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STUDY OF THE SCOUR MODEL AROUND THE SLUICE GATE OF OPEN CHANNEL

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ABSTRACT

This study aims to determine effects of variations in gate opening at constant discharge on scour depth and flow pattern of the bed of open channel using clay around the sluice gate. Each experiment used a constant discharge and starts from a flat bottom during an hour of flowing. The results of this study indicated that the gate opening affected the flow pattern of energy.. Flow Changes can be observed visually or based on the number Froude. In addition, the flow occurred in upstream and supercritical flow downstream is sub-critical flow. At the gate opening of 0.5 showed that scour pattern was the deepest compared to the gate openings of 1.0 and 1.5. Based on the observation that the greater the discharge the scour depth.

Key words: Discharge, Sluice gate, Gate openings, Scour depth, Clay

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1. INTRODUCTION

A sluice gate of irrigation is used to adjust the water level according to the planned discharge. However, the use of sluice gate causes the changes of flow characteristics on upstream and downstream of the channel, such as speed and turbulence. This causes sediment transport and scouring. At the sluice gates, the flow that passes under the door (under flow) can be in the form of supercritical flow which has high energy causing scour problems downstream of the gate, especially if the bottom of the channel is composed of fine or soft material (Puspitarini et.all, 2002: 420).

When the gate is operated there will be a flow pattern in around the gate opening, where the flow will interact with the materials. The interaction of flow with the channel bottom will cause the material at the bottom of the channel to be eroded. If at the bottom of the channel is soft or loose material, scouring patterns will occur which reflect the effect of flow. This phenomenon can cause erosion and degradation around water constructions. This degradation continues until the balance between supply and sediment transport. Flow pattern changes create an imbalance while the sediment transport is greater than the sediment supply. This results in deeper scour holes.

A gate opening is one of the parameters that affect the flow patterns. Gate openings will greatly affect the flow pattern. Therefore, there is a need for research on the effect of sluice openings on flow patterns of open channels.

2. TEORITICAL SCOUR OF OPEN CHANNEL ASPECTS

2.1. Scour

The morphology of river is one of the determining factors in the process of scouring. This is due to the open channel flow having a free surface. Open channel flow conditions based on the position of the free surface tend to change with time and space. The process of erosion and deposition generally occurs due to changes in flow patterns, especially in alluvial rivers. Changes in flow patterns occur due to obstacles in the river flow, in the form of river buildings such as pillars and abutments of bridge. This kind of building is considered to be able to change the flow geometry and flow pattern which is then followed by local scouring around the building.

Generally, there are three types of scouring. Firtsly, General scouring in a river channel, not at all related to the presence or absence of river buildings. Secondly, Scour is localized in the river channel which occurs because the narrowing of the river flow becomes centralized, and the last, local scouring around buildings which occurs because of local flow patterns around river buildings.

2.2. Scour Mechanism

Discharge through the sluice gate forms a jet on an erodible basis. High jet velocity causes a large frictional stress exceeding the critical friction stress of the grain which is the initial limit of grain motion and this causes local scouring on the apron downstream [3]. The scour hole formed causes an increase the local scour depth. This results the frictional stress on the bottom less than the critical friction of the basic material. So there is a decrease in the material transported. Finally, the equilibrium stage is reached where scouring does not increase. The development of scour depends of time. Initially the scour develops rapidly then decreases until it reaches the equilibrium stage.

2.3. Hydraulics and Water Flow

Water flow can be either an open channel flow or a pipe flow. Both types of flow are the same in many ways, but differ in one important thing. Open channel flow has a free surface. It is influenced by atmospheric pressure. But the pipe flow does not, because water must fill the entire channel. Pipe flow, which is confined in a closed channel, is not directly affected by air pressure, except by hydraulic pressure [4].

2.4. Flowing Under the Sluice Gate Opening

In general, the flow under the sluice gate opening is divided into two cross sections, the cross section of the upstream (Section 0) and the downstream section (Section 1). The flow scheme of the sluice gate is displayed in Fig. 1. The water level in the scheme is explained by the symbols Y_0 (water level upstream), Y_1 (water level downstream) and Y_g (the sluice gate opening height).

