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CHARACTERISTIC OF CONTRACTION AND DISCHARGE COEFFICIENT FOR FLOW UNDER SLUICE GATE

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Abstract: The contraction coefficient (Cc) and discharge coefficient (Cd) always rise in flow while sluice gate operated with variation of open gate and discharge (Q). This experimental research used prototype model made from fiberglass (horizontal channel), sluice gate installed on it. Two models of trapezoid baffle block installed as three rows, specified location 25 cm after sluice gate pair using sill with different dimension. Water depth (y) and velocity (v) were measured during each running test then Froude number, contraction coefficient (Cc) and discharge coefficient (Cd) were calculated. The result showed that trapezoid baffle block model T2 (used no sill, sill 2 cm and sill 2.7 cm, Fr = 0.11 - 0.75) gives the better performance modelling of Cc and Cd in term of the initial Froude number with R2 = 0.8086 (Cc) and R2 = 0.8273 (Cd).

Keywords: trapezoid baffle block, sill, contraction coefficient, discharge coefficient

INTRODUCTION

Research of free-surface flow (depend on the tailwater depth) under sluice gate is important to provide a prediction tool for optimize hydraulic infrastructure operation (irrigation and drainage channels). Placement sluice gates in channel to control and rises water level have been used as a hydraulic structure commonly. The discharge through a sluice gate is affected by the upstream flow depth for free flow (Henderson, 1966).

Simulation operation flow under sluice gate with variation open gate will rise contraction coefficient (Cc) and discharge coefficient (Cd). Contraction coefficient (Cc) define as the ratio of water depth at vena contracta Discharge coefficient (Cd) define as the ratio of actual discharge to the theoretical discharge. In this research, flow under sluice gate was simulated, contraction coefficient (Cc) and discharge coefficient (Cd) was analyze. Adding structure as baffle block (to reduce velocity and energy of flow) or sill (to increase the water level at the downstream-end of the channel) usually placement in front of sluice gate with certain distance for energy dissipator while running flow being simulation. Benchmark value of Cc and Cd must be under 1 as a safe value for sluice gate and adding structure stabilization.

This research was development from earlier research (Sunik, 2001) and aims to analyze characteristis of Cc and Cd with two models of trapezoid baffle block (T1, T2) that located in front of sluice gate in a channel using prototype channel model test.

LITERATURE

Many experiment have been made to research free flow through the sluice gate to get some characteristics of contraction and discharge coefficient. Some research as (Benjamin, 1956), (Betts, 1978), (Cheng et.al, 1980), (Dae-Geun, 2007), (Fangmeier and Strelkoff, 1967), (Hager, 1999), (Isaacs, 1977), (Masliyah, et. al, 1985) (Mohammed and Khaleel, 2013), (Montes, 1997), (Nago, 1978), (Noutsopoulos and Fanariotis, 1978), (Oskuyi and Salmasi, 2011), (Rajaratnam, 1977), (Rajaratnam and Subramanya, 1967), (Roth and Hager, 1999), (Sunik, 2001), (Swami, 1990), (Yen et. al, 2001) had been investigated about contraction coefficient and coefficient discharge for flow under sluice gate.

Henderson (1966) derived two equations to compute Cd for each flow condition:

Free flow $C_d = \frac{C_c}{\sqrt{1+\eta}}, \eta = \frac{C_c\, x\, b}{y_1}$ (1)

The contraction coefficient is defined as the ratio of the water depth at vena contracta, y2 to gate opening (Cc = y2/b).

RESEARCH METHOD

These experimental was development from earlier research (Sunik, 2001). Configuration about experiment laboratory explain below as seen in Figure 1. The channel after the sluice gate separated into 12 section for measurement. Running measurement for water depth (y) and velocity (v) implemented in 12 section. Measurement was done in 12 section of flow (1-upstream-y1, 2-under the gate, 3-before baffle block installation, 4-before the jump (the initial depth, y2), 5-above the baffle block, 6-the end baffle block, 7-after the jump (sequent depth, y3), 8-end of roller, 9-end of jump, 10-3/4 length before the sill, 11-1/2 length before the sill, 12-1/4 near the sill) for the depth (y) of water. Measured for each section consist of left, middle and right part that each part measure in above, middle and bottom of height flow (one section consists of nine measured). The local velocity (v) for 12 section was measured in the same procedure The Froude number (Fr) affected by value of velocity and the depth.

The prototype model as horizontal channel made from fiberglass (used for trial running flow, with dimension as width (B) = 50 cm, length (L) = 9 m). Sluice gate placed on it with dimension, width (b) = 50 cm, thick (t) = 1 cm, height (h) = 80 cm, using added device (trapezoid baffle block and sill) as energy dissipator, present in Figure 1.

