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Original research papers

An experimental study of the influence of open channel hydraulic parameters and soil gradation on jet pump sand removal`s efficiency

Abstract

Removing deposits is one of the most important maintenance activities that applied to irrigation canal. This research aims to study experimentally the effect of different flow conditions such as discharge and water depth on removing sand by using jet pump. To achieve this goal, an experimental program was set up and a small proto type of jet pump was tested under different conditions. The flow discharge , water depth and sand type were related to sand removable by jet pump. It is found that both of water depth and discharge of open channel had no direct effect on jet pump efficiency. The efficiency of jet pump is mostly effected by soil gradation. It is recommended to use jet pump in limited maintenance work where the soil is loose.

Keywords : Sediment removable , Jet pump, Flow discharges , water depth , grain size distribution

Introduction

Sediment Deposition is a serious issue facing water sector . Solid material or organic matter that transported and deposited by water or wind is defined as sediment **(Langland & Cronin,2003).** Sediment deposition has a harmful effect on the capacity of the reservoir , the life of dams , hydropower operation efficiency , intake and outlet structure as it may be clogged **(ISI,2011).** Besides that it may cause flooding , navigation problems and environmental negative impact **(EA , 2011)** . So without routine removing for sediment deposition , the water based activates will confront several problems.

Jet pumps are a hydraulic dredge devices used to remove sediment (sand/water mixture) from water courses. According to **(Richardson and McNair,1981)** Jet pumps bypassing system don't have moving parts and the jet of water can power it, so the primary component of jet pumps is differ from other pumps. In the suction

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chamber of jet pump, mixing occurs between (sand/water mixture) and central water jet, the surrounding sediment is crumbled by small water jet near the intake end of the suction tube , thus enables the sediment to flow towards suction tube end **(Bosman et al ,2002)**.

The properties of the sediment plays a major role on the jet pump performance. The sediment properties description is important in designing the system and the properties must include grain size distribution, in situ porosity, specific gravity of sediment solids, presence of cohesive material or cementing agents , presence of large objects such as debris and Subsurface profiles in areas where jet pump system may operate, preferably obtained from core samples**(Richardson and McNair,1981).**

Most studies focused on the jet pump geometry relations to improve the performance , but few studies explored experimentally the effect of flow characteristics and sediment type on the sediment removable by using jet pump, although it can play an important role in the performance and designing the jet pump. **(Bosman et al ,2002)** studied the removal of sediment from water intakes on rivers by using jet dredge pump to develop a reliable and simple jet pump design for the application in water intakes . **(El- Sawaf et al , 2011)** illustrated experimentally the Influence of the pump geometries and operating conditions on the performance, the result showed that the jet pump head and the head ratio decrease with increasing suction capacity. **(Saker and Hassan, 2013)** showed experimentally the effect of different jet pump parameters on the performance. **(Mueller,1964)** explored experimentally the optimum dimensions for water jet pump at best performances. (**El-Sibaie and El-Haggar,1987)** reported experimentally the particle size and nozzle outlet location on the slurry jet pump performance.

Aims of the Research

Most applied studies on the topic of water jet pump interested in studying the effect of jet pump geometry on its performance. However, the flow characteristics and sand type can play a role in the performance of jet pump. Therefore , the research aims to study experimentally the effect of flow discharge, water depth and different grain size

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distribution of sand on deposit removal efficiency by using jet pump to understand the phenomena and give an integrated outline for designing the jet pumps.