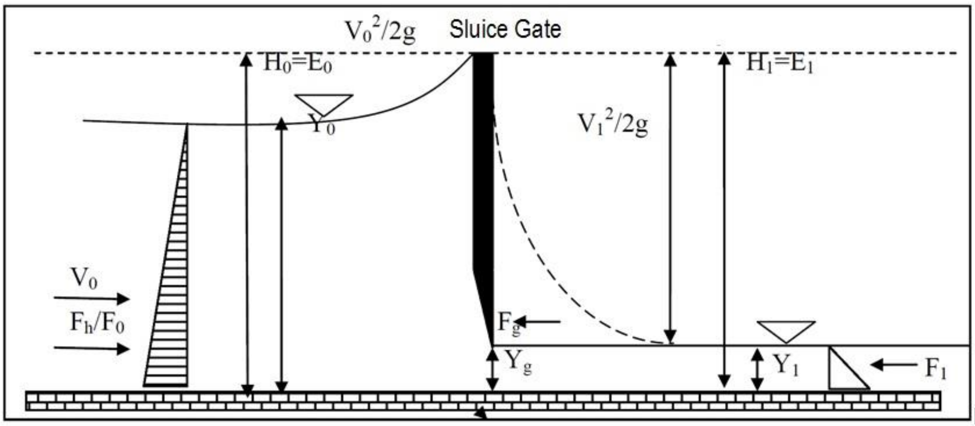


Figure 1 Flow under a sluice gate with a horizontal base

The Bernoulli equation can be applied only in cases where energy loss is ignored from one section to another, or when a high energy loss is known. (Bambang Triatmodjo, 1996). The flow under the sluice gate is an example of a convergent flow where the discharge equation is obtained by equalizing the energy at cross sections 0 and 1. Because the distribution of velocity on the cross section is uniform so the total energy height (H) of each current line is:

$$\mathrm{H_0} = \mathrm{H_1} \quad (1)$$

The energy lines on cross-section 1 are parallel because the free surface is parallel with the bottom of the channel. The bed is considered as datum, z = 0, so:

$$\mathrm{E} = \mathrm{Y} + \frac{\mathrm{V}^2}{2\mathrm{g}} \quad (2)$$

where E-energy (cmHg), Y-water level (cm), g-gravity (cm/s^2), V-velocity (cm/s)

The minimum value of a specific energy is in a critical flow. Its depth is called the critical depth (Yc). The critical depth can be determined by the following formula:

$$\mathrm{Y}_c = \left(\frac{q^2}{\mathrm{g}}\right)^{1/3} \quad (3)$$

where q-discharge per unit width (cm2/s), g-gravity (cm/s^2), Y_c-critical depth (cm) The discharge per unit width is obtained by the following formula.:

$$\mathrm{q} = \frac{\mathrm{Q}}{\mathrm{B}} \quad (4)$$

where q- discharge per unit width (cm2 /s), Q - discharge (cm/s2), B-channel width (cm).

The value range of Cv is 0.95 up to 1.00 (0.95 <Cv <1), depending on the shape of the flow pattern (expressed by the Yg / Yo ratio) and friction.

The downstream depth (Y_1) can be expressed as part of the height of the sluice gate opening, $Y_1 = C_c.Y_g$. The coefficient of contraction (C_c) is calculated using the equation 5.

$$C_c = \frac{Y_g}{Y_o} \quad (5)$$

A contraction coefficient, C_c, usually is 0.61. The coefficient of contraction is almost independent of the Yg / Yo ratio which is calculated as follows.

$$Q = \frac{Cv.Cc.b.Y_g\sqrt{2g.Y_0}}{\sqrt{\frac{Cc.Y_g}{Y_0}+1}} \quad (6)$$

The above equation is sometimes written as follows (Bambang Triatmodjo, 1996)

$$Q = Cd.b.Y_g\sqrt{2g.Y_0} \quad (7)$$

Discharge coefficient, Cd, depends on C_v, C_c, Y_g, and Y_o which is explained by the following formula

$$Cd = \frac{Q}{B \times Yg \times (2 \times g \times Y0)^{0.5}} \quad (8)$$

The value of speed coefficient, Cv, is calculated using the following formula.