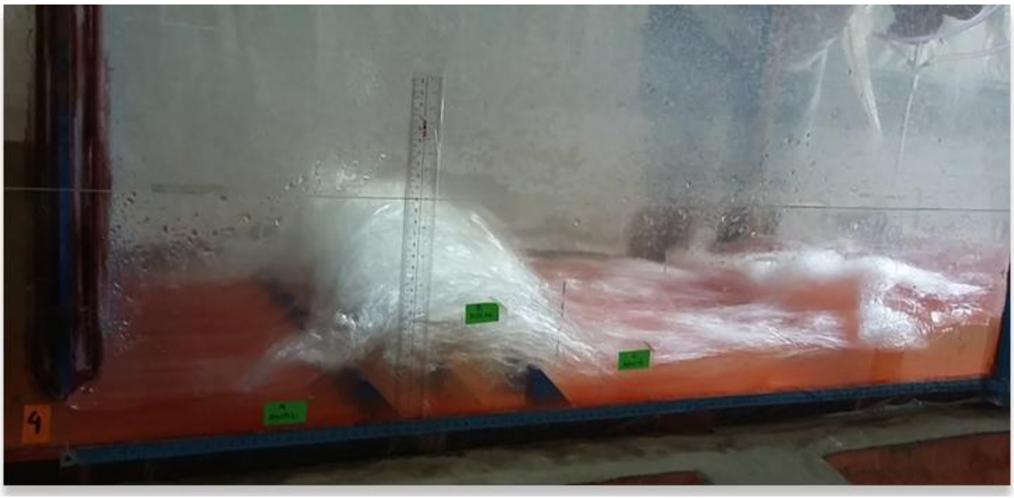

Figure 1. Trapezoid baffle block configuration in front of sluice gate

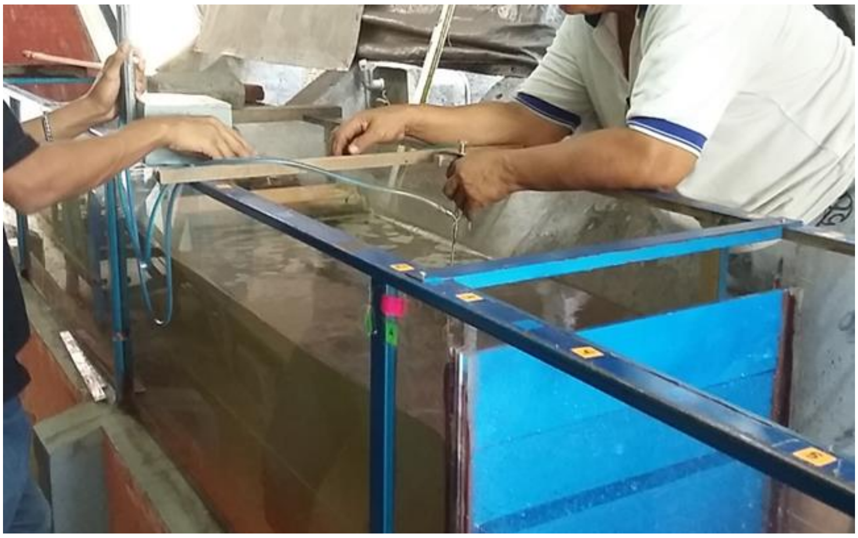

Figure 2. Water depth and velocity measurement for 12 section

Configuration dimension of trapezoid (T) baffle block type of T1, width (bb1) = 7 mm, length (lb1) = 7 mm and height (hb1) = 7 mm; type of T2, width (bb2) = 14 mm, length (lb2) = 14 mm and height (hb2) = 14 mm. Sill placed in downstream channel with dimension width (bs1) = 50 cm, thick (ts)= 1 cm, height (hs1, hs2, hs3 = no sill, 2 cm, 2.7 cm). Variation of open gate (a) = 1 cm, 2 cm, 3 cm, 4 cm.

Table 1 present two set of experiments test with a total of 24 run, using trapezoid baffle block in cross sectional (three rows, each baffle block made from fiberglass) mixing with configuration of sill that placed in downstream as present in Table 2. Simulation of flow was trial till configuration of hydraulic jump was perform in stabilized to the desire location of 25 cm downstream from the sluice gate.

