



A Method of Sediment Transportation by Special Ejector Pump System in the Dam Reservoir

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ABSTRACT:

Several techniques have been applied to reduce the sedimentation problems in the reservoirs such as: flushing, bypassing, density current venting and dredging, which practiced successfully and found to be inexpensive in some cases. This paper mainly deals with the filed case studies of a dredger system that newly developed in Japan. This system is composed of Special Ejector and that is why named Special Ejector Pump System (SEPS). The SEPS has two specific applications. One is called Suction-SEPS, which sucks deposit sediment up from the bottom of reservoir and then transports them to the downstream area. The other one is called Hopper-SEPS, which transports sediment from a specific site to a disposal site without any suction, called Hopper-SEPS. For Suction-SEPS tests, the sediment suction and transportation rate was approximately 35 m³/h. While, for Hopper-SEPS, the measured sediment transport rate was approximately 50 m³/h and 30 m³/h for 600 m and 1000 m transport length respectively.

Keywords: Sediment Management Strategy, Sedimentation, Dredging, Ejector Pump

1. INTRODUCTION

For reducing the drastic consequences of sedimentation in the reservoirs and sustaining its long-term useful life of a reservoir, de-siltation has received worldwide attention owing to the lack of suitable dam sites, the high cost of dam construction, strict environmental regulations and resident's resistance. Therefore, it is necessary to develop ingenious solutions for integrated sediment and water management; otherwise the human being will lose the struggle to enhance the available water resources and ecological environment.

Several techniques have been proposed by researches to solve the problems of sedimentation in reservoirs; including flushing, bypassing, density current venting, dredging and etc, which all can play an important role in extending the useful life of dams. Nowadays, dredging method is commonly utilizing in dam reservoirs. This technique is considerably efficient; because it can dredge sediment from reservoir continuously without any stop. However, usual dredging pump with impeller is hard to excavate the deposit sediment at the bottom of reservoir due to the large number of big size gravels and rubbish accumulated there. To solve the problem of usual dredger pump and enhance the efficiency of sediment removal in

this method, a Special Ejector Pump System (SEPS) has been developed by authors. This system is composed of special ejector and that is why named SEPS. Fig. 1 shows the schematic side view of special ejector in SEPS.

The SEPS is designed, to be able to utilize for two main purposes: first to suck deposit sediment up from the bottom of reservoir and then transport them to the downstream area, called Suction-SEPS; and second, to transport sediment from a specific site to a disposal site without any suction, called Hopper-SEPS.

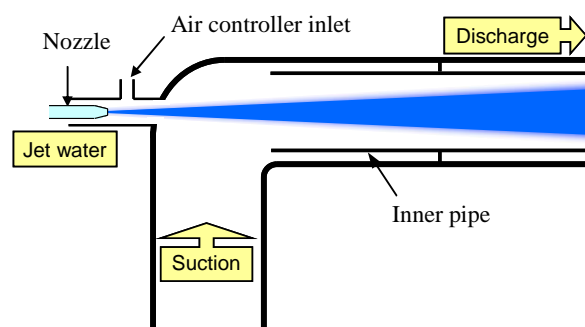


Figure 1. Schematic Side View of Special Ejector

In previous field tests, the maximum size of gravel that removed by SEPS was around 150 mm. However, commercial version of SEPS needs to be applicable for removing coarser sediment larger than 150 mm. Thus, new field tests were conducted aim to enhance the efficiency of SEPS, to be able to remove coarser materials from reservoir.

2. SUMMARY OF APPARATUS

The SEPS is distinguished by several unique innovations for its special ejector as well as its structurally simple and easy to maintain design. In contrary to usual dredger system, there is no rotary part (impeller wheel) inside of the special ejector. The energy to vacuum sediment is provided by differential pressure between inside of special ejector and bottom of reservoir. The commercial SEPS includes five distinct sections: high pressure pump, special ejector, air compressor, suction section and transport section. The details about each section and their function were given below.

2.1. High Pressure Pump

A high pressure pump supplies water jet with high velocity into the special ejector in the pump system. This unit run with 220kW power engine aims to create a pressure equivalent with 1.5MPa (5 m³/minute flow rate). The high pressure pump used in this field test was shown in Fig. 2.

2.2 Air Compressor

In order to transport sediment effectively, air was injected into the system by air compressors, which was installed at the beginning of transport pipeline just after special ejector.

2.3. Special Ejector

The special ejector is known as heart of SEPS. As mentioned above, pressure gradient between inside of special ejector and bottom of reservoir leads to sediment suck up to the system. To create a negative pressure domain inside of special ejector, the high pressure pump should discharge water jet with high velocity into the special ejector through a tiny nozzle. Then, the pressure gradient between the entrance of suction pipeline and inside of special ejector vacuums the mixture of sediment and water into the system. Thereafter, the sediment will be pushed forward into the inner pipeline and finally transports to the downstream area.

