Effective Sediment Control In A Reservoir

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"EFFECTIVE SEDIMENT CONTROL IN A RESERVOIR"

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INTRODUCTION

Sedimentation in a reservoir cannot be avoided. The average rate of sedimentation on the storage volume reduction of a reservoir in the world is about 1 % per year (Yoon,1992), meanwhile, the storage volume reduction in several reservoir in Indonesia reaches 1,64% to 2,83% per year (Atmojo,2012). These sediment's accumulations in the reservoir will continually reduce the storage volume, thus the intended functions of reservoirs for flood control (Atmojo, 2013), irrigation and water supply, electric generation, etc. will also reduced and not optimal.
Some of techniques for reservoir sedimentation control are available. Principally they are:

1. To prevent sediment material from entering the reservoir,
2. To prevent settlement of the sediment material in the reservoir, and
3. To remove sediment material which are already settled in reservoir.

The measures to prevent sediment material to enter into a reservoir is by reducing erosion upstream i.e., by constructing check dam, sand pocket, and/or by diversion channel. The measures to prevent the sediment material from settled down is by opening flushing gate during river flood or by opening under sluice gate such that higher consentrated sediment to flush out and not settling in (venting) (Morris and Fan, 1998; Emamgholizadeh et al., 2006). Meanwhile, the sediment already settled in a reservoir can be removed by flushing, disturbing flushing, and dredging (Jugovic et al., 2009; Tallebbeydokti and Naghshineh, 2004; Shen, 1999).
This paper discusses the performance of reservoir sedimentation control by sluicing, flushing, and disturbing flushing based on physical model.

METHOD AND MATERIAL

This paper presents the sediment control with the physical hydraulic model, to model sediment removal by means of sluicing, flushing, and flushing with disturbed (disturbing flushing). The model is performed at River Research Center Surakarta, based on prototype of design flushing gate at Gajah Mungkur Dam (JICA, 2007), and the sediment material is represented by coal ash. Basically, the data used is from research on the sluicing and disturbing flushing performed by River Research Center Surakarta, in addition to the flushing model by Pranoto.SA.

Modelling Procedures:

The physical model made is using length scale 1:66.67.
Slucing Modeling: The sediment material poured at upstream 350 cm from gate at the rate of 60 liter/hour. The discharge and gate openings are 5.5 l/s with opening 2.50 cm; and 11.02 l/s with opening 5.30 cm. The water level at upstream of the gate is constant 13.95 cm. After each model running is finish, the sediment material leaved behind will be measured. Therefore the "flushed" sediment can be calculated, and efficiency is known by comparing with the poured sediment number before running.
Flushing Modeling: it is aimed to analyse the scouring of sediment already settled in by opening flushing gate. It's modeled with 3.00 cm sediment thickness and maintained upstream water level at 13.95 cm. the gate is then opened for one hour for each discharge variation. It uses discharge variation similar to those used for sluicing model. The sediment material is first made wet by 14% of water to prevent it from floating. It is then slightly compacted with 3.00 cm thicks. After each modeling is finish, the remaining sediment material can be measured. Therefore the "flushed" sediment can be also analysed.

Disturbing Flushing: is aimed to model the amount of flushed away of sediment when the sediment has already settled in by flushing with disturb (disturbing flushing). In reality, the disturbed may caused by excavator action. The sediment thickness is similar to flushing model, i.e. 3.00 cm. However, during the flushing it is also combined with disturbing the sediment. After finishing each model run, the remaining sediment material as well as the flushed away sediment can be calculated. The modeling used the similar discharge and opening with sluice model.

Material:

The water used is circulating water pump from ground reservoir and the used water flow back into the ground storage. The model situation and the gate position is shown at Figue 1, 2, and 3. The flushing gate has dimension of 2x11.25 cm. The length of storage 495.00 cm, the width of storage 250.00 cm. The velocity measurements at upstream is conducted by Laboratory current meter SV. 108 with blade seri-A, at downstream it used V-Nocth B=0.945 m, D=0.331 m which has been calibarated. The sediment material used is coal ash with unit weight 1.558 kg/l. The sediment used before and after model running is measured at the same water content.

