

Bed configuration under sluice gate at Sandy–Loam Bed Channel

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Abstract. Sluice gate operation is necessary to keep the continuity the design discharge. The mis-operation of sluice gate occurs endanger stucture and destruct the bed irrigation channel. Investigation about sluice gate operation and bed configuration are needed to avoid the destruction of the structure bed irrigation channel. The changes in bed form result from interaction of the flow, fluid and bed material. The aim of this paper is to investigate the influence of different flow parameter, height of opening gate and types of bed material. Fourty five runs were executed at different discharge started from 1.0 l/s to 5.0 l/s with an increment of 0.5 where each discharge has five different opening gate to get all characteristics of bed configuration. The material used in the experiments were sandy loam. The experimental were conducted in an acrylic side flume with recirculating water at Applied Hydraulics Laboratory in Water Resources Engineering Faculty, Brawijaya University, Malang, Indonesia. The result of investigation showed that the bed configuration of sandy loam is ripple for most of the condition. At the same opening gate and various discharge the configuration is start by plane bed (no motion) and ripplee. Meanwhile, for the same discharge at the various opening gate occurs the ripple bed configuration. The various velocity that occur during the runing process cause the changing of bed configuration. For the greater discharge at the same opening gate occur the highest velocity. This condition cause the grain sediment material of the bed channel lift up and start to moving. This result is suitable with equation approaches from the van Rijn, Simon Richardson and Garde Albertson.

1 Introduction

The sluice gate is a part of an irrigation channel that divided and adjusted water level. The operation of sluice gate due to increasing the effectivity and performance the distribution of water to irrigation area. The sustainability of flow velocity with the design discharge will maintain the stability of water distribution to the quarterly irrigation channel. During the operation and maintenance time of the sluice gate, the up and down of movement the gate should be suitable with the design of water flow. However, the operation of sluice gate not always be well-done. Because of the manual movement of operation, sometimes the gates

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are jammed and even damaged. Thus, the water distribution is not in accordance with the design. When the velocity is high, the bed channel will receive the jet attack velocity which destroys it. When it happens continuously, the bed channel and the material below the bed will be exfoliated [1].

The water flow velocity influence the sediment movement especially bed channel sediment. The bed channel sediment form changes as long as increasing the velocity. In the natural river, the sediment movement divided in plane, dunes, ripple, antidunes, breaking waves and back to plane form. In a laboratory channel, this movement not always looks like the natural channel. Because of the complexity and three-dimensional form of the river could not take all in laboratory condition. The model of laboratory investigation made approaches natural behavior. Thus, the result has differences with the natural phenomena. All the laboratory results are not precisely the same with the natural river. Thus, the research of bed configuration still done till now to evaluate the alluvial river condition [2].

The existence of bedforms and their influence on the flow can be observed and is recognized and studies by hydraulicians and geomorphologists. Some researchers investigate about bed configuration of bed channel. Talebbeydokhti [3] investigate of dune form in sandy bed channel. The laboratory experiments were conducted to investigate the geometry of dunes in a sand bed channel and its influence on total channel resistance. Mahgoub [4] find out that where at Froude Number ($Fr \ll 1$), typical ripple pattern is configured, then transferred to dunes with ripples and when the value is a little increased ($Fr < 1$) only dunes were formed, later dunes are washed out, and the plane bed started to appear. In the study of Simon and Richardson [5] the plane bed with sediment moving in the upper flow regime only occurred when the medium size of bed material was approximately 0.4 mm and smaller. Another researcher also investigated about the bed configuration namely: Goel [6] investigated the bed channel changes in front of the sluice gate under two condition of flow flowing over and below the gate with different tailwater condition. Meanwhile, Monatti et al. [7] investigate the variation of the scour-hole geometric features with respect to the jet hydraulic parameters and tailwater depth conditions. Xie Lim [8] investigate the variation of the scour-hole geometric features concerning the jet hydraulic parameters and tailwater depth conditions is investigated. Halim [9] analyze about the bed form in the open channel caused by discharge variation under equilibrium condition based on experimental investigation.

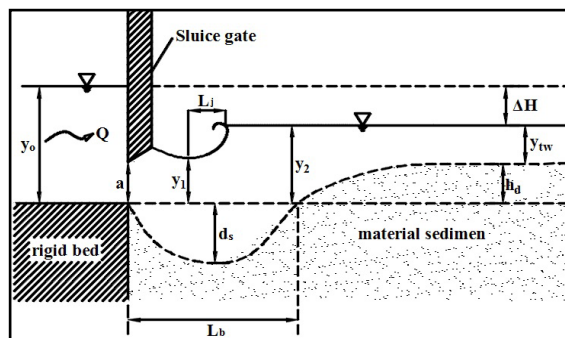


Fig. 1. Parameters of the calculation of scour characteristics.

