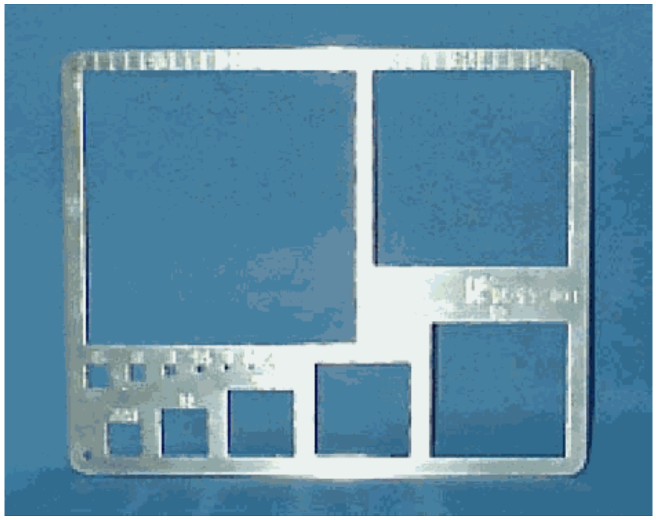
SAMPLING WITH THE US SAH-97 HAND-HELD PARTICLE SIZE ANALYZER



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Published by

FEDERAL INTERAGNECY SEDIMENTATION PROJECT
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http://fisp.wes.army.mil

October 2002

Sponsored by:

U.S. Army Corps of Engineers
U.S. Geological Survey
USAD Agricultural Research Service
U.S. Bureau of Reclamation
USDA Forest Service
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Sampling with the US SAH-97™ Hand-held Particle-Size Analyzer

Characteristics

Description: The US SAH-97™ is a hand-held sieving device used to grade or measure the size of gravel and small cobble bed-material particles in the field. Generic names are gravel templates, gravelometers, and pebblemeters.

The 11 inches by 13.5 inches (28 cm x 34 cm) device is constructed from 1/8 inch (0.32 cm) thick 6061 aluminum alloy. The US SAH-97™ has 14 square holes ranging in size from 2 mm to 180 mm so that individual holes advance in size by 1/2 phi units. A scale in 10 mm increments along one side can be used for measuring larger particles.

Sampler Function: The US SAH-97™ is used to sort the size of individual gravel and cobble particles into 1/2 phi size classes, very similar to sieving. The hand-held particle size analyzer reduces measurement errors among observers by eliminating incorrect identification and measurement of the intermediate particle axis. Classifying particle sizes on the basis of square openings in the size analyzer has the further advantage of providing a measure of size that is compatible with conventional sieving using square-hole mesh openings.

Limitations: Use of the US SAH-97™ is typically restricted to wadeable streams where pebble counts can be done. Particles sizes measurable with the device start at 2 mm. The largest particles that can be directly measured with the device are 180 mm. When encountering larger particles, the observer uses the ruler on the side of the template to visualize the size of a square hole with a side length of 256, 360, or 512 mm (etc.). The observer then visually estimates whether a boulder would pass through those square openings. Simply measuring the b-axis length often puts a boulder in a size class too large (see below) and thus overestimates the sizes of boulders.

Instructions for use of the US SAH-97™ Particle Size Analyzer

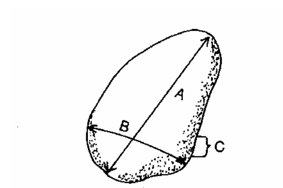
S**ampler Use:** Templates such as the US SAH-97™ particle size analyzer are commonly used for measuring particle sizes during pebble counts (Wolman 1954). They are also a convenient device for field sieving the cobble and coarse gravel portion of volumetric bed material samples. For pebble counts, samples should be collected within areas of equal grain-size composition. A riffle, for example, may have a relatively even grain-size distribution over its entire area and could serve as an appropriate sampling area. By contrast, a bar often shows systematic fining downstream and towards the banks and in this case, the bar should be divided into areas of equal grain-size composition. Similarly, if a streambed can be distinguished into areas with coarse, medium, fine and bimodal gravel, each of these areas should be sampled individually. The reach-average particle-size distribution is obtained by weighting the frequency distribution of each area by is relative size.

Other sampling strategies may be employed to address specific study objectives (Bunte and Abt 2001a; Kondolf 1997).

Particles should be sampled at regularly spaced points over the sampling area. This can be achieved by sampling along a tape measure across channel cross-sections, setting up a grid over the area to sample, using pace transects, or by using a portable sampling grid along a transect (Bunte and Abt 2001 b).