Table 1. Configuration dimension of cubic baffle block

No	Model Baffle Block	Type	Run	(b_b) mm	(l_b) mm	(h_b) mm
1	T	T1	12	7	7	7
		T2	12	14	14	14

Table 2. Configuration dimension of sill for the channel

No	Model Baffle Block	Type	Sill type	(hs) (cm)
1	T	T1	s_1,s_2	no sill; 2
		T2	s_2,s_3	2 and 2.7

Relation between Froude number, Fr and contraction coefficient (Cc) and discharge coefficient (Cd) was analyze using regression method (Nawari, 2007) to know influence of Fr against to Cc and Cd. Determination coefficient value was criteria that showed the variable against to the response (Sembiring, 1995) as:

$$R^2 = 1 - \frac{\Sigma JKG}{\Sigma JKT} \qquad (2)$$

where:

Σ JKG = sum of error square

Σ JKT = total sum of squares

RESULT AND DISCUSSION

Contraction coefficient (Cc)

Correlation result between Froude number and contraction coefficient model T1, T2 show in Figure 3; value of Cc present in Table 3.

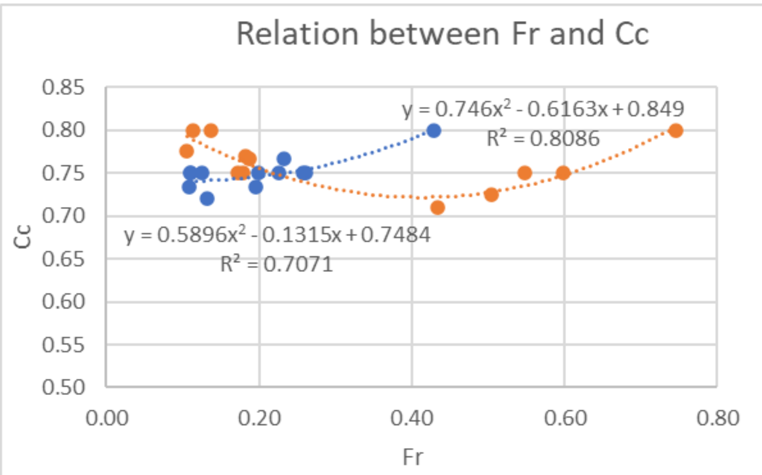

Figure 3. Contraction coefficient (Cc) for trapezoid baffle block model T1, T2

Based on R2 value, the better performance showed by trapezoid baffle block type K2 that used no sill, sill = 2 cm and sill = 2.7 cm at the channel, with Fr = 0.11 - 0.75, Cc = 0.75 – 0.80. the equation presented as:

$y = 0.746x^2 - 0.6163x + 0.849$,
R^2 value = 0.8086

The value R2 close to 1 for determination coefficient. It means that a strong relation between value Fr to contraction coefficient had present (value of Cc influenced by Fr, while Fr depend on velocity (v) and depth of water (y)). Adding device i.e. sill at the channel influenced velocity of flow, affected to Cc value. All value of Cc under 1 as benchmark mean that configuration of trapezoid baffle block K2 model safe for implementation.

Table 3. Value of Contraction Coefficient (Cc) for T1 and T2 model

No	Run	Type	Q (l/s)	a (cm)	sill (cm)	Fr	Cc		No	Run	Type	Q (l/s)	a (cm)	sill	Fr	Cc
1	39	T1	4.01	1	-	0.13	0.72		1	72	T2	4.66	1	-	0.18	0.75
2	37	T1	6.86	2	-	0.13	0.75		2	73	T2	4.76	1	-	0.18	0.77
3	35	T1	9.91	3	-	0.11	0.73		3	79	T2	12.79	4	-	0.11	0.78
4	34	T1	14.11	3	-	0.20	0.73		4	80	T2	14.51	4	-	0.11	0.80
5	32	T1	13.31	4	-	0.11	0.75		5	91	T2	7.73	1	2	0.75	0.80
6	40	T1	18.03	4	-	0.11	0.75		6	88	T2	12.27	2	2	0.43	0.71
7	42	T1	7.84	1	2.7	0.43	0.80		7	87	T2	15.47	3	2	0.14	0.80
8	43	T1	11.51	2	2.7	0.20	0.75		8	86	T2	16.03	3	2	0.19	0.77
9	44	T1	12.27	2	2.7	0.26	0.75		9	85	T2	15.47	4	2	0.17	0.75
10	45	T1	16.31	3	2.7	0.23	0.77		10	92	T2	8.85	1	2.7	0.60	0.75
11	46	T1	18.03	4	2.7	0.23	0.75		11	93	T2	13.57	2	2.7	0.50	0.73
12	47	T1	20.71	4	2.7	0.26	0.75		12	94	T2	17.88	2	2.7	0.55	0.75

Discharge coefficient (Cd)

Correlation result between Froude number and discharge coefficient model T1, T2 show in Figure 3; value of Cd present in Table 4.

