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Effective Distance on Placing Discharge Measurer Structure of Wide Treshold Type at the Downstream of Sluice Gate (Physical Model Test at Hydraulic Laboratory of Opened Channel)

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ABSTRACT

This paper studied about the placing discharge measurer structure at downstream of sluice gate. The discharge measurer at this research was the kind of wide treshold. Physical model test was conducted at Hydraulic Laboratory of opened channel which was as the laboratory of Water Resources Department, Faculty of Engineering, University of Brawijaya. Regulator gate was as a utilization which used for dividing water to agricultural areas. There was needed measurer structure at downstream of the gate for being easy to exploitate the gate. Wrong placing would cause the measurer structure became non efficient. Based on the reason as above, this study was intended to find the effective distance on placing the discharge measurer structur at downstream of sluice gate. The methodology consisted of physical model test. In depth research, this study was focussed on the changes of flow condition at sluice gate when measurer structure of wide treshold was placed at downstream of the gate. Analysis was carried out with statistical approach of inter-related variables that used in research design. Existing condition before installing measurer structure that was flow at downstream of the gate was as free flow with Froude number: Fr > 1. Result of study showed that flow condition at downstream of the gate after installing sluice gate at downstream was sudmerged condition with boundary of H_1 was < 0.7 H_0 and Froude number: Fr < 1. This condition was safe from super-critical flow that could cause hydraulic jump Hydraulic jump would cause water depth at the upstream would go through changes which caused inaccurate on measuring discharge.

Keywords: regulator gate, discharge measurer structure, effective distance

INTRODUCTION

Stream confluences were the elements of river networks that played a major role in the dynamics of fluvial systems [1]. Substantial changes in hydrodynamics flow usually occured within downstream of junction. A region referred to as the confluence hydrodynamics zone and mixing of tributary flows might extend many kilometres downstream of confluences [2].

Process of physical model test in Hydraulic sciences had a primary goal that was the prediction of a variable in time or space from a given input. However, how well a model, referred to a model validation or evaluation, fitted the observed data generally was determined by wise comparisons models of simulation and predicted value with observation [3]. Low flow in natural channel had been investigated using both of numerical mathematical model and laboratory experiments [4]. Laboratory experiment and test involved the collection of channel geometry, hydraulic and dispersion test data. The hydraulic jump was the transition between the supercritical and subcritical regimes of flow [5]. This transition involved the changes of water depth at the upstream which caused inaccurate measuring of discharge. It was also depended on velocity and depth of supercritical flow that generated the jump which were embodied in the Froude number of the supercritical flow. This feature might be as the most outstanding characteristic of the jump and the reason why this hydraulic phenomenon had accepted such wide utilization in hydraulic structures used for irrigation, hydropower, etc [5].

One of structures which was often found at irrigation network was regulator gate. This gate was used for dividing water so all of irrigation areas could be in average supplied. Type of regulator gates which were functioned at irrigation area were sluice gate, radial gate, segmental block scot and sluice gate. As initial step of sluice gate design, it was nacessary to be attended demand of water level depth at the upstream of gate, water level depth at downstream, and opening gate. Discharge under the gate could be known based on the depth of opening gate and it was nacessary to be supported with discharge measurer structure for being the ease.

This research want to place discharge measurer structure at downstream of sluice gate. The discharge measurer at this research was the kind of wide treshold.. Flow condition at downstream of the gate after installing sluice gate at downstream was hoped as sudmerged condition with boundary of H_1 was < 0.7 H_0 and Froude number: Fr < 1. This condition was safe from super-critical flow that could cause hydraulic jump which would cause water depth at the upstream.