$$Cv = \frac{Q \times (^{Y1}/_{Y0} + 1)^{0.5}}{Cc \times B \times Y1 \times (2 \times g \times Y0)^{0.5}} \quad (\mathbf{9})$$

where Cd-coefficient of discharge, Cv-speed coefficient, Cc-contraction coefficient, Y1-water level before the jump (cm), Yg-sluice gate opening (cm), Y0-water level upstream (cm), A-cross-sectional area (cm^2), B-channel width (cm), g-gravity (cm/s^2), Q-Discharge (cm^3/s).

2.5. Flow Regime

Flow on channels with easily eroded bed material can be categorized in two flow regimes with transition regions. Each category of this flow regime has characteristics related to the bed form of the channel. There are three categories of flow regime in relation to the configuration of the bed form of the channel. Firstly, Lower flow regime has Froude number <0.4-1, with bed form of ripples and dunes. Secondly, transition area with bed form of dunes to plane bed or to antidunes. Thirdly, upper flow regime has Froude number> 0.4-1, with bed form with sediment movement, antidunes standing waves and breaking waves, as well as, chutes and pools.

2.6. Bed Forms Analysis

Simon and Richardson (1960) explain that there are three configurations of the bed form, namely plane bed, rippless, and dunes (Yang, 1996: 60). To calculate the scour depth, It is used the Lacey method. The equation of the Lacey method is as follows.

$$R = 0.47\,(\frac{Q}{f})^{1/3} \quad (10)$$

$$f = 1.76\,(D_m)^{0.5} \quad (11)$$

Where R - scour depth (m), Q-outflow discharge (m3/s), f-Lacey mud factor, Dm-average diameter of material.

3. MATERIALS & EXPERIMENTAL PROCEDURES

3.1. Materials

The clay was taken from around the Civil Engineering Department Building, Hasanuddin University, Parangloe District, Gowa Regency, South Sulawesi Province. In this study clay was used as the bed of the channel.

Figure 2 Samples of clay

Physical properties of the clay is displayed in table 1.

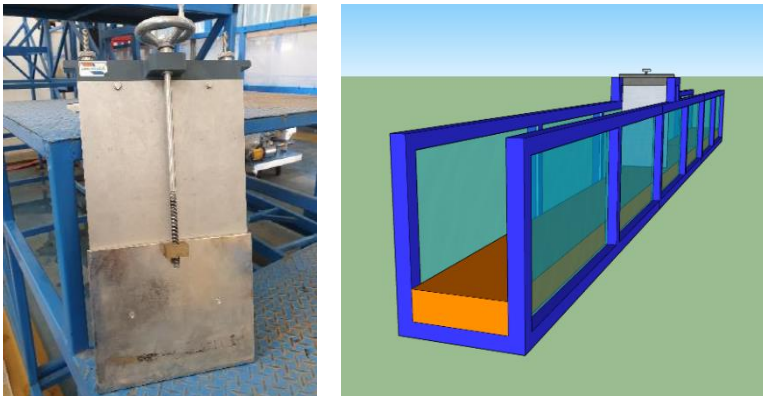
Table 1 Physical properties of Clay

Physical properties	Results
Spesific gravity (Gs)	2.705
Water content	38.63%
Plasticity Index (PI)	40.26
Liquit Limit (LL)	71.77%
Plastic Limit (PL)	31.51%
Spesific gravity (Gs)	2.705

3.2. Tools

3.2.1. Sluice Gate

The sluice gate is used to adjust the water level in the flume channel. To adjust the water level, the sluice gate lever is turned until the gate opening determined. The sluice gate is installed on a flume channel with a distance of 5.3 m from the upstream channel. The installation of sluice gate is shown in Figure 2.