It notes worthy to mention, special ejector is also equipped by two specific accessories: air controller inlet and a straight inner pipeline. Both tow above mentioned accessories are very effective to preserve special ejector against the cavitations and abrasion resistance of the pump. By changing the combination of diameter of



Figure 2. High Pressure Pump



Figure 3. Special Ejector



Figure 4. Screw Crusher



Figure 5. Screw Crusher with Long Armed Excavator

nozzle, diameter of inner pipeline, the suction rate of SEPS can easily be adjusted. The outside view of special ejector is shown in Fig. 3.

2.4. Suction Section

The suction section includes an excavator arm, a screw crusher and a suction pipeline. The excavator arm was used to bring down the suction pipeline deep inside the reservoir and keep its entrance close to the sediment surface. A screw crusher was also attached to the excavator arm to crush deposit gravels and ease their suction by SEPS. The screw crusher's shaft was conical shape, which could crush the gravels placed between conical shaft and lining plates in the shell. The gravels with maximum size of 300 mm could be crushed with screw crusher's shaft. The used screw crusher and long excavator arm are shown in Fig. 4 and Fig. 5, respectively.

2.5. Transport Section

The transport section was consisted of pieces of pipe with 6m length and 400mm diameter, which connected to each other by rubber pipe with 1m length. To make the transport pipeline float on water surface, 2 sets of float tube were attached to the each individual tube.

3. FIELD TESTS PROCEDURE

Field tests were conducted for both two type of SEPS, Suction-SEPS and Hopper-SEPS. In this part, the tests procedure was given in details. The image of the system is shown in Fig.6.

3.1. Test Procedure for Suction-SEPS

Several places in the reservoir area were considered as a target site for dredging with different water depth

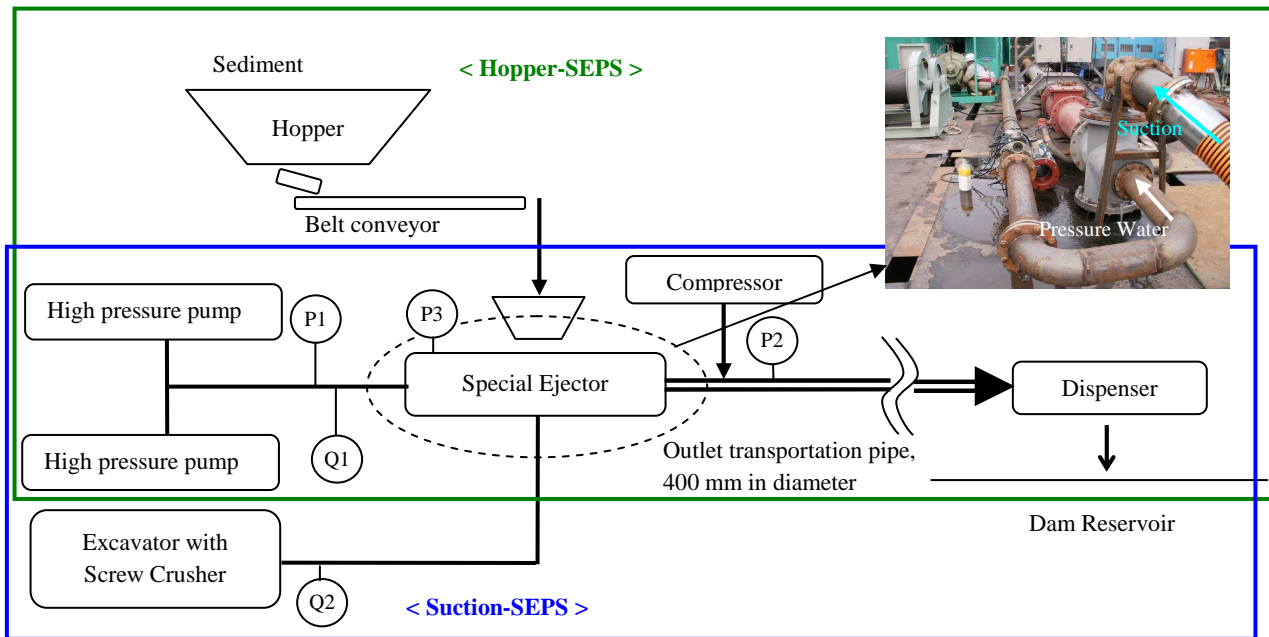


Figure 6. System Image of the SEPS



Figure 7. Overall view of Suction-SEPS

ranging from 4 to 9 m. Also, different suction pipeline length (5, 10, 15 and 20 m) was used to check the performances for suction of sediment.

