ERROR INTRODUCED IN MEASUREMENTS OF BED LOAD TRANSPORT

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Abstract

High accuracy in calculating the transport rate of bed load in natural channels is required for design purposes. This can be achieved through good sampling and reliable data sets. However, measurements of bed load transport can be a difficult task for rivers with flow depths exceeding one meter owing to the methods of measurements that uses either a cableway or an A-Frame. Therefore this study is confined to rivers with flow depths less than one meter only. Method of measurements employed is wading technique using Helley-Smith bed load sampler that is the most superior to other methods.

Study has been conducted on two rivers namely Sungai Lui and Sungai Semenyih with cross-section spanning between 14 m to 15 m. Sampling was done at every meter through out the river cross-section. The main aim of this paper is to make comparisons on the amount of bed load transport taken at every meter with the bed load transport taken at every two meter points at each observation. Results are tabulated and presented in graphical forms showing the percentage errors introduced between the two procedures. A qualitative and quantitative discussion on the improved accuracy of the former sampling method are presented.

A formula in computing the actual bed load has been established to make possible the estimation of bed load if less number of samples were taken at each traverse.

INTRODUCTION

In the past, various methods of measurements have been established in determining bed load discharge. The instruments and the measurement techniques employed vary and the instrument used may be expensive, difficult to operate and requires high skilled operators. This may be uneconomical and does not promise accurate results. To acquire bed load transport in low flow conditions, a more simple, robust and inexpensive instrument is sufficient. The factors that govern good and accurate results are the techniques used during sampling operation.

Numerous works on bed load measurements have been carried out both in the field and in the laboratory by several researchers and these include Carson, Whiting and Dietrich, Kuhnle and Willis, Gaweesh and van Rijn and others.

Carson (1987) emphasized the significance of grain shear stress as a factor responsible for bed load transporting capacity[1]. Whiting and Dietrich (1990) did several measurements of bed load on three rivers with river width ranging between 5.2 m to 6.0 m and depth ranging between 0.4 m to 0.5 m[2]. However, the sampling points were not specified in their study.

Kuhnle and Willis (1992) studied the mean bed-load size distribution using weighting coefficients of the rate of transport and stage frequency[3]. A substantial amount of bed load samples were collected during the study but the sampling points and procedure were not documented.

Gaweesh and van Rijn (1994) studied bed load sampling in large sand bed rivers. The experiment was conducted both in field and laboratory to determine the sampling performance of their newly designed sampler[4]. Even though the research was extensively being carried out both in laboratory and fields but this cannot be generally applied to smaller rivers with different bed materials.

Most of the previous studies are primarily concerned with the development and efficiency of bed load sampler. There are also studies done to determine the transport capacity of large rivers but with insufficient range of data. A standard method on the number of samples to be taken on each observation during the sampling operation is still rather vague thus results may vary from one observation to the other. The results become less reliable if the study is to be conducted in the field with several variables.

Techniques used during the sampling operations have not been clearly discussed due to the difficulties experienced by the operators, especially during high flows in which wading technique is impossible. The number of samples taken at each traverse varies depending on the condition of flow and other factors such as sediment size[5].

With unsteady flow the bed load discharge varies with time up to a certain extent along with other hydraulic parameters. In general the flow and bed load discharge is unsteady and is subjected to variation in most natural channels. In this study, considerable attention has been devoted to developing equations for bed load transport under field conditions. To reduce the effect of variation bed load has been observed at every meter to obtain a more accurate results. A formula to calculate the actual bed load rate has been established based on field measurement. The actual bed load for the whole river cross-section can be estimated even though measurements are to be taken at two-meter interval.

RESEARCH METHODS

Study Site

Data used in this study were collected from two rivers namely Sungai Lui and Sungai Semenyih. The catchment sizes are 68.1 km^2 and 225 km^2 respectively. These rivers under study are categorised as large river with aspect ratio greater than 10. Detail description of the study area can be found from [6].

A total of 12 field studies were conducted, that resulted in 24 data sets.

Velocity and Depth Measurements

Flow velocities were measured using a standard C-31 current meter attached to a wading rod with a propeller that measured flow in terms of revolutions per second. The current meter was connected to a counter that registered the velocity of flow.

Flow velocities were measured using two-point method for flow depths exceeding 0.4 m and at 0.6D from the water surface for flow depths less than 0.4 m. Measuring period was 50 seconds. Measurements were made at bed load sampling points.