Experimental Work

The experiments were carried out in the hydraulic lab of the channel maintenance research institute, national water research center , Egypt. The used flume is a reinforced concrete flume of re-circulating type as shown in figure (1) . It has a total length of 22.10m. An underground reservoir with the dimensions 24.10 m long, 1.75 m wide, and 1.50 m height was used to supply the flume with water. The main part of the flume is the trapezoidal concrete section that has the dimensions of 16.22 m length, 0.60 m width, 0.42 m maximum depth and 1:1 side slope. The inlet part of the flume has the dimensions of 4.52 m long, 1.63 m wide, and 1.16 m height, with two vertical reinforced concrete walls to dissipate any excessive energy. The two walls are in a basin with the dimensions 3.00 m length, 1.63 m width and 1.21 m height, the inlet bed has a ramp with slope 3:1 is located downstream the two vertical walls. The outlet part of flume consists of outlet basin of dimensions 0.96 m length, 1.63 m width and 1.21 m height. The water was drained through Two pipes, 8-inch diameter to the underground reservoir.

A sand basin of 1.00 m length, 0.60 m width, and 0.10 m depth was constructed. Three soil gradation were used to represent fine, medium, and coarse sand. The medium grain size of the experiment sand soil (D_{50}) were 0.41 mm, 0.47 mm, and 0.58 mm respectively.

An experimental model was built up. The jet pump and the sand basin were attached to the hydraulic flume. The main components and dimensions of the used jet is shown in the figure (2). The output mixture of sand and water was collected in 4 m^3 sediment basin. The collecting basin is provided with filter at its drainage hole to prevent sand from escaping. Five discharges were selected to pass through the flume (30, 35, 40, 45, and 50 l/s). For each discharge three water depths were applied (25, 30, and 35 cm). for each run both discharges and water depths were adjusted and both the volumes of mixture and sand in the collecting basin were measured. Photo No. (1) shows the components of the experimental model.

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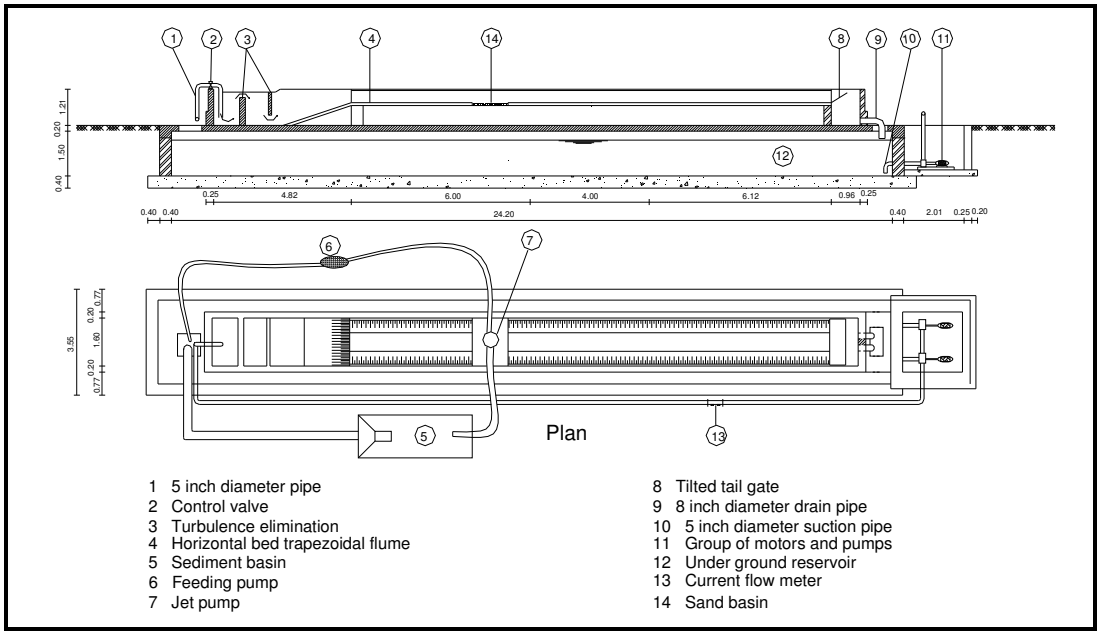

