Trial dredging by a new ejector-pump system for the reservoir sedimentation

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ABSTRACT: To develop an economical, versatile and environmental friendly dredging system, trial dredging has been carried out by using a new ejector-pump system. The result shows that the maximum grain size of the sediment that the system is able to convey is approximately 150mm in diameter. In addition, the transportation ability of the system is approximately 120 cubic meter per hour for 100 m distance.

1 INTRODUCTION

To solve the reservoir sedimentation problem, there are some measures such as excavation, dredging, by-pass tunnel, flushing, sluicing, and transportation pipe. As these measures have both advantages and disadvantages, the most suitable method has been adopted by considering the particular condition of the reservoir. Among these methods, the dredging by using the conventional pump system is quite common. However, it has some severe problems such as lacking resistance to abrasion of the impeller wheel and limited applicability of the sediment size. Therefore, we have developed a new ejector-pump system to overcome these problems (Sumi et al, 2009, Temmyo et al, 2009) and, in this paper, we show some results of field tests to transport sediments deposited in a reservoir.

2 A NEW EJECTOR PUMP

By discharging the high-pressured jet water from the nozzle, a new ejector-pump (Fig. 1,2) is able to produce the energy required to transport the dredged sediment. Since the new pump does not have any rotary part (impeller wheel), it is structurally simple and easy to maintain. The ejector-pump has two specific characteristics: one is a controlled air inlet into the pump; the other is the inner straight pipe that is not throttled. These are very effective for the cavitation control and abrasion resistance of the pump. By changing a combination of diameters of the nozzle and the inner pipe, the suction flow rate is able to be adjusted easily. Another advantage is that the jet flow washes the sediment while passing through the ejector-pump.

Figure 1. A new ejector-pump.

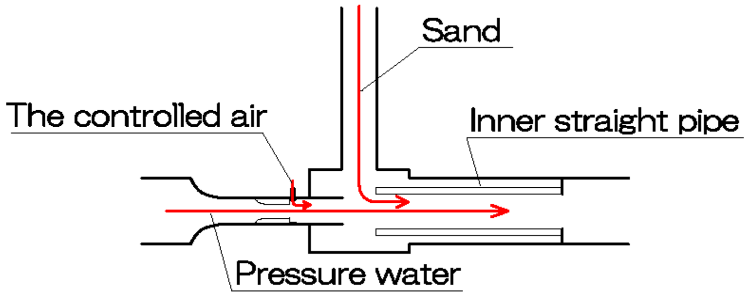

Figure 2. Sketch of ejector-pump.

The system consists of the new ejector-pump, high-pressure pumps and pipes. The plane view and photograph of the system are shown in Figures 3 and 4 respectively. The total transportation distance can be changed up to 100 m.

Two sets of high-pressure pumps suck up water from the reservoir, and then supply it to the ejector pump. The specification of the high-pressure pump is the engine output of 220 kW, pressure of 1.5 MPa, and flow rate of 5 m^3/minute.

The water from each high-pressure pump through the hard pipes (diameter of 150 mm) meets at the confluence just before the new ejector pump.

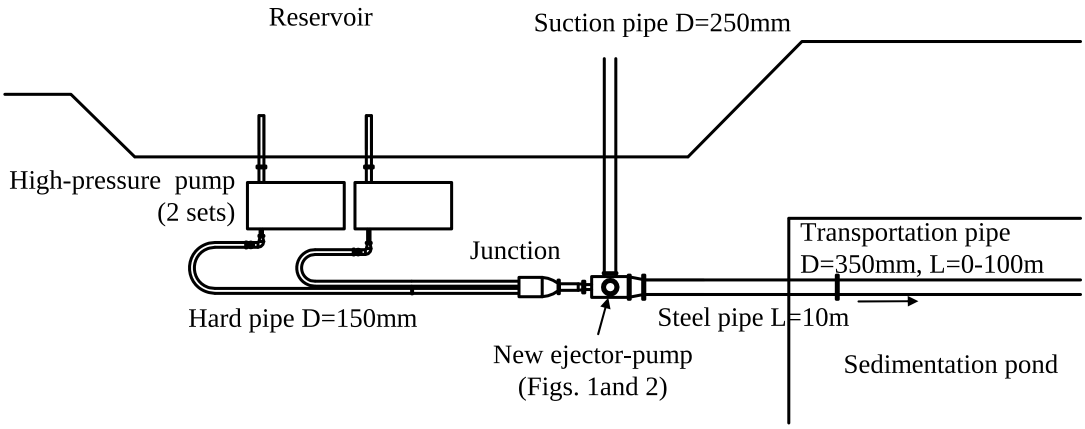

Figure 3. Plane view of new ejector-pump system.

