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# The efficiency of basket type bed load samplers

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ABSTRACT Experiments were conducted in a sediment flume using three models of a basket sampler to determine their sampling efficiency. The results, together with analysis of data from the literature, indicate that the sampling efficiency of basket samplers is not constant but may be a function of two dimensionless variables.

<u>L'efficacité des appareils à prélever des échantillons du type paniers</u>
RESUME Des expériences ont été faites dans un canal jaugeur conçu pour l'étude des sédiments sur trois modèles d'appareils à prélever les échantillons du type panier en vue de déterminer leur efficacité en ce qui concerne la prise d'échantillons. Les résultats étudiés conjointement avec l'analyse des données extraites de la documentation montrent que l'efficacité de ces appareils n'est pas constante mais est fonction de deux variables sans dimension.

## NOTATION

| | |
|---|---|
| $B$ | width of the flow |
| $D_{50}$ | median grain size |
| $E$ | efficiency of sampler |
| $h$ | average depth of flow |
| $L_s$ | width of the sampler |
| $q_a$ | actual bed load discharge passing the measuring section if the sampler were not there |
| $q_t$ | bed load discharge obtained with the sampler |
| $S$ | water surface slope |
| $t_*$ | duration of sampling for one sample |
| $Wt$ | average submerged weight of samples |
| $U_*$ | shear velocity |
| $\gamma_s$ | submerged unit weight of sediment |
| $\mu$ | viscosity of the fluid |
| $\psi$ | grain size distribution factor given as $\frac{1}{2}(D_{16}/D_{50}+D_{84}/D_{50})$ |
| $\rho$ | density of the fluid |
| $\rho_s$ | density of the sand grains |

## INTRODUCTION

Many attempts have been made to devise methods to measure the bed load discharge passing a given cross section of a river. By far the most concentrated effort has been devoted to developing portable bed load samplers, and the large number of different types bears witness to the fact that this approach has not yet been perfected. It would be desirable to have a sampler which is designed so that the bed load discharge is unaffected by its presence. Unfortunately, this condition cannot be met by any of the samplers in use. The basic problem is that the sampler must rest on the stream bed and, therefore, the flow pattern and bed load movement in the vicinity of the sampler are altered to some extent. As a result, samplers do not catch material at the true rate and must be calibrated to determine their trapping efficiency under different conditions. To date, such calibrations have not been very reliable.

In view of these problems, investigators have searched for alternative means of measuring the bed load. Various methods such as the use of tracers (Hubbel & Sayre, 1963; Nelson & Coakley, 1974), acoustic devices (Jonys, 1976), and pits excavated (Einstein, 1937); Hubbel, 1964) or placed into the stream bed (Murphy & Amin, 1979; Waslenchuk, 1976) have been attempted. These have either failed to work or are too costly and impractical. Methods using dune profile measurements have given good results with flume tests (Engel & Lau, 1980a, Engel & Wiebe, 1979), but must still be further investigated. Therefore, for some time to come, portable bed load samplers must still be used.

When the bed material is composed of coarse particles (i.e. gravel), it is customary to use a basket type sampler (Novak, 1957; Hubbel, 1964; Gibbs, 1973). Engel & Lau (1980b) examined some experimental calibration data for a basket sampler obtained by Gibbs (1973) and found that the efficiency of such a sampler may be a function of several independent dimensionless variables. In this paper some results from new experimental data are presented to define the relationship between the sampling efficiency and the dimensionless variables more exactly. Although this analysis is restricted to basket type samplers, it is expected that a similar approach can be used for other types of samplers.