This paper investigates the bed configuration under the sluice gate with the sandy loam bed material. The concept of the research is discharge variation and opening gate influence the bed configuration with the type of bed sediment material. The experiments of this present study have been carried out the scour characteristics under sluice gate without apron of non-cohesive bed in the clay-sand mixture (sandy loam). The aims of the study are to

knowing the scour characteristics of the non-cohesive bed model. The scour holes characteristics can be observed and calculated from the discharge, the differences of water level upstream and downstream of the sluice gate as shown in Fig. 1.

2 Materials and methods

The experimental was carried out in an acrylic open flume model with recirculating water at Applied Hydraulics Laboratory in Water Resources Engineering Faculty, Brawijaya University, Malang, Indonesia. The flume length is 9.0 m and 0.50 m in width and 0.60 m in height. The uniform water flow depth could be adapted by means of a tailgate installed at the channel end. Continuously the water pumped from the downstream tank into the upstream head tank with the maximum capacity is 10.0 l/s. A Rechbock device mounted on the upstream end of the open channel to measuring and calculating the flow into the channel. A Rechbock was calibrated to measure the discharge. The mixture sand and clay laying over the bed of the flume with 0.20 m depth and the density of the mixture is 2.735. The water depths and bed levels were measured by point gauges. The velocity was measured by a calibrated Pitot tube. The sluice gate was installed in the flume and can be lifted and lowered to a desired under-gated opening height that permits to form submerged hydraulic jump condition on the movable bed. Schematic of the experimental apparatus is shown in Fig. 2. Water was pumped from reservoir to upstream tank, and flow to the Rechbock measurement and water entered the channel through stilling tank. The non-cohesive bed material was used in this experiment. Where $d_{10} = 0.181$ mm, $d_{50} = 0.451$ mm, $d_{60} = 0.6$ mm, $d_{90} = 1.913$ mm and $G_s = 2.735$.

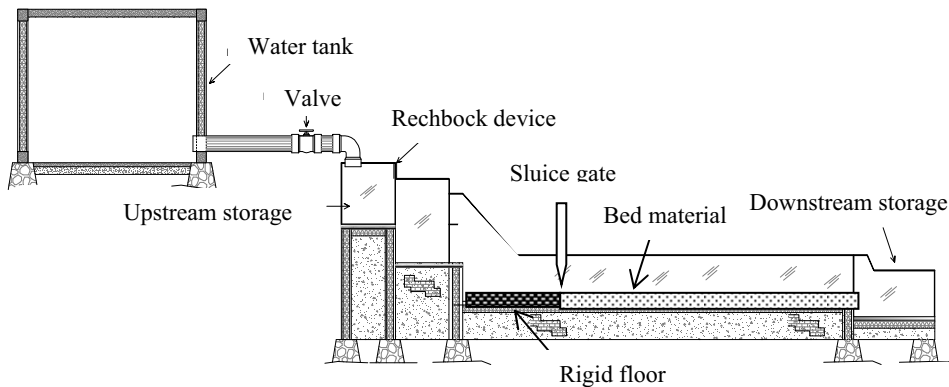


Fig. 2. Laboratory experiment sketch.

Sieve analysis was carried out to determine the grain size distribution for each type of bed material and the median grain size (d_{50}). Downstream of the sediment box was equipped with a sand trap to prevent any incidental transport of the fine sand into the flow system. The draft of treatment was intended to get an overview of the flow behavior due to variations in the opening gate to the hydraulic and scour characteristics on the sandy-clay bed channel. For the channel bed material, treatment variations were directed to obtain data that illustrate the effect of submerged flow to change the velocity and scouring. With the variation of the discharge start = 0.5 l/s to 5.0 l/s with water depth measurements upstream and downstream of the gate, while openings gate (a) ranging from 0.5 cm to 2.5 cm. The preliminary study goes to know the boundary condition of the research. The flume was initially filled with water to avoid the undesirable erosion of the sediment bed. The first running with the amount of discharge of 0.5 l/s. The water flows through the channels, and the appropriate discharge began the measurement. The data obtained was the height of at

the upper gate (y_o), the depth of the flow in front of the vena contracta (y_{ob}), the depth in the area of turbulence (y_1) and the depth in the downstream flow (tailwater/ y_2). Meanwhile, the scour process was recorded with handy-cam and camera. Each experiment was run for one hour to knowing the scouring process. At the end of the runtime, the flow was stopped, and the characteristics of the scour hole and sediment such as the maximum depth of scouring, the length of scouring were measured.

