Advances in Environmental Biology, 9(5) April 2015, Pages: 300-305

AENSI Journals

Advances in Environmental Biology

ISSN-1995-0756 EISSN-1998-1066

Journal home page: http://www.aensiweb.com/AEB/

Effect of Gradation on Sediment Extraction (Trapping) Efficiency in Structures of Vortex Tube with Different Angles

Sina Dashtbozorgi and Ali Asareh

Department of Water Science and Engineering , Ahvaz branch, Islamic Azad university , Ahvaz , Iran.

ARTICLE INFO

Article history:
Received 12 October 2014
Received in revised form 26 December 2014
Accepted 17 January 2015
Available online 28 February 2015

Keywords:
vortex tube, trapping, percent of orifice, sedimentation, the Froude number.

ABSTRACT

Unfamiliarity with sediment problems in the watershed has outdated a number of projects during their work, brought up heavy costs .Usually it is tried to prevent entering the sediment that moves as bedload in the rivers to the basin that methods such as increasing the basin bed level, mounting floor wall or submerged plates for removing sediment from the inlet, and desilting basin, using vortex tube include such methods. Since lots of variables are effective in sediment trapping and loss of vortex tube water, the aim of this study was to evaluate the performance of the vortex tube in vitro and in controlled discharge at four angles of 30, 45, 60 and 90 degrees in the flow path and using three gradation include: D_1 (particles passed the sieve 8 and remaining on the sieve 10), D_2 (particles passed the sieve 16 and remaining on the sieve 20) and D_3 (particles passed the sieve 20 and remaining on the sieve 30) and the ratio t:t/d the crack width on tube and d: tube diameter0.25. The results showed that decreasing the particle size, the sediment trap efficiency increases, provided that the sediments are as bedload. Also the angle 45 degrees with an average rate of trapping 92.01% and angle 60 degree with an average rate of trapping91.23%had the highest efficiency. The lowest efficiency is related to the angle of 90° with the average rate of trap 85.22%. The highest efficiency in this index was related to angle 45 with gradation D_3 with a value of 98.86% and the least was 70.16% related to angle 90 and gradation D_1. The results also show that the trap efficiency in all angles increases by increasing Froude number and then it decreases. The highest trap efficiency occurred in the Froude number 0.56.

To Cite This Article: Amir Hossein Firouzan and Somayeh Mohammadi Nejad., Study the Effects of Soil Compaction on Growth Characteristics of Alnus Glutinosa. ***Adv. Environ. Biol., 9(5),*** *300-305, 2015*

INTRODUCTION

It is usually tried to avoid the entry of sediment to basin which moves as bedload in the rivers, that some of the methods are as following: increasing the basin level balance ,mounting bed walls or, submerged plates for removing sediment from the basin span, desilting basin and using vortex tube. Even by designing these structures and due to the constant number of the structures and variability of hydraulic conditions, particularly in times of flood that has a large amount of sedimentation, the possibility of entering sediment in times of flood to basin is certain. So it is essential to design simple and economical structures that can remove the bed sediment and return it to the river. Inattention to sedimentation entering basins resulted in transferring them into the facilities and creates lots of problems as a result of loading sedimentation or accumulating them in different parts. Transferable sedimentations largely depend on the amount of sediment in the catchment and river characteristics. While, in the parts of the transmission system, particularly in systems where the water is passed gravitationally, flow rate is low, so that the water is unable to hold material transferred in a suspended state, additional sediments are deposited in channels. It starts from the basin and spread gradually throughout the system. As a result of sedimentation channels are encountered and by rising channel bottom elevation, the free board is decreased and the water delivery capacity is reduced. That's why the sediment control in the inlet is very important. One of the new desilting methods of river flows is using vortex tube that is more economical due to the small size compared with conventional rectangular desilting basins, and can be continuously utilized. The sediment control method is created based on using vortex force and sediment gravity force. The desilteris used when the bed capacity concentration is high for continuous flushing of sediments and its main

Corresponding Author: Ali Asareh, Department of Water Science and Engineering, Ahvaz branch, Islamic Azad university, Ahvaz, Iran.
E-mail: ali_assareh_2003@yahoo.com

part is formed by the tube or horizontal channel which is embedded within and under the bottom of the channel and transfer the sediments near the bed outside. Then the flowis discharged into a desilting basin, river or drainage. Figure (1) shows a view of the vortex desilter.

