P-21 A Method for Identifying the Grain Size Distribution Type and Estimating the Porosity

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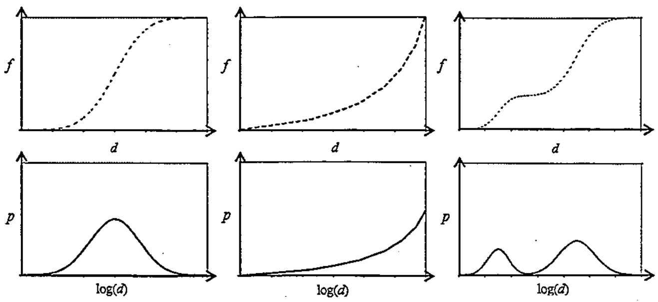
1 INTRODUCTION

Assessing the change in porosity of riverbed material is very important for an ecological issue in rivers. We have already developed a framework of the bed variation model available for the analysis of the change of porosity of bed material as well as the bed variation. In this framework, the porosity is assumed to be dependent only on the grain size distribution. Thus, it is necessary to relate the porosity of sediment mixture with the grain size distribution in the model. Actual sediment mixtures have various types of grain size distribution. However, it is not practical to obtain the porosity for each grain size distribution one by one in calculation of bed variation. It is better to install some relationships between porosity and typical grain size distribution in the bed variation model in advance. For that modeling, classification and identification of the grain size distribution type are necessary.

The purpose of this study is to develop a method for classifying the type of grain size distribution curves and estimating the porosity for the different type of grain size distribution.

2 TYPICAL GRAIN SIZE DISTRIBUTION

Riverbed materials have a variety of different characteristic size of bed surface sediment, but the grain size distribution could be classified into some types. In this study, the grain size distributions are roughly classified into three types of grain size distribution, namely, log-normal distribution, modified-Talbot distribution and bimodal distribution. Typical of the grain size distributions of sediment mixture are shown in Figure 1, where f is the percentage of the finer grain size and p(=df/d(log$d$)) is the density function of grain size.



(a) Log-normal type (b) Talbot type (c) Bimodal type

Fig.1 Typical of grain size distribution of sediment mixture and the density function of grain size

The density function of log-normal grain size distribution is as follows:

$$p(\ln d)=\frac{1}{\sqrt{2\pi}\sigma_L}\exp\left[-\frac{(\ln d-\ln d_{mg})^2}{2(\sigma_L)^2}\right] \quad (1)$$

where d_{mg} is the geometric average of grain size and σ_L is the standard deviation of ln$d$. Normalizing d with d_{mg}, σ_L is only a parameter of the log-normal distribution. The porosity of the mixture is, therefore, dependent on σ_L. For Talbot distribution, we modified the original Talbot distribution function, Eq.(2), with considering the minimum diameter of the grain size. The porosity of the mixture is determined with a coefficient namely Talbot number, n_T with $n_T > 1$, and ratio of maximum and minimum diameter, $d_{\max}/d_{\min}$.

$$f(d)=\left(\frac{d}{d_{max}}\right)^n \quad (2)$$

$$f(d)=\left(\frac{\log d-\log d_{\min}}{\log d_{\max}-\log d_{\min}}\right)^{n_T} \quad n_T>1 \quad (3)$$

A grain size distribution is said to be bimodal if the density distribution $p(d)$, displays two distinct peaks. Each peak is a mode of a portion of the distribution. When the geometric averages of grain size are d_{mgA} and d_{mgB}, the standard deviation are σ_{LA} and σ_{LB}, the mixing ratio are p_A and p_B (=1-p_A), the parameters governing porosity are σ_{LA}, σ_{LB}, d_{mgA}/d_{mgB} and p_A.

3 IDENTIFICATION AND CLASSIFICATION OF THE GRAIN SIZE DISTRIBUTION

A type of the grain size distribution can be determined by the shape of grain size distribution, the shape of density distribution, and the values of indices β and γ.

$$\beta=\frac{\log d_{\max}-\log d_{\text{peak}}}{\log d_{\max}-\log d_{\min}}\ ;\ \gamma=\frac{\log d_{\max}-\log d_{50}}{\log d_{\max}-\log d_{\min}} \quad (4)$$

where $d_{\max}$ is maximum size, $d_{\min}$ is minimum size, d_{50} is 50% size, and d_{peak} is a diameter which give maximum value of p. These indices designate the relative locations of d_{50} and d_{peak} between $d_{\min}$ and $d_{\max}$.

Based on the shape of grain size distribution and density distribution, the grain size distributions were classified into log-normal distribution if the trend of the size distribution curves similar to log-normal curve and the density distribution has a single peak. If the density distribution is skewed towards a high-end tail of distribution, the grain size distribution is classified into Talbot distribution. If the density distribution has two peaks, it's classified into bimodal distribution.

