International Journal of Multidisciplinary Research and Publications

ISSN (Online): 2581-6187

Local Scour Analysis of Kuala Samboja Bridge Piers Kutai Kartanegara East Kalimantan

Daru Purbaningtyas[1], M. Ridwan[2], Ahmad Arsy P[3], SSN. Banjarsanti[4], Tommy Ekamitra[5]
[1,2,3,4,5]Civil Engineering Department, Politeknik Negeri Samarinda, Samarinda, East Kalimantan, Indonesia-75131
Email address: daru_purbaningtyas@polnes.ac.id[1]; mridwan2000@yahoo.com[2]; ahmadarsip@gmail.com[3];
ssnbanjarsanti@polnes.ac.id[4]; tommysutarto@gmail[5]

Abstract— *Kuala Samboja Bridge which has been built in 1992 and is located on Jalan Poros Balikpapan-Handil II, Samboja District, Kutai Kartanegara Regency. Cause of the flow of ship traffic under this bridge, the riverbed around the piers has the potential scouring. This study was conducted to determine the depth of local scour that occurs on the piers of the Kuala Samboja Bridge using several empirical equations. This study begins with collecting data on daily rainfall, maps of the Samboja River watershed, and measurement of river cross-section, flow rate and sampling of riverbed material. The dominant discharge was designed using the Nakayasu Unit Hydrograph. Testing the soil samples in the laboratory to obtain* d_{50}*, an then predicting the local scour depth using the empirical method. The local scour depth was calculated using HEC-18, Froehlich, Laursen & Toch, and Salim & Jone. The shape of the piers analyzed is a group of cylindrical piers with a distance between piers of 1.2 m with a diameter of 0.5 m. The dominant discharge used is 401.203* m^3*/second. The results of the calculation of the scour depth are as follows: the Froehlich method is 0.739 m, the HEC-18 method is 0.895 m, the Laursen & Toch method is 0.933 m, and the Salim & Jone methods are 0.675 m for the envelope curve, 0.54 m for the best fit curve.*

Keywords— *Bridge Pier; Empirical Method; Kuala Samboja; Local Scour.*

I. INTRODUCTION

The Kuala Samboja Bridge is located on Jalan Poros Balikpapan-Handil District, Kutai Kartanegara Regency. Built in 1992, this bridge connected the Poros Balikpapan and Kuala Samboja. Under this bridge is the traffic lane for the motor boats of the fishermen who live in the vicinity. This flow of ship traffic beneath it, the river bed around the piers has the potential to experience a scourge. If the local scour around the piers occurs over a long time, the depth of scour around the piers will be deeper and can result in damage or collapse of the bridge construction.

Local scour around the bridge piers is caused by changes in flow patterns. This change occurs due to the part of the flow that is held by the piers. Scour is a natural phenomenon that occurs due to erosion of the flow of water at the bottom and cliffs of alluvial channels. It is also a process of decreasing or deepening the river bed material. Local scour around the piers is caused of a vortex system. Caused by the flow is blocked by the piers. The flow approaches the pier and the stagnation pressure will decrease and cause downflow, the flow from high speed to low speed. Downflow strength will reach its maximum when it is right at the bottom of the channel (Rahmadani, 2014). In addition, scour is also defined as the flow with the displacement of material through the action of fluid motion. Local scour occurs at a flow velocity where the transport will increase with increasing sediment shear stress when changes in flow conditions cause an increase in bed shear stress (Laursen, 1952 in Daties, 2012).

II. LITERATURE REVIEW

A. The Factor that Affect the Depth of Scour

There are several factors that affect the depth of scour, these factors include flow rate, water depth, and grain size.

Chabert and Engeldinger (1956) in Hanwar (1999) concluded that maximum scour depth is obtained at a speed close to the critical flow velocity while scouring begins approximately at half the critical flow speed.

The local scour is influenced by the depth of the riverbed from the water (water flow height), the relative velocity U*/U*c and relative depth (y0/b) are important factors for estimating the local scour depth.