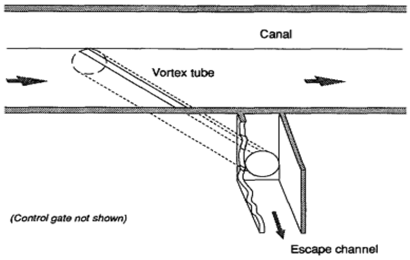

Fig. 1: View of vortex tube.

Vertex tube can be placed close to catchment facilities or far enough from the downstream of facilities where sediment distribution is reached an equilibrium state. The idea of using vortex tube under appropriate circumstances has some advantages compared with various sediment control methods and is more efficient, since all work is done in a totally controlled level. In this structure, the water enters a vertex tube under an angle and creates a strong vortex and eddy current will be created. Flow in tube is controlled by a valve in the downstream, and is discharged from there into a channel. Vortex desilter shows a high efficiency when the suspended load is low and bed load is considerable. However, good efficiency is recorded for this even when the suspended load is high and dominant .Parshal can be seen as the innovator of this plan .Blench stated that vortex desilting is used for large channels with flow loading capacity m^3/s280 $1000\ ft^3/s$. Robinson and Ahmad offered a Froude number $\left(\frac{v}{\sqrt{gh}}\right)$ 0.8 in the channel. Parshal (1952) observed that the lowest efficiency occurs when the Froude number is 1. Atkinson [2] by researches on the angle of tube position (θ) and ration of tube gap width with a diameter of ($\frac{t}{d}$), showed that the tangential velocity in the tube is maximum when the tube has a 90 degree angle to the flow path or near it and when the ratio of ($\frac{t}{d}$) is low (About 0.3 or less).

NikMehr *et al*., [6] examined the factors influencing the trapping of vortex tube such as tangential velocity, approaching speed and energy loss, with controlled and uncontrolled (free) discharge in irrigation canals. Their research was done with 4 relative width of the entrance slit of sediments in diameter (t/d) 0.15, 0.2, 0.25 and 0.3 and influenced by4 controlled discharge flow rate 2.5%, 5%, 7.5 % and 10%. The results showed that when the ratio of the entrance slit of sediments to tube diameter is0.15, parameters effective in sediment trapping are in controlled and uncontrolled states and in optimal conditions. Muazzen *et al* [5], by building the experimental model attempted to examine the effect of variables such as tube diameter and angle of the tube placement under different hydraulic conditions. The results showed that the trapping efficiency depends on the Froude number, so that increasing Froude number, the trapping efficiency is firstly increased and then decreased. The maximum trapping efficiency was in the Froude number 0.6. The rate of water loss is decreased by increasing Froude number so that the maximum loss was8.5% for the Froude number 2.0 and the lowest rate was 4% for the Froude number 1.09. Water loss amount was maximum 7% for Froude number 0.6 to 0.8.

Due to the fact that many variables are effective in the sediment trapping and water loss in vortex tubes, this study aimed to evaluate the performance of vortex tubes in vitro and controlled discharge in four angles of 30, 45, 60 and 90 using three different gradations with the ratio t/d 0.25(t: gap width on the tube and d: tube diameter).

MATERIALS AND METHODS

This research tests were conducted in laboratory of Ahwaz Islamic Azad University, located in Chonibeh to evaluate the effect of gradation on trap efficiency in the vortex tube structures with different angles. The practical steps of this test were planned by installation of vortex tube with a 2 inches diameter and orifice to diameter ratio(t/d) 0.25 at the bottom of the flume with four different angles (30, 45, 60 and 90) and under four different discharges and three different gradations D_1, D_2 and D_3 in a flume with a length of 13 m, width 50 cm, depth 60 cm. For hydraulic experiments, first the flow path was completely clean to make the flow of water in the flume visible and clear, and then using a water tankers, ground reservoir was dewatered. After the main flume pump was turned on after dearation and after a while ensured that the flow overflowed from the air reservoir, the water inlet valve has been opened to flume to let water into the main canal. Inlet valve was opened so to provide the average desired discharge. After a while, the discharge through the 13-meter flume at the downstream entered the basin, and its amount was measured by triangle spillway with a 60° angle .The output flow from the slotted pipe that was transferred to a ground reservoir through a 3.5-meter flume was measured by a triangular spillway with the apex angle of 90°. Figure 2 shows a view of the 90 degrees spillway.

Fig. 2.90: degrees spillway of measuring output discharge from vortex tube.

The sum of two discharges is the discharge entering the flume that if it is different from the desired discharge ,inlet valve is a little open or closed to make the discharge equal to the desired one. To ensure the constant flow ,discharge was again measured in the downstream of the flume and the passed discharge from the basin. In the same conditions, flow depth at the upstream, beginning, end, and downstream of the vortex tube was realized by rulers installed in the body of the flume as well as depth gauge.