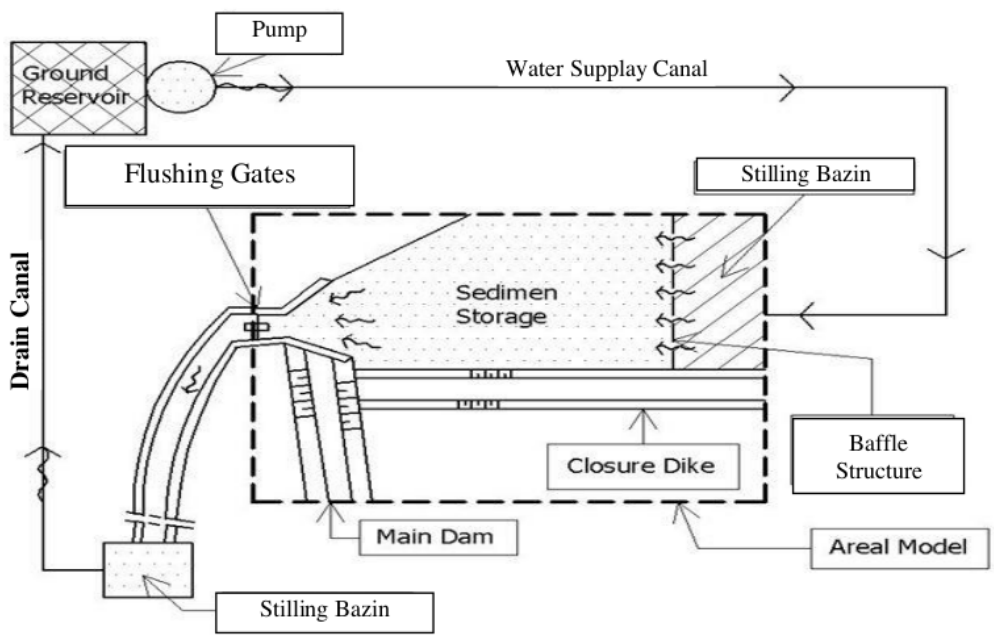

Figure.1 Model Situation

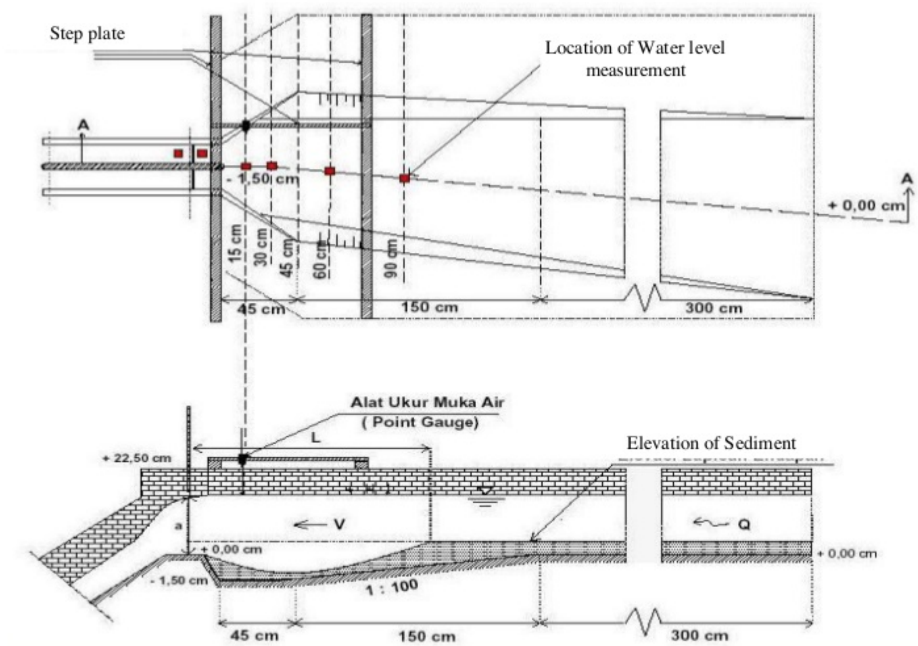

Figure.2 Long Section of Flushing Gate (Atmojo P.S, 2012)