The grain size of the sediment transport is one of the factors that affect the depth of scour in clear water scour conditions. The dimensionless scour depth (ys/b) is a function of the grain size characteristic of the base material (σg) a function of the standard deviation of the grain size geometry.

B. Dominant Discharge

According to Knighton (1988) in the Flood Control Training River Hydrology and Hydraulics Module (2017), the dominant discharge is necessary because based on the investigation of many experts, this discharge makes a dominant contribution or plays a role in the formation of the hydraulic geometry of the cross-section of a river.

Blench (1965) in the Flood Control Training River Hydrology and Hydraulics Module (2017) defined a dominant discharge as a discharge with a probability of occurring equally to greater than 50% of the time (can be called a discharge with a return period of 2 years).

C. Bridge Piers

Bridge piers have various shapes such as lenticular, round or elliptical which can influence the flow pattern. The flow in rivers is usually accompanied by processes of erosion and sediment deposition. The scouring process can be caused by the morphological conditions of the river and the existence of river structures that block the flow. Making bridge piers will cause changes in river flow patterns and the formation of three-dimensional flows around these piers. Changes in the

Daru Purbaningtyas, M. Ridwan, Ahmad Arsy P, SSN. Banjarsanti, and Tommy Ekamitra, “Local Scour Analysis of Kuala Samboja Bridge Piers Kutai Kartanegara, East Kalimantan,” *International Journal of Multidisciplinary Research and Publications (IJMRAP)*, Volume 5, Issue 7, pp. 42-46, 2022.

flow pattern will cause local scour around pier construction. (Wibowo, 2017)

D. Rating Curve

The definition of a discharge curve is a curve that describes the relationship between the water level and the discharge of a river/ open channel in a cross-section. (Dirjen Sumber Daya Air, Departemen Pekerjaan Umum, 2009)

The measurement results from a hydrometric station are two basic quantities: water level and discharge. The discharge is obtained as a result of measuring the velocity through the cross-section of the river. Measuring the flow depth can be done manually by placing a manual staff gauge which can be read easily and accurately at any time. It can also use an automatic water level recorder, which will record all changes in the water level continuously. (Sri Harto, 1993)

E. Empirical Formulas for Predicting Depth of Local Scour

Several formulas are available for predicting the local scour depth around the piers. These are four formulas can be used: Froehlich; HEC-18; Laursen & Toch; and Salim & Jone.

1. The Froehlich

The equation developed by Froehlich (1988) in Ahmadi (2001) said that the scour depth is a function of Froude number, pier type, grain size, and the angle of attack flow. This formula is shown in (1):

$$d_S = 0.32bK\left(\frac{b'}{b}\right)^{0.62}\left(\frac{y}{b}\right)^{0.46}Fr^{0.2}\left(\frac{b}{D_{50}}\right)^{0.08} + b \qquad (1)$$

Where

d_s = scour depth (m)
b = pier width (m)
fr = Froude number
y = water depth (m)
l = pier length (m)
b’ = b cos θ + l sin θ
θ = angle of attack flow (º)
D_{50}= grain size of 50% sieve pass (mm)
K = Coefficient of pier type
(K = 1,0 for round pier and round nose;
K = 1,3 untuk square nose pier)

2. The HEC-18

The HEC-18 Formula is commonly used in America. This equation is shown in (2)

$$y_S = 2yK_1K_2K_3K_4\left(\frac{b}{y}\right)^{0.65}Fr^{0.43} \qquad (2)$$

where ys is the scour depth, y is the flow depth upstream of the pier, K_1 is the correction factor for pier nose shape, K_2 is the correction factor for angle of attack flow, K_3 is the correction factor for riverbed shape, K_4 is the correction factor for riverbed grain size ($K_4 = 1$ for $d_{50} < 2$ mm or $d_{95} < 20$ mm), b is the pier width, and Fr is the Froude number at upstream of the pier.

3. The Laursen & Toch

Laursen & Toch (1956) in Ahmadi (2001) developed an equation for local scour in the bridge piers as a function of the width of the piers, and the depth of flow. This formula is as follows (3).

$$d_S = 1.35b^{0.7}y^{0.2} \qquad (3)$$

Where ds is the scour depth, y is the flow depth at the upstream of the pier, and b is the pier width.