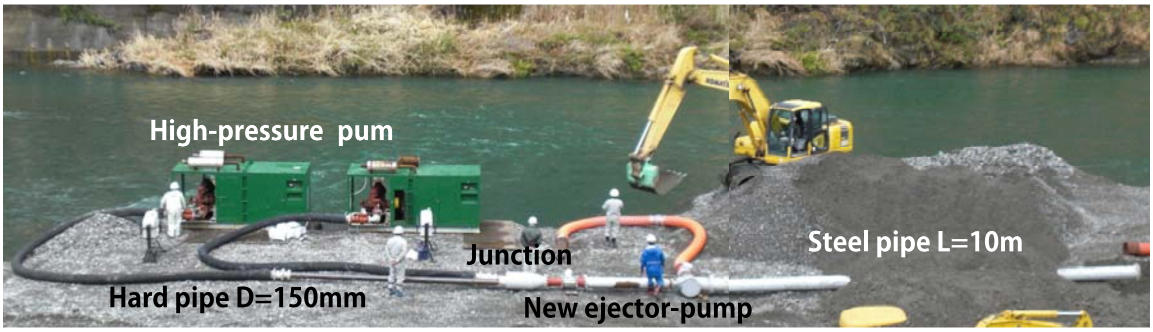

Figure 4. Photograph of new ejector-pump system.

3 SUCTION AND TRANSPORTATION TESTS OF WATER

3.1 *Procedure*

To check the performance of the ejector-pump, we studied the relation between the flow rate and the water head by using water.

First, setting the pressure of the high-pressure pump at 1.5 MPa, 1.3 MPa, 1.0 MPa, 0.8 MPa, the flow rate is measured. The diameters of the inner pipe are 200 mm and 250 mm respectively. The air inlet valve of the controlled air (as shown in Fig. 2) is set as three statuses, namely opened, half-opened and closed.

Second, maintaining the pressure of the high-pressure pump at 1.5MPa, and setting the air inlet valve at half-opened, the flow rate was measured while the end of the 100m long pipe was raised up to 16m.

3.2 *Relation between flow rate vs pressure*

The relations between the flow rate in the suction pipe and pressure of the high-pressure pump are shown in Figure 5. Figures 5a and b show the performance of pipes with an inner diameter of 200 mm and 250 mm, respectively.

It can be seen that the flow rate decrease with the reduction of the pressure. The trend of the diameter of 250 mm is more pronounced than 200 mm. Therefore, we should use the diameter of 200 mm rather than 250 mm under the conditions carried out in this trial.

Besides, when the inlet air valve is opened and installs large amount of controlled air, the flow rate reduces. Therefore, we should keep the inlet valve half opened.

3.3 *Relation between flow rate and water head*

In the water head of the system, the energy loss by friction in the pipe and potential energy at the top of the pipe has to be considered. The energy loss by friction in the pipe is calculated by the Darcy-Weisbach formula as shown below.

$$h_f = f \cdot \frac{L}{D} \cdot \frac{V_d^{\ 2}}{2g} \quad (1)$$

where; h_f: energy loss, *f*: friction coefficient, *L*: length of the pipe (m), *D:* diameter of the pipe (m), V_d: velocity of the flow (m/s), *g*: acceleration due to gravity (9.81 m/s^2)

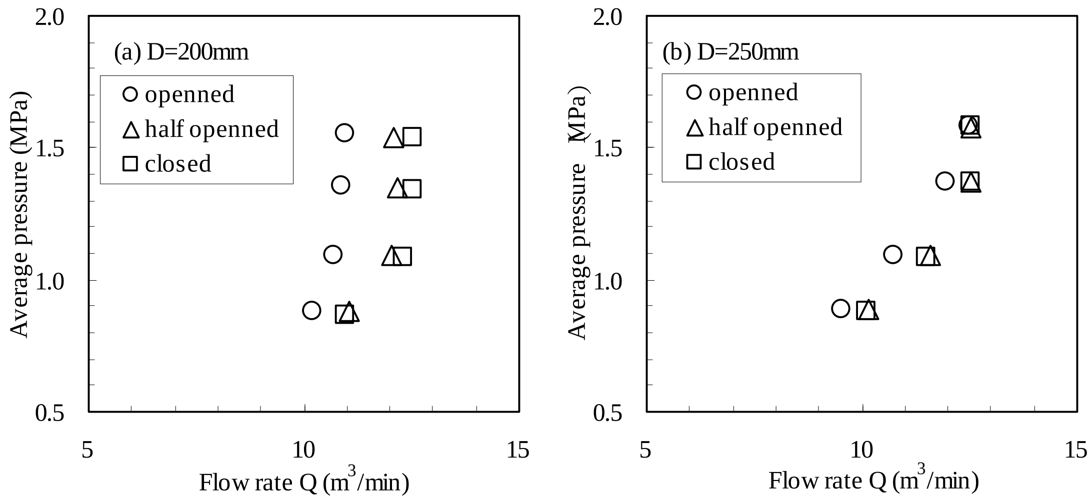

Figure 5. Relation between flow rate and average pressure of high-pressure pump for diameters of 200 mm and 250 mm.

