EXPERIMENTAL STUDY OF A DEVICE FOR DREDGING OF DAMS

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ABSTRACT

One of the main problems have several dams in Mexico, is the reduction of its operational life accelerated by effects of sedimentation in the absence of a management plan of sediments in the basin. The removal of sediments by dredging is a technique used to recover the storage capacity. However, it may be limited by the associated costs. New methods for dredging of dams are required. With intent of facing these problems, in the Hydraulic laboratory Enzo Levi at Mexican Institute of Water Technology (IMTA), an experimental study was conducted to test a device dredging works.

The Device Consist of: Main pipe, disc, inner tube, air chamber, siphon, compressed air supply. The device was immersed in a tank with water and bottom sediment. The air starts to fill the chamber gradually until it reaches the lower curve siphon and it was expelled into the main tube. A bubble was formed in the main tube, which rises to the surface and moves out the water contained within the tube and the resuspended sediment. Tests were conducted with different geometries and length of siphon. The speeds of the air bubble, pressure and volume of sediment removed were measured. The volume of sediment increases as the diameter of the disc increases, but not so with the siphon length. It is recommended to follow testing in the laboratory and the field validation.

Keywords: Dredging of dams, Device for dredging, Experimental study, Dams

INTRODUCTION

One of the main problems has in dams in Mexico, it is the accelerated reduction of its operational life by effects of sedimentation in the absence of a management plan sediment basin runoff. The removal of sediments by dredging is a technique used to recover the storage capacity. However such activity may be limited by the associated costs. It is required to have alternative methods for desilting of dams in our country, thus increasing its operational life and function

In an attempt to address these problems in our country, in the laboratory of Hydraulic Enzo Levi Mexican Institute of Water Technology (IMTA), the task of investigating a method to assist in the desilting of small dams and reservoirs she was raised.

From experience of the authors of this work on projects contamination of water bodies, it was decided to evaluate the usefulness of an aerating device, which have been used to aerate the water in aquatic systems where they have eutrophication problems [1]; and in areas with low or no flow circulation [3].

Recently, the device evaluated in this study, has been used to form clumps or flocs in the process plant wastewater treatment [2].

From experimental laboratory tests, different geometries of the aerator device were evaluated by determining the variables or parameters that influence in the resuspension potential or dredging of sediment.

EXPERIMENTAL SETUP AND PROCEDURE

The device basically consists of the following elements: main pipe, disc, inner tube, air chamber, siphon, compressed air supply. The size of the air chamber depends on the diameter of the disc and length of the siphon. The device was immersed in a tank with water and bottom sediment, allowing free discharge tube above the water surface. The air was supplied through a hose connected to the valve located on the disc of the air chamber. The air starts to fill the chamber gradually pushing the water contained therein. When the level of the displaced water reaches the lower curve of the siphon, the volume of supply air was expelled into the main tube. Within main tube, the air forms a bubble of pipe diameter, which rises to the surface by density difference. Each time the bubble ascends, moves out of the device the water contained within the tube, achieving thus a movement of the water at the bottom and resuspended sediment and expelled through the main tube (Fig. 1).

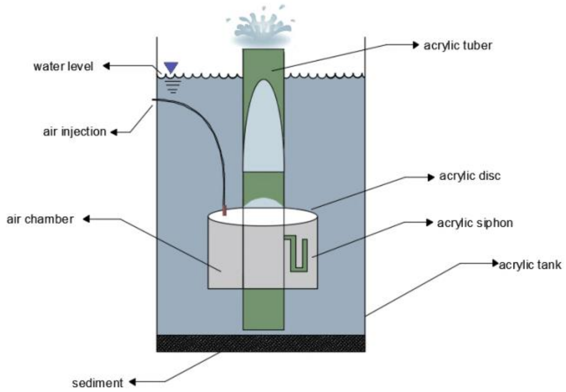


Fig. 1 Characteristics of the experimental device.

Initially preliminary tests were conducted in a reservoir built in acrylic box 0.40 m x 0.40 m x 0.89 m, for the purpose of take sensitivity to device operation. It later emigrated to a larger tank dimensions 1.67 m x 0.77 m x 1.62 m, Fig. 2.