Serial correlation occurs if the size of particles sampled at a given location is influenced by the size of neighboring particles. To avoid serial correlation in the sample, the distance between successively collected particles should be chosen so that successive particles are at least several grain diameters apart. This can typically be achieved by setting the spacing between sampled particles to a distance larger than the intermediate axis of the largest particles in the population being sampled. If this distance still happens to place two neighboring sampling points onto one boulder, that boulder should only be counted once.

Field Operation: The observer picks up a particle and pushes the particle through one or smallest hole on the hand-held particle size analyzer through which the particle can pass. This hole size determines the particle's sieve diameter, also referred to as the intermediate, or b-axis, that is, the dimension of the particle that controls whether or not it passes a particular sieve size. This process is equivalent to hand-sieving particles one-by-one. Measuring particle sizes with the size analyzer is expedient because observers typically determine the appropriate size in the first or second try. Using size analyzers (templates) is about as fast as using rulers or calipers when particles are rounded and evenly shaped. Templates are faster than rulers or calipers when particles are angular or odd-shaped, because the operator does not have to search for the proper particle axis to measure. After measuring, the particle is placed back on the bed approximately at the same location from where it was picked. This procedure helps to keep bed disturbance at a minimum and avoids measuring the same particle a second time if it was inadvertently tossed into a cross-section still to be measured.



A = LONGEST AXIS (LENGTH)
B = INTERMEDIATE AXIS (WIDTH)
C = SHORTEST AXIS (THICKNESS)

Data Recording and presentation: Measured particle size is listed as "less than" the size of the smallest hole that the particle could pass. For example, a particle passing the 64 mm hole, but not the 45 mm hole, is listed as "less than 64 mm."

The total number of particles in each size class is tallied and divided by the total number of particles per sample to yield the percent frequency for each size class. Data are typically computed as cumulative frequency-by-number distributions and displayed with the x-axis showing the particle size in mm and the y-axis as "percent finer than." Figure 1 shows a typical spreadsheet for data analysis. When plotting the data, the x-axis is scaled logarithmically for particle size-classes in mm or linearly for particle sizes in phi (ϕ) units (ϕ_i = -3.3219 log D_i; $D_i = 2^{-\phi_i}$). For easy plotting, one can use a line or bar graph in a spreadsheet program and plot each particle-size class of mm units in even spacing, thus mimicking a logarithmic scale (Figure 2). However, such a plot is not well suited for graphical determination of percentiles.

Class Name	Size Class (mm)	Total Number	Percent Frequency	Cumulative Percent Finer
Fines	< 2.0	6	5.0	5.0
Very fine gravel	< 2.8	1	0.8	5.9
Very fine gravel	< 4.0	1	0.8	6.7
Fine gravel	< 5.6	0	0.0	6.7
Fine gravel	< 8.0	1	0.8	7.6
Medium gravel	< 11.3	3	2.5	10.1
Medium gravel	< 16.0	3	2.5	12.2
Coarse gravel	< 22.6	5	4.2	16.8
Coarse gravel	< 32.0	8	6.7	23.5
Very coarse gravel	< 45.3	10	8.4	31.9
Very coarse gravel	< 64.0	13	10.9	42.9
Small cobble	< 90.5	12	10.1	52.9
Small cobble	< 128	16	13.4	66.4
Large cobble	< 181	19	16.0	82.4
Large cobble	< 256	13	10.9	93.3
Boulder	≥ 256	8	6.7	100
	Totals:	119	100.0	

Figure 1. Example computation and size class data collected with a hand-held size analyzer.

Sample size: Typically, at least 100 particles are sampled. The user should consider, however, that in poorly-sorted coarse gravel and cobble beds, a 100-particle sample will only allow an accuracy of about ± 20-25% in the D_{50} (in mm) and D_{84} particle sizes. Sample size needs to approach 400 particles if the D_5 or D_{16} particle sizes are to be evaluated, or to cut the 20-25% error in the D_{50}, D_{84}, and D_{95} sizes to about ±10% (Rice and Church 1996). Increasing the sample size in the example data set (from 119 to perhaps 200 or 300) might have provided a smoother frequency and cumulative frequency distribution in Figure 2.