4. The Salim & Jone

This is a modification of the HEC-18 formula to calculate the local scour depth on a pier group using equation (2) (Hosseini, 2015). It is recommended to substitute the diameter of the pier group into a single pier. The dimensions of all the pier are combined and multiply the result by one of the correction factors below, (4) and (5).

$$K_S = 0.57\left[1 - e^{\left(1-\frac{S}{D}\right)} + e^{0.5\left(1-\frac{S}{D}\right)}\right] \qquad (4)$$

$$K_S = 0.47\left[1 - e^{\left(1-\frac{S}{D}\right)} + e^{0.5\left(1-\frac{S}{D}\right)}\right] \qquad (5)$$

Where Ks is the correction factor of pier group, S is the distance between pier or spacing (m), D is the diameter of pier group (m).

III. RESEARCH METHODOLOGY

This research begins with observations at the bridge location, collecting data on daily rainfall, topographic maps of watersheds, and land use. Measuring the cross section of the river, depth, and velocity of the flow and taking riverbed sediment samples.

A. Research Sites

This research was conducted in Kuala Samboja Village, Samboja District, Kutai Kartanegara Regency, East Kalimantan. This location is shown in Fig. 1 below.

Fig. 1. Samboja Kutai Kartanegara (Kompasiana)

And the object of this research is the river flow under the Kuala Samboja Bridge, especially on the bridge pier as Fig. 2.

Fig. 2. The Kuala Samboja Bridge

B. *Maximum Daily Rainfall*

Daily rainfall of the Samboja river area during 2010-2020 which was obtained from Balai Wilayah Sungai Kalimantan III as shown in Table 1.

TABLE I. Maximum Daily Rainfal of Samboja

Year	Max. Daily Rainfall (mm)	Year	Max. Daily Rainfall (mm)
2010	85.5	2016	132.3
2011	67.5	2017	230.2
2012	180	2018	181
2013	146.7	2019	237
2014	184	2020	180
2015	184		

C. *The Samboja Watershed*

The Kuala Samboja Bridge is located on a tributary of Samboja River, precisely on the Husu River section. The Samboja watershed is shown in Fig. 3.

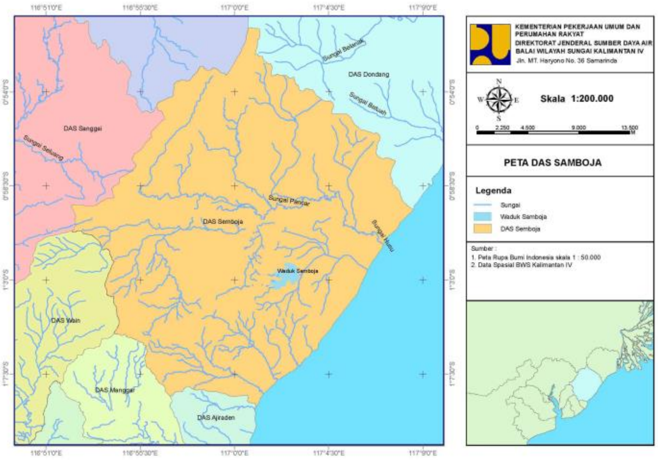

Fig. 3. The Samboja Watershed
(Balai Wilayah Sungai III Kalimantan)

The catchment area of the Husu River was obtained from the map of the Samboja watershed which was imported to Google Earth Pro. With conversion of longitude and latitude coordinates, the result is shown in Fig. 4 below.

Fig. 4. The Husu River and the Samboja River Watershed

Based on the watershed map, it is obtained that the Husu Watershed is 161.780.197 m^2 and the river length is 24.674 m.

D. *The River Cross Section*

The cross-section of the river at the bridge location is shown in the following Fig. 5.

