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The Simplified of Suspended Sediment Measurement Method for Predicting Suspended Sediment Load as a Basic of Reservoir Capacity Design as Renewable Energy Resource

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Abstract-The amount of suspended sediment discharge is often required in hydraulic structures design, such as reservoirs design, irrigation-canals design, etc.; but this data is often unavailable or theavailability of such datais very limited. The most appropriate and precise method for determining of suspended sediment discharge in channels (or in rivers)is by sampling of suspended sediment as well as the velocity data directly from the channels.Due to many constraints of the field measurements and of the expensive cost to get thesuspended sediment discharge data, measurements of suspended sediment, and of velocity are often taken only at certain positions, which areoften not in accordance with the standard sampling methods. These conditions resulted in inaccuracies in predicting suspended sediment discharge;thus,it is necessary to find a simpleand an accurate method for determining suspended sediment discharge. The purpose of this study is to findhow the suspended sediment concentration and how the velocity taken at certain positions in trapezoidal channels correlate with the suspended sediment discharge. The study also aimed to determine the possibility of errors, including finding correction factors to the improper suspended sediment sampling methods, that are still often carried out in the field. Location studies are focused on nine (9) segments of trapezoidal channel in Mataram Irrigation Channel, in Yogyakarta, Indonesia. The velocity and suspended sediment concentration profiles were measured by using Propeller Current meter and Opcon probes, respectively. The results of the study show that the suspended sediment discharge of trapezoidal channel can be obtained from the measurement of velocity and suspended sediment concentration profiles at z/B=0.25, measured from the channel side, z, with B is the channel width.

Keywordsvelocity, suspended-sediment concentration, trapezoid channel, suspended-sediment discharge.

1. Introduction

Studies of erosion, transportation and deposition of sediments are essential in environmental study problems, such as study problem of sedimentation in reservoirs, silty problems in an estuary, etc. The amount of suspended sediment discharge is often needed in hydraulic structures design, such as reservoir capacity design, intake structure of irrigation channels design, etc. However, the main problems associated with the hydraulic structure design is often unavailability or the availability of sediment discharge data is very limited.Sampling of suspended sediment and measuring velocity for determining suspended sediment discharge should be taken in the whole flow-cross section, from the left to the right side of the channel, and from the bottom up to the free water surface(Gray and Landers [1]).However, due to many constraints of the field measurements and of the expensive cost to get the suspended sediment discharge data, measurements of suspended sediment, and of velocity are often taken only at certain positions. These conditions resulted in inaccuracies in predicting suspended sediment discharge; thus, it is necessary to find a simple and an accurate method for determining suspended sediment discharge.

Particle size distribution and suspended sediment concentration not only vary in vertical depth, but also vary considerably across channel cross section. Therefore, measuring of suspended sediment concentration should take into account these variations. This becomes very essential when suspended sediment discharge being used for the purpose of reservoir capacity design, in which, the useful life of reservoir is very closely related with the accuracy of predicting suspended sediment discharge. Thedeposition behavior of reservoir sediment relates closely to the size of the particles and flow patterns ofriver into the reservoir, as shownexperimentally by Yu et al. [2].

So far, the most reliable method to determine the suspended sediment discharge in channels is through the direct measurement of the flow rate together with measurement of suspended sediment concentration for a certain period. Multiplication between the flow rate and suspended sediment concentration will give the suspended sediment discharge. The measurement of velocities and of suspended sediment concentration in channels should be taken in the entire flow-cross section, from the edge to the other edge of the cross section, *i.e*., from the left to the right side of the channel, and from the bottom up to the free water surface of the flow. Sampling of suspended sediment in natural rivers or in channels are often conducted not in accordance with the appropriate sampling standards due to many constraints generally found in the field.Due to constraints found in the field, sampling of suspended sediments are often taken only at certain positions in the channels, that may easy to be reached and/or to be measured, and often do not follow the standard sampling method; for example taking samples of suspended sediment (and measure the flow rate) only at the edge of the channels, and not on the entire flow cross section of the channel; suspended sediment sampling is also often carried out only near the free water surface and not the entire flow depth of the flow. This will lead to inaccuracies in determining the suspended sediment discharge in channels

Sampling of suspended sediment only at the edge and near the free water surface tend to provide information ofsuspended sediment discharge which is "underestimate" compared with the actual value; and *vice versa*, if the suspended sediment sampling is taken only at the middle of the channel. However, since consideration of the ease of implementation in the field, and the limitations that exist (time, funds, etc.), the improper sampling methods as stated above are still often carried out in the field. In connection with the issues, thisstudyalso aimed to determine the possibility of errors, including finding correction factors to the improper suspended sediment sampling methods, that are still often carried out in the field.