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MATERIALS AND METHODS

This research was intended to find effective distance on placing wide treshold of measurer structure and it was conducted at Hydraulic Laboratory of Water Resources Department, Faculty of Engineering, University of Brawijaya, Malang, East Java of Indonesia. A discharge measurer was expressed effective if discharge measured by the measurer was the same as flowed discharge under sluice gate. This research was carried out experimentally so it was really different with field physical condition. The utilizations used for carrying out this research were as follow:

1. Opened channel aids with the conditions as follow:
   Material was included metal at the base of flume and perspex glass at the side with n of Manning = 0.01, length = 9 m, width = 0.078 m, maximum depth = 0.22 m, and slope = 0.0001
2. Control storage of constant discharge with length of 0.5 m, width of 0.6 m, height of 0.31 m, fiber glass with n of Manning = 0.010
3. Point gauge
4. Pitot tube
5. Stopwatch
6. One set model of sluice gate
7. Model of wide treshold included reshold block with length of 30 cm, height of 5.00 cm, and block was made of wood.

Sketch of experimental tool was as in Figure 1 below.

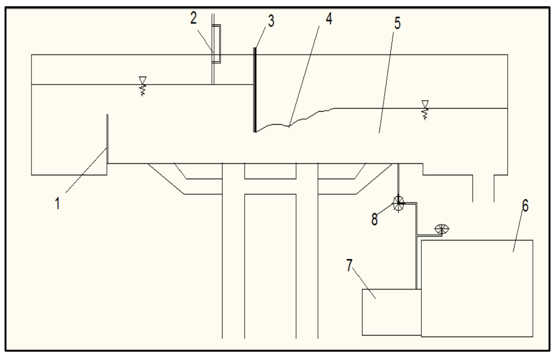

Figure 1 Sketch of experimental tool

(Note: 1. Long throated flume; 2. Point gauge; 3. Sluice gate; 4. Spreading of wave; 5. Experimental channel; 6. Water pump; 7. Underside storage; 8. Regulator valve).

Calibration and verification

1. Calibration of pitot tube
   This calibration was intended to get correction number of pitot and to produce the new equation due to the corection number. The steps of pitot calibration were as follow:
   a. At opened channel aids: water was flowed by certain discharge and addition for wide treshold with certain height at the upstream of sluice gate, then velocity was measured by pitot at each section and the distance inter section was taken of 3.0 m.
   b. To measure water volume which was through out at the upstream of channel aids for ±10 times and time for measuring water volume was recorded. Based on this step, flow velocity, discharge, and velocity coefficient of pitot (c) was formulated as follow: [6][7][8]

$$u_{pt} = c.\sqrt{2.g.\Delta h_{pt}}$$

Note:

u_{pt} = theoritical flow velocity of pitot (m/s)
c = velocity coefficient of pitot
g = gravity (m/s^2)
Δh_{pt} = difference of height from pitot (m)

c. The first step was returned for 3 different discharges. After knowing the value of Δh from pitot and velocity coefficient of pitot, it could find the velocity of pitot. Then it was illustrated in scatter diagram which was as the relation between velocity of discharge and Δh of pitot.
d. Result of scatter diagram as above was approached with regression curve fitted to indicator of determination coefficient. This regression equation was as new equation of pitot for determining flow velocity.

2. Calibration of C_0 and C_1
This calibration was carried out to get constraction coefficient of gate which using in this research and coefficient of discharge, and then it was used in calculation of Froude Number. The steps of calibration of C_0 and C_1 were as follow:
a. Coefficient of construction
- The first step was to determine water level heght at upstream (H_0) with regulating valve opening, one value of h_1 expressed one value of discharge (Q)
- To determine gate opening (a) from the least one
- After the flow was constant, it was carried out to measure the velocity at gate opening and to measure discharge for 10 times.
- Measuring discharge and velocity was used as input of the equation for finding C_c as follow: [6][7][8]

$$C_c = \frac{Q}{a.B.V_1}$$

Note: a = height of gate opening (m) and B = width of gate (m)

- This experiment was returned for the height of H_0 and different of a, so that would be got the variation of C_c for the value of a/H_0.