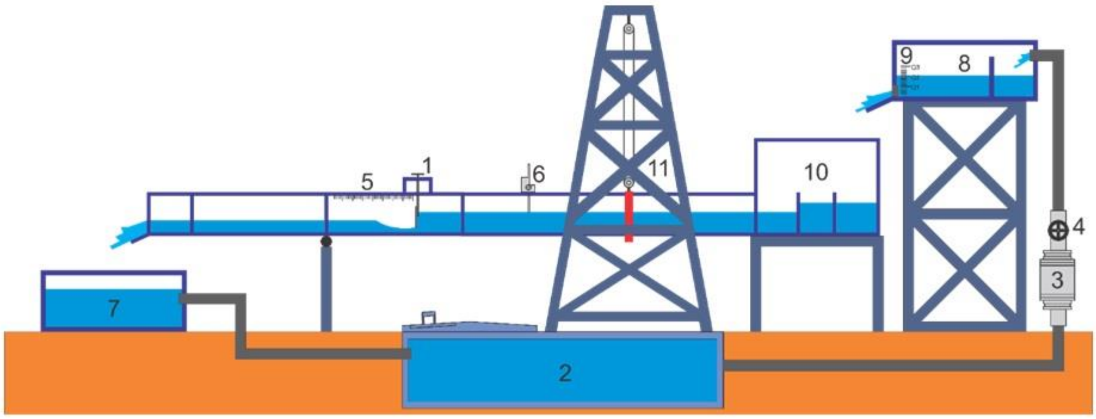


a. Sluice gate b. Open Chanel

Figure 3 Physical Model of Open Channel

3.2.2. Flume

The flume used in this study has a dimension of length 9 m, width 30.5 cm, and height 45 cm. The slope variation of flume can be adjusted.



Note: 1.Sluice gate, 2.Underground reservoir, 3.Pump, 4.Regulating Tap, 5.Point Gauge, 6.Meter, 7. Sediment storage tanks, 8. Discharge controlling tank, 9.Discharge crossbar, 10 Flow settling tank, 11. Slope control

Figure 4 Design of open channel for sluice gate experiments

3.3. Methods

The preparations of testing is carried out flow pattern measurement with the following steps. Firstly, prepare a set of open channels model with a length of 9 m, width 30.5 cm, and height 45 cm. Secondly, Turn on the water pump to drain the water from the underground reservoir to a set of open channels model. Thirdly, turning the tap to regulate the discharge while observing the water level in the discharge control tub until it reaches the water level has a discharge of Q = 1,46 m3/s which has been determined in determining the discharge variation. Fourthly, install the sluice gate models that correspond to open channels at a distance of 5.3 meters from the upstream channel. Fifthly, adjust the sluice gate openings with openings 0.5 cm from the bottom of the channel. Sixthly, wait until the water flow is constant, then take measurements. Seventhly, measuring water level at 3 points (left, center and right) of the open channel at a distance of 10 cm, 20 cm, 30 cm, 40 cm, 50 cm, 60 cm, 70 cm, 80 cm, 90 cm and 100 cm to the downstream direction and the upstream direction of the sluice gate and where the water jumps are before the jump and after the jump by using a point gauge. The last, Record the results of water level measurements on the flow pattern measurement form.

4. RESULTS AND DISCUSSION

The measurement data which is obtained in laboratory was analyzed to get flow patterns using the Surfer application. A comparison value of X: Y: Z is 1: 1: 1. The flow pattern formed was analyzed at Q = 1.46 m3/s with each gate openings of 0.5 cm; 1.0 cm and 1.5 cm.

4.1. Effect of Discharge on Scour

After observing the calculation results of the parameters affecting the flow pattern, it is shown that the process of the flow pattern occurs due to flow obstacles by the sluice gates. The use of sluice gate can cause changes in flow characteristics upstream and downstream of the channel, such as speed and turbulence. Here causes changes in flow patterns. At the sluice gate, underflow can be in the form of supercritical flow that has high energy, giving rise to a flow pattern. The flow depth affects the scour depth. The relationship between the flow depth and the scour depth is seen in fig. 4.

It shows that increasing of the flow depth at the upstream of the gate causes increasing the scour depth. This is different from the relationship of the flow depth at downstream of the gate and the scour depth which actually has an inverse relationship.

