex tube has higher efficiency to exiting sediment particles for frontal intakes structures. Parshall observed that minimum efficiency of vortex tube is related to critical condition of flow in the channel. Efficient function of these desilter devices directly depend on grain size to be removed, location of installation, flow velocity, Froude no, and flushing discharge. So it become necessary to select these parameter suitably in accordance with type of ejector used and to attain maximum trapping efficiency.

This review-paper focuses on the latest research and improvement of desilter devices and the challenges of improvement are summarized. This paper is organized as follows; section (2) describes literature review of development of these desilter devices, section(3) describe challenges in development of these devices; section (4) describe optimum location and at last conclusion and benefits are discussed in section(5)

2. LITERATURE REVIEW OF DEVELOPMENT OF DESILTING DEVICES

Desilting devices used in hydropower and irrigation projects are broadly classified into following sub headings.

1) Settling basin
2) Vortex settling basin
3) Silt excluder
4) Silt ejector ; a) tunnel type silt ejector, b) vortex tube

Settling basin

Settling basin are used in irrigation and hydropower canal for removing horrible sediment of specific size and quantity. The main key is to afford a section wide and long enough so that the resulting reduced flow velocity will permit the sediment to settle out. Such reduction in the velocity also reduces the bed shear stress and the turbulence. Reduction in velocity, shear stress, and the turbulence, if satisfactory, stop the bed material from moving and also causes part of the suspended material to deposit. The flow into the basin is regulated by gates at intake. The sediment which will be settled is flushed out of the basin through the flushing conduit/tunnel back into the river.

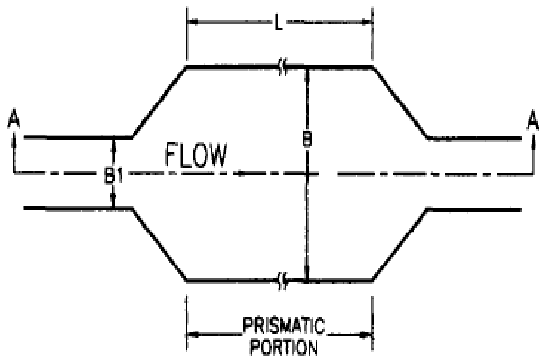

Fig. 1. 1 Definition Sketch of settling basin

Nandana Vittal et al. [1] settling basin were created by widen the approach channel and lowering its floor through an expansion transition, so as to reduce the mean velocity of flow. However, various combination of length, width and depth of the basin are possible to attain wanted removal efficiency in a given condition. Taking the cost of the straight and prismatic portion of the basin as the standard, equations have been developed for its best and efficient dimensions

R. J. Garde et al. [2] Experiments have been carried out in concerning the efficiency of settling basins. The data point out that the offered methods of their design were not acceptable. Analysis of all the available data has led to a new relationship for the efficiency. The parameters L/D and w/ u* were found to govern the efficiency. Where L was basin length, D was depth of flow in the basin, u* was shear velocity and w fall velocity of the sediment in clear water.

S. B. Weerakoon et al [3] offered a chain of laboratory experiments carried out to scan the effect of the entrance zone on the sand trap efficiency of the desilting tanks using a scale replica of a desilting tank with variable entrance expansion angles. The sand trapping efficiency was found to vary from50% to 85% with the reduction of expansion angle from 30 to 10 degree.

K. G. Ranga Raju et al. [4] trial investigation have been conceded out on the sediment removal efficiency of settling basins. Lab data on removal efficiency from the present and prior studies were first used for scrutiny the accuracy of the existing empirical and analytical methods for determination of the sediment removal efficiency of settling basins

Vortex settling basin

Classical settling basins generally suffer from two main disadvantages: (i) requirement of large dimensions of basin compared with other types, and (ii) longer settling time for sediment particles. Sediment extractors of vortex type would defeat the mentioned disadvantages. VSB utilizes centrifugal forces to produce a vortex motion around its central axis to eliminate sediment particles from the incoming flow by means of secondary currents in the chamber through the central flushing orifice.

In this device the high velocity flow is introduced tangentially into cylindrical basin having an orifice at the center of its bottom. This gives rise to the combined vortex surroundings (Rankine type) having a forced vortex near the orifice and a free vortex at the outer region towards the periphery of the basin. As a end result, sediment concentration gradient build up transversely the vortex and a diffusive flux, proportional but opposite to the centrifugal flux, is induce (Athar et al. , 2002). Resulting secondary flow causes the flow layers nearby to the floor of the basin moving towards the central outlet orifice. Therefore, the sediment particles reaching the center of the chamber could be flushed out continuously through the orifice and a relatively sediment free water would leave the basin through its overflow weir crest

Athar, M. , Kothyari [5],observed in performance analysis of VSB that for similar condition of flow for different grain size, trapping efficiency is maximum for bigger grain size. The removal efficiency of the basin was increased in accordance with the increase in discharge upto certain limit and with particular inlet velocity, however, it was observed that when the access discharge increased above that limiting discharge corresponding to maximum efficiency, the removal efficiency of the chamber was slightly decreased unlike the foregoing conclusions which could be attributed to the presence of turbulence in the chamber disturbing the free water surface and leading sediment particles towards the overflow current.