Based on R2 value, the better performance showed by trapezoid baffle block type K2 that used no sill, sill = 2 cm and sill = 2.7 cm at the channel, with Fr = 0.11 - 0.75, Cd = 0.69 – 0.73, describe as:

$y = 0.4285x^2 - 0.2756x + 0.7401$,
R^2 value = 0.8273

The value R2 close to 1 for determination coefficient. It means that a strong relation between value Fr to disharge coefficient had present (value of Cd influenced by Cc). All benchmark value under 1, it means that configuration of trapezoid baffle block K2 safe for implementation.

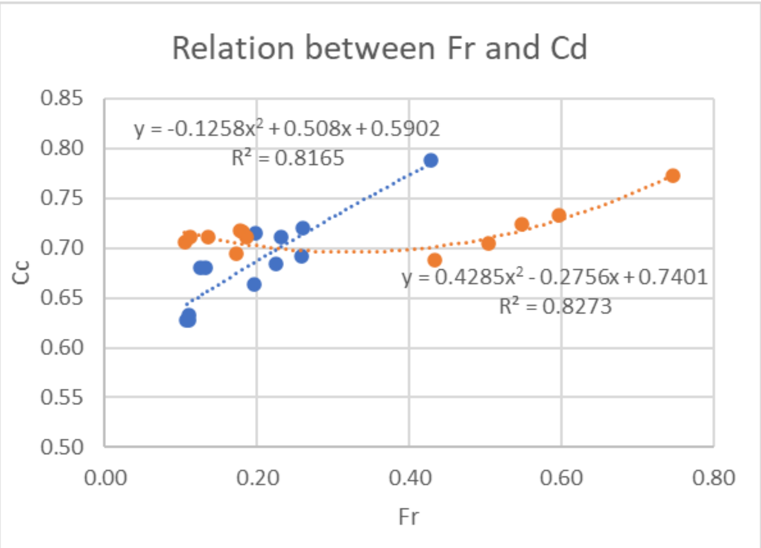

Figure 4. Discharge coefficient (Cd) for trapezoid baffle block model T1, T2

Table 4. Value of Discharge Coefficient (Cd) for T1 and T2 model

No	Run	Type	Q (l/s)	a (cm)	sill (cm)	Fr	Cd		No	Run	Type	Q (l/s)	a (cm)	sill	Fr	Cd
1	39	T1	4.01	1	-	0.13	0.68		1	72	T2	4.66	1	-	0.18	0.72
2	37	T1	6.86	2	-	0.13	0.68		2	73	T2	4.76	1	-	0.18	0.72
3	35	T1	9.91	3	-	0.11	0.63		3	79	T2	12.79	4	-	0.11	0.71
4	34	T1	14.11	3	-	0.20	0.66		4	80	T2	14.51	4	-	0.11	0.71
5	32	T1	13.31	4	-	0.11	0.63		5	91	T2	7.73	1	2	0.75	0.77
6	40	T1	18.03	4	-	0.11	0.63		6	88	T2	12.27	2	2	0.43	0.69
7	42	T1	7.84	1	2.7	0.43	0.79		7	87	T2	15.47	3	2	0.14	0.71
8	43	T1	11.51	2	2.7	0.20	0.72		8	86	T2	16.03	3	2	0.19	0.71
9	44	T1	12.27	2	2.7	0.26	0.72		9	85	T2	15.47	4	2	0.17	0.69
10	45	T1	16.31	3	2.7	0.23	0.71		10	92	T2	8.85	1	2.7	0.60	0.73
11	46	T1	18.03	4	2.7	0.23	0.68		11	93	T2	13.57	2	2.7	0.50	0.70
12	47	T1	20.71	4	2.7	0.26	0.69		12	94	T2	17.88	2	2.7	0.55	0.72

CONCLUSION

Configuration of baffle block (depend on number of baffle blocks, spacing between adjacent blocks, width of the block, dimension of block) paired with matched sill placement will gave better performance of Cc and Cd (< 1) while sluice gate operated with variation open gate.

It concluded that trapezoid baffle block model T2 (1.4 cm) combine with no sill and two model of sill (2 and 2.7 cm) gave better performance for Cc and Cd value (determination coefficient $R^2 = 0.8086$ and $R^2 = 0.8273$) than model T1.

Research of free-surface flow under sluice gate is important to provide a prediction tool for the optimal management of irrigation and drainage channels. Flow through the gate may be free or submerged depending on the tailwater depth.

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