The studyisconductedbased on the measurement data of suspended sediment concentration and velocity profilesobtained at Mataram Irrigation Channel, Yogyakarta, Indonesia,atnine (9) selected segments of trapezoidal channel (Kironoto and Yulistiyanto [3]). These measurement locations along Mataram Irrigation Channel are given in the following map (Fig.1).

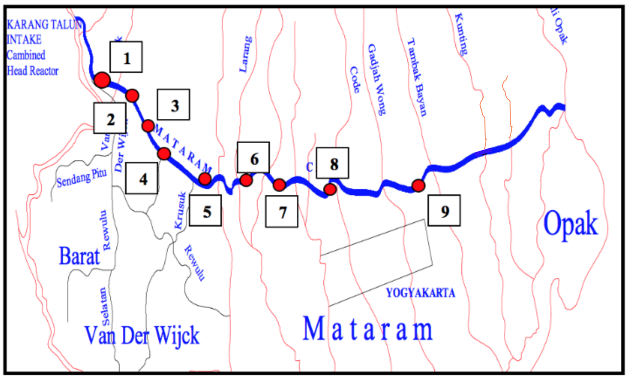

Fig. 1. Measurement locations along Mataram Irrigation Channel, Yogyakarta, Indonesia

2. Literature Reviews

Coleman [4, 5]reported that the existence of suspended sediment can affect the shape of velocity distribution, although it still follows the logarithmic velocity distribution in the inner region. Cole's parameter which describes the deviation of the measured velocity data against known logarithmic velocity equation affected by the presence of sediment suspension.

Bartram and Balance [6] conducted a study of freshwater quality, and reported that a complete flow measurement across the cross section of the river should be carried out for determining the suspended sediment discharge. The cross-section of the river is divided into five (or more for large or complex rivers) increments (*i.e.* vertical sections) having equal discharge. The number of increments is based on experience. Depth-integrated suspended sediment sampling is carried out at one vertical within each of the equal-discharge-increments, usually at a location most closely representing the centroid of flow for the increment sections.

Shah-Fairbank et al. [7], purposed a method for calculating total sediment load calculations – named as the series expansion of the modified Einstein procedure (SEMEP) – on the basis of depth-integrated sediment concentration measurements for channels with significant sediment transport in suspension. SEMEP calculations require field measurements of flow discharge, depth-integrated suspended sediment (SS) concentration, and suspended particle sizes. A large sediment transport data set collected from 14 rivers in America was used for testing SEMEP.

Lv et al. [8], purposed a new method to measure the suspended sediment concentration (SSC) by using ADV (Acoustic Doppler Velocimeter). They carried out a series of experiments and analized the working principle of the ADV, to clarify the relationship between the SSC and the signal amplitude. Experimental results show that when SSC is lower than 0.014 (ratio by volume), ADV can work effectively.

Kironoto et al.[9] and Kironoto and Ikhsan [10] conducted studies to determine the correlation between the location of suspended sediment concentration sampling (and flow rate) againstthe discharge of suspended sediment, measured, respectively,inthe laboratory and in the field of rectangle channels. The results of the data analysed in their study showedthat the discharge of suspended sediment that isdetermined on the basis of data taken at the edge of the channel will give too small valuestoactual suspended sediment discharge, whereas,when the sampling of suspended sediment concentration is taken at the middle of the channel, it will givetoo large values. Accordingly, it has been proposed correction factorsfor predicting the suspended dischargewhen the sampling of suspended sediment areconductedonly at certain points in the transverse direction;it gives a correctionfactor value of one (1), whichoccurs at the position of z = 0.195 $B \approx$ 0.2 B, where$B$ is the channel width.

Kironoto [11] in his research of laboratory and field data of rectangle channels showedthat the averaged values of suspended sediment concentration in a cross section can be obtained by sampling of suspended sediment concentration at certain point of z = 0.20 B.

3. Theoretical Consideration

To calculate the friction velocity, u_* and a constant value of numerical integration of logarithmic velocity distribution, Br, the Clauser's methods can be used. The data used in the calculations are obtained from the measurement of velocity profiles in the inner region ($y/\delta \leq$ 0.2; where δ is the distance from the channel bed to the maximum point velocity or to the free water surface), together with the equation of logarithmic velocity distribution (log-law) as given in Kironoto and Graf[12] as follows:

$$\frac{u_y}{u_*} = \frac{1}{\kappa}\ln\left(\frac{y}{k_s}\right) + Br \qquad (1)$$

with y is the distance from a measurement point to the channel bed, k_s is the Nikuradse roughness values, Br is an integration constant, and κ is a Von Karman's constant.

