Assessment to the sediment concentration affected by river water current during dry and monsoon seasons at Kanor village-Bengawan Solo River

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ABSTRACT

Sediment transport is the natural phenomenon which is occurred along river stream. Many factors are influencing on this process, but the main parameters are current velocity and flow discharge. The velocity and flow discharge are two river components which intercorrelated each other. Current velocity may cause scouring at the river stream continuously. The materials from scouring process would be become the primary sources of sediment load. There are two sediment load types, suspended load and bed load. The quantity of sediment load that expressed by sediment concentration plays an important part in river morphology changing. This study is focused to assess the sediment concentration affected by current velocity. The sediment samples were taken from Kanor village-Bengawan Solo River during the dry and monsoon seasons. Suspended load samples were taken by suspended trap equipment. River water current was measured by current meter magnetic. This paper is mainly investigated the differences between the quantity of sediment concentration affected by river water current during the dry and monsoon seasons. The investigation results were sediment concentration in milligram per liter (mg/L) and river water current. Based on the data analysis result, the sediment concentrations and current velocities shows the linear correlation. During dry season the sediment concentration and current velocity are lower than in the monsoon season. The highest sediment concentrations were at 0.8 of water depth. This phenomenon is thought be due the effect of particle settling process, so the sediment concentrations are accumulate at the lower point of water column.

Keywords: suspended concentration, river water current, dry and monsoon season, Bengawan Solo River

1. INTRODUCTION

Sediment transport that resulted from large rivers is contribute to the land topographic changing (Lu et al., 2013). The suspended sediment transport is determined by the particle size and sediment particle distribution (Mouri et al., 2014). Almost all of suspended sediment transport studies are conducted based on the laboratory experimental. The increasing of flow velocity affected to the grain-size distribution of suspended load changed from a skewed pattern to a bimodal one at higher suspension heights. (Ghoshal and Pal, 2014). It has been observed that the effect of sediment concentration on equilibrium scour hole parameters such as maximum equilibrium scour depth, and longitudinal and transverse extent of scour hole can be significant (Debnath and Chaudhuri, 2010). River bends are formed by a combination of current velocities, sediment transport and bed morphology (Dugue et al., 2013).

Previous research has shown that the sediment concentration is relatively follows the flow discharge function. In other hand, the flow discharge is depend on to the flow velocity. The relationship between flow discharge and sediment concentration is not often homogeneous (Romero et al., 2008). In many regions, the flow conditions are determined by the climate circumstance. Indonesia has two major climate conditions, dry and monsoon season in which are greatly influence to the river flow characteristics.

The sediment characteristics during dry and monsoon season is thought be plays an important role in the river morphology changing, thus the correlation between sediment concentration and current velocity are needed to study in detail.

2. STUDY LOCATION

Indonesian rivers are usually classified as alluvial rivers as they are normally situated in residual soil (Nugroho and Soemitro, 2007). The most important river especially in Java Island is Bengawan Solo River. Bengawan Solo River is the longest river in Java Island with 600 km of length. The average width of this river is around 100 m. The upstream is located in Wonogiri, Central of Java while the downstream is at Gresik, East Java. Unfortunately, illegal sand river mining is
occurred in this river and triggering the sedimentation and degradation (Mountassir et al., 2011).

Bengawan Solo River characterized by high differences water level and flow discharge during dry and monsoon season. The water level amplitude between dry and monsoon season is approximately 7 m. The record data shows that the range of flow discharges are between 10 m$^3$/s to 2000 m$^3$/s. The great variation of river flow contributed to the high variation of sediment concentration.

Fig. 1. High water level condition of Bengawan Solo River.

3 INSTRUMENTATION

The river profile was measured manually using gauge stick. This measurement is aimed to get the river profile contour in cross sectional direction. Furthermore, this river cross section will use to analyze the flow discharge.

Fig. 2. Map of Bengawan Solo River and sampling site location.

The water level observation was also conducted during river profile measurement. During observation, the river condition shows the high water level condition indicated that monsoon season was occurring.

The current velocity were measured with current meter magnetic. The measurement was conducted at three points of depth (0.20d, 0.60d and 0.80d).

The sediment samples were collected using suspended sediment trap. The suspended load samples were taken as well as current velocity observation point.

Fig. 3. Measured cross section of Bengawan Solo River with the water level condition on January 15, 2014.

4 EQUATION

The current velocity measurement data can be determined by three point method analysis as follows.

$$v = 0.25v_{0.2} + 0.5v_{0.6} + 0.25v_{0.8}$$

where $v_{0.2}$, $v_{0.6}$ and $v_{0.8}$ are the measured velocity at 0.2d, 0.6d and 0.8d from the water surface (Boiten, 200).

The sediment concentration can be calculated using the formula as follows:

$$C_{ff} = \frac{F x 10^6}{W}$$

where $C_{ff}$ is fine-fraction concentration (mg/L), $F$ is mass of sediment in the dish (g), and $W$ is mass of entire sample (g) (ASTM D 3977-97).

5 DATA ANALYSIS

The current velocity measurements were conducted at 0.2d, 0.6d and 0.8d of river depth. The observation schedules were on January, February, May and August 2014. During January until February the monsoon season was occurring, while May until August the dry season likely dominated.