Based on the visual identification and the relation between β and γ from the eighteen grain size distribution data of natural riverbed material and produced sediment, the critical value of these indices for each type distribution can be determined. β and γ are 0.5 for ideal log-normal distribution and 0.0 for ideal Talbot distribution. The critical values of the indices were determined by adding and reducing a certain value α from the value of β and γ for log-normal distribution. According to the relation between β and γ, the value of $\alpha=\pm0.2$ is reasonable. Grain size distributions are classified into Talbot type if $\beta\leq0.3$ and $\gamma\leq0.3$, log-normal type if $0.3<\beta<0.7$ and $0.3<\gamma<0.7$ and anti-Talbot type if $\beta\geq0.7$ and $\gamma\geq0.7$.

4 MEASUREMENT OF POROSITY

Porosity is the most widely used parameter for assess the interstitial space both in sediments and in soils. The porosity is normally defined as the ratio of the pore volume to the total volume of a given sample. The porosity could have been calculated from the measured sediment volume base on a water displacement process (Figure 2).

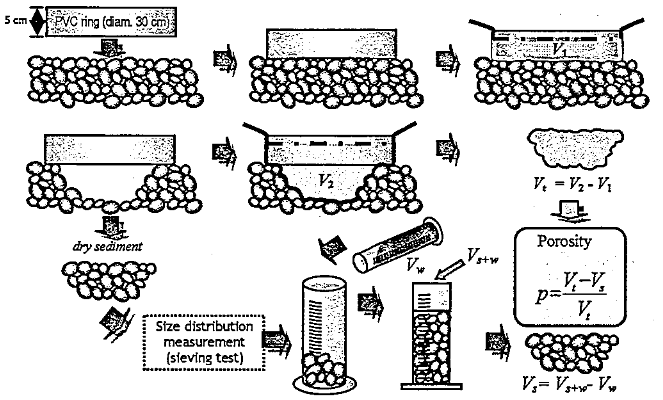


Fig.2 Measurement of porosity

The process for determining the porosity is as follows:

1. Set the ring on the streambed where the bed material porosity is to be measured.
2. Determine the volume of the ring below some datum (V_1) by fill the water.
3. Sample the surface bed-material layer
4. Determine the volume of the hole dug to remove the surface bed-material sample (V_2) by fill the water
5. Calculate the volume of the hole (V_t) = (V_2)-(V_1)
6. Sieve the sample and determine the size distribution curve.
7. Measure the volume of the sediment (V_s)
8. Calculate the porosity: $p=\frac{V_t-V_s}{V_t}$

A laboratory experiment and field observation were conducted to obtain the porosity of the sediment mixtures. Twelve different kinds of particle size distribution were prepared; consist of five lognormal distributions, two Talbot distributions and five bimodal distributions. The grain size distributions and observed porosities as related to the grain size parameter for each type distribution are presented in Figure 3. The relationship between the standard deviation, Talbot number, fine proportion of bimodal mixtures and the calculated porosities are also shown in Figure 3(a), 3(b) and 3(c) respectively.[1),2)]

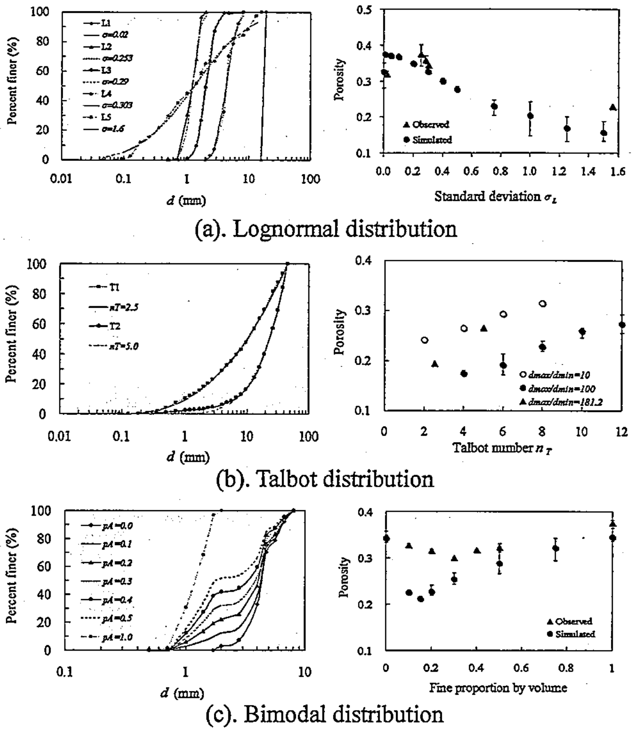


Fig. 3 Porosity sediment mixture

The results show that the porosity of log-normal distributions decreased with an increasing standard deviation. The porosity of Talbot distributions increased with an increasing of the Talbot number n_T. The porosity of bimodal distribution depends on the percentage of each fraction in the mixture and a porosity minimum is observed.

5 CONCLUSION

Grain size distribution of actual sediment mixture can be roughly classified into three types of distribution, namely, log-normal distribution, Talbot distribution and bimodal distribution, based on the mode of density distribution and indices β and γ. The porosity could be reasonably estimated by means of the presented method.

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