Fig. 1. Lay out of the experimental flume

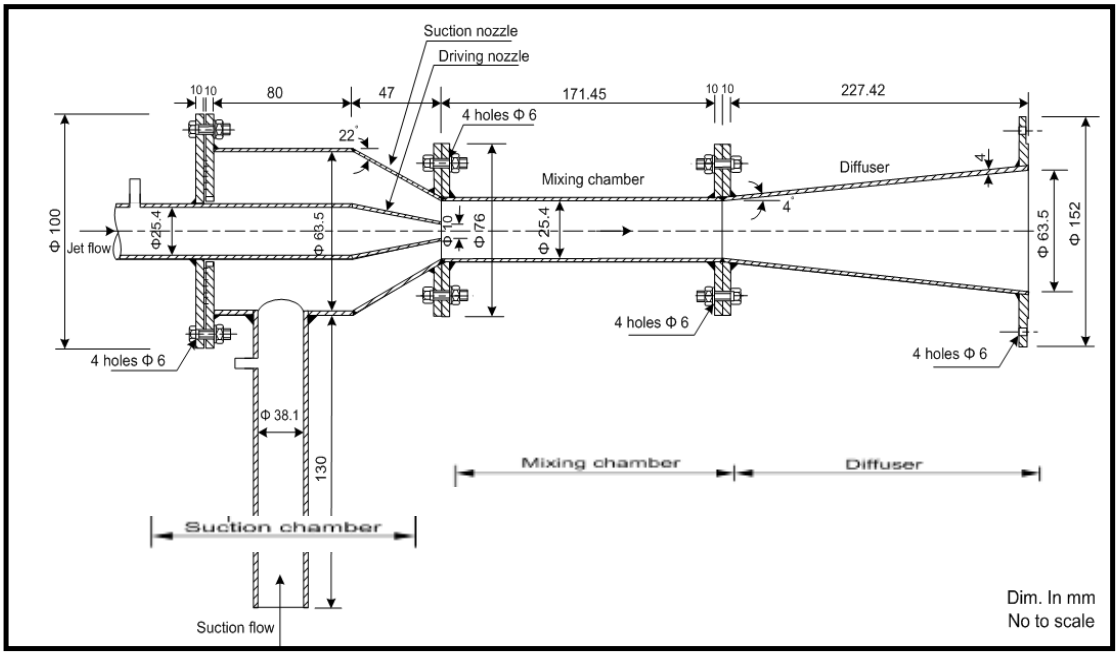

Fig. 2. Principal Components of the used jet-pump

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photo (1). Components of the experimental model

3- Theoretical Approach.

Dimensional analysis is used in the derivation of general equation to detrmin the efficiency of the used experimental jet pump.

$$\varepsilon = f\left\{\left(D_{50}/V_t^{0.33}\right),\left(Y/V_t^{0.33}\right),\left(V_s/(Q*T)\right)\right\} \quad (1)$$

Where (ε) is jet pump soil removal efficiency = (V_s/V_t) , (V_s) is volume of removed soil, (V_t) total volume of jet pump out put (mixture sand / water) ,(Q) is the discharge of the flume, (V) is the flow mean velocity of the flume, (T) is the time of run, (Y) is the water depth of the flume, (D_{50}) is the medium grain size of the used soil.

4- Analysis and Discussion

Forty five runs were applied on the physical model using small prototype of jet pump to identify the effect of changing water depth, discharges, and soil gradation on the efficiency of jet pump in removing soil.

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4-1 Effect of water depth on jet pump sand removal`s efficiency.

Three water depths were applied through the experiment with five flow discharges and three soil gradation. The used jet pump prototype is the same for all runs. Figure (3) represents a sample of experimental results. It shows a comparison between the efficiency of different water depths when passing different discharges for coarse sand removal. Maximum values for the efficiency were corresponding to water depth 30 cm which is not the maximum or minimum depth of the experimented water depths. Figure (4) shows the relation between the efficiency of jet pump in removing sand (ε)=(V_s/V_t) and the term ($Y/V_t^{0.33}$).The curve representing the relationship did not show a definite trend. The efficiency was increased with increasing ($Y/V_t^{0.33}$)to a certain value then it started to decrease. This may be due the fact that for each jet pump (size, geometric dimensions, and feeding pump properties) an ideal water depth which gives maximum efficiency.