The Nikuradse roughness value, k_s, can be evaluatedfrom the following equation [13] :

$$\frac{C_c}{\sqrt{g}} = \sqrt{\frac{8}{f}} = 5.6\log\left(\frac{R}{k_s}\right) + 6.25 \qquad (2)$$

where C_c is the Chezy coefficient, $f$is the friction coefficient, and R is hydraulic radius. Suspended of sediment concentration distribution, C, can be predicted by using Rouse'equation (1937, given in [14]):

$$\frac{C}{C_a} = \left(\frac{D-y}{y}\frac{a}{D-a}\right)^z \qquad (3)$$

or using Tanaka and Sugimoto equation (1958; given in [14]):

$$\frac{C}{C_a} = \left[\left(\frac{\sqrt{D}+\sqrt{D-y}}{\sqrt{D}-\sqrt{D-y}}\right)\left(\frac{\sqrt{D}-\sqrt{D-a}}{\sqrt{D}+\sqrt{D-a}}\right)\right]^{\frac{w_s}{u_*\kappa}} \qquad (4)$$

where$D$ is the flow depth, C is suspended sediment concentration at a distance y from the channel bed, $C_a$is the reference of suspended sediment concentration at a certaindistance, a, from the bed, w_s, is the fall velocity of suspended sediment, and κ is a Von Karman's constant. In Eq. (3), $z = w_s/(u_* \kappa)$, is defined as the Rouse's parameter.

The depth-averaged velocity,$\overline{U}_y$, can be calculated by using the following equation:

$$\overline{U}_y = \frac{1}{D}\int_0^D u_y dy \qquad (5)$$

The mean velocity or the cross-section averaged velocity, $\overline{U}$, can be obtained by multiplying the depth-averaged velocity, $\overline{U}_y$, with increment vertical section from the centre to the both sides of the channel wall, A_{yi}, for i = 1, 2, …, n, according to the following equation:

$$\overline{U} = \frac{\overline{U}_{y1}A_{y1} + 2(\overline{U}_{y2}A_{y2} + ... + \overline{U}_{yn}A_{yn})}{(A_{y1} + A_{y2} + ... + A_{yn})} \qquad (6)$$

and the flow discharge, Q, can be calculated by:

$$Q = \overline{U}\,A \qquad (7)$$

The depth-averaged of suspended sediment concentration, $\bar{C}_y$, can be calculated using the following equation:

$$\overline{C}_y = \frac{1}{D-a}\int_a^D C\,dy \qquad (8)$$

The suspended sediment concentration for each equal-increment sections are measured and the cross-section suspended sediment concentration, than, can be obtained by multiplying the depth-averaged suspended concentration, $\bar{C}_y$, with increment vertical section from the centre to the both sides of the channel wall, A_{yi}, for i = 1, 2, …, n, according to the following equation.

$$\overline{C} = \frac{\overline{C}_{y1}A_{y1} + 2(\overline{C}_{y2}A_{y2} + ... + \overline{C}_{yn}A_{yn})}{(A_{y1} + A_{y2} + ... + A_{yn})} \qquad (9)$$

Suspended sediment sample are taken at each of the intervals. Because of each verticals have different depths and velocities, the sample area will vary with each verticals sampled. The average of these analyses is defined as the meancross-sectional suspended sediment concentration;and the suspended sediment discharge, Q_s, then can be calculated by:

$$Q_s = \overline{U}\bar{C} \qquad (10)$$

4. Research Methodology

In this paper, the discussion pointed out on the measurement data obtained by Kironoto and Yulistiyanto [3] at Mataram Irrigation Channel with trapezoidal shape, through the measurement of velocityand of suspended sediment concentration profiles– measured by using propeller current meter and Opcon probes,respectively –, for different flows condition, differentchannel bed slopes, different trapezoidalchannel side wall slopes, etc. In addition to the primary data of velocities and suspended sediment concentrationof trapezoid channel obtained by Kironoto and

Yulistiyanto [3];secondary data obtained by Sjarbainy and Kironoto[15]were also analysed as complement data.

2. Results and Discussion

2.1. Location of Measurements

Measurements were conducted at 9 segment sections along the Mataram Irrigation Channel. These locations were chosen based on the shape of cross section that form trapezoidal channel; the channel characteristics and their locations are presented at Table 1.

At each locations, the velocities and the suspended sediment concentrations are measured at 7 vertical positions, in whichthree vertical positions were placed above the sloping side of the channel wall. Beside of velocities and suspended sediment concentrations, channel dimensions, flow depth, water surface slope, and water temperature were also measured. The flow velocities were measured using propeller current meter, while opcon probe were used to measure suspended sediment concentrations.