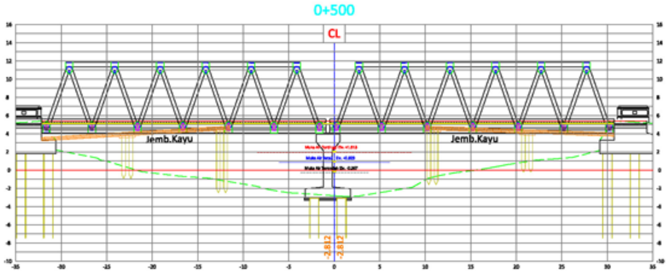

Fig. 5. The River Cross-Section at the Bridge Location

From the result of measurement in the field, the cross-sectional width of the river is 70 m and the existing depth on the piers is 2.812 m.

IV. RESULT AND DISCUSSION

A. *Discharge Dominant of Husu River*

Dominant discharge analysis is approached by flood discharge with a 2-year return period using the Nakayasu Unit Hydrograph. Hydrological analysis of maximum daily rainfall using the Log Pearson III Method produces a 2-year design rain of 153.49 mm.

The design rain, watershed, river length, and land use (C= 0.315) produce a flood discharge based on Nakayasu Unit Hydrograph as shown in Fig. 5 below. And the maximum discharge for 2-year return period is 401.203 m^3/s.

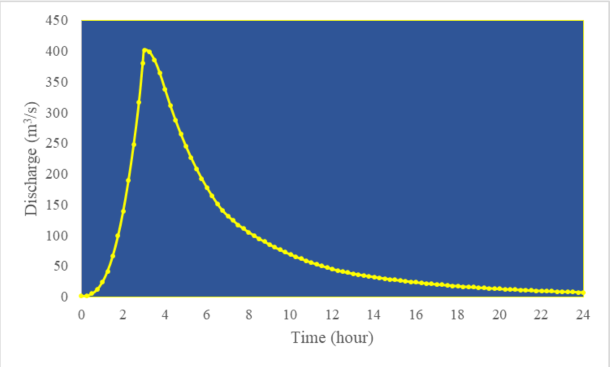

Fig. 6. Flood Hydrograph of the 2-Year Return Period

B. *The Rating Curve of Husu River*

The preparation of the rating curve requires data on velocity, cross-section, and depth of flow. Measurement of flow velocity using a float gauge based on SNI 8066:2015. Velocity measurements were carried out three times for a depth of flow. The Recording of float velocity and water depth (for h = 1.1 m) can be seen in Table II.

An example of velocity for a yellow float is the following:

$$\alpha = \frac{0.2}{0.7} = 0.286$$

$$k_p = 1\text{-}0.116[(1–0.286)^{0.5}–0.1)] = 0.802$$

$$V_p = 0.802 \text{ x } \frac{177}{3.51\text{x}60} = 0.674 \text{ m/s}$$

TABLE II. Water Depth and Velocity of Flow

Upstream cross section			Downstream cross section			
Distance from the river bank (m)	**Water depth (m)**		**Distance from the river bank (m)**		**Water depth (m)**	
13.2	0.7		21.5		0.7	
19.9	1.7		14.8		4	
24.3	2.1		10.4		3.2	
Float gauge	**Distance**			**Time (minute)**	**Coefficient**	**Velocity (m/s)**
	L	α	d			
Yellow	177	0.286	0.2	3.51	0.802	0.674
Red	177	0.118	0.2	3.32	0.791	0.703
Green	177	0.095	0.2	3.46	0.790	0.673

Where d is the floating depth, and L is the distance upstream and downstream. The average velocity of the cross-section at a depth of 1.1 m is 0.683 m. And corrected velocity is the result of multiplying the correction factor (0.5 – 0.98) with the measured velocity. So that the corrected velocity is obtained at 0.55 m/s.

The cross-sectional area of the flow upstream of the bridge is 88.876 m^2, under the bridge is 92.384 m^2, and downstream is 103.154 m^2. The discharge was calculated based on average velocity and cross-sectional area. Then discharge at a depth of 1.1 m is 63.615 m^3/s.

The same procedure has been done for other water depths. The relationship between discharge and depth of flow is shown in Fig. 7.