Bed load measurements

The technique employed during the sampling operation of bed load in this study was the wading technique. Samples of bed load were collected using a Helley-Smith bed load sampler. The sampler has a weight of about 60kg. Bed loads were collected through a nozzle of 74.0 mm $\times$ 74.0 mm size into a bag with a mesh size of about 150 μm. Bed load was sampled at every meter across the river cross-section. A total of 13 to 14 bed load samples were measured at each observation.

Twelve field experiments under low flow conditions were conducted. In each of the experiments two different sampling intervals, namely one-meter and two-meter, were adopted. Measurements were carried out at the points of gauging. Measuring period varies from 3 minutes to 5 minutes depending on locations and nature of flow. The sampler was carefully placed on the bed to avoid any disturbance to the flow of sediments into the sampler. It was placed on the channel bed with the nozzle facing the upstream end opposing the direction of flow to enable bed load to be collected through its nozzle.

RESULTS AND DISCUSSION

Basic physical and flow characteristics of the two rivers are shown in Table I.

TABLE I
SUMMARY OF RIVER DATA

Discharge Q	**Sungai Lui**	**Sungai Semenyih**
Discharge m3	0.744-4.719	2.601-6.099
Area, m2	3.62-8.22	5.46-8.14
Velocity, m/s	0.194-0.574	0.447-0.776
Bed load discharge, kg/s	0.0125-0.0702	0.0607-0.145
Flow depth, m	0.241-0.548	0.39-0.581
Width of river, m	15	14
Ave. Sediment size, mm	0.911	1.774
Bed load composition, %	G(6.59%) S(93.4%)	G(39%) S(60%)

Figure 1 show typical distributions of bed load discharge over the cross-section for both Sungai Lui and Sungai Semenyih. Samples dated 20/10/01 and 9/11/01 were taken from Sungai Lui, while samples dated 11/10/01 and 27/10/01 were taken from Sungai Semenyih. It has been observed for all samples that the variation in bed load discharge is reasonably small. From the analysis it was found that on average the total bed load transport is about 0.00482 kg/s for the whole river cross-section. This is shown in TABLE II.

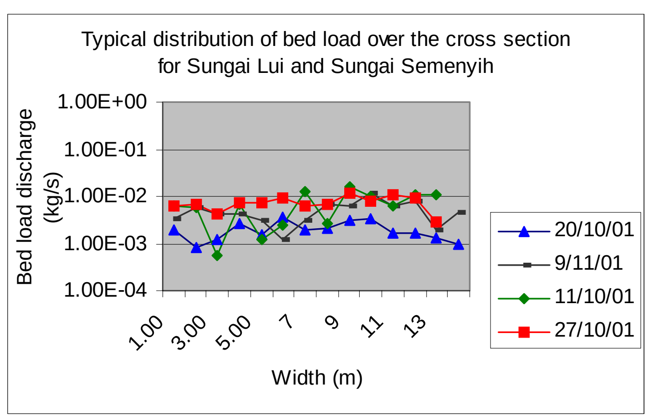

Fig.1 Typical distribution of bed load over the cross section for Sungai Lui and Sungai Semenyih

TABLE II
MAXIMUM AND MINIMUM BED LOAD

Samples	Max.B/L	Min.B/L	Average
1	0.0020759	0.0001826	0.0011293
2	0.0044073	0.0003503	0.0023788
3	0.0206874	0.0010124	0.0108499
4	0.0156832	0.0005498	0.0081165
5	0.0031296	0.0002093	0.0016695
6	0.0026519	0.0003989	0.0015254
7	0.0143171	0.0012196	0.0077684
8	0.0145806	0.0002912	0.0074359
9	0.0036631	0.0009826	0.0023229
10	0.0035873	0.0002629	0.0019251
11	0.0167394	0.0040611	0.0104003
12	0.0150826	0.0018416	0.0084621
13	0.0049411	0.0002589	0.0026
14	0.0049495	0.001182	0.0030658
15	0.0113219	0.0027934	0.0070577
16	0.0168021	0.0039049	0.0103535
17	0.0037792	0.0003932	0.0020862
18	0.0049552	0.000562	0.0027586
19	0.0062343	0.0010441	0.0036392
20	0.0047215	0.0003094	0.0025155
21	0.0051615	0.000904	0.0030328
22	0.0043757	0.0011635	0.0027696
23	0.0114114	0.001256	0.0063337
24	0.010279	0.0007938	0.0055364

Figure 2 shows the individual bed load transport rates at the two locations. The bed load discharge calculated from measurements taken at one-meter interval on average is about two times more than the bed load discharge calculated from measurements made at two-meter interval.