Table 1. Characteristics of measurement sections along Mataram Irrigation Channel (Kironoto and Yulistiyanto [3])

Section Location	Channel Width (m)	Flow Dept, D (m)	Slope of Side Wall (-)	Slope of Water Surface (-)	Mean Velocity, $\overline{U}$ (m/s)	Chezy Coeff., C_c (-)	Nikuradse Coeff. k_s (m)	Type of Channel Side Wall
L1	6.06	0.85	1.5	0.00017	0.396	36.9	0.084	stonemasonry wall
L2	7.60	1.12	1.6	0.00016	0.486	41.3	0.062	plastered concrete wall
L3	3.45	0.58	1.2	0.00018	0.297	32.7	0.096	plastered concrete wall
L4	2.70	0.30	1.0	0.00023	0.218	28.7	0.088	stonemasonry wall
L5	2.60	0.80	1.5	0.00023	0.468	41.7	0.037	stonemasonry wall
L6	6.90	0.78	1.5	0.00020	0.624	54.8	0.008	stonemasonry wall
L7	8.94	0.96	1.6	0.00018	0.358	29.9	0.245	stonemasonry wall
L8	10.20	0.62	1.5	0.00018	0.413	41.3	0.038	stonemasonry wall
L9	9.36	0.97	1.6	0.00016	0.391	34.3	0.139	stonemasonry wall

Figure 2 shows positions of measurement at each cross sections, which indicate its distance from the side channel edge, normalized by the width of channel water surface, B, namely $\frac{1}{2}B$, $\frac{3}{8}B$, $\frac{1}{4}B$, $\frac{1}{8}B$, $\frac{3}{32}B$, $\frac{1}{16}B$, and $\frac{1}{32}B$. The last three locations were placed above the sloping side of the channel wall. In Fig. 2, b is the bed channel width.

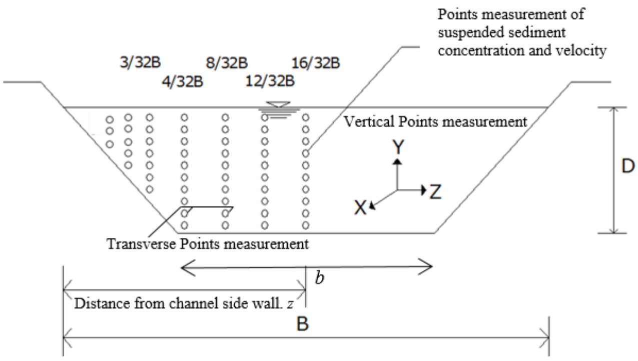

Fig. 2. Position of measurement points at cross section (Kironoto and Yulistiyanto [3])

2.2. Velocity Distributions

As being explained before, measurements were conducted at 9 different locations, where for each location, 7 vertical positions are measured. At each vertical position, the measurement points of velocity and suspended sediment concentrations were conducted at 7 points in the inner regions and 10 points in the outer regions, except for the measurement positions above the sloping side of the channel wall. Fig. 3 presents a typical example of velocity profiles obtained at location L5;it can be seen from the figure that the highest velocityoccurs at the middle of the channel, L5V1, and then decrease at the locations near the channel sides. It is also shown in the figure,the small values of velocities at the positions above the sloping side of the channel wall, *i.e.*, at L5V5, L5V6, and L5V7. Results forthe other velocity profiles at 8 other locations also give similar trends, however these results are not presented in this paper.

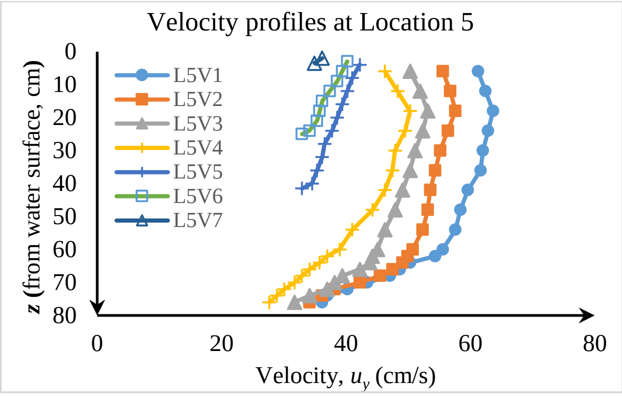

Fig. 3. Typical example of velocity profiles at location 5

The depth-averaged velocity at each vertical sections were calculated by integrating velocity profilesdata from the bed to the free water surface, and devide it with the flow depth. The depth-averaged velocities obtained in this study are presented in Fig. 4, where the depth-averaged velocities at each vertical measurements are normalized by the cross-section averagedvelocity of eachcross section,$\overline{U}_y/\overline{U}$vs.*z*/*B*. It is shown from the figure that the depth-averaged velocity reach its maximum value at the center of the cross section, this values decrease in approaching to the edge of the channel. The depth-averaged velocity to the cross-section averaged velocity, $\overline{U}_y/\overline{U}$= 1, occurs at *z*/*B* = 0.25.

Using these measured velocity profiles, friction velocities, u_*, then can be analyzed by applying Clauser's Method. Velocity obtained from measurements were plotted against its positions from the channel bed, in Cartesian coordinate, where ln (y/k_s) are plotted against u, as given in Fig. 5.