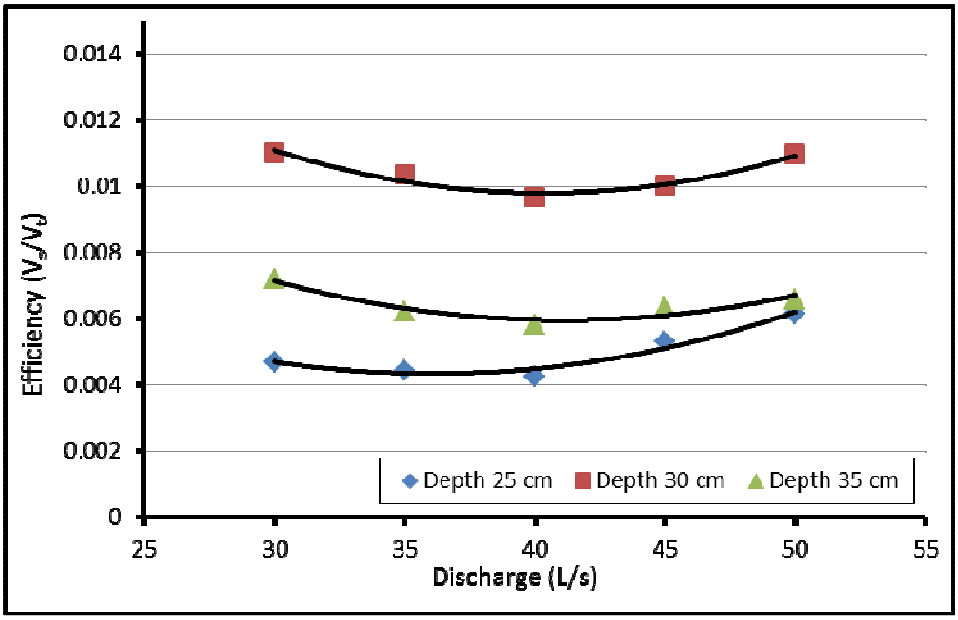

Fig. (3)The relation between jet pump sand removal`s efficiency (V_s/V_t) and discharge for different water depths.

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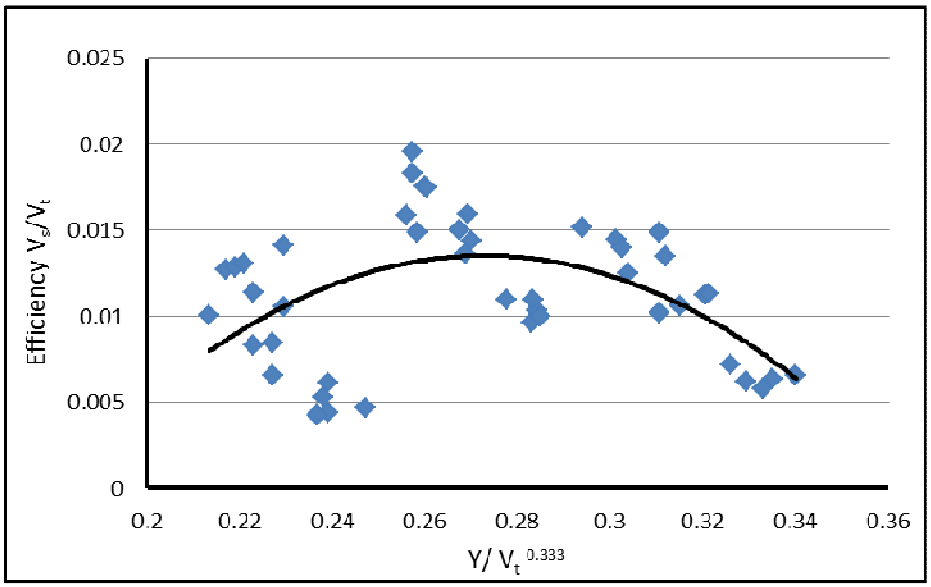

Fig. (4)The relation between Jet pump sand removal`s efficiency(V_s/V_t) and ($Y/V_t^{0.33}$)

4-2 Effect of soil gradation on jet pump sand removal efficiency.