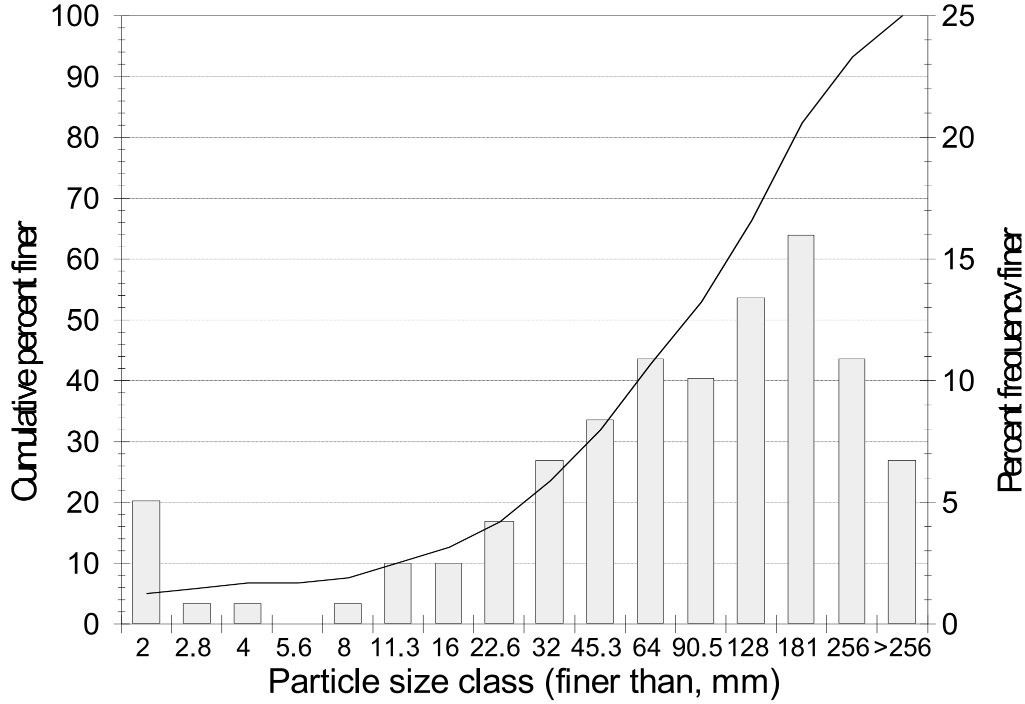


Figure 2: Plot of the frequency distribution (gray bars) and cumulative frequency distribution (curved line) of the data reported in Figure 1.

Deviation from ruler or caliper measurements: Intermediate diameters measured in the square holes of the hand-held particle size analyzer produce systematically smaller particle diameters than those measured with a ruler or calipers. This is because flat particles with a 70 or 80 mm b-axis can usually pass diagonally through the 64 mm square hole (Hey and Thorne 1983). By contrast, a ruler or caliper measurement of a 70 or 80 mm b-axis would place the particle in the size class of smaller than 90.5 mm. Thus, ruler or caliper measurements produce coarser particle-size distributions than those measured with square-hole sieves or a hand-held size analyzer. The magnitude of the differences depends on the shape of the particle: the flatter the particle shape, the larger the difference. Data can be computationally corrected as a function of the ratio between the b-axis (intermediate) and the c-axis (shortest principal axis) (Church et al. 1987). For very well-rounded river stones with almost equal b- and c-axes lengths, ruler and template measurements become identical and data adjustment is unnecessary.

Avoidance of observer errors: Measurement with the hand-held particle size analyzer is preferred over the use of a ruler or caliper because it eliminates two important sources of observer error: Incorrect reading of the ruler when measuring the b-axis and improper identification of the b-axis. When multiple operators re-measured pre-measured particles using a ruler, individual observers produced different results (Wohl et al. 1996). Incorrect identification of the b-axis is most pronounced among observers if the particle is angular or odd-shaped or has foliation or bedding structures that suggest a b-axis different from the morphological b-axis (Marcus et al. 1995). The use of hand-held particle-size analyzers virtually eliminates these observer errors.

Operator bias against fine and coarse particle sizes is a general problem of particle selection in pebble counts. The bias against fines is a result of the difficulty of identifying and picking up small particles with the tip of the finger. The practical lower limit of the sizes that may be sampled is usually between 2 and 8 mm (Church et al. 1987). Bias against fine sizes can be minimized by only sampling particles larger than 8 to 16 mm (the width of a typical finger). Particles smaller than the predetermined minimum size are recorded as less than the selected minimum size (e.g., less than 8 mm). Bias against coarse particles may stem from an operator's involuntary avoidance of particles that are difficult to extract from the streambed and results in an under-representation of cobbles within the sample. A sampling frame with thin elastic cross bands that expand over large particles may be used to precisely identify the particle to be sampled. This device helps to avoid observer bias against both fine and coarse particle sizes (Bunte and Abt 2001 b).

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