Overall view of Suction-SEPS and dredging shipboard is shown in Fig.7 and Fig. 8 respectively. High pressure pump and air compressor ($18 \text{ m}^3/\text{min}$) were set to inject different values of water and air rate into the system, respectively from 1 to 3 set of high pressure pumps and 0 to 1 set of air compressor. When the target place for dredging was deeper than 10m, to suck up sediment effectively, the special ejector was tried to install under the water. These tests were executed with some extra modifications and adjustments. The total numbers of test cases was 58.

3.2. Test Procedure for Hopper-SEPS

In Hopper-SEPS tests, sediment was fed into the system through a hopper installed above special ejector. The used Shipboard of Hopper-SEPS in this field test is shown in Fig. 9. As can be see in Fig. 9, the hopper, belt conveyor and SEPS was mounted on the shipboard.

In this case, the maximum transportation length was considered 1000 m. To transport sediment in longer distance, considerable amount of air was injected into the transportation pipeline to assist the sediment through it. In order to release the transported sediment into the reservoir, as shown in Fig. 10, a distributor is set at the end of transport pipeline. Silt fences of 5m in depth are installed to avoid water pollution.

Since Hopper-SEPS test is executed nearby the test field for Suction-SEPS, the characteristics of both of the sediment are almost same. However, since original sediment included big size gravels, it was screened by a sieve with 120 mm and 80mm mesh, which are called D 150 mm and D 100 mm respectively. The sediment grain size curve is shown in Fig. 11. The tests were conducted using various transport length, different sediment grain size, dissimilar diameter of the nozzle and inner pipeline.

4. PARAMETERS & MEASUREMENT DEVICES

The main parameters and used measurement devices are as follow:

- 1) Initial discharge (Q_1 , m^3/min) measured by flow meter.
- 2) Initial pressure of water (P_1 , MPa) measured by pressure gauges (which both initial discharge and initial water pressure were supplied by high pressure pump).
- 3) The negative pressure in the special ejector (P_3 , MPa).
- 4) The pressure at the initial point of the outlet pipeline (P_2 , MPa).
- 4) Flow rate of suction pipeline (Q_2 , m^3/min).
- 5) Air injected concentration into the transport pipeline



Figure 8. Shipboard of Suction-SEPS



Figure 9. Shipboard of Hopper-SEPS



Figure 10. Shipboard of Distributor

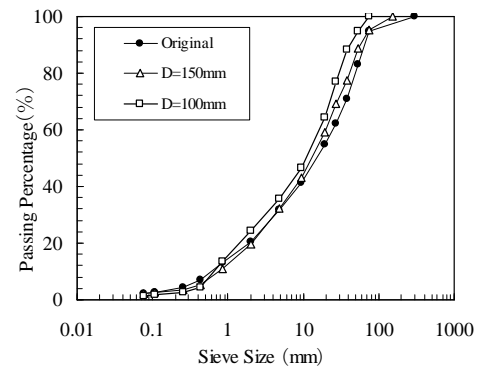


Figure 11. Grading Distribution of the Sediment

(A, m³/min) which measured by air flow meter. The locations of the each instrumentation are shown in Fig. 6.

5. RESULTS AND DISCUSSION

5.1. Results of field test on Suction-SEPS

Two sets of high pressure pump were used in this field test. Although some instrumentations were partially out of order, the initial water pressure provided by high pressure pump ranged from 1.40 MPa to 1.55 MPa, and discharge flow rate ranged from 10 m³/min to 11 m³/min. Additionally, P_2 , P_3 and Q_2 were set to be in the range of 0.08 MPa to 0.18 MPa, -0.04 MPa to -0.08 MPa and 7.9 m³/min to 12.0 m³/min respectively.

The relationship between water depth and sediment transportation rate taken from all data was plotted in Fig. 12. Sediment transportation rate is defined as the volume of landed sediment from the bottom of the reservoir per one hour. When Suction-SEPS tried to suck up sediment from a deeper area in reservoir, the suction rate was significantly reduced. For instance, in case of suction pipeline with 20 m length when the sediment discharge was equal to 25m³/min, blockage in the system has often happened. The reasons why transported rate of system was reduced by increasing suction pipeline length are discussed below:

- 1) A longer suction pipeline length causes more lose of energy and consequently less transported rate value.
- 2) Since fine sediment is easily transported and coarse gravel is tend to remain on the reservoir bed, as the result of the continuous dredging works, the sediment grading size has changed. Namely, the big pieces of gravel are concentrated in the bottom of the reservoir, and they obstructed continuous dredging as shown in Fig. 13. The performance of dredging works is substantially depended on the condition of the bottom of reservoir.

Fig. 12 depicts that when special ejector was installed under the water surface, the greater values of transportation rate was measured. It proves that the shorter suction pipeline can provide more advantages for the system.