Due to the limitations of the laboratory and the discharge of pump, experiments were done with maximum discharge 20 Lit/S and at least 10 Lit/S. In this study, 4 input discharges 10, 13, 15 and 20 liters per second with the ratio 0.25 t/d was planned, and diversion discharge and water depth values were measured at the points mentioned earlier. To slow down the flow of pump into the flume, a lattice pump was used to amortize the energy. Sediments used in this experiment consist of three gradation include: D_1 (particles passed through sieve 8 and remaining on the sieve 10), D_2 (particles passed through sieve 16 and remaining on the sieve 20) and D_3(particles passed through sieve20 and remaining on the sieve 30), that was used in a layer with a thickness of 3 cm for experiments. To measure the diversion sediments ,at the end of each test, a lattice plate was used with a diameter less than the diameter of particles. (Fig. 3) Then dry sediments and were weighted by digital balance in laboratory conditions.

Fig. 3: Discharge output tube and diversion sediment and collecting sediment.

To measure the passed sediment (which was not trapped), the deposited sediments on the bed of the main channel and the sediments entered the system were collected at the end of each test and then dry sediments were weighted by digital balance in laboratory conditions.

Discussion and conclusion:

Generally, in performed tests, the deviation discharge, the output and total discharge were weighted in liters per second and sediment diversion (trapped), the sediments entering the system and remaining sediments were measured in kilograms which results are given in table (1) to (4).

In examining the results presented in the table above, by comparing the amount of trapped sediments at different angles, it can be said that 45 degrees angle with an average rate trapping 92.01 and angle 60 degree with average rate of trapping92.01have the greatest efficiency. The minimum efficiency is related to 90 degrees angle with an average amount of trapping 85.22 percent. In this index, the highest efficiency is for angle 45 and gradation D_3 with a value of98.86 percent and the lowest efficiency 70.16 percent is for angle 90 degrees and gradation D_1. Also, the results of the charts (1) to (4) indicate that the trap efficiency in all angles for gradation D_3 is more thanD_2andtrapped sediment forD_2 is more than D_1. In other words, the smaller the gradation, the trap efficiency increases. Of course, it appears that this result will be true as long as sediment move as bed load and in the higher discharges, it is predicted that by suspending particles, the trap in smaller particles decreases than larger particles. This result is true at all angles.

Table 1: Results of diversion discharge and sediment for30 degrees angle.

Water losses percentage (R%)	Sedimentation rate of diversion (Te%)	Sediment transport Weight Qst (kg)	Sediment Terminal Weight Qso (kg)	Weight sediment diversion Qsi (kg)	total discharge Qt (lit/s)	Terminal discharge Qo (lit/s)	diversion discharge Qi (lit/s)	Sieve	Froude number(Fr)	ROW
13.53	75.36	2.6	0.64	1.96	10	8.65	1.35	10		1
12.96	91.17	4.52	0.40	4.13	10	8.70	1.30	20	0.43	2
14.12	94.67	6.49	0.35	6.15	10	8.59	1.41	30		3
11.33	78.93	5.28	1.11	4.17	13	11.53	1.47	10		4
10.86	93.87	9.31	0.57	8.74	13	11.59	1.41	20	0.56	5
11.81	96.68	12.33	0.41	11.93	13	11.47	1.53	30		6
10.23	74.69	9.40	2.38	7.02	15	13.47	1.53	10		7
9.82	89.56	13.08	1.36	11.71	15	13.53	1.48	20	0.65	8
10.23	91.55	16.28	1.37	14.90	15	13.47	1.54	30		9
8.32	72.96	13.13	3.55	9.58	20	18.34	1.66	10		10
7.96	87.55	19.11	2.38	16.74	20	18.40	1.60	20	0.87	11
8.32	89.32	19.40	2.07	17.32	20	18.34	1.66	30		12
10.55	86.36	Average								

Table 2: Results of diversion discharge and sediment for45 degrees angle.

