Computers & Geosciences 92 (2016) 104–116

Contents lists available at ScienceDirect

Computers & Geosciences

journal homepage: www.elsevier.com/locate/cageo

Case study

SANDY: A Matlab tool to estimate the sediment size distribution from a sieve analysis

Gabriel Ruiz-Martínez [a,*], Germán Daniel Rivillas-Ospina [b], Ismael Mariño-Tapia [a], Gregorio Posada-Vanegas [c]

[a] Departamento de Recursos del Mar, Centro de Investigación y de Estudios Avanzados del IPN, Mérida 97310, Yucatán, México
[b] Departamento de Ingeniería Civil y Ambiental, Instituto de Estudios Hidráulicos y Ambientales (IDEHA), Universidad del Norte, Barranquilla 1569, Colombia
[c] Laboratorio de Procesos Costeros, Instituto de Ecología, Pesquerías y Oceanografía del Golfo de México, Campeche 24029, México

ARTICLE INFO

Article history:
Received 20 February 2016
Received in revised form
13 April 2016
Accepted 20 April 2016
Available online 22 April 2016

Keywords:
Sand
Sediments
Size distribution
Sieving
Coast
Rivers

ABSTRACT

This paper presents a new computational tool called SANDY© which calculates the sediment size distribution and its textural parameters from a sieved sediment sample using Matlab®. The tool has been developed for professionals involved in the study of sediment transport along coastal margins, estuaries, rivers and desert dunes. The algorithm uses several types of statistical analyses to obtain the main textural characteristics of the sediment sample (D_{50}, mean, sorting, skewness and kurtosis). SANDY© includes the method of moments (geometric, arithmetic and logarithmic approaches) and graphical methods (geometric, arithmetic and mixed approaches). In addition, it provides graphs of the sediment size distribution and its classification. The computational tool automatically exports all the graphs as enhanced metafile images and the final report is also exported as a plain text file. Parameters related to bed roughness such as Nikuradse and roughness length are also computed. Theoretical depositional environments are established by a discriminant function analysis. Using the uniformity coefficient the hydraulic conductivity of the sand as well as the porosity and void ratio of the sediment sample are obtained. The maximum relative density related to sand compaction is also computed. The Matlab® routine can compute one or several samples. SANDY© is a useful tool for estimating the sediment textural parameters which are the basis for studies of sediment transport.

1. Introduction

The size distribution (SD) and textural characteristics (TC) of sediments are fundamental tools in Sedimentology, Geomorphology and Soil sciences. This involves the estimation of the cumulative mass percentage of established size fractions of the total mass of sediment. However, the quantification of SD and TC depends on the shape and density of the sediments, for this reason different techniques have been developed to compute them, which include: sieving, pipette-hydrometer, X-ray attenuation, scanning electron microscopy and laser diffraction. In the particle size analysis with sieves, the particles pass through a set of woven wire screens, with square apertures (rigidly mounted in a shallow cylindrical metal frame), and according to their size the sediments are retained in the sieves. The sieving technique is useful when the sizes of the sediment sample are between 2000 and 50 µm. The main advantages of this technique are that it can be performed at almost any location, and sieving is a simple, quick and reliable method of size analysis. On the other hand, the disadvantage of this technique is related to the size range of fine sediments since particles <50 µm need to be analyzed using other techniques (Gee and Bauder, 1986). The pipette and hydrometer techniques are used for particles with a size of <50 µm (clays and silts). The X-ray attenuation technique is based on the pipette method: in a vertical container with water, the number of particles which are settling is inferred by measuring the attenuation of an X-ray over time. The quantification of the attenuation allows the concentration of the particles to be determined. The X-ray attenuation technique can be applied to samples with a size range of 0.1–100 µm (McCave and Syvitski, 1991). In the scanning electron microscopy technique, the particle sample is scanned with a high-energy beam of electrons which produces an image of the surface of the sample. Using image analysis methods, the particles can be classified in different size fractions. The size range analyzed with this technique is 1–0.005 µm (Cheetham et al. 2008).