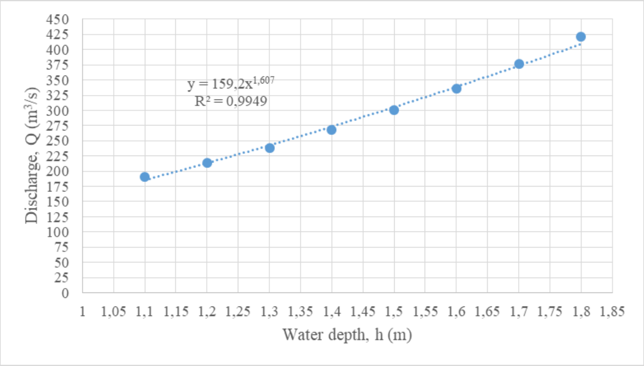

Fig. 7. The Relationship between Discharge and Depth of Flow

The regression equation that states the relationship between water depth and discharge is Equation (6).

$$Q = 159.2h^{1.607} \quad (6)$$

This equation is used to predict the depth of flow of the dominant discharge. For dominant discharge, Q_2 = 401.203 m^3/s, the depth of flow is 1.78 m and the velocity is 1.15 m/s.

C. Soil Laboratory Test

Laboratory testing of the riverbed sediment samples was carried out to obtain specific gravity values and grain size distribution. Specific gravity testing follows procedures according to SNI 1964:2008. Grain size analysis follows procedures according to SNI 3423:2008, and hydrometer analysis according to SNI 3423:2008.

The specific gravity (Gs) of soil samples taken was 2.54. The result of the sieve analysis showed that the largest retained percentage was in sieve number 100. The hydrometer test was carried out because the weight of the soil passing through the number 200 sieve was more than 50 gr. And the combined grain size distribution chart can be seen in Fig. 8 below.

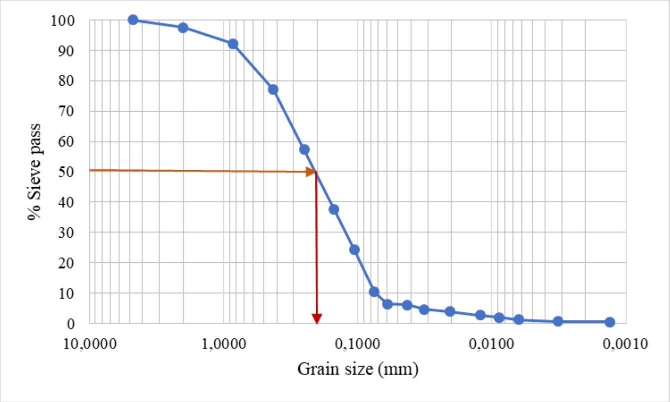

Fig. 8. Grain Size Distribution

The result of the graph shows that the sample gradation includes poorly graded gradation. It can be concluded that the grain size of the samples taken is almost the same. And from Fig. 8. it can be seen that d_{50} is 0.2 mm.

D. Prediction Depth of Local Scour

Based on the discharge values, the velocity and depth of flow at the dominant discharge, and the grain size of d_{50}, the prediction of local scour depth with several empirical formulas is as follows.

The Froehlich:

$$d_s = 0.32 * 0.5 * 1.0 * \left(\frac{0.5}{0.5}\right)^{0.62} * 0.275^{0.2} * \left(\frac{0.5}{0.2}\right)^{0.08} + 5$$

$$d_s = 0.739\,\text{m}$$

Where the width of pier b is 0.5 m; the flow angle is 0; the depth of flow is 1.78 m; the velocity is 1.15 m/s; the Froude number (fr) is 0.275 and K is 1 (round nose).