Fig. 14 shows the representative sediment grain size and rubbishes, which was sucked and transported by Suction-SEPS to the disposal site. The Suction-SEPS was able to remove gravels with maximum 200 mm diameter and woods with 500 mm length.

5.2. Results of field test on Hopper-SEPS

Fig. 15 shows the pressure at the beginning of the pipeline versus transportation rate of Hopper-SEPS with different transportation length. Sediment transportation

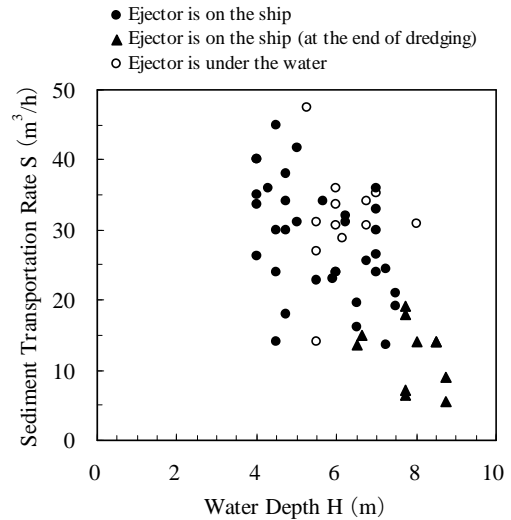


Figure 12. Water Depth and Sediment Transportation Rate



(1) Initial Stage



(2) Middle Stage



(3) Final Stage

Figure 13. Bottom of the Reservoir during Dredging



Figure 14. Sucked Gravels and Debris

rate is proportional to pressure, P2 by each transportation length. When the pressure at the beginning of pipeline is higher, transportation rate is higher. On the other hand, the relation between the pressure at the beginning of the pipeline divided by transportation length (P2/L) and sediment transportation rate (S) is shown in Fig.16. Sediment transportation is also proportional to P2/L. The transportation rate is inversely proportional to the transportation length. It is found that to transport sediment long distance and to increase the transportation rate, enough pressure at the beginning is important.

The air concentration injected into the transportation pipeline was equal to 36 Nm³/min and 54 Nm³/min for 600 m 1000 m transport pipeline, respectively. Since the initial water discharge into the system set around 10 m³/min, then the injected air concentration in system was approximately 3 to 6 times of water discharge. The measured transportation rate was around 30 m³/h and 50 m³/h for 600 m and 1000 m transport pipeline length, respectively.

6. CONCLUSION

The sediment suction and transportation rate by Suction-SEPS were approximately 35m³/h, and the sediment transportation rate by Hopper-SEPS was 30m³/h and 50m³/h for 600 m and 1000 m transport pipeline length respectively. Above mentioned sediment dredging and transportation system can be effectively used at dam sites without any interruption in their daily operations.

Field research efforts show that this system could be effectively applicable as a countermeasure to solve the sediment problem in reservoirs. At last but not least, the authors hope that this newly upgraded system contributes to the supply of sediment at downstream area of reservoirs, and is considered as a positive jump for environmental remediation of rivers.

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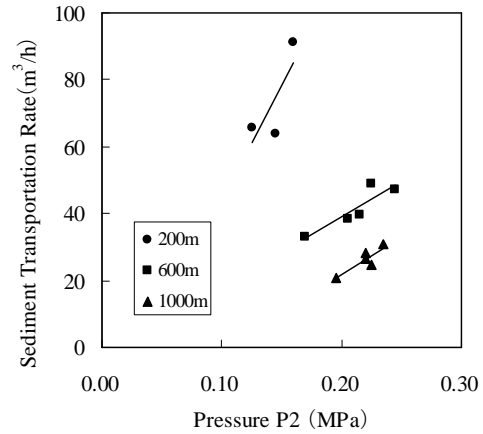


Figure 15. Pressure at the Beginning of the Pipeline versus Sediment Transportation Rate

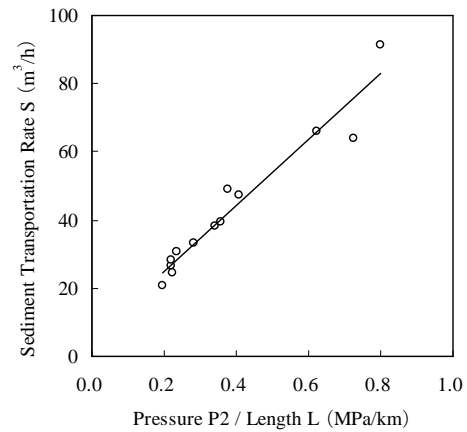


Figure 16. Pressure at the Beginning of the Pipeline Divided by Transportation Length versus Sediment Transportation Rate