Water losses percentage (R%)	Sedimentation rate of diversion (Te%)	Sediment transport Weight Qst (kg)	Sediment Terminal Weight Qso (kg)	Weight sediment diversion Qsi (kg)	total discharge Qt (lit/s)	Terminal discharge Qo (lit/s)	diversion discharge Qi (lit/s)	Sieve	Froude number (Fr)	ROW
16.64	83.05	3.21	0.54	2.67	10	4.34	1.64	10	0.43	1
15.60	96.28	6.41	0.24	6.17	10	8.40	1.60	20		2
18.00	97.47	8.30	0.21	8.08	10	8.20	1.80	30		3
12.80	85.64	8.77	1.26	7.50	13	11.34	1.66	10	0.56	4
12.30	97.91	12.26	0.26	12	13	11.40	1.60	20		5
14.38	98.86	12.25	0.14	12.11	13	11.13	1.87	30		6
12.00	81.74	11.72	2.14	9.58	15	13.20	1.80	10	0.65	7
11.54	95.69	12.80	0.55	12.25	15	13.27	1.73	20		8
11.99	96.60	17.67	0.60	17.08	15	13.20	1.80	30		9
9.70	80.42	20.30	3.97	16.32	20	18.06	1.94	10	0.87	10
9.70	94.39	22.35	1.25	21.10	20	18.06	1.94	20		11
10.07	96.23	22.35	0.84	21.52	20	18.00	2.01	30		12
12.93	92.01	Average								

Table 3: Results of diversion discharge and sediment for60 degrees angle.

Water losses percentage (R%)	Sedimentation rate of diversion (Te%)	Sediment transport Weight Qst (kg)	Sediment Terminal Weight Qso (kg)	Weight sediment diversion Qsi (kg)	total discharge Qt (lit/s)	Terminal discharge Qo (lit/s)	diversion discharge Qi (lit/s)	Sieve	Froude number (Fr)	ROW
12.96	81.51	2.83	0.52	2.31	10	8.70	1.30	10	0.43	1
13.53	94.48	6.82	0.38	6.44	10	8.65	1.35	20		2
14.73	96.65	7.95	0.83	7.82	10	8.53	1.47	30		3
10.86	84.92	8.70	1.31	7.39	13	11.59	1.41	10	0.56	4
11.33	97.58	12.88	0.58	12.30	13	11.53	1.47	20		5
11.81	98.35	7.95	0.26	15.63	13	11.47	1.54	30		6
9.82	80.82	12.03	2.30	9.72	15	13.53	1.47	10	0.65	7
9.82	95.41	13.15	0.60	12.55	15	13.53	1.47	20		8
10.66	95.43	17.39	0.79	12.60	15	13.40	1.60	30		9
8.00	80.12	20.22	4.01	16.20	20	18.40	1.60	10	0.87	10
8.32	94.24	21.62	1.24	20.37	20	18.34	1.66	20		11
8.65	95.21	22.08	1.06	21.15	20	18.27	1.73	30		12
10.87	91.23	Average								

The results also show that in all angles, trap efficiency first increases by increasing the Froude number and then decreases. The highest trap efficiency occurs in the Froude number 0.56 which is consistent with the result of Moazzen and Shafaei [5], and DashtBozorg, Morteza. The results also show that in the Froude numbers more than 0.8, trapping is greatly reduced. Since an amount of discharge is require dnaturally in vortex tube system for diversion and withdrawal of sediments, given the above tables; these results suggest that regardless of gradation ,the least water loss is for 90 degrees as7.73% and maximum water loss is related to a 45 degree angle as12.92 percent. This result is consistent with the results of Moazzenand Shafaei [5].

Table 4: Results of diversion discharge and sediment for60 degrees angle

Water losses percentage(R%)	Sedimentation rate of diversion (Te%)	Sediment transport Weight Qst (kg)	Sediment Terminal Weight Qso (kg)	Weight sediment diversion Qsi (kg)	total discharge Qt (lit/s)	Terminal discharge Qo (lit/s)	diversion discharge Qi (lit/s)	Sieve	Froude number (Fr)	ROW
9.34	76.15	1.50	0.36	1.14	10	9.07	0.93	10	0.43	1
9.34	89.65	3.90	0.40	3.50	10	9.07	0.93	20		2
9.81	93.84	4.95	0.31	4.78	10	9.02	0.98	30		3
7.92	79.99	5.59	1.11	4.47	13	11.97	1.03	10	0.56	4
7.55	94.64	6.33	0.34	5.99	13	12.02	0.98	20		5
8.31	96.44	9.33	0.32	8.99	13	11.92	1.08	30		6
7.20	74.10	7.87	2.04	5.83	15	13.92	1.08	10	0.65	7
7.20	85.65	12.22	1.75	10.47	15	13.92	1.08	20		8
7.54	90.64	14.36	1.34	13.01	15	13.87	1.13	30		9
5.93	70.16	14.52	4.33	10.18	20	18.82	1.18	10	0.87	10
6.20	82.88	18.20	3.11	15.09	20	18.76	1.24	20		11
6.48	88.61	17.89	2.04	15.85	20	18.70	1.30	30		12
7.73	85.22	Average								