## THE FORM OF THE CALIBRATION EQUATION

The basket samplers are basically screened rectangular boxes secured in some suitable way to a suspension frame. A model of the type used by Water Survey of Canada is shown in Fig. 1. For such a sampler with a given size of wire screen, Engel & Lau (1980b) showed that its trapping efficiency should be expressed in general terms as

$$E = f_1\left[L_s,\ t_*,\ U_*,\ h,\ D_{50},\ \psi,\ \rho_s,\ \rho,\ \mu,\ \gamma_s,\ B\right] \tag{1}$$

Dimensional analysis yields the relationship

$$E = f_2\left[\frac{L_s}{D_{50}},\ \frac{t_*U_*}{L_s},\ \frac{h}{D_{50}},\ \psi,\ \frac{\rho_s}{\rho},\ \frac{U_*D_{50}\rho}{\mu},\ \frac{\rho U_*^{\,2}}{\gamma_s D_{50}},\ \frac{L_s}{B}\right] \tag{2}$$

Engel & Lau (1980b) reasoned that $h/D_{50}$, $\rho_s/\rho$, $U_*D_{50}\rho/\mu$ and $L_s/B$ (if $L_s/B$ is small) do not significantly affect E. One can also expect that the effect of $\psi$ is small and that the effect of bed

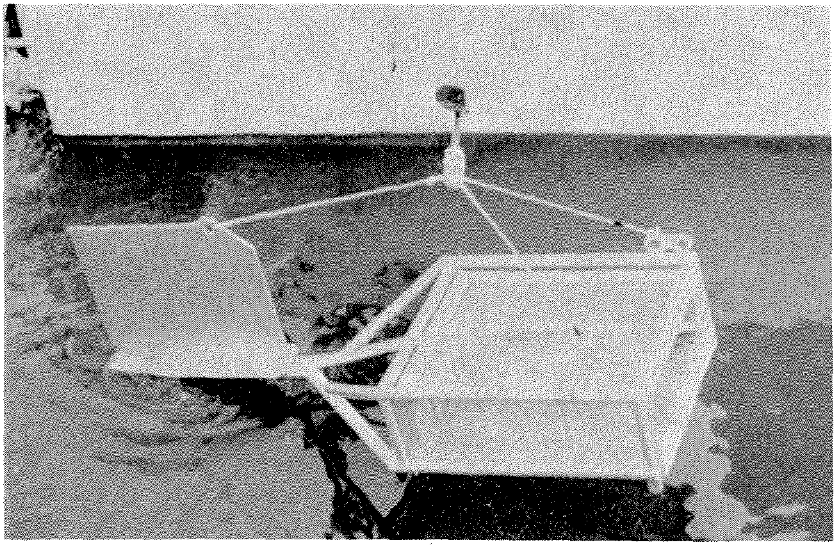


**Fig. 1** Basket sampler (courtesy of Water Survey of Canada).

material is primarily accounted for by $D_{50}$. Therefore, $\psi$ can also be deleted from equation (2) which can now be reduced to

$$E = f_3\left[\frac{L_s}{D_{50}}, \frac{t_*U_*}{L_s}, \frac{\rho U_*^2}{\gamma_s D_{50}}\right] \tag{3}$$

Engel & Lau (1980b) examined data from Gibbs (1973) for which $\psi$ was constant, $L_s/D_{50}$ was approximately constant at 27 and the mobility number $\rho U_*^2/\gamma_s D_{50}$ varied from 0.074 to 0.123. It was found that a single curve of E *vs.* $t_*U_*/L_s$ described the data very well, indicating that the mobility number did not have any significant effect on the efficiency.

The equation for the sampling efficiency of a basket type sampler may now be stated as

$$E = f_4\left[\frac{L_s}{D_{50}}, \frac{t_*U_*}{L_s}\right] \tag{4}$$

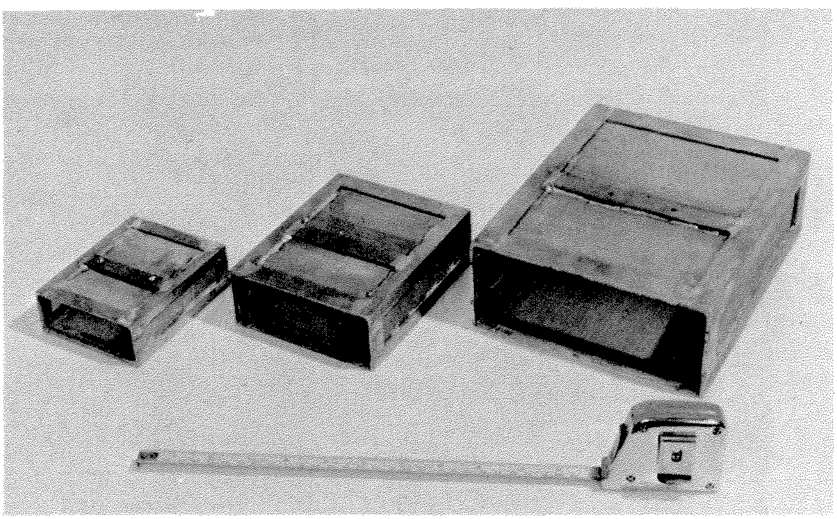
Some experiments have been conducted to determine the effect of $L_s/D_{50}$ on the sampling efficiency and the available data are used to examine equation (4) more closely.