b. Coefficient of discharge (C_d)
Value of C_d was calculated using the equation due to calculated of C_c and H_0 as follow: [9][10]

$$q = h_0 . V_0 = h_1 .V_1 = C_c .a . V_1$$

3. Study of wide treshold installing
The steps were as follow:
- Discharge was flowed to the channel aids with certain gate opening and the condition of channel downstream was free (there was no wide treshold)
- This initial condition was recorded which included Froude Number, length of jump, depth of conjugation, water level depth at dowstream, distribution of velocity, and discharge
- To install wide treshold with random distance and minimum height
- To measure occured condition which included Froude Number, length of jump, depth of conjugation, water level depth at downstream, distribution of velocity with the same of discharge and gate opening
- Position of treshold was changed with direction towards upstream with interval of certain distance and flow condition was recorded.
- The steps as above were stopped until the boundary condition which there was submerged condition at the upstream of sluice gate
- The next step was to return the third step with the other height of treshold and with different gate opening. Water level height was taken measure constant for every change of treshold placing distance
- To record the result and to be made relation curve between upstream water level depth and height of gate opening with placing of distance.

4. Design of treatment
Table 1 dan Figure 2 below presented design of treatment with being carried out in this research

Table 1 Design of treatment

Number	Treatment		
	Distance of placing (Ls)	Height of gate opening (a)	Water level depth at upstream (Ho)
1			Ho 1
2			Ho 2
3		a1	Ho 3
4			Ho 4
5			Ho 5
6			Ho 6
7			Ho 1
8			Ho 2
9		a2	Ho 3
10			Ho 4
11	Ls1		Ho 5
12			Ho 6
13			Ho 1
14			Ho 2
15		a3	Ho 3
16			Ho 4
17			Ho 5
18			Ho 6
19			Ho 1
20		a4	Ho 2
21			Ho 3

In this design of treatment, it was determined that the same treatment would be carried out at some placing distances of measurer structure (L_s).

5. Analysis of relation between parameter and variable [11]
   - Hydraulic parameter used in this study was shape and dimension of channel (the channel was as opened channel aids with rectangular shape, certain base width and height), and height of wide treshild measurer structure.
   - Variables used in this study were included: 1) depended variables those were initial water depth of jump (h_1), velocity underside of sluice gate (u_1), water depth at jump upstream/ depth of conjugation (Lh_2); 2) regulated variables those were height of sluice gate opening (a), water depth at gate upstream (H_0), horizontal distance of wide treshold placing toward gate (L_s); and 3) the other variables those were gravity (g) and mass density (ρ)

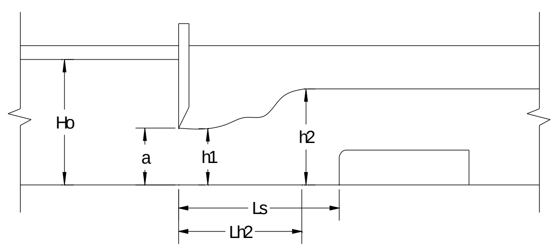

Figure 2 Sketch of research treatment

Group of variables	Dependent variable				Regulator variable			Other variable	
	h1	U1	h2	Lh2	a	Ho	Ls	g	ρ
M	0	0	0	0	0	0	0	0	1
L	1	1	1	1	1	1	1	1	-3
T	0	-1	0	0	0	0	0	-2	0

$k_9 = 0$
$k_1 + k_2 + k_3 + k_4 + k_5 + k_6 + k_7 + k_8 - 3k_9 = 0$
$- k_2 - 2 k_8 = 0$
Eliminating k_5, k_8, it would produced
$k_8 = - 0.5 k_2$
$k_5 = - k_1 - 0,5k_2 - k_3 - k_4 - k_6 - k_7 + 3 k_9$
Then, for determining non dimentional number, it was used Langhaar matrix as described below: [6]