The HEC-18:

$$y_s = 2.0 * 1.78 * 1.0 * 1{,}0 * 1.1 * 1.0 * \left(\frac{0.5}{1.78}\right)^{0.65} * 0.275^{0.43}$$

$$y_s = 0.895\,\text{m}$$

The Laursen & Toch:

$$d_s = 1.35 * 0.5^{0.7} * 1.78^{0.2}$$

$$d_s = 0.933\,\text{m}$$

The Salim & Jone:

$$y_s = 2.0 * 1.78 * 1.0 * 1.0 * 1.1.1 * 1.0 * \left(\frac{6.0}{1.78}\right)^{0.65} * 0.275^{0.43} = 4.5\,\text{m}$$

$$K_s = 0.57\left[1 - e^{\left(1 - \frac{1.2}{0.5}\right)} + e^{0.5\left(1 - \frac{1.2}{0.5}\right)}\right] = 0.15\,(\text{envelop curve})$$

$$K_s = 0.47\left[1 - e^{\left(1-\frac{1.2}{0.5}\right)} + e^{0.5\left(1-\frac{1.2}{0.5}\right)}\right] = 0.12\ \text{(best fit curve)}$$

$$y_s = 4.5 * 0.15 = 0.675\ \text{m (envelop curve)}$$

$$y_s = 4.5 * 0.12 = 0.54\ \text{m (best fit curve)}$$

The calculated local scour depth varies. Using the Froehlich formula, the local depth scour is 0.739 m, and the parameters that influence are the width of piers, the angle of flow, the type of pier, and the size of d_{50}. Based on the HEC-18 formula, it is equal to 0.895 m, with parameters that influence the shape of the tip of the pier, the angle of the stream, the type of riverbed shape, and the grain size of the riverbed. The Laursen & Toch formula produces a scour depth of 0.933 m where the only parameter that affects it are the depth of flow and the width of the pier. Salim & Jone formula gives results of 0.675 m for the envelope curve and 0.54 m for the best fit curve with the review parameters used being the same as HEC-18 plus the distance between the piers as an additional parameter.

V. CONCLUSION

The smallest value of the calculation of the local scour depth of 0,54 m already indicated that the bridge's piers need protection. This is necessary to prevent deeper scouring that can endanger the bridge construction.

REFERENCES

[1] Achmadi, T., "Model Hidraulik Gerusan pada Pilar Jembatan," Thesis, Diponegoro University, Semarang. Indonesia, 2001.
[2] Daties, Y., "Kajian Perubahan Pola Gerusan Pada Tikungan Sungai Akibat Penambahan Debit," Civil Engineering Diponegoro University, Semarang. Indonesia, 2012.
[3] *Gerusan yang Terjadi di Sekitar Pilar Sungai*, Penerbit Pradnya Paramita, Jakarta. Indonesia, 2014.
[4] Hanwar, S., "Gerusan Lokal di Sekitar Abutment Jembatan," Thesis, Civil Engineering, Pascasarjana Faculty, Gadjah Mada University, Yogyakarta. Indonesia, 1999.
[5] Hosseini, R., "Scour Depth Estimation Methods Around Pile Groups," *KSCE Journal of Civil Engineering*, vol. 9, 2144–2156, 2015.
[6] *Modul 5 Hidrologi dan Hidrolika Sungai*, Kementerian Pekerjaan Umum dan Perumahan Rakyat Badan Pengembangan Sumber Daya Manusia Pusat Pendidikan dan Pelatihan Sumber Daya Air dan Konstruksi, Indonesia, 2017.
[7] NN, "Hydrology Manual Report," Balai Wilayah Sungai III Kalimantan., Samarinda. Indonesia, 2020
[8] SNI 1964:2008, "Tata Cara Pengujian Berat Jenis Tanah," Badan Standardisasi Nasional. Jakarta., Indonesia, 2008.
[9] SNI 3423:2008, "Tata Cara Pengujian Analisis Ukuran Butir Tanah," Badan Standardisasi Nasional. Jakarta., Indonesia, 2008.
[10] SNI 8066:2015, "Tata Cara Pengukuran Debit Aliran Sungai dan Saluran Terbuka Menggunakan Alat Ukur Arus dan Pelampung," Badan Standardisasi Nasional. Jakarta., Indonesia, 2015.
[11] Wisata (Kaya) Alam Samboja, Walrina Munangsir (2018, October 29), *Maps.Google.com* , 2018. Available: https://www.kompasiana.com/image/rinmuna0416/5bd649e2c112fe64d4266055/wisata-kaya-alam-samboja?page=2