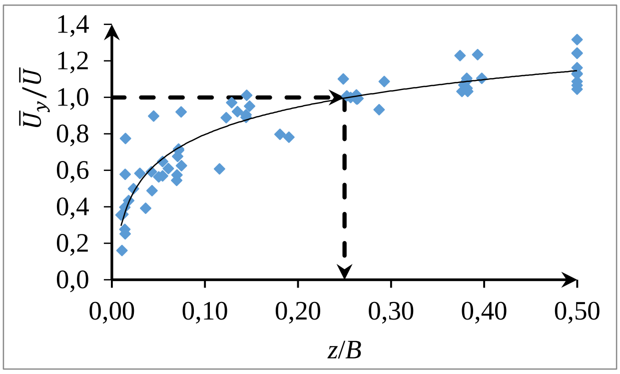

Fig. 4. The normalized depth-averaged velocity to the cross-section averaged velocity atthe channel sections

As presented in Fig. 5, the measurement points in the inner region, *y*/*h*<0.2, are quietlyfollow logarithmic distribution, however in the outer region, measurement points are deflected from logarithmic line, notably points near water surface.

The Nikuradse roughness coefficients, k_s, used in the Clauser methods can bedetermined from the slope measurements of free water surface. Assumed the uniform flow condition, friction slope is defined to be equal to the free water surface slope, and$k_s$then, can be calculated by using Eq.(2);these values are also presented in Table 1.

Results of friction velocity calculated by Clauser'smethod for all velocity profilesdata are presented at Table 2 and given in Fig. 6. In this figure, the friction velocity at all locations normalized by its average valuesat each cross section, $u_*/\bar{u}_*$, are plotted againstthedistanceof the measured vertical position from the channel side wall, *z*/*B*. In Fig. 6, the position points of*z*/*B*< 0.1 are friction velocities near the sloping side of the trapezoidal channel, having values less than the values near the bed of the main channel.

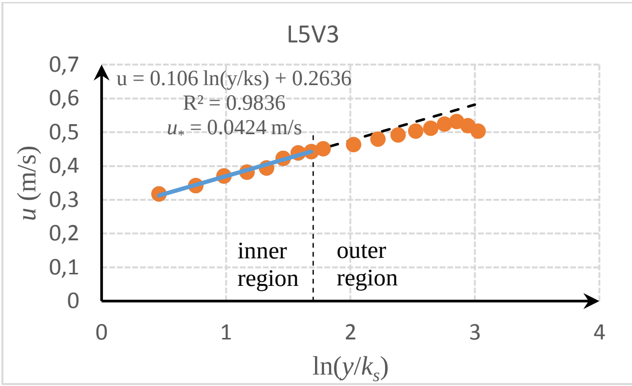

Fig. 5. Typical example of friction velocity, u_*, calculated using Clauser's Method

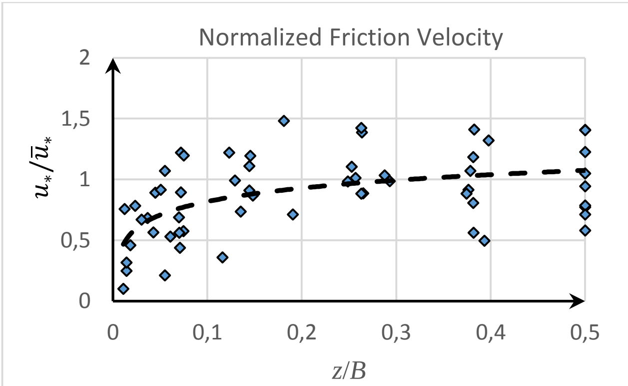

Fig. 6. Plot of friction velocities, $u_*/\bar{u}_*$, against *z*/*B*

The scattered of velocity frictions in each sections may also influenced by the existence of sediment bed load, however, this data was not measured. Best, et al. [16], based from their results of studies showed that the presence of mobile sediment (bed load sediment) increases the near-wall velocity gradient and shear velocity when compared with the clear water values.

Table 2. Friction velocities, u_*, calculated using Clauser'smethod

Vertical / Location	Friction Velocity, u_* (m/s)						
	V1	V2	V3	V4	V5	V6	V7
L1	0.037	0.027	0.066	0.057	0.043	0.051	-
L2	0.019	0.035	0.022	0.021	0.014	0.022	-
L3	0.053	0.051	0.038	0.039	0.024	0.075	-
L4	0.080	0.061	0.058	0.042	0.030	0.039	0.043
L5	0.061	0.057	0.042	0.031	0.015	0.030	0.034
L6	0.036	0.031	0.038	0.034	0.042	0.007	0.008
L7	0.028	0.026	0.029	0.036	0.027	0.020	0.075
L8	0.024	0.016	0.034	0.049	0.040	0.015	0.003
L9	0.026	0.036	0.064	0.050	0.020	0.025	0.014

The averaged values of *Br*, obtained from Clauser'smethod are plotted in Fig. 7. At the centre of the channel, the*Br*-valuesis about, *Br* = 10, and getting smaller to the edge of the main channel, in which, *Br*-values are approximately, Br = 6. However above the sloping side of the channel wall, its values increase sharply reach to *Br* = 18. As a comparison, *Br*-values for rectangular channel, obtained by Kironoto and Ikhsan[10], is also shown in the figure.