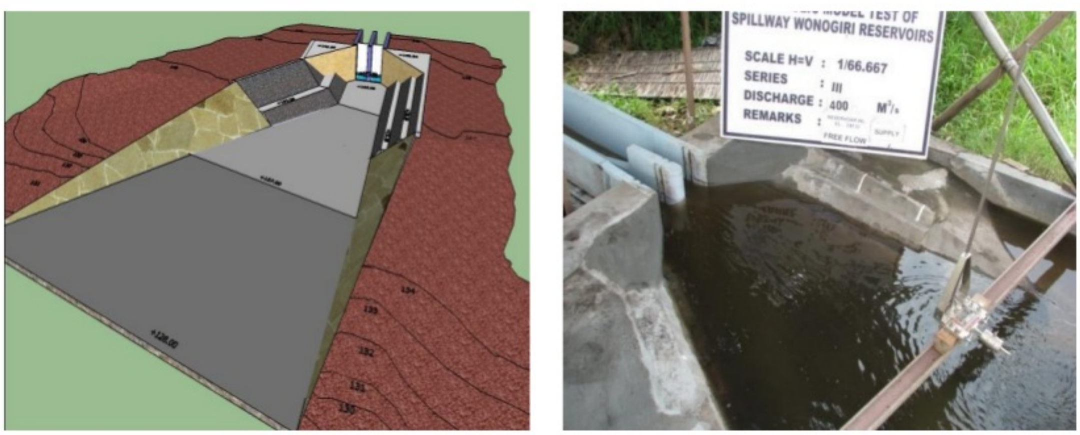

Figure.3 3D of The Flushing Gate and Photo

MODELLING AND RESULT

The modeling result of sluicing, flushing and disturbing flushing are shown at Table 1, 2, and 3 respectively.

Sluicing Model:

The result of the sluicing model run is shown at Tabel.1. It shows that the percentage of sediment removal is 30% (from discharge 5.51 l/s) and 35.83% (for discharge 11.02 l/s). It shows common trend that higher discharge is higher sediment removal

Table 1 Percentage of Sediment Release Result From Sluicing Method

Discharge (l/s)	Vol Sediment Before Running (liter)	Gate Opening (cm)	u/s Water level (cm)	Vol Sediment After Running (liter)	Sediment Removal (%)
5.51	60	2.50	13.95	42.00	30.00
11.02	60	5.30	13.95	38.50	35.83

Flushing Model:

The result of flushing model is shown at Tabel.2. It shows that the percentage of sediment removed using this flushing method is 4.21% and 6.18% which are much smaller than that used by sluicing.

Table 2 Percentage of Sediment Release Result From Flushing Method

Discharge (l/s)	Vol Sediment Before Running (liter)	Gate Opening (cm)	u/s Water level (m)	Vol Sediment After Running (liter)	Sediment Removal (%)
5.51	272.00	2.50	13.95	260.55	4.21
11.02	275.00	5.30	13.95	258.00	6.18

Disturbing Flushing:

The results from using disturbing flushing is shown at Tabel.3. It a glance, the percentage of sediment removal is 22.48% and 23.52% for discharge 5.51 l/s and 11.02 l/s respectively.

In general that we see only the sediment remove, we will conclude that the most effective measure is sluicing, then disturbing flushing, and the lastly by flushing only.