Group of variables	h1	U1	h2	Lh2	Ho	Ls	ρ	a	g
	k1	k2	k3	k4	k6	k7	k9	k5	k8
π1	1	0	0	0	0	0	0	-1	0
π2	0	1	0	0	0	0	0	-0.5	-0.5
π3	0	0	1	0	0	0	0	-1	0
π4	0	0	0	1	0	0	0	-1	0
π5	0	0	0	0	1	0	0	-1	0
π6	0	0	0	0	0	1	0	-1	0
π7	0	0	0	0	0	0	1	3	0

$$\pi_1 = \frac{h_1}{a} \qquad \pi_5 = \frac{H_o}{a}$$

$$\pi_2 = \frac{u_1}{\sqrt{a.g}} \qquad \pi_6 = \frac{L_s}{a}$$

$$\pi_3 = \frac{h_2}{a} \qquad \pi_7 = \rho.a^3$$

$$\pi_4 = \frac{Lh_2}{a}$$

Based on the 7 non dimensional numbers, then it could performed the other non dimensional number. Non dimensional number that could performed related to this case was as follow:

$$\pi_8 = \frac{\pi_1}{\pi_3} = \frac{\frac{h_1}{a}}{\frac{h_2}{a}} = \frac{h_1}{h_2}$$

Note: π_2 was Froude Number if $a = h_1$.

RESULTS AND DISCUSSION

Condition of before installing Discharge Measurer Structure

Initial treatment was carried out at the channel aids which was flowed certain discharge with certain opening gate and upstream water level depth. Then there was observed and recorded the occured varaibles.

a. Calibration of constraction coefficient (C_c) and discharge coefficient (C_d)
To make easy in controlling flow and accurately in data measuring, it was needed a trial to find the value of C_c and C_d of sluice gate which would use as the shaping of Froude Number. In this case, C_d was produced from H_0 and C_c was calculated with the foemula as follow: [9][10]

$$Cd = \frac{Cc}{\sqrt{1 + (a/Ho).Cc}}$$

Figure 3 was presented the relation between coefficient of constraction and a/H_0

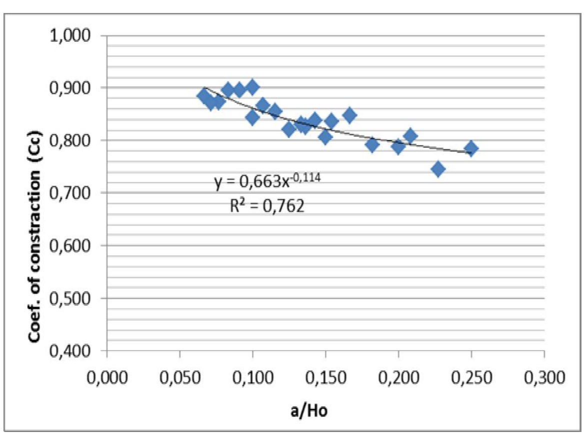

Figure 3 Relation between coefficient of constraction and a/Ho

b. Relation inter variables

Relation between a/Ho and Froude Number (Fr) was presented as in Figure 4. Height of gate opening was expressed by a and water level height of gate upstream by H_0. Based on this relation curve, it could produced Froude Number with water level depth of dowstream gate which had been determined.

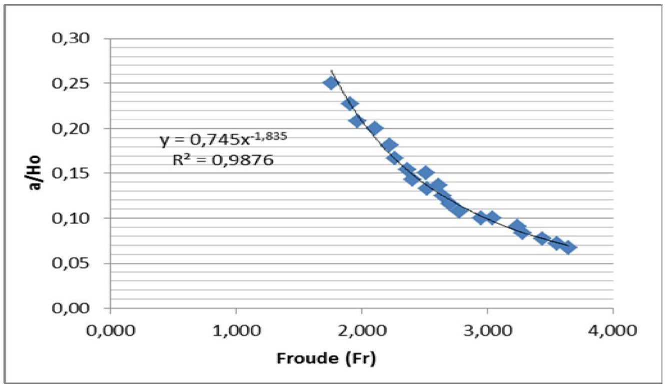

Figure 4 Relation between a/H_0 and Froude Number

Figure 5 presented the relation between h_2/a and Froude Number. Then, based on this relation, it was made table and curve for determining h_2 if there was the same Froude Number and gate opening at the previous condition.