The efficiency of jet pump in removing san was determined when using three soil gradations. Figure No. (5) represents a sample of experimental results. It shows comparison between the efficiency of different soil gradations when passing different discharges for water depth 35 cm. the efficiency of removing sand is decreased with increasing soil particle size. Figure No. (6) shows the relation between the efficiency of jet pump in removing sand (ε) and the term ($D_{50}/V_t^{0.33}$). the efficiency is inversely proportional to the term ($D_{50}/V_t^{0.33}$).

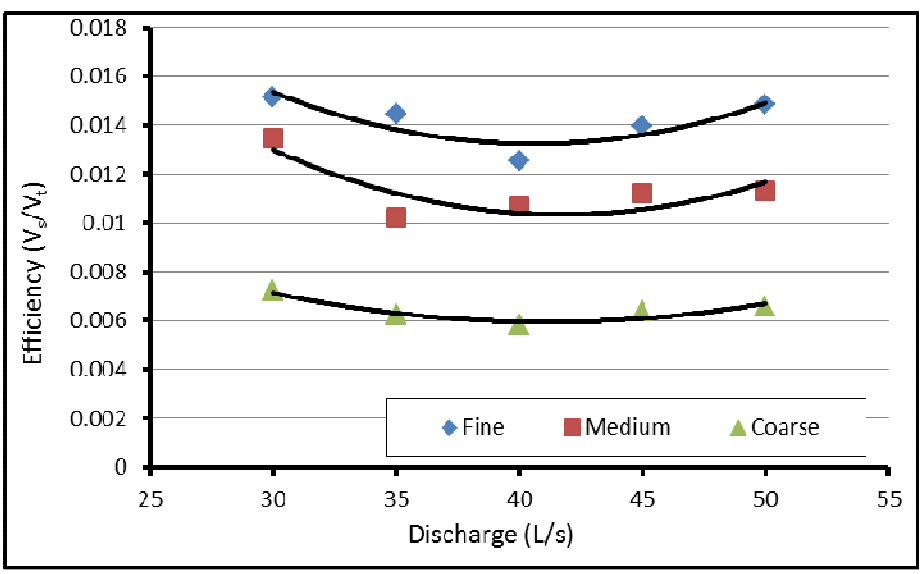

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Fig. (5)The relation between jet pump sand removal`s efficiency (V_s/V_t) and discharge for different sand gradations.