In addition to, scour depth is also influenced by the Froude number under the gate. The results of the study show that the Froude number is directly proportional to the scour depth.

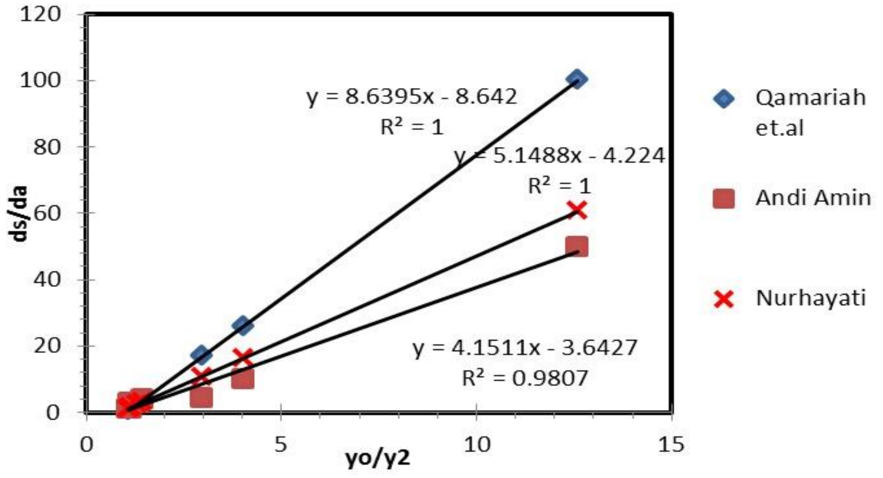


Figure 5 Relationship between the flow depth vs the scour depth

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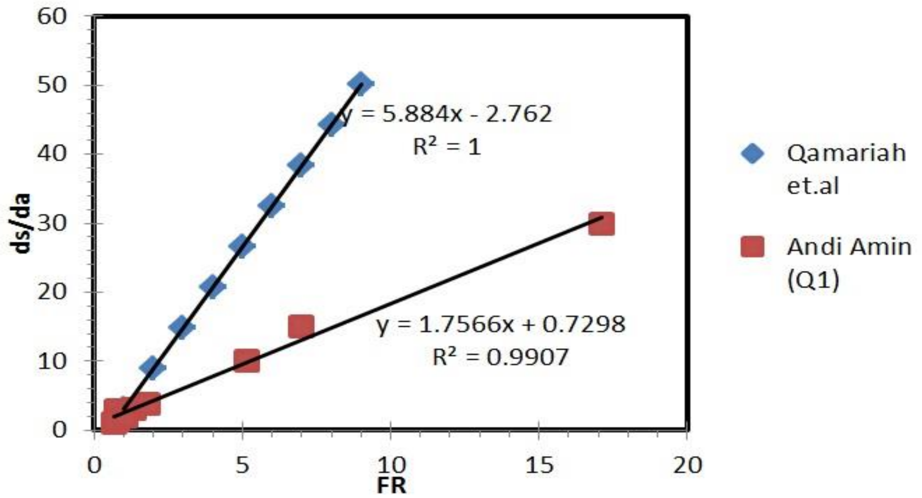

Figure 6 Relationship between froud number vs scour depth

Increasing Froude number causes increasing scour depth. Conversely, if the Froude number is small, the scour depth will be small. Meanwhile, Froude number has an inverse relationship with the gate opening. This means that the Froude number will be even greater if the door opening is smaller.

4.2. Effect of Gate Openings on Flow Patterns

After observing the calculation results of the parameters affecting the flow pattern, it is shown that the process of the flow pattern occurs due to flow obstacles by the sluice gates. The use of sluice gate can cause changes in flow characteristics upstream and downstream of the channel, such as speed and turbulence. Here causes changes in flow patterns. At the sluice gate, underflow can be in the form of supercritical flow that has high energy, giving rise to a flow pattern as shown in Figure 5.