Table 3 Percentage of Sediment Release Result From Disturbing Flushing Method

Discharge (l/s)	Vol Sediment Before Running (liter)	Gate Opening (cm)	u/s Water level (m)	Vol Sediment After Running (liter)	Sediment Removal (%)
5.51	231.76	2.50	13.95	179.65	22.48
11.02	231.76	5.30	13.95	177.25	23.52

DISCUSSION

In order to justify the efficiency of sediment removal, it need to also consider the sediment removal per unit of water discharge. The sluicing method is more effective due to mainly to the stage of sediment material which are not yet settled in. Therefore, in this case, there does not requires energy to overcome initial tractive force to move the sediment material. Meanwhile, the purely flushing will require energy to overcome the initial tractive force in order to move the sediment material, which therefore reducing the sediment to be removed. Similary, in disturbing flushing, although additional energy has been given to "strirred" the settled in sediment, still not all settled in sediment can be strirred up. The removal of sediment result from that method is higher than purely flushing, but still lower then that result from sluicing. In fact, for disturbing flushing will also depend on the duration and speed of disturbing.

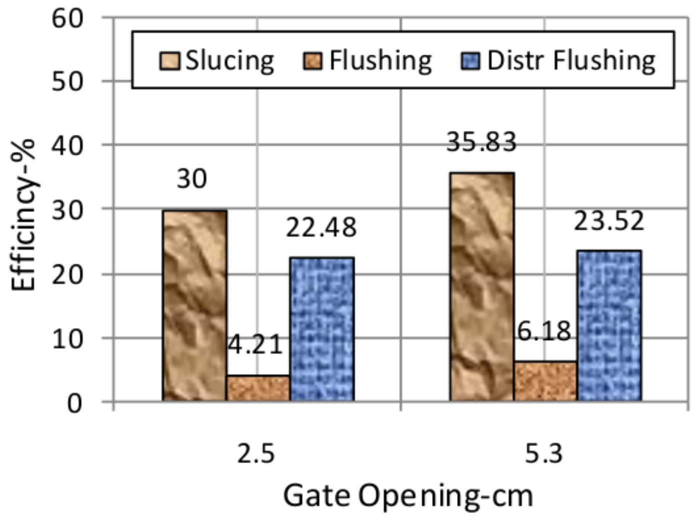

Figure.4 Sediment's Removal Efficiency

Table 4 Average Removal of Sediment Result From Sluicing

Discharge Q (l/s)	Gate Opening Cm	Sediment Remove (%)	Sed Remove per liter Disch (%)	Average Removal of Sediment %
(1)	(2)	(3)	(4)=(3)/(1)	(5)
5.51	2.5	30	5.44	4.35
11.02	5.3	35.83	3.25	

Table 5 Average Removal of Sediment Result From Flushing

Discharge Q (l/s)	Gate Opening Cm	Sediment Remove (%)	Sed Remove per liter Disch (%)	Average Removal of Sediment %
(1)	(2)	(3)	(4)=(3)/(1)	(5)
5.51	2.5	4.21	0.76	0.66
11.02	5.3	6.18	0.56	

Table 6 Average Removal of Sediment Result From Disturbing Flushing

Discharge Q (l/s)	Gate Opening Cm	Sediment Remove (%)	Sed Remove per liter Disch (%)	Average Removal of Sediment %
(1)	(2)	(3)	(4)=(3)/(1)	(5)
5.51	2.5	22.48	4.08	3.11
11.02	5.3	23.52	2.13	

CONCLUSION AND RECOMMENDATION

Conclusion:

1. The sluicing method is more efficient compare to the flushing and disturbing flushing
2. The efficiency of sluicing 1.4 times higher than disturbing flushing, and 6.6 times higher than flushing.
3. Sediment flushing by maintaining upstream water level constant is more efficient for frequent small discharges than bigger discharges.

Recommendation:

In order to the sharper modeling result, advanced modeling needs to include:
-More discharge variation
-Large running time
-More upstream water level variation.

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GENERAL COMMENTS

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