The relation between flow rate of the suction pipe and water head is shown in Figure 6. From this figure, it can be seen that when the water head is approximately 10 m, the flow rate is almost the same for both 200 mm and 250 mm diameter pipes. However, in the range of low flow rates the 200mm pipe has a higher water head than the 250 mm pipe.

This result shows that for a long transportation distance the small inner pipe is of advantage. However, when the water head is less than 10 m and long transportation is not required, a large inner pipe is of advantage because it can be applied for large sediment grain sizes. It is important to select the pipe diameter to meet requirements for transportation distance, grain size of sediments, and water head.

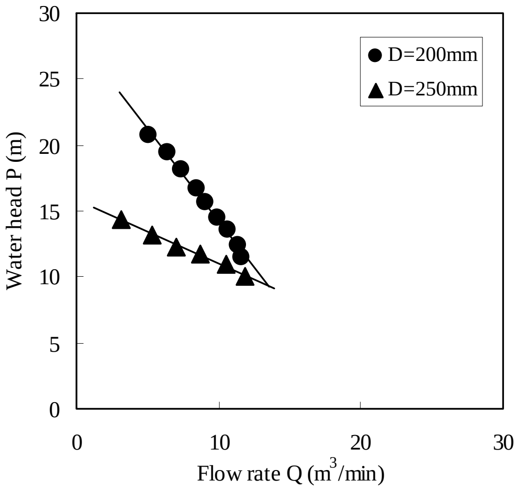

Figure 6. Relation between flow rate and water head.

4 SUCTION AND TRANSPORTATION TESTS

The sediments in the reservoir selected for the field tests consisted of coarse-grained boulders, gravel and sand. The maximum grain size is approximately 150 mm and the sand (under 5 mm) ratio is approximately 30%.

About the suction and transportation test, the following dredging methods were compared during the trial as shown in Figure 7.

(A) sucking both sediment and water underwater condition;
(B) casting sediment into the hopper mounted on the special ejector; and
(C) sucking sediment in a normal-atmosphere environment.

The best method of dredging depends on the location and the local conditions. We have to adopt the suitable method to pump up and transport the sediment.

The water pressure of the high-pressure pump is 1.5 MPa, and the diameters of the inner pipe in the new ejector-pump are 200 mm and 250 mm. The tested sediment is sieved and classified into three categories, i.e. 50 mm, 100 mm, 150 mm (maximum size).

(A) Under water (B) Cast into the hopper (C) Direct suction

Figure 7. Methods of suction tests.

Figure 8. Original sediment in the reservoir.

Table 1. Results of suction tests.

Dredging method	Diameter of inner pipe (mm)	Performance	Maximum size of sediment		
			< 50 mm	<100mm	<150mm
(A)	ϕ 200	Sediment (m^3/h)	55	46	—
		Water (m^3/min)	20	20	—
		Sediment rate (%)	4	4	—
	ϕ 250	Sediment (m^3/h)	67	63	55
		Water (m^3/min)	20	20	20
		Sediment rate (%)	5	5	4
(B)	ϕ 200	Sediment (m^3/h)	86	55	—
		Water (m^3/min)	9	9	—
		Sediment rate (%)	14	10	—
	ϕ 250	Sediment (m^3/h)	120	120	100
		Water (m^3/min)	9	9	9
		Sediment rate (%)	19	19	16

The photograph of the original deposited sediment in the reservoir is shown in Figure 8. The results of the suction tests are shown in Table 1. The sediment rate is specified by volume percentage of sediment in water.

The results show that the best way from the viewpoint of the performance is method (B). Method (C) did not work properly. When we want to remove the sediment directly from underwater by method (A), the ability is approximately half of the maximum rate which was recorded in method (B). The method depends on the condition how to handle the sediment. Finally, we found that the system is able to convey sediments with maximum size of less than 150 mm. The performance is approximately 120 m^3 per hour for 100 m distance.

5 CONCLUSIONS

The trials by using the new ejector pump system proved the high ability of dredging and transportation for the reservoir sediment. One of the major features of the new system is that the system is applicable to coarse-grain sized sediments and sediments that include obstacles such as small pieces of wood. Another feature is that the system is compact and handling is simple. We expect that the new ejector-pump system can be applied to the sediment control project if the specification meets the site conditions.

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