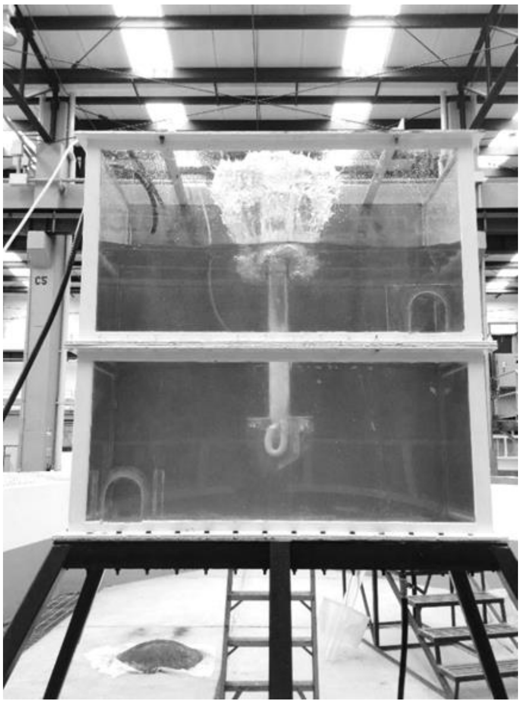


Fig. 2 Experimental Installation.

For the latter configuration 15 tests were performed with different sizes of acrylic discs (30 cm, 37 cm and 43 cm) and siphons of an inch in diameter with different lengths (11.5 cm, 13.5 cm, 15.0 cm, 18.5 cm and 20.0 cm) The variability of the disk geometry and length of the siphon were established according to the results of preliminary tests, in communion with the dimensions of the largest deposit.

For each condition of tested geometry, the air pressure supplied is varied and the rate of rise of the bubble was analyzed by a high speed camera. The tested device geometry, supplied air pressures and velocities of the air bubble for 15 tests are shown in Table I.

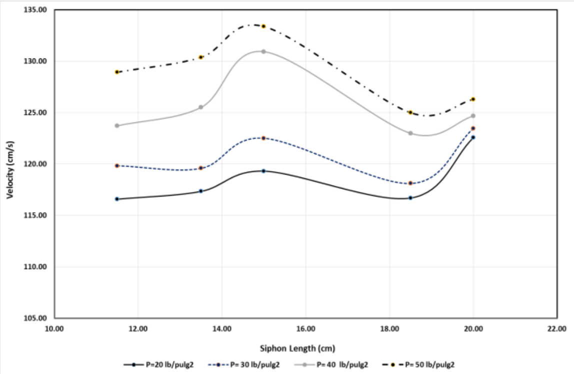
Table I. Ascent velocity of the air bubble for different device geometries.

Test No.	Siphon L. [cm]	Disk size [cm]	Velocity (cm/s)			
			20 [Ib/pulg^2]	30 [Ib/pulg^2]	40 [Ib/pulg^2]	50 [Ib/pulg^2]
1	11,50	30	116,6	119,8	123,7	128,9
2	13,50	30	117,3	119,6	125,5	130,4
3	15,00	30	119,3	122,5	130,9	133,4
4	18,50	30	116,7	118,1	123,0	125,0
5	20,00	30	122,6	123,5	124,7	126,3
6	11,50	37	112,7	118,1	122,1	126,1
7	13,50	37	104,3	105,9	120,8	120,8
8	15,00	37	120,9	120,9	138,1	136,4
9	18,50	37	118,5	123,2	131,9	133,4
10	20,00	37	131,7	132,6	133,0	136,9
11	11,50	43	112,3	119,8	122,6	128,1
12	13,50	43	105,1	116,0	116,3	116,6
13	15,00	43	116,3	120,6	121,2	123,5
14	18,50	43	121,3	123,2	125,2	127,2
15	20,00	43	119,0	121,1	122,1	122,2

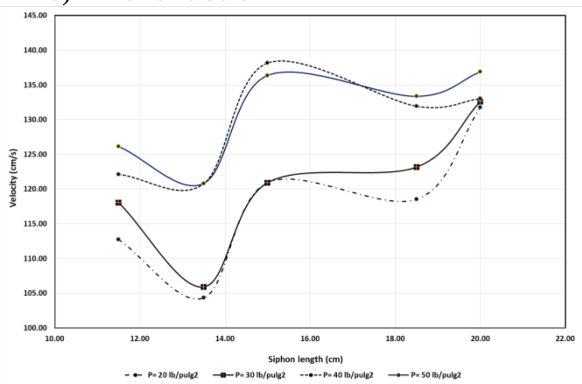
RESULTS

From the data in the table above, the rates of rise of air bubble respect to the variables of geometry air chamber and the air pressure supplied were plotted. In Fig. 3 the results of experiments for two cases of disk diameter air chamber for 30 cm and 37 cm are shown. The behavior of the variation of the speed of the bubble is irregular in both cases. Some features defined, for example tend to higher air pressure higher speed of the bubble, in some cases the speed of the bubble increases with the length of the siphon but others decreases. The same pattern occurs with the disc diameter of the air chamber, the fact said value increase does not guarantee higher speeds in the air bubble, see Fig. 3 and Table I.