4.3. The 3-Dimensions Contour and Scour Pattern

The 3-dimensional contours and scour patterns at discharges of 1.406 cm3/sec caused by gate openings of 0.5 cm, 1.0 cm, and 1.5 cm is displayed in Fig.6. At the gate opening of 0.5 cm shows that the scour pattern deeper than the gate openings of 1.0 cm and 1.5 cm. This is caused by water level differences, including the hydraulic radius affecting the difference in speed and energy flow.

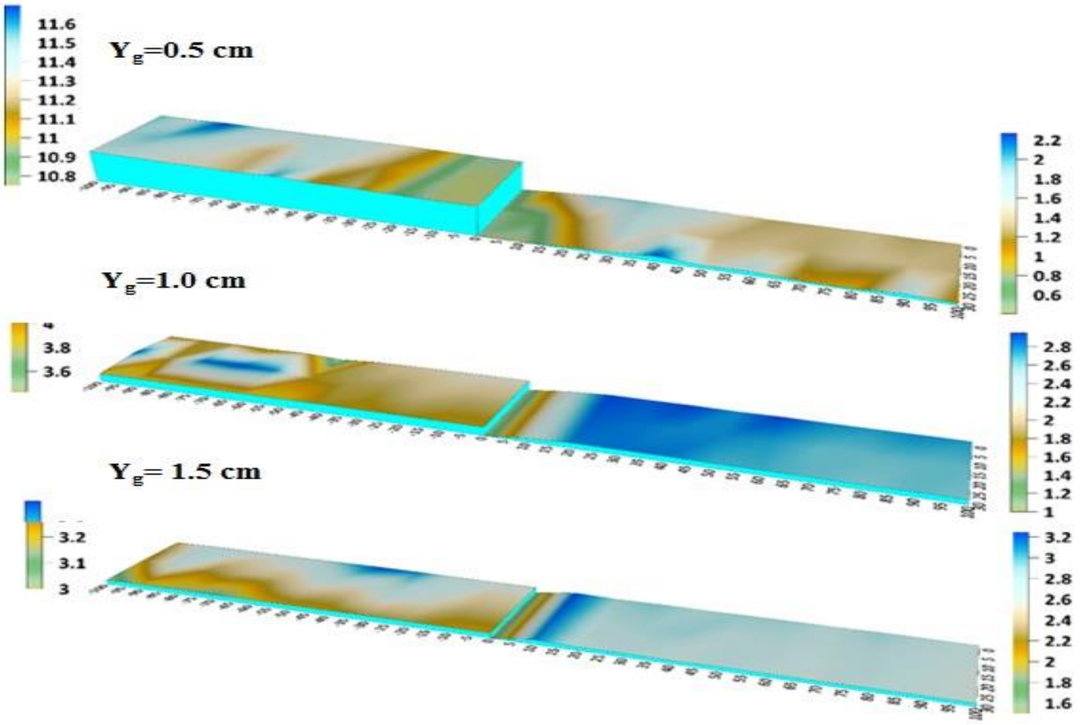

Figure 7 Flow Patterns at Q = 1,406 cm3/s with gate openings of 0.5 cm; 1.0 cm and 1.5 cm

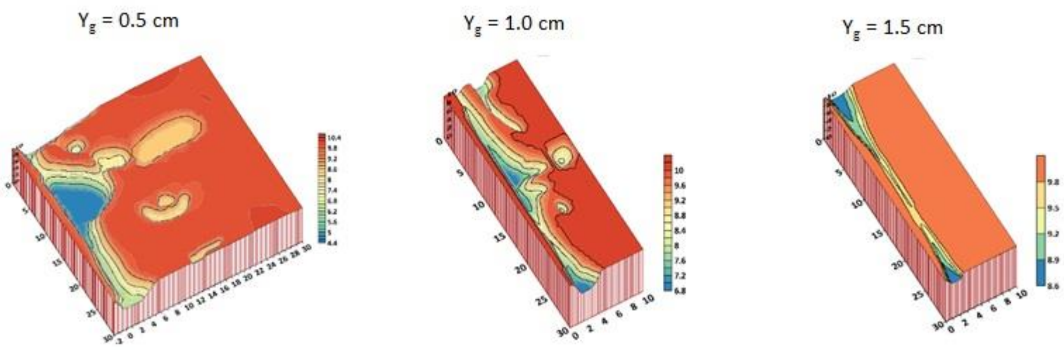

Figure 8 3 Dimensions Contour and Scour Pattern at Q = 1,406 cm3/s with gate openings of 0.5 cm; 1.0 cm and 1.5 cm