The laser diffraction technique involves the analysis of the patterns of scattered light produced when particles of different size are exposed to a beam of light. The size distribution is computed when the composite scattering pattern is analyzed by measuring the angular variation in intensity of light scattered; the

* Correspondence to: Ant. Carretera a Progreso km. 6, Cordemex, Merida 97310, Yucatan, Mexico.
E-mail address: gruizm@mda.cinvestav.mx (G. Ruiz-Martínez).

http://dx.doi.org/10.1016/j.cageo.2016.04.010
0098-3004/

relative amplitude of each angular variation is a measure of the relative volume of equivalent spherical particles of that size. The laser diffraction technique is suitable for particle sizes between 0.017 μm and 2000 μm. Underestimation of the particle sizes can occur for finer grains when the sediments have a lower sphericity (Hayton et al., 2001).

In order to compute the statistical parameters of sediment samples, graphical and statistical methods are used (Folk, 1964). These allow the properties of the sediment sample to be expressed in terms of statistics of deviations with respect to the normal distribution function. It is also possible to express the frequency analysis on the basis of statistical-mathematical principles which cover the entire distribution of sample sizes, without practical or theoretical limitations (Inman, 1952). Parameters that depend on statistical measures, including the median, sorting, skewness and kurtosis are applied with great ease using different methodologies (moments, quartiles, logarithmic graphics methods, etc.).

A methodology adopted to analyse the size distribution and textural characteristics of sediments is to compute the statistical parameters through a logarithmic expression which describes the conversion of the diameter (d) in millimeters to a function of phi-units (ϕ), using the equation $\phi = -\log_2 d$ (Krumbein, 1936). In the case of sediments, the mean diameter of the sample is taken as a measure of central tendency. In a normal distribution, the mean is the diameter that represents the center of gravity of the frequency distribution (Inman, 1952). On the other hand, the dispersion of the sediment size distribution of the sample can be measured by means of the sorting, which is a measure of the degree of uniformity or classification of the particles of sediment. The relevance of estimating this statistical variable lies in the desire to measure the dispersion of the sediment diameters with respect to the mean. Skewness is a statistical parameter that measures the degree of asymmetry of a distribution function, and indicates the proportion of coarse (positive asymmetry) or fine (negative asymmetry) material in the sample. This characteristic is also a measure of the distribution's deviation from normality. Kurtosis is a parameter that is used to measure the peakedness of the statistical distribution. It relates to the flatness/peakedness of the distribution in comparison to a normal distribution, and therefore also represents a measure of the deviation from normality e.g. when the sediments are poorly sorted, there is a tendency for the distribution curve to be flat and therefore the kurtosis will be considered platykurtic. If the distribution curve is strongly peaked, it can coincide with sediment exhibiting a good sorting and its kurtosis is leptokurtic (Friedman and Sanders, 1978).

The use of statistical parameters such as the skewness and kurtosis serve as a mechanism for identifying the origin of sediment or sedimentary environments. Furthermore they can help to identify whether there is a source of sediment that prevails in quantity with respect to other sources or conversely, all the sources of the area have sediment types with similar characteristics (Folk and Ward, 1957; Selley, 2000).

The process for establishing the size distribution tends to be a tedious task, since it requires setting the frequency distribution of the particle size and using a graphical method or statistical moments, to determine the different percentiles of the size of the sediment. However, with the advent of calculators and personal computers, the procedure for determining the size distribution of sediment and its textural characteristics from a sample has become simple (Kane and Hubert, 1963; Schlee and Webster, 1967; Mayo 1972; Slatt and Press, 1976; Sawyer, 1977; Benson, 1981; Pye, 1989; Poppe and Elisaon, 1999; Awad and Al-Bassam, 2001; Poppe, Eliason and Hastings, 2004). Moreover, the evolution of programming languages, the development of mathematical software and the growth of the internet have enabled the scientific community to create and share computational routines that help them to rapidly process the data. At present, Excel®, Matlab®, Python™ and R™ are the most commonly used software to perform numerical calculations. For example, Blott and Pye (2001) created a