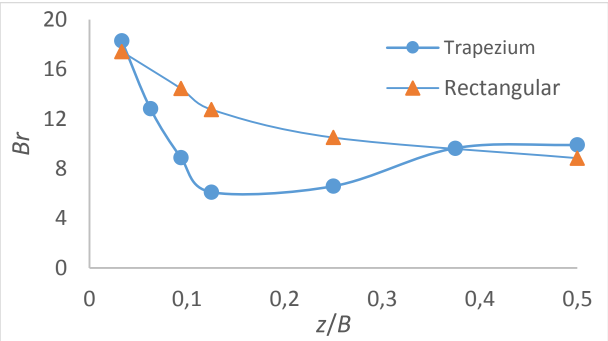

Fig. 7. The *Br*-values in rectangular and trapezoidal channels

2.3. Distributions of Suspended Sediment Concentration

Measurements of suspended sediment concentration were conducted in the same locations with velocity measurements. Fig. 8 gives typical examples of suspended sediment concentration distributions at Location L6. Vertical distributions of suspended sediment concentration at 7 vertical positions are shown in the figure, where 4 vertical positions were measured in the main channel, whereas the others profiles were measured above the sloping side of the channel wall. As shown in Fig. 8, the suspended sediment concentration profiles at 4 vertical positions in the main channel show uniform distributions, from the channel bed to some distances from the free water surface, and then decrease significantly. Different trend of concentrations are clearly shown for profile measured at positions above the sloping side of the channel wall, where approachto the water surface, the concentrations decrease evidently.

Fig. 9 presents the comparison of the calculated of suspended sediment concentration obtained by Rouse (Eq. (3)) and by Tanaka-Sugimoto (Eq. (4)) with the measured data, which show clearly its differences. This quasi-uniform distributions of suspended sediment concentrations resulted from the measurements are probably due to the locations of measurements in the irrigation channel, where the high size of sediments particle have been deposits in the upstream part of the channel where the sediment trap is found, consequently the sediment bed load is diminished in the channel.

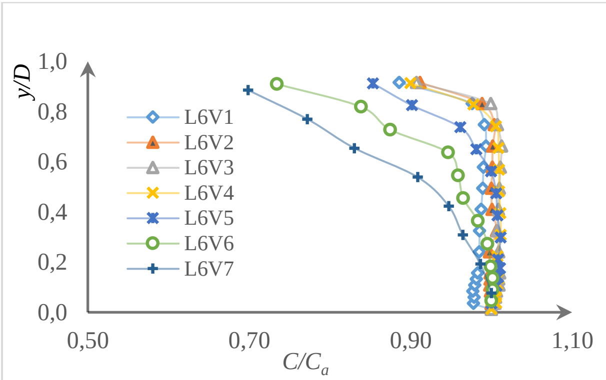

Fig. 8. Typical example of suspended sediment concentration profiles at Location 6

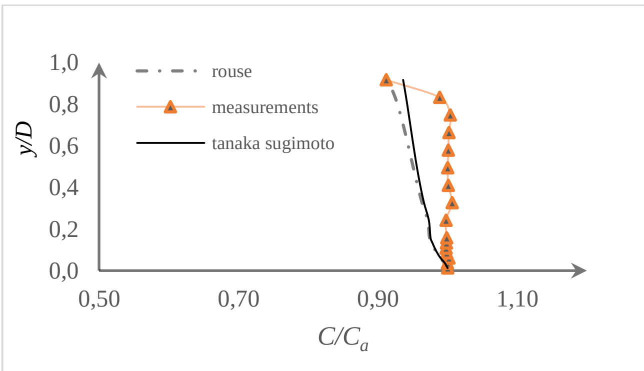

Fig. 9. Comparison of measurement of suspended sediment concentration with equations Rouse and Tanaka-Sugimoto

Using measurement data of suspended sediment concentration for each vertical positions, its depth-averaged values are calculated at each positions with Eq. (8), give average values at each positions, $\bar{C}_y$. These values, then normalized with the averaged values of each cross section, $\bar{C}$. These values are plotted against *z/B*. In Fig. 10, it is shown the value of$\bar{C}_y/\bar{C}$= 1 is located at *z/B* = 0.27. It can be concluded that the depth-averaged value of suspendedsediment concentration at location *z/B* = 0.27 represent average value of suspended sediment concentration at a cross section of the trapezoidal channel. It is noted that this location, *z/B* = 0.27, is measured from the edge of the water surface at the trapezoidal channel; because of scattered data given in Fig. 10, for practical purposes, this value can be taken as *z/B* = 0.25. Sjarbainyand Kironoto [15], with very limited data of measurements above the sloping side of the channel wall, found a value of *z/B* = 0.25 for trapezoidal channel. Kironoto [6] published a value of *z/B* = 0.20 for rectangular channel.