For improved clarity the behavior of the rate of ascent of bubble regarding geometric variables of the device, the data of Table 1 were analyzed with the program 1.0.2 Statigraphics Centurion v15, as a statistical tool using a factorial design 2^3 . Table II shows the results of estimated effects of each variable and interaction among them, compared to the rising velocity of the air bubble. The average speed value was found to be 122.04 cm / s, the pressure supplied to generate the bubble has a greater effect on increasing the speed of said bubble and then siphon length. With increasing disk size, the speed of the bubble decreases. However these results are modified when the interaction between the variables analyzed.



a) Disk size 30 cm



b) Disk size 37 cm

Fig. 3 Results ascent velocity of the air bubble.

Figure 4 confirms the above, the rate of rise of the bubble increases with air pressure and the size of the siphon and decreases with increasing disc size. The interaction between variables is very important, see Fig. 5, the disc-pressure combination has positive effects on the speed of the bubble, while the siphon-pressure combination has negative effects, opposite result when analyzed individually each variable.

From these results, three of the 15 tests performed in which were recorded the highest rates of ascent of the bubble and the experiments were repeated to now analyze the volume of suspended sediment to an operating time of the device were selected. The material used in these additional experiments was volcanic sand with a specific gravity of γ = 2650 kg / m^3, d_{50} = 0.00019 m. The results are shown in Table III. As can be seen, the volume of suspended sediment increases with the size of the disk, it was not for the length of the siphon. With this it is verified that respect to the geometry of the air chamber, a key part of the operation of the proposed device, the disk size is more important than the length of the siphon on the rising velocity of the air bubble.

Table II Effects estimated for the ascent rate of the bubble.

Effect	Estimated	Error Std.	V.I.F.
Average speed	122.043	0.278934	
A:Siphon	1.02252	0.648532	1.00013
B:Disk	-3.44739	0.584257	1.00664
C:Pressure	8.60108	0.640123	1.0052
AB	-0.586931	0.649255	1.00168
AC	-5.27784	0.650893	1.0002
BC	0.675455	0.643851	1.00012

Standard errors based on the total error with 8 G. L.

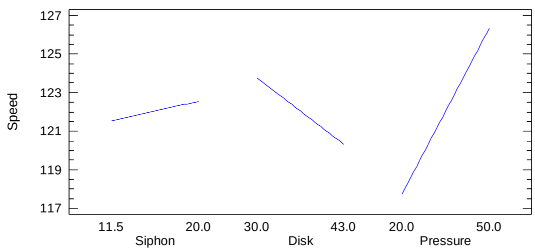


Fig. 4 Pareto chart standardized for speed.

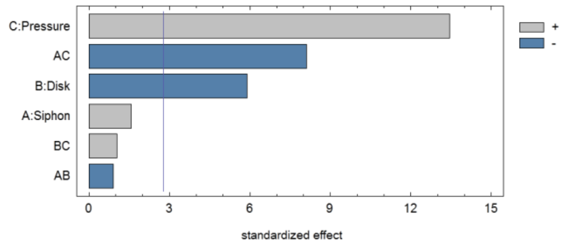


Fig. 5 Siphon, Disk and Pressure effect analysis in ascent speed bubble.

Table III. Sediment volume dislodged in 5 minutes.

Test No.	Disk Size [cm]	Siphon size [cm]	Sediment volume dislodged in 5 min [m^3]
1	30	13.5	0.00058839
2	37	15.0	0.00141214
3	43	11.5	0.00181060

CONCLUSIONS AND RECOMMENDATIONS

The removal of sediment of storage dams is an alternative to increase the operational life of the works. In Mexico the vast majority of vessels are azolvados dams, with little or no regulation capacity. There are more than 2,000 small dams and levees with potential risk of out of service. To contribute to reducing this problem, in this paper an alternate device was experimentally analyzed to help the desludging of small water bodies. This device works through the generation of an air bubble whose ascent rate is a function of the geometry of the air chamber and the supplied pressure. For a better understanding of the functioning of the device, the assays performed were analyzed using a factorial statistical design 2^3, using the Statigraphics Centurion v15 1.0.2 software. The variables analyzed were: the disk size, siphon length and air pressure supplied regarding the rate of ascent of the bubble. Each variable individually presents a different behavior when they interact with each other. The air pressure proved to be of greater importance than the disc diameter and length of the siphon to increase the rate of rise of the bubble. The pressure-disk combination is more relevant than the combination pressure-siphon for a faster rise of the bubble. It is convenient to comment that for the tested above the maximum pressure ($P = 50$ lb / in^2) has been difficulties for forming the bubble, indicating that the results are valid for the tested geometry in these experiments. It is recommended to continue testing and exploring the applicability of the alternate device presented in this paper, should even be tested in a real and practical field case and evaluate its functionality globally, involving not only the process of resuspension of sediment, but also analyze the process of capture, transport and deposition of sediment removed.

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