The process runs for all the variation of discharge and height of the opening gate. Total running experiment goes to forty-five running process. Before starting the new running, the bed channel always stays real flat position to guarantee the same condition for the beginning of next process. The water pass needed to make sure the surface of the sandy clay bed channel on the zero point position.

3 Results and discussion

3.1 Sediment characteristics

Because of grain size considered to be different then gradation analysis will be done. Bed material sediment is classified to obtain the sediment characteristics based on its size. Sediment material analysis is carried out by mechanical methods, namely sieve analysis. Whereas for materials smaller than 0.075 mm, sieve analysis was carried out by hydrometric methods. This research using sediment bed material was suitable for the field sediment material. This research aims to know the scour characteristics at sandy clay bed material channel thus sediment material used is a mixture of sand and clay sediment material with specific gravity materials.

3.2. Initiation of sediment motion

Experimental research was done with the variable investigation of scouring mechanism under the sluice gate which determines the discharge and opening gate height. The results of discharge investigation showed this Table 1.

Table 1. Experimental discharge.

No.	$y_{Rechbox}$		Q	
	Cm	m	m^3/dt	lt/dt
1	1.25	0.0125	0.0010	1.0
2	1.65	0.0165	0.0015	1.5
3	2.00	0.0200	0.0020	2.0
4	2.35	0.0235	0.0025	2.5
5	2.70	0.0270	0.0030	3.0
6	3.00	0.0300	0.0035	3.5
7	3.30	0.0330	0.0040	4.0
8	3.55	0.0355	0.0045	4.5

Table 2. Initiation of motion of bed sediment material Sandy-Loam.

No.	Q (l/s)	A (cm)	ds (cm)	y ₃ (cm)	U ₃ (cm/s)	C ^{''}	U*	U* _{cr}	Information	
1	1.0	0.5	2.8	1.25	13.80	25.16	1.72	1.6	$U_* > U_{*cr}$	motion
2	1.5	0.5	4.8	2.40	19.50	30.26	2.02	1.6	$U_* > U_{*cr}$	motion
3	1.5	1.0	3.4	1.50	5.32	26.59	0.63	1.6	$U_* < U_{*cr}$	no motion
4	2.0	0.5	3.4	2.70	25.10	26.70	2.94	1.6	$U_* > U_{*cr}$	motion
5	2.0	1.0	3.4	2.65	25.10	31.04	2.53	1.6	$U_* > U_{*cr}$	motion
6	2.0	1.5	3.4	2.70	25.10	31.18	2.52	1.6	$U_* > U_{*cr}$	motion
7	2.5	0.5	3.4	2.80	7.26	31.47	0.72	1.6	$U_* < U_{*cr}$	no motion
8	2.5	1.0	3.4	2.75	7.20	31.33	0.72	1.6	$U_* < U_{*cr}$	no motion
9	2.5	1.5	3.4	3.10	7.64	32.26	0.74	1.6	$U_* < U_{*cr}$	no motion
10	2.5	2.0	3.4	3.00	7.52	32.01	0.74	1.6	$U_* < U_{*cr}$	no motion
11	3.0	0.5	3.4	3.15	25.90	32.39	2.50	1.6	$U_* > U_{*cr}$	motion
12	3.0	1.0	3.4	3.05	7.58	32.14	0.74	1.6	$U_* < U_{*cr}$	no motion
13	3.0	1.5	3.4	3.00	26.70	32.01	2.61	1.6	$U_* > U_{*cr}$	motion
14	3.0	2.0	3.4	3.00	26.70	32.01	2.61	1.6	$U_* > U_{*cr}$	motion
15	3.5	0.5	3.4	3.85	8.52	33.96	0.79	1.6	$U_* < U_{*cr}$	no motion
16	3.5	1.0	3.4	3.25	27.10	32.63	2.60	1.6	$U^* > U_{*cr}^*$	motion
17	3.5	1.5	3.4	3.45	8.06	33.10	0.76	1.6	$U^* > U_{*cr}^*$	no motion
18	3.5	2.0	3.4	3.20	25.90	32.51	2.50	1.6	$U^* > U_{*cr}^*$	motion
19	3.5	2.5	3.4	3.30	27.10	32.75	2.59	1.6	$U^* > U_{*cr}^*$	motion
20	4.0	1.0	3.4	3.40	28.30	32.99	2.69	1.6	$U^* > U_{*cr}^*$	motion
21	4.0	1.5	3.4	3.40	28.30	32.99	2.69	1.6	$U^* > U_{*cr}^*$	motion
22	4.0	2.0	3.4	3.20	25.90	32.51	2.50	1.6	$U^* > U_{*cr}^*$	motion
23	4.0	2.5	3.4	3.25	27.10	32.63	2.60	1.6	$U^* > U_{*cr}^*$	motion
24	4.5	1.0	3.4	4.20	8.90	34.64	0.80	1.6	$U^* > U_{*cr}^*$	no motion
25	4.5	1.5	3.4	3.65	8.29	33.54	0.77	1.6	$U^* > U_{*cr}^*$	no motion
26	4.5	2.0	3.4	3.18	7.74	32.46	0.75	1.6	$U^* > U_{*cr}^*$	no motion
27	4.5	2.5	3.4	3.28	7.86	32.70	0.75	1.6	$U^* > U_{*cr}^*$	no motion
28	5.0	1.0	3.4	4.30	52.30	34.82	4.70	1.6	$U^* > U_{*cr}^*$	motion
29	5.0	1.5	3.4	4.00	8.68	34.26	0.79	1.6	$U^* > U_{*cr}^*$	no motion
30	5.0	2.0	3.4	3.55	8.18	33.32	0.77	1.6	$U^* > U_{*cr}^*$	no motion
31	5.0	2.5	3.4	3.75	8.41	33.75	0.78	1.6	$U^* > U_{*cr}^*$	no motion