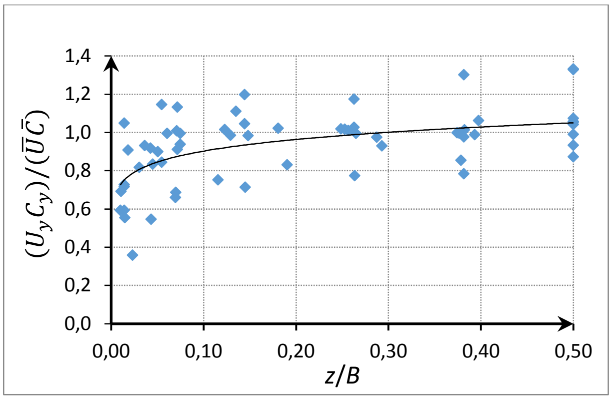

Fig. 10. Transversal distributions of averaged suspended sediment concentration

2.4. Discharge of Suspended Sediment

Using measurement values of flow velocity and concentration of suspended sediment, it is possible to calculate the suspended sediment discharge, presented as, $(U_y C_y)/(\bar{U}\bar{C})$, where U_y and C_y are, respectively, the depth-averagedof velocity and of suspended sediment concentration, calculated with Eq. (5) and Eq. (6), and $\bar{U}$ and $\bar{C}$ are the cross-section averagedof velocity and of suspended sediment concentration, calculated with Eq. (8) and Eq. (9) above. These values are presented in Fig. 11; which show that the suspended sediment discharges occur in the middle ofthe channel arehigher than thoseoccur near the edge of the channel, above the sloping side of the channel.

At *z/B* = 0.25, the value of $(U_y C_y)/(\bar{U}\bar{C})$is equal to 1, which means that the suspended sediment discharge of each cross section of trapezoidal channel can be determined from the measurement of depth-averaged of velocity and of suspended sediment concentration at*z/B* = 0.25.

Based on the curve obtained in Fig. 11, if the depth-averaged of velocity and of suspended sediment are carried out at any locationsacross the channel section, the suspended sediment dischargecan be determined using the following equation:

$$Q_s = \bar{U}\bar{C} = Cte_{z/B}(U_y C_y)|_{z/B} \quad (11)$$

where $Cte_{z/B}$is a correction factorforcertain value of *z/B*, which can be determinedfrom Fig. 10; for *z/B*=0.25, the value of $Cte_{z/B} = 1$.The value of $Cte_{z/B}$ can also be interpreted as the level of errors of suspended sediment discharge measurement, if the sampling is not conducted improperly.

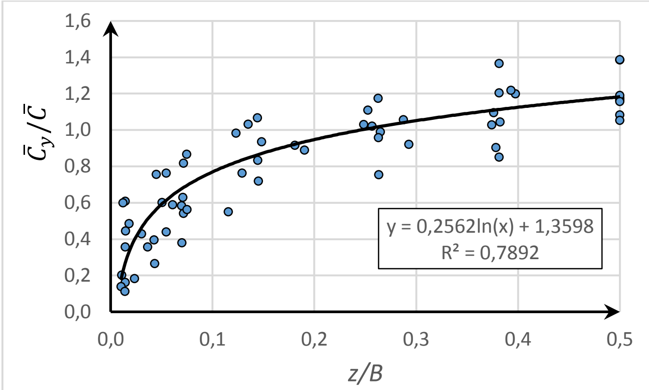

Fig. 11. Plot of suspendedsediment dischargeacross the channel cross-section

3. Conclusion

Based on the data analysed in this study, it can be concluded some results as follows:

1. The measured velocity profiles data indicate the highest values at the midle of the channel, and then decrease at location near the channel edge; and smaller values of velocities occur at positions near the sloping side of the channel wall.
2. The depth-averaged of velocity reachs its maximum value at the center of cross section; this value decreasesatthe locations approaching to the edge of the channel. The average-velocity value of $\bar{U}_y/\bar{U}$ = 1, occur at *z/B* = 0.25
3. The results of Clauser methodgivethe friction velocities near the sloping side of the trapezoidal channel are smaller then the values near the bed of main channel. The values of *Br* get smaller values to the edge of the main channel, and increase sharply in the sloping side of the channel.
4. The quasy uniform distributions of suspended sediment concentrations resulted from the measurements are probably due to the locations of measurements in the irrigation channel, where the high size of sediment sediments are deposits in the upstream part of the channel where the sediment trap is found, consequently the sedimentbed load is diminished in the flow
5. The depth-averaged value of suspended sediment concentration measured at location *z/B* = 0.27 – because of scattered data, for practical purposes, this value is taken as *z/B* = 0.25 – represent average value of suspended

sediment concentration at a cross section of the trapezoidal channel.