The current velocities on January 15 are quite similar with February 12. But the situation is increasing significantly on February 25 indicated that the monsoon season was at the peak level. The lowest current velocities were occurred on May and August indicated the dry season was happening at around Java Island. The lowest current velocity is stated at around 0.01 to 0.05 m/s while the highest is at around 1.0 to 1.10 m/s.

The differences of sediment concentration in the dry
and monsoon season can be seen from water turbidity condition. According to visual assessment on river water, the preliminary condition of sediment concentration is possible to be conducted.

Fig. 4. Observed current velocities during monsoon and dry season.

The laboratory work have been done to analyze sediment content in the river on various conditions. The suspended samples were investigated and resulted the sediment concentration during the dry and monsoon seasons.

Fig. 5. River water condition during the dry and monsoon seasons.

The highest total sediment concentration was 3992.38 mg/L on February 25th. Meanwhile, on May 20th was the lowest with 1053.58 mg/L sediment content in the river flow. The sediment concentration analysis result shows the various season give the significant value to the river flow condition.

Moreover, the characteristics of sediment concentration at every observation point are indicated that sediment concentrations are mostly accumulated at the lowest observation point. It thought be due to the sediment particle settling process take a part in this phenomenon.

According to the current velocity and sediment concentration analysis result, the correlation between them could be evaluated. The current velocity and sediment concentration at the same observation point would be compared to get the direct relation.

Fig. 6. Linear relationship between sediment concentration and current velocity.

The graphic shows that both of sediment concentration and current velocity relatively have the linear function. The previous study resulted that the sediment concentration is follow the flow discharge function. According to this study, the sediment concentration in Bengawan Solo River could be assessed based on the current velocity measurement data.

6 DISCUSSION

The current velocities pattern are relatively follows the river flow conditions. The current velocities are greatly varied during monsoon season. January and February are represented the monsoon season. The river flows are in high velocity condition. On the contrary, in May until August were the lowest conditions of current velocities. According to the visual observation, the water turbidity on monsoon seasons are likely containing high sediment concentration. In the opposite, the clear water on the dry season indicated the sediment concentrations are in low condition.

The sediment concentration were observed at three point of water depth shows that the sediment distribution at every sampling point. According to the data analysis result, the sediment concentration classified into two conditions. At the low current velocity (0-0.5 m/s), the sediment loads are distributed low concentration at the surface water to the high concentration at the lower water column. On the contrary, the high current velocities give the different
result. The sediment loads are distributed in high to low concentration from the surface to the lower water column. This phenomenon is thought to be due to affected by turbulent flow condition during monsoon season. The current velocity in February shows the similar pattern in which the highest velocities are relatively occurred at the surface water. This condition was affecting the sediment load distribution accumulated at around the surface water column.

7 CONCLUSIONS

The main conclusions of the present study are:
1) The current velocities characteristics at every observation point shows that the lowest velocities were relatively at the lower water depth during dry season. But the opposite condition occurred in the monsoon season where the highest velocities were at around surface water.
2) During the dry season, the characteristics of sediment load shows that the highest sediment accumulation was at the lowest observation point. In the opposite, the monsoon season was resulted the highest sediment load quantities at around surface water.
3) The sediment concentrations characteristics could be described by the relation between current velocities and sediment content in the river flow.

ACKNOWLEDGEMENTS

This study was supported by the Indonesian Directorate General of Higher Education (DIKTI) and Institut Teknologi Sepuluh Nopember (ITS) Surabaya.

Sincere appreciation goes to Dr. Ria Asih Aryani Soemitro and Assoc. Prof. Toshiyumi Mukunoki for their comments in both a contextual and academic sense, to Dr. Dwa Desa Warnana and Mr. Wardoto for their help in the field sampling.

REFERENCES

1) Boiten, W. (2000): Hydrometry, ISBN 90 5410 419 8, A.A. Balkema Publishers, 82-83.
2) Debnath, K. and Chaudhuri, S. (2010): Effect of suspended sediment concentration on local scour around cylinder for clay -sand mixed sediment beds, Engineering Geology 117, 36-245.
3) Dugué, V., Blanckaert, K., Chen, Q. and Schleiss, A.J. (2013): Reduction of bend scour with an air-bubble screen - morphology and flow patterns, International Journal of Sediment Research 28, 15-23.
4) El Mountassir G, Marcelo S, Romero E, Soemitro R.A.A. (2011): Behaviour of Compacted Silt Used to Construct Flood Embankment, Proc. ICE Geotechnical Eng. Journal.
5) Ghoshal, K. and Debasis Pal, D. (2014): Grain-size distribution in suspension over a sand-gravel bed in open channel flow, International Journal of Sediment Research Vol. 29, 184-194.
6) Lu, X X., Ran, L.S., Liu, S., Jiang, T., Zhang S.R. and Wang, J.J. (2013): Sediment loads response to climate change: A preliminary study of eight large Chinese rivers, International Journal of Sediment Research 28, 0-14.
7) Mouri, G., Ros, F.C. and Chalov, S. (2014): Characteristics of suspended sediment and river discharge during the beginning of snowmelt in volcanically active mountainous environments, Geomorphology 213, 266–276.
8) Nugroho, A.J. and Soemitro, R.A.A. (2007): Assessment to Bengawan Solo River embankment affected by water level fluctuations, Undergraduate Final Project Report.
9) Romero, E.N., Regüés, D. and Latron, J. (2008): Relationships among rainfall, runoff, and suspended sediment in a small catchment with badlands, Catena 74, 127–136.