Tabel 3. Approximate basic form of Sandy-Loam I

Q (ls)	a (cm)	U_{lw} (cm/s)	ρ_s (kg/s ² /m ⁴)	ρ_w	C'	d*	U* (cm/s)	U* _{cr} (cm/s)	T	Bed config. van Rijn
1.0	0.5	13.8	2616	1000	25.82	11.297	1.72	1.6	-0.030	plane bed
1.5	0.5	16	2616	1000	29.38	11.297	2.02	1.6	0.007	plane bed
1.5	1.0	15.2	2616	1000	27.91	11.297	0.63	1.6	0.004	plane bed
2.0	0.5	26.3	2616	1000	29.18	11.297	2.94	1.6	1.765	ripple
2.0	1.0	17.8	2616	1000	29.75	11.297	2.53	1.6	0.211	ripple
2.0	1.5	15.7	2616	1000	28.99	11.297	2.52	1.6	0.001	plane bed
2.5	0.5	26.7	2616	1000	31.56	11.297	0.72	1.6	1.438	ripple
2.5	1.0	18.9	2616	1000	30.28	11.297	0.72	1.6	0.323	ripple
2.5	1.5	17.1	2616	1000	30.28	11.297	0.74	1.6	0.081	plane bed
2.5	2.0	15.9	2616	1000	29.75	11.297	0.74	1.6	-	plane bed
3.0	0.5	27.1	2616	1000	33.10	11.297	2.50	1.6	1.276	ripple
3.0	1.0	23.4	2616	1000	31.67	11.297	0.74	1.6	0.85	ripple
3.0	1.5	19.9	2616	1000	30.93	11.297	2.61	1.6	0.406	ripple
3.0	2.0	19.5	2616	1000	30.77	11.297	2.61	1.6	0.358	ripple
3.5	0.5	29.7	2616	1000	33.45	11.297	0.79	1.6	1.683	ripple
3.5	1.0	27.1	2616	1000	33.10	11.297	2.60	1.6	1.276	ripple
3.5	1.5	26.7	2616	1000	32.35	11.297	0.76	1.6	1.317	ripple
3.5	2.0	25.1	2616	1000	31.53	11.297	2.50	1.6	1.156	ripple
4.0	0.5	28.3	2616	1000	33.33	11.297	2.59	1.6	1.443	ripple
4.0	1.0	27.5	2616	1000	33.10	11.297	2.69	1.6	1.343	ripple
4.0	1.5	26.3	2616	1000	33.03	11.297	2.69	1.6	1.159	ripple
4.0	2.0	25.9	2616	1000	32.86	11.297	2.50	1.6	1.117	ripple
4.0	2.5	20.5	2616	1000	32.09	11.297	2.60	1.6	0.386	ripple
4.5	1.0	30.3	2616	1000	37.23	11.297	0.80	1.6	1.242	ripple
4.5	1.5	29.9	2616	1000	36.65	11.297	0.77	1.6	1.254	ripple
4.5	2.0	25.5	2616	1000	35.70	11.297	0.75	1.6	0.738	ripple
4.5	2.5	20.2	2616	1000	34.70	11.297	0.75	1.6	0.153	ripple
5.0	1.5	57.3	2616	1000	36.58	11.297	4.70	1.6	7.331	ripple
5.0	2.0	52.8	2616	1000	36.11	11.297	0.79	1.6	6.26	ripple
5.0	2.5	52.3	2616	1000	35.26	11.297	0.77	1.6	6.471	ripple