Mohammad Athar et al [6] laboratory outcome on sediment exclusion efficiency of vortex chamber type sediment extractors were reported. A geometric configuration of the extractor is identified that is able to remove even the fine sediment ($0.055 < d < 0.22$ mm) from flow with high efficiency. Since the existing relations were not found to produce satisfactory results, a new relationship is developed for purpose of the sediment removal efficiency of the vortex chamber type sediment extractors.

M. Athar et al. [7]In this study an attempt has been made to study the distribution of suspended sediment concentration within the chamber of vortex type sediment Extractor. A agreeable accord was found to exist between the practical values of sediment concentration and its values computed using the method proposed.

Alired D. Mashauri [8] discussed the hydraulic performance of vortex-type settling basins both, with horizontal and sloping floor in the sediment removal problem for water treatment intakes, hydropower plants and irrigation schemes.

Silt excluder and silt ejector

Silt excluder are installed in river bed for u/s of diversion work and silt ejector are installed in canal bed d/s of regulator work. In tunnel type ejector, the sediment-laden water, which flows mainly near the bed, is made to flow through the tunnels provided at the canal bed. It may be then discharged back into the river downstream through the under sluice bays. Presently, the only hydraulic principle utilize in its design is that energy loss is kept to a minimum and a minimum velocity of flow is ensured through the tunnel for the non deposition of the coarse material.

Garde and Pande (1976) used some of the concepts on sediment transport of uniform sediments to outline a procedure for design of sediment excluders, which facilitates the choice of the various parameters involved and at the same time ensures proper functioning of the excluder.

U C Kothari[9] and Garde, R. J., and Pande, P. K.[10] ,Hydraulic design consists of selecting the followings: (1) Excluder discharge, Q_{ex} (2) width of excluder Bex (3) depth of tunnels, t; (4) number of tunnels and tunnel lengths; (5) entrance of tunnels; and (6) location of mouth.

The excluder discharge Q_{ex} should be the minimum required. The reason is dual. During low flows, the intention would be to preserve as much water as possible. During the flood season, though sufficient discharge may be available for the excluder, a larger value of Q_{ex} would result in a larger sediment load coming into the pocket.

The tunnel height t is generally kept equal to the height of the canal-head regulator crest minus the thickness of the roof slab. A minimum value of t is necessary to facilitate inspection and maintenance of the tunnels. Length of sub tunnels are given by acceptable head loss consideration and non deposition on silt entered into tunnel criterion.

Vortex tube

Vortex tube is a tube with a longitudinal slit in the top, which is installed crossways the bed of channel. Vortex Tube is pipe with one slit at up side of it, this pipe will locate at bed of channel, and stretch at width directing of channel to move sediment deposit.

The performance of the tube based on the gravity of sediment particles, and the rotational force of the spiral form, which occurs within the tube. And sediment particles have fallen from the high slot (due to weight) into the tube, conduct to end of the pipe.

Blench (1952) said that vertex tube is very useful for Giant channel with capacity more than 280 cms. Ahmad (1962) offered to use the vortex tube in the flow strand. He concluded that vortex tube has higher efficiency to exiting sediment particles for frontal intakes structures. Robinson (1962) presented Froude number equal to 0.8 for use of vortex tube .Parshal observed that minimum efficiency of vortex tube is related to vital condition of flow in the channel.

Atkinson [11],in the research of vortex tubes angle (θ) and t/d, (width t slot pipe and tube diameter d) did showed its maximum tangential velocity in the pipe happen when the pipe angle relative to the flow direction is 90 or close to it, and the ratio (t/d) is low (about 0.3 or less).

Froude no effect

In general, increasing the Froude number near the vortex tube caused that sediment trap efficiency is gradually decease. But this process, in particular Froude numbers (with respect to the angular position of the tube) will be increased dramatically.

Trapping efficiency in the vortex tube angle of 60 degrees is significantly greater than the vortex tube at 90 degree angle, which could be increased.

3. CHALLENGES IN DEVELOPMENT OF DESILTING DEVICES

Methods of sediment control have been described by Huffered et al. (1975). To take away the sediment that has entered a canal, vortex tubes, tunnel type sediment extractors, and settling basins are often used but each of these devices have their own limitation. Vortex tube installations are very unusual, presumably because of the no availability of a dependable design method. Vortex tubes are not so efficient in extracting suspended sediment, though the water abstraction ratio,Q_0/Qc, is 10-25%. Here Q_0 is the flushing discharge and Qc is the inlet canal discharge.

Trapping efficiency, of tunnel-type sediment extractors is about 40%, while Q_D/Q_C is 15-25%. But use of tunnel type silt has one limitation of requirement of 20% extra discharge for flushing out sediment laden bottom layer through escape channel. So design discharge of canal with tunnel ejector is increased by 20%. Vortex tube and tunnel ejector are not efficient for removal of suspended very fine material.