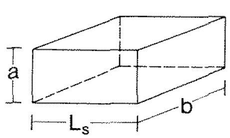
## EXPERIMENTAL SET UP AND PROCEDURE

The experiments were conducted in a tilting flume, rectangular in cross section, 2 m wide with glass side walls 0.75 m high and having an overall length of about 22 m. The flume and its auxiliary equipment are described in detail by Engel & Lau (1980a). A river wash sand was used and this was fairly uniform in size with a median sieve diameter of 1.10 mm. Most grains were not particularly spherical and their edges were of intermediate roundness. The specific gravity of the sand was found to be 2.65 and its average porosity was 0.45.

Three basket samplers were used to collect the sediment samples required to determine their trapping efficiency. The dimensions of these samplers are given in Fig. 2. The samplers were simply identified as big, medium and small. The small and medium samplers were half and two-thirds as large as the big sampler in every respect except for the screen size. For all three samplers, the same standard 0.6 mm stainless steel screen was used. The samplers were suspended by a rod which was connected to the top of a sampler with a swivel joint. This permitted the samplers to be placed lightly on the sand bed and to have them align themselves freely with the bed contours.

The experiments were divided into runs and sampling sequences. A run was a test for a specific flow condition and consisted of four sets of sampling sequences. A run was set up as described by Engel and Lau (1980a). When equilibrium conditions were reached, several water surface and bed profiles were taken to obtain the average water surface slope and flow depth from which the shear velocity $U_*$ was computed. Once this was completed, sampling began. Each sampling sequence consisted of 25 samples at a predetermined sampling duration $t_*$, with a 2 min time interval being maintained between successive samples (Gibbs, 1973). At the end of each run the samples were weighed under water and the average weight for each sampling sequence was obtained. In all, four runs were made and, for each, the ratio of flow depth to sampler height was kept approximately constant. Independent measurements of the actual average bed load transport occurring in the flume were obtained from the 2 m flume sediment trap in the manner described by Engel & Lau (1980a). The data for the experiments are given in Table 1.






| Basket | a(cm) | $L_s$(cm) | b(cm) |
|---|---|---|---|
| Small | 3.8 | 8.8 | 11.5 |
| Medium | 5.0 | 11.7 | 15.3 |
| Large | 7.6 | 17.6 | 23.6 |