Based on the laboratory investigation, height and length of scouring within sedimentation occurred at downstream open channel. To determine the initiation of motion sediment material using flow velocity (U), shear velocity (U^*), critical shear velocity (U^*_{cr}). When the unit of U^* more than U^*_{cr} , those bed sediment material start to moving. Meanwhile, when the U^* is less than the U^*_{cr} , the bed sediment material is not moving. Table 2 shows that determination initiation of motion.

The table above showed that the height of opening gate influence the bed channel changes. Its related with the flow velocity that occur under the gate.

Within looking at the Table 3 above, showed that not all the investigation data used to analyze. The completed data was recorded. The thirty data is complete, that means it is used to analyzed and explained. When the discharge higher and the height of the opening gate is still the same, the flow velocity is higher and create the turbulence velocity downstream of the gate. This condition influences the bed material around the gate start to shearing, rolling and even though jumping. The movement occurs the hole scouring. The continuity of the phenomena cause scouring longer and deeper. Meanwhile, the sediment bed material is lifted up and transported along the channel. As longer away upward of the gate, the flow velocity lower. As a result, the sediment material will be deposited and form a configuration downstream of the channel.

The bed configuration changes from plane bed at lower velocity and ripple at a higher velocity. Higher velocity occurs at the variation of discharge cause ripple form at downstream of bed channel. According to the van Rijn theory the bed changes from plane bed form to ripple based on the flow velocity higher than the critical velocity of the grain material. This condition is suitable with the investigation along the running experiment. The variation of the opening gate (a) at the same discharge unit (Q) will occurs the plane bed form condition. Its because the velocity is getting lower and the critical velocity of grain material sediment is not passing the flow velocity.

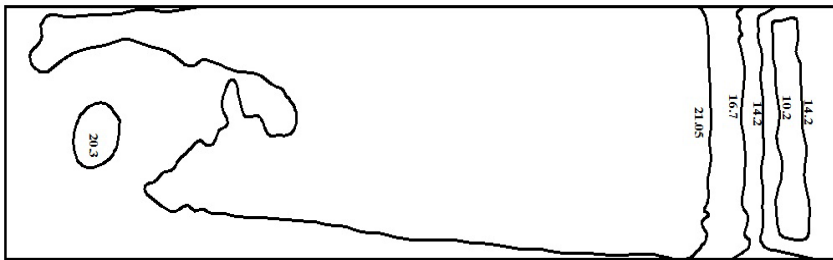


Fig. 3. The bed configuration at $Q = 2.5$ l/s and $a = 0.5$.

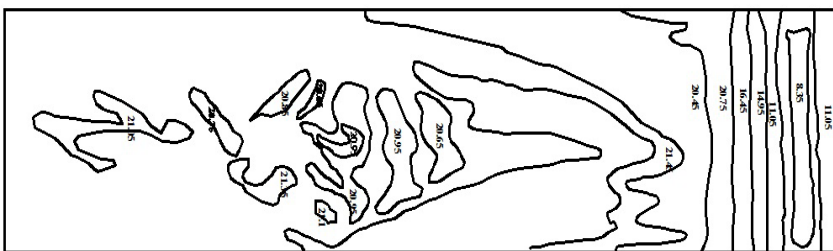


Fig. 4. The bed configuration at $Q = 3$ l/s and $a = 0.5$.

This condition has done for all the variation of discharge at the same opening gate, and so for all the variation of the opening gate with the same condition of discharge. There is no equation apply in this research because of the limitation of time running process as long as

the all research done. This Fig. 3 showed that the differences between the two condition of the investigation.

For the next experiment, running time will be considered to be investigated. Because as long as the process running, the form of sedimentation is not stopped along the channel. To looking forward the characteristics of sedimentation, running time will be added. Besides, this form of ripple and plane bed dimension needed to figure out to complete the behavior of the sedimentation process.

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