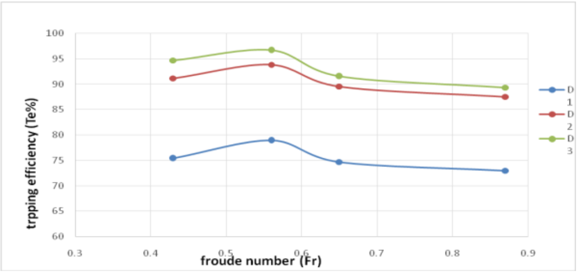

Fig. 1: Impact of Froude number on the efficiency of trapping in vortex tube at three gradations in30°.

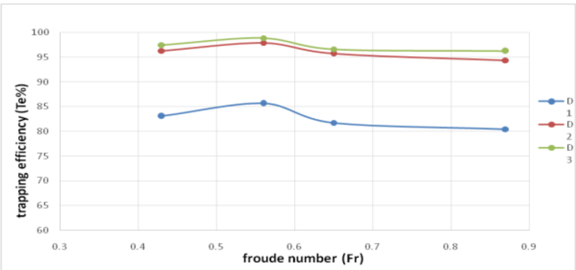

Fig. 2: Impact of Froude number on the efficiency of trapping in vortex tube at three gradations in45°.

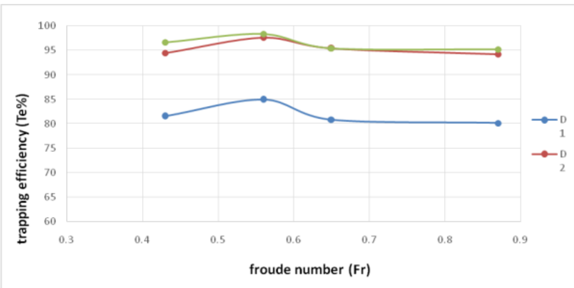

Fig. 3: Impact of Froude number on the efficiency of trapping in vortex tube at three gradations in60°.

Conclusion:

The results showed that the maximum sediment trap efficiency is related to the angle 45 and then angle 60, but since the rate of water loss at angle 45 is more, it is recommended to use angle 60. Increasing Froude

Advances in Environmental Biology, 9(5) April 2015, Pages: 300-305

number, trap efficiency initially increased and then decreased. The maximum trapping efficiency was obtained in the Froude number 0.56. Also, in smaller grading, trapping had a higher efficiency, which is certainly true when the fine-grained sediments are as bed material load.

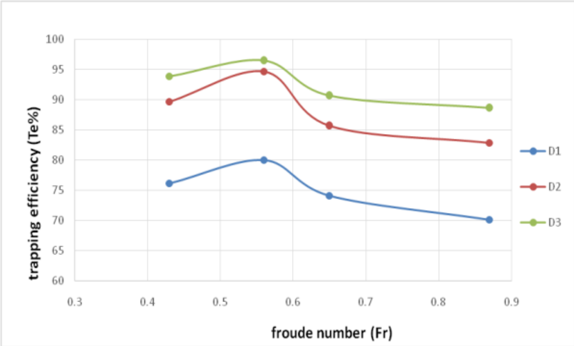

Fig. 4: Impact of Froude number on the efficiency of trapping in vortex tube at three gradations in90°.

REFERENCES

[1] Ahmad, M., 1958. Final recommendation from experiments of silt ejector of DG Kahn canal. Hydraulic research. IAHR.
[2] Atkinson Edmund, 1994. Vortex-Tube Sediment Extractors. Journal of Hydraulic Engineering, 120-10.
[3] Atkinson Edmund, 1995. A Numerical Model for Predicting Sediment Exclusion at Intakes. HR Wallingford, Report OD, 130.
[4] Blench, T., 1952. Discussion of 'Model and Prototype studies of sand traps. by R.L. Parshall. Trans., ASCE, 117-213.
[5] Muazzen, A., M. ShafaeiBajestan, 2003. Evaluation of hydraulic flow in vortex tube desilter. M.A. thesis on irrigation facilities, Faculty of Agriculture, University of martyr Chamran.
[6] Nick Mehr, S., J. Farhoudi, M.H. Omid, 2010. Evaluation of Parameters Affecting Sediment Extraction of Vortex Tube with Controlled and Uncontrolled Discharge (free). Journal of Irrigation and Drainage. Spring.