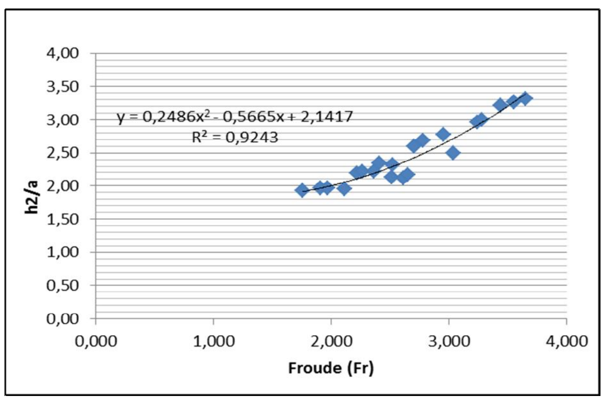

Figure 5 Relation between h_2/a and Froude Number

Relation between h_1/h_2 and Froude Number was presented as in Figure 6. Based on the relation between water level height at initial jump (h_1) and at end of jump (h_2) with Froude Number nue to the result of obseration, it could be made relation curve between h_1/h_2 and Froude Number and based on this curve it was determined the value of h_1 due to the certain of Froude Number and h_2

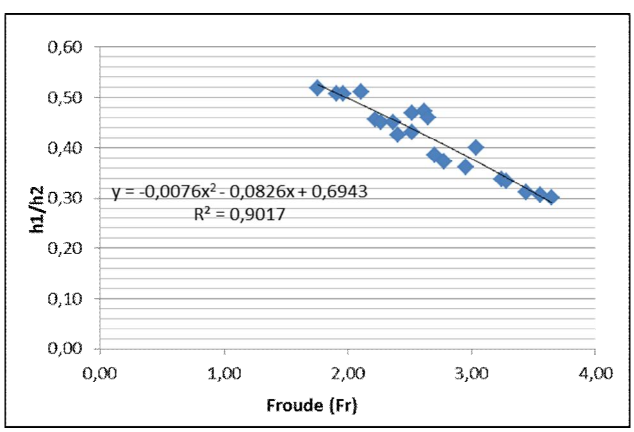

Figure 6 Relation between h_1/h_2 and Froude Number

The next step was to find the relation between quiet water level and Froude Number. Figure 7 presented the relation between Lh_2/a and Froude Number. Then based on the observation, it was made relation curve inter the variables. Based on this curve it could determine the position where reached quiet flow (sub critical flow) of the gate according to the treatment as above

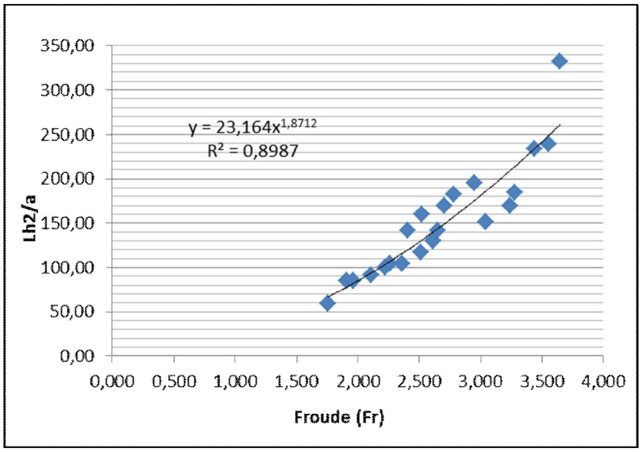

Figure 7 Relation between Lh_2/a and Froude Number

Condition of after installing Discharge Measurer Structure

The same treatment of before installing Discharge Mrasurer Structure was carried out to the condition after installing one. The tretment was also in the variation of placing distance of sluice gate (L_s). After being carried out the flow condition at gate before and after installing measurer structure of wide treshold, there was got the comparison of water level depth at upstream (H_0) and height of gate opening (a) due to the same discharge before and after installing measurer structure. Based on the relation, it could be made the relation curve between H_0/a (before installing measurer structure) and H_0/a' (after installing measurer structure) which could be used to determine height of gate opening after installing measurer structure at gate upstream. Relation curve between H_0/a and H_0/a' was presented as in Figure 8.