Settling basins perform reliably as long as the suspended sediment is larger than 0.06mm.Velocity in the basin ranges from 0.08-0.45 m/s, whileQ_0/Qc is 0.5-3%.A vortex settling basin (VSB) is a fluidic device that uses only the vortices of the flow to extract the bed and suspended loads in the inlet canal. Principal features of VSB designs after Salakhov (1975), Cecen and Bayazit (1975),Ogihara and Sakaguchi (1984). The size of a VSB is very small, compared with conventional settling basins treating the same volume of water and sediment load (Cecen and Akmandor 1973). Thus the cost of construction of a VSB is just a small part of the cost required for the construction of a classical settling basin to extract comparable particles (Mashauri 1986). The VSB structure holds guarantee as an economical, efficient, and water-conserving alternative to the other available sediment-extraction devices. Investigators have carried out a detailed investigation on the performance of vortex type sediment extractors of various configurations, with the object of determining their removal efficiency basin. Trap efficiency relationship of vortex settling basin proposed by various investigators given in table no.1

Investigator	Relationship	
Curi et al.(1979)	$\eta o = 1.74 + \ln[\frac{d_0^{0.11}\left(\frac{\gamma_s}{\gamma_f}\right)^{0.88}}{Q^{0.58}}]$	
Mashauri (1986)	$\eta_0 = 0.835 - \frac{0.0292}{k_1} + 1.71 \times 10^{-2} \times \frac{d}{d_o} - 5.93 \times 10^{-4} \frac{d}{d_0 k_1}$	
Paul et al.(1991)	$\eta_0 = 73.4 + 8\log(\frac{\omega_0}{W})$	$\eta_0 = 2.16(\frac{\omega_0}{V_w})^{0.04}(\frac{Q_0}{Q_t})^{1.27}$
	$\eta_0 = 98 + 0.92\log(\frac{\omega_0}{W})$	$\eta_0 = 97.8(\frac{\omega_0}{V_w})^{0.0045}(\frac{Q_0}{Q_t})^{0.0}$
Athar et al (2002)	$\eta_0 = k_0(Q_0/Q_t)^{0.25}(Z_h/h_p)^{0.35}(\omega_0 d_s/\vartheta)^{0.15}({Q_w}^2/gR^3{h_p}^2)^{0.11}$	

4. OPTIMUM LOCATION AND ORIENTATION OF EXTRACTORS AND SETTLING BASIN

Location of fitting of these extractor devices has direct impact on removal efficiency. So it becomes quite important to find out optimum location of installation to maximize the benefits in terms of enhancing removal efficiency.

The ejector should not be sited too near the head regulator as the residual turbulence may cause the sediment load to remain in suspension and prevent its ejection to the desired extent. At the same time it should not be far away from the head reach otherwise the sediment may settle down earlier and reduce the channel capacity upstream.

The settling basin may be suitably located in the head reach of the water conductor system, just downstream of the hydropower intake structure. The orientation of the basin has to be proper with respect to the alignment of the inlet tunnel/channel on the upstream to achieve satisfactory distribution of flow, as naturally as possible. The tunnel upstream of the basin should be straight for at least a length equal to ten times the average width of the channel, or diameter of the tunnel, to achieve uniform flow in the basin. In case the approach channel is curved due to unavoidable site conditions.

The transition reach of suitable length and proper design should be provided. Turbulence can be minimized to a great extent by providing proper transitions. Upstream and downstream slope of the desilting chamber should be such so as to avoid silt deposition on the slopes.

5. CONCLUSION

The main objective of this review paper is to give an overview in the development of desilting devices, Classification and working principle of desilting devices, development and the challenges of desilting devices. The extent of sediment removal is governed by the operating requirements imposed in order to increase the useful life of hydro-mechanical equipment i.e. penstocks, valves, turbines etc. The operating requirements are approximately specified by the diameter of the particle size to be settled out and the allowable concentration of sediments.

The settling basin should normally be provided if the total suspended sediment concentration in water is greater than 0.2 kg/m^3 (200 ppm). However, the opinion of turbine manufacturer/designer should be obtained. Use of tunnel type ejector require 20% extra canal discharge for flushing sedimented bottom layer of water, otherwise at low discharge vortex tube extractors are used. The vortex chamber has overcome the disadvantages of conventional settling basins, i.e. the requirement of large dimensions and long residence time. Vortex settling basin can mitigate "Operation and Maintenance" problems face by Power Stations such as;

1. Harm to runner vanes of the turbines
2. Wear IN penstock
3. Regular choking of strainers
4. Choking and puncturing of coolers tubes
5. Scratch to cooling water pumps, valves etc
6. Frequent damage of turbine shaft seal
7. Damage to drainage and dewatering system besides siltation of sumps
8. Higher leakage through runner labyrinths resulting in high top cover pressure

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