6. Based on the curve of $(U_y C_y)/(\bar{U}\bar{C}) vs.\ z/B$, given in Fig. 11, the suspended sediment discharge at cross section of trapezoidal channel can be obtained from the measurements of depth-averaged of velocity and of suspended sediment carried out at any locations across the channel section, and multiplying it with the a correction factor given in Fig. 11.

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References

[1] J.R. Gray and M.N. Landers, Measuring Suspended Sediment. In: Ahuja S. (ed.) Comprehensive Water Quality and Purification, Vol. 1, pp. 157-204. United States of America: Elsevier Inc., 2014. (Report).

[2] W. Yu, H. Lee, and S. Hsu, “Experiments on Deposition Behavior of Fine Sediment in a Reservoir." J. Hydraul. Eng., 12, 912-920, 2000. (Article).

[3] B.A. Kironoto and B. Yulistiyanto, Suspended Sediment Sampling Method for Determining Suspended Sediment Discharge in Artificial Channel and Natural River, Competitive Research Grant Report, Research and Community Service Institution (LPPM), Universitas Gadjah Mada, Yogyakarta (in Indonesia), 2015. (Report).

[4] N.L. Coleman, “Velocity profiles with suspended sediment”, J. Hydr. Res., 19(3), 211–229, 1981. (Article).

[5] N. L. Coleman, “Effects of Suspended on the Open-Channel Velocity Distribution”, Water Resources Research, Vol. 22, No. 10, 1986. (Article)

[6] J. Bartram, and R. Balance, R. A Practical Guide to the Design and Implementation of Freshwater Quality Studies and Monitoring Programs, Water Quality Monitoring, UNEP/WHO. New York, 1996. (Report).

[7] S. Shah-Fairbank, P. Julien, P., and D. Baird, "Total Sediment Load from SEMEP Using Depth-Integrated Concentration Measurements." J. Hydr. Eng., Vol. 137, No. 12, 1606–1614, 2011. (Article)

[8] S. Lv, H. Tang, Y. Xue, S. Yuan, X. Bai, Laboratory Measurement of Suspended Sediment Concentration by Using ADV, Proceedings of the 6th International Asia Conference on Industrial Engineering and Management Innovation, pp 91-100, Date: 13 October 2015. (Conference Paper)

[9] B.A. Kironoto, T. Andoyono, F. Yustiana, and C. Muharis, Study of Suspended Sediment Sampling Method for Determining Suspended Sediment Discharge in Open-Channel Flow, Competitive Research Grant Report, XII/1. Research and Community Service Institution (LPPM), Universitas Gadjah Mada, Yogyakarta (in Indonesia), 2004. (Report)

[10] B. A. Kironoto, and C. Ikhsan, Study of Suspended Sediment Sampling Method for Determining Suspended Sediment Discharge in Open-Channel Flow. Competitive Research Grant Report, XII/2. Research and Community Service Institution (LPPM), Universitas Gadjah Mada, Yogyakarta (in Indonesia), 2004. (Report)

[11] B.A. Kironoto, “Study of Suspended Sediment Sampling Location in Transverse Direction for Determination of Cross-Section Suspended Sediment Concentration (Comparaison of Laboratory and Field Data)”. Dinamika Teknik Sipil, Vol. 7, No. 2, ISSN : 1411-8904. Surakarta (in Indonesia), 2007. (Article)

[12] B.A. Kironoto and W.H. Graf, “Turbulence Characteristics in RoughUniform Open-Channel Flow*”,* Water Maritime and Energy - Proceedings of The Institution of Civil Engineers, 106, pp. 333-344, 1994. (Article)

[13] W.H. Graf and M.S. Altinakar. Fluvial Hydraulics – Flow and Transport Processes in Channels of simple Geometry. Presses polytechniques romandes, Lausanne, CH., John Wiley & Sons Ltd, West Sussex, England, 1998, (Book).

[14] R.J. Garde and K.G.R. Raju, Mechanics of Sediment Transportations and Alluvial Stream Problems. 2nd Edition, Wiley Eastern limited, New Delhi, 1977 (Book).

[15] C. Sjarbainy and B.A. Kironoto, Suspended Sediment Distribution in Trapezoid Uniform Open Channel Flow (Case Study in Mataram Irigation Channel, Yogykarta, Indionesia, : Saluran Mataram, Yogyakarta). Master Thesis Report of Civil Engg. Program, Universitas Gadjah Mada, Yogyakarta, 2006. (Unpubished Report)

[16] J. Best, S. Bennett, J. Bridge, J., and M. Leeder, “Turbulence Modulation and Particle Velocities over Flat Sand Beds at Low Transport Rates”, J. Hydraul. Eng., 123, 1118-1129, 1997.(Article).