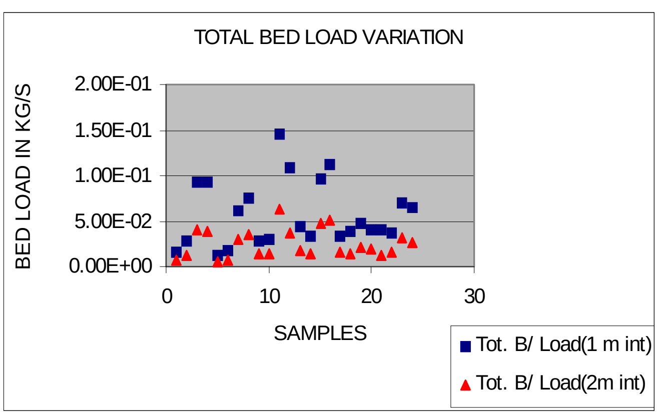

Fig. 2 Total bed load variation

The analysis showed that the average relative error of the total bed load measurements taken at two-meter interval were about 56% on average less than bed load measurements taken at one-meter interval for all the 24 data samples. Since this is true for all samples measured, an equation to compute the actual bed load values on field can be established.

Fig. 3 shows a graph of average bed load discharge measured at one-meter interval against average bed load discharge measured at two-meter interval across the river.

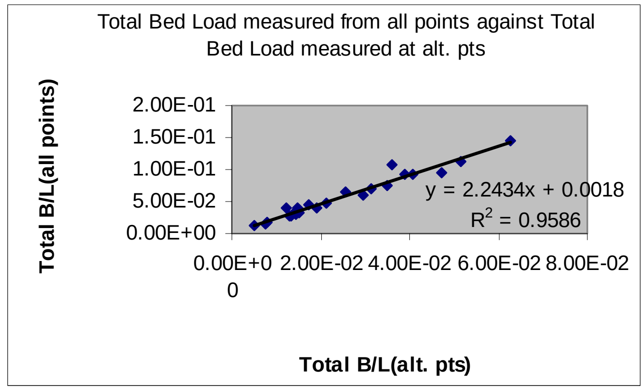

Fig. 3 Total bed load measured at one-meter interval with total bed load measured at two-meter interval.

It is interesting to note that there is a good relationship between the two methods of measurements made. A correlation coefficient of 0.979 has been obtained. Using the formula gained from this relationship it was observed that there is a good agreement between the calculated and the observed values for all the 24 samples. The distribution of accuracy on using this formula is shown by the use of difference ratio in Table II. Difference ratio is the ratio between calculated and observed values. From the analysis the ratio between calculated and observed bed load were found to be within 0.5 - 2.0 limit.

TABLE III
SUMMARY OF COMPARISON BETWEEN COMPUTED AND OBSERVED TOTAL BED MATERIAL LOAD USING THE PROPOSED FORMULA

No. of samples	Data in the range of 0.5 to 2.0 limit
24	100 %

CONCLUDING REMARKS

A study on the errors introduced on bed load discharge due to sampling intervals under field conditions were conducted. It was found that large interval under estimates the bed load values. Comparisons on the sampling procedure for bed load has been made and analysis showed that actual bed load can be estimated even if less bed load samples were taken. A formula for the computation of actual bed load discharge has been established. Variation of bed load transport over the cross-section is reasonable small and was found to be about 0.00482 kg/s for the whole river width. Further works are necessary to be done in the future for more sets of good field data to achieve a better prediction of bed load discharge.

ACKNOWLEDGEMENT

The writers appreciate the provision of grants by the Bureau Research and Consultancy Universiti Teknologi MARA for this study. The administrative support by the staffs of Drainage and Irrigation Department, Selangor, program on particle size distribution written by Bahardin Baharom of the Faculty of Civil Engineering, Universiti Teknologi MARA, assistance in sediment sampling by Rasyidi, Fahzan, Hasbuddin, Izzdy, Nor Shariza, Mazita, Azizan and Mohd Rasyidi, final year students of the Faculty of Civil Engineering, Universiti Teknologi MARA are gratefully acknowledged.

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