5. CONCLUSION

Based on data obtained from laboratory studies, it is found that gate openings affect the flow patterns. The greater the gate opening causes the smaller the energy in the channel. Types of submerge flow that occur in observations in the laboratory similar to the results of analytical calculations. Analytically, the flow that occurs is sub-critical flow on upstream and supercritical flow on downstream. This is obtained with considering that the results of energy flows close to theoretical calculations.

Discharge is one of the variables affecting the scour depth. Based on the observation that the greater the discharge causes the greater the scour depth, At discharge of 1,303 cm3/s, 1,406 cm3/s, and 2,069 cm3/s was obtained the scour depth of 2.9 cm, 3.1 cm and 3.85 cm respectively. In addition, another factor that influences the scour depth is the Froude number. The greater Froude number causes the greater scour depth. Conversely, if the Froude number is small, the scour depth will be small. Meanwhile, Froude number has an inverse relationship with the gate opening. This means that the number Froude will be even greater if the door opening is smaller.

REFERENCES

[1] Bambang Triatmojo, Dr. Ir.CES.DEA., Hidraulika, (1996) Beta Offset, Yogyakarta.

[2] Breuser, H.N.C & Raudkivi, A.J. (1991) Scouring. Netherland: International Association for Hydraulic Research.

[3] Breuser, H.N.C., (1974-1975). Lecture Notes on Sediment Transport 1.International Course in Hydraulic Engineering, Delft.

[4] Chatterjee, M., Chatterjee, S.S. and Ghosh, S'N., (1994) Local Scour Due To Submerged Horizontal let. *Journal of Hydraulic Engineering*, 120 (8), pp 973-991,. Hoffmans, G.C.M. dan Verheii, H.

[5] Chow, V. T. 120997.128. (1959). Hidrolika Saluran Terbuka. Jakarta : Erlangga.

[6] Ettema, R., Yoon, B., Nakato, T. and Muste, M. (2004) A Review of Scour Conditions and Scour-Estimation Difficulties for Bridge Abutments. *KSCE Journal of Civil Engineering.* 8(6), pp. 643-650.

[7] Halim, M.F. (2014) Pengaruh debit terhadap pola gerusan di sekitar Abutmen jembatan (uji laboratorium dengan skala Model jembatan). *Jurnal Ilmiah Engineering*, Ã(1), pp. 32-40.

[8] Hughes, W. C., Urbonas, B. and Stevens, M. A. (1983) Guidelines for the design of riprap channel linings. *D. B. Simons Symposium on Erosion and Sedimentation*, R. M. Li and P. S. Lagasse, Fort Collins, Colo., 4.106-4.127.

[9] Melville, B.W. and Raudkivi, A.J. (2010) Flow characteristics in local Scour at bridge piers. *Journal of Hydrolic Research*, pp. 373-380.

[10] Nurhayati and Aprilia. Uji Model Fisik Gerusan Lokal Di Hilir Bukaan Pintu Pada Dasar Saluran Pasir Bertanah Liat (Loamy Sand). Malang: Universitas Brawijaya.

[11] Puspitarini, S., Yulistyanto, B., Kinoroto, B.A. (2002) Model Pengendalian Gerusan Lokal Akibat Aliran Superkritik di Hilir Pintu Air. *Jurnal Tekno Sains*, XV (3): 419: 431.Yogyakarta: Universitas Gadjah Mada.

[12] Qamariyah, H. Analisis Kedalaman Gerusan di Hilir Pintu Sorong pada Dasar Saluran Tanah Liat Berpasir (Sandy Loam) dengan Uji Model Fisik Hidraulik. Malang: Universitas Brawijaya.