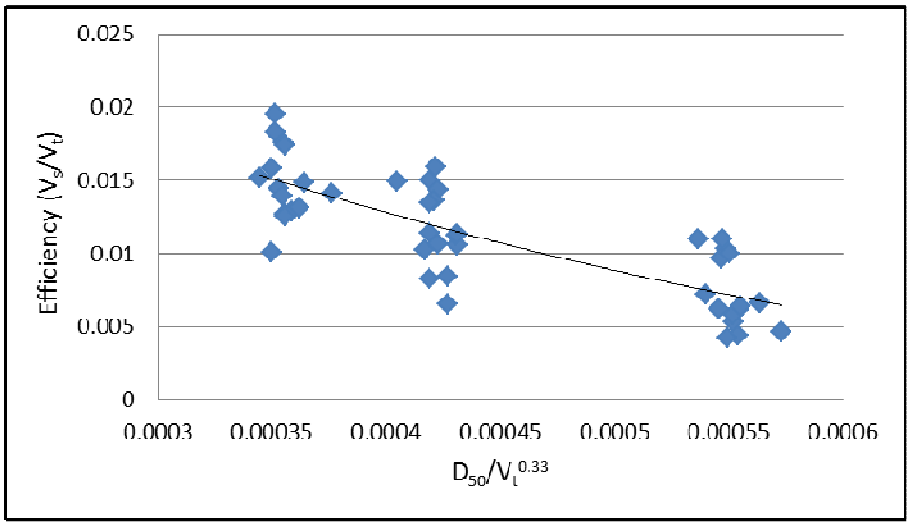

Fig. (6)The relation between jet pump sand removal`s efficiency (V_s/V_t) and ($D_{50}/V_t^{0.33}$).

4-3 Relation between jet pump sand removal`s efficiency (V_s/V_t) **and the term (V_s/QT)**

The Relation between jet pump sand removal`s efficiency and the term (V_s/QT) is represented in the figure No. (7). The removal efficiency is increasing with increasing the value of the term (V_s/ QT). The rate of increasing is high for smaller values of the term (V_s/QT). for higher values, the rate of increasing getting lesser. The relation between the two terms could be stated in the following equation:-

$$\varepsilon = 0.59\left[\frac{V_s}{Q \times T}\right]^2 + 0.20\left(\frac{V_s}{Q \times T}\right)$$

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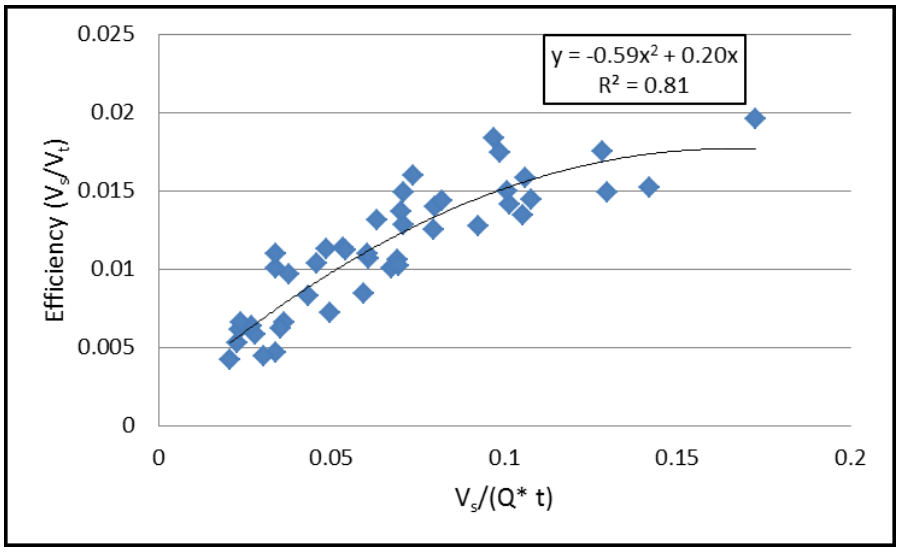

Fig. (7)The relation between jet pump sand removal`s efficiency (V_s/V_t) and (V_s/QT)

5- Conclusions

The experimental investigation focused on exploring the effect of the change in open channel hydraulic parameters and soil gradation on the efficiency of jet pump in removing loose deposit. The conclusion of the experimental investigation could be summarized in the following statements.

1. Both of water depth and discharge of open channel had no direct effect on jet pump efficiency of removing loose deposits. There is an optimum water depth and discharge for each jet pump geometrical dimensions.

2. The efficiency of jet pump is inversely proportion to soil gradation. It increased by average percent of 67% when using medium sand instead of coarse sand. The increscent reaches an average percent of 116% when using fine sand.

3. The jet pump could be used in removing small quantities of loose deposits which represent a problem nearby hydraulic structures. It is not encouraged to be used in large scale in open channel maintenance due to the high percentage of water in the resulting mixture.

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