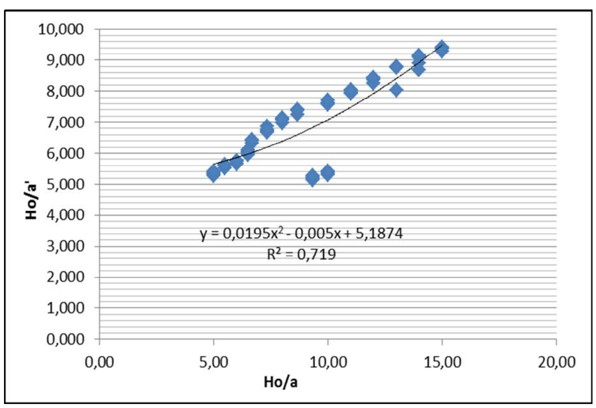

Figure 9.Relation between Ho/a' and Ls/a'

Either relation curve between Ho/a' and Ls/a', placing distance of treshold could be found from relation curve between Froude Number (Fr) before installing treshold and Ls/a', but this curve was only limited for Froude Number between 1 to 3.5 (Figure 10)

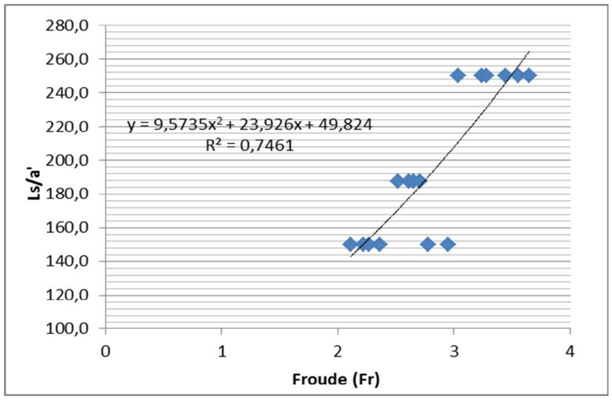

Figure 10 Relation between Froude Number and Ls/a'

CONCLUSION

Based on observation at laboratory and analysis of the results, it was concluded as follow:

1. Flow at upstream of sluice gate before installing wide treshold at free flow condition had Froude number of $1 < Fr < 4$. After installing measurer structure there was change at discharge which flowed underside of gate at the same condition of water height at the upstream of gate (H_0) and opening height (a) as before installing measurer structure, it had Froude Number of $Fr < 1$and at the condition of submerged flow with $H_1 < 0.7\ H_0$
2. Effective distance of placing of wide treshold measurer structure could be determined by knowing the comparison of Ho/a before installing treshold and Ho/a' after installing treshold with using the equation of $Ho/a' = 0.019\ (Ho/a)^2 – 0.005\ (Ho/a) + 5.187$. Then, after finding the value of Ho/a after installing treshold, it could be found the velue of Ls/a due to the equation of $Ls/a' = 18.51.(Ho/a')^{-0.162}$. Therefore, it was known effective distance of treshold placing (Ls). For Froude Number between 1 to 3.5, distance of treshold placing could be found by using the equation of $Ls/a' = 9.573(Fr)^2 + 23.92(Fr) + 49.82$. Based on the result of this study, if there was designed a tertiary channel with channel width: b = 1,00 m and ho = 0,50 m, effective distance of placing of wide treshold measurer structure was 14 m from sluice gate.

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