**Fig. 2** Basket samplers used in tests.

**Table 1** Experimental data

| Sample sequence | $q_a$ ($kg\ s^{-1}\ m^{-1}$) | h (m) | S | $t_\star$ (s) | $U_\star$ ($m\ s^{-1}$) | Wt (g) |
|---|---|---|---|---|---|---|
| *Medium basket* | | | | | | |
| 1 | 0.006 07 | 0.143 | 0.001 32 | 240 | 0.043 | 52.0 |
| 2 | 0.006 07 | 0.143 | 0.001 32 | 180 | 0.043 | 45.8 |
| 3 | 0.006 07 | 0.143 | 0.001 32 | 120 | 0.043 | 33.6 |
| 4 | 0.006 07 | 0.143 | 0.001 32 | 60 | 0.043 | 23.1 |
| 5 | 0.006 07 | 0.143 | 0.001 32 | 180 | 0.043 | 40.4 |
| 6 | 0.006 07 | 0.143 | 0.001 32 | 120 | 0.043 | 36.9 |
| 7 | 0.006 07 | 0.143 | 0.001 32 | 60 | 0.043 | 20.1 |
| 8 | 0.006 07 | 0.143 | 0.001 32 | 30 | 0.043 | 17.5 |
| *Large basket* | | | | | | |
| 9 | 0.005 25 | 0.171 | 0.000 885 | 300 | 0.039 | 105.9 |
| 10 | 0.005 25 | 0.171 | 0.000 885 | 180 | 0.039 | 76.3 |
| 11 | 0.005 25 | 0.171 | 0.000 885 | 120 | 0.039 | 66.1 |
| 12 | 0.005 25 | 0.171 | 0.000 885 | 60 | 0.039 | 37.6 |
| *Small basket* | | | | | | |
| 13 | 0.004 24 | 0.106 | 0.001 38 | 180 | 0.038 | 23.9 |
| 14 | 0.004 24 | 0.106 | 0.001 38 | 120 | 0.038 | 20.9 |
| 15 | 0.004 24 | 0.106 | 0.001 38 | 60 | 0.038 | 12.9 |
| 16 | 0.004 24 | 0.106 | 0.001 38 | 45 | 0.038 | 11.1 |
| 17 | 0.005 80 | 0.110 | 0.001 79 | 210 | 0.044 | 40.0 |
| 18 | 0.005 80 | 0.110 | 0.001 79 | 150 | 0.044 | 34.4 |
| 19 | 0.005 80 | 0.110 | 0.001 79 | 90 | 0.044 | 25.5 |
| 20 | 0.005 80 | 0.110 | 0.001 79 | 60 | 0.044 | 19.5 |

**Table 2** Values of dimensionless parameters

| Test no. | $L_s/D_{50}$ | $U_\star^2/\gamma_s D_{50}$ | $t_\star U_\star/L_s$ | E (%) |
|---|---|---|---|---|
| *Medium basket* | | | | |
| 1 | 106 | 0.104 | 88.2 | 30.5 |
| 2 | 106 | 0.104 | 66.2 | 35.8 |
| 3 | 106 | 0.104 | 44.1 | 39.4 |
| 4 | 106 | 0.104 | 22.1 | 54.1 |
| 5 | 106 | 0.104 | 66.2 | 31.6 |
| 6 | 106 | 0.104 | 44.1 | 43.3 |
| 7 | 106 | 0.104 | 22.1 | 47.2 |
| 8 | 106 | 0.104 | 11.0 | 82.1 |
| *Large basket* | | | | |
| 9 | 160 | 0.085 | 66.5 | 38.2 |
| 10 | 160 | 0.085 | 39.9 | 45.9 |
| 11 | 160 | 0.085 | 26.6 | 59.6 |
| 12 | 160 | 0.085 | 13.3 | 67.8 |
| *Small basket* | | | | |
| 13 | 80 | 0.081 | 77.7 | 35.6 |
| 14 | 80 | 0.081 | 51.8 | 46.7 |
| 15 | 80 | 0.081 | 25.9 | 57.6 |
| 16 | 80 | 0.081 | 19.4 | 66.1 |
| 17 | 80 | 0.109 | 105.0 | 37.3 |
| 18 | 80 | 0.109 | 75.0 | 44.9 |
| 19 | 80 | 0.109 | 45.0 | 55.5 |
| 20 | 80 | 0.109 | 30.0 | 63.4 |

## RESULTS AND SUMMARY

The data in Table 1 were used to compute values of $L_S/D_{50}$, $t_*U_*/L_S$ and E for the sampling sequences. These values are given in Table 2. Values of E were plotted *vs.* $t_*U_*/L_S$ in Fig. 3 with $L_S/D_{50}$ as a parameter as suggested by equation (4). The plotted data, allowing for experimental error, fall on a single curve of E *vs.* $t_*U_*/L_S$, suggesting that for the values of $L_S/D_{50}$ tested the latter is not a significant independent variable. Data from Gibbs (1973) were then examined and compared with the results of the present tests. Gibbs used a basket sampler of the same size and shape as the medium basket for the present tests, obtaining two sets of data using a 1.4 and a 2.4 mm screen size. In both of these cases, $L_S/D_{50}$ was about 27. The data from Gibbs were plotted in Fig. 4 also as E *vs.* $t_*U_*/L_S$. The plot shows that the use of two markedly different screen sizes did not have an appreciable effect on the sampling efficiency because both sets of data can be well described by a single curve.

The curve from Fig. 3 is also drawn on Fig. 4. Comparison of these curves shows that the efficiency from the present tests is always higher. The difference is largest at small values of $t_*U_*/L_S$ and decreases as $t_*U_*/L_S$ increases, becoming very small as $t_*U_*/L_S$ approaches 100.

The only variable which can reasonably account for the

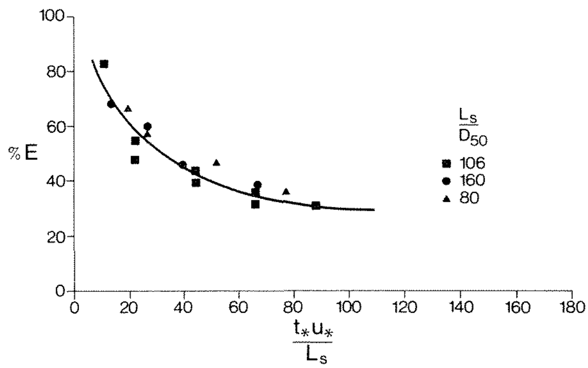



**Fig. 3** Efficiency as a function of $t_*U_*/L_s$ for three values of $L_s/D_{50}$.

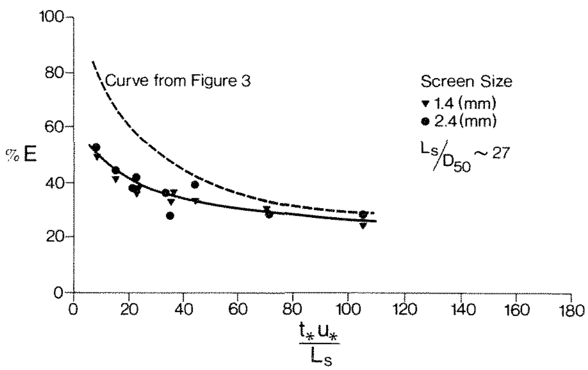



**Fig. 4** Efficiency as a function of $t_*U_*/L_s$ from data by Gibbs (1973).

differences in Figs 3 and 4 is $L_s/D_{50}$. The lowest value of $L_s/D_{50}$ in the present tests was 80 whereas the average value for the data of Gibbs was 27. This represents a difference by a factor of 3. Although data from the present experiments do not reveal any effect of $L_s/D_{50}$, it is quite possible that at some value of $L_s/D_{50}$ in the range of $27 \leq L_s/D_{50} \leq 80$, the variable $L_s/D_{50}$ begins to affect the relationship of E *vs.* $t_* U_* / L_s$. One could then visualize that the effect of $L_s/D_{50}$ would increase as $L_s/D_{50}$ decreased below values of 80 and expect to find a family of curves of E *vs.* $t_* U_* / L_s$ with $L_s/D_{50}$ as a parameter.

The values of $L_s/D_{50}$ of 80, 106 and 160 used in the present tests were quite large in relation to the values likely to be obtained in a river situation which are closer to the values of $L_s/D_{50} \sim 27$ used by Gibbs. Therefore, further tests in the range of $27 \leq L_s/D_{50} \leq 80$ are required to determine the effect of $L_s/D_{50}$.

For an ideal sampler the hydraulic efficiency is constant and hence its trapping efficiency should be constant. However, that this is not the case for a basket type sampler can be seen from the curves in Figs 3 and 4. The hydraulic efficiency of the basket sampler decreases as it fills up, resulting in a decrease in trapping efficiency. Hubbel (1964) suggested an efficiency of 45% for basket type samplers and Novak (1957) recommended efficiencies of 65%, 40% and 60% for the "wire mesh" type, "Nesper" type and "Ehrenberger" type basket samplers. However, examination of Fig. 3 shows that such values would be only obtained for very low values of $t_* U_* / L_s$. Therefore, calibration curves are necessary in order to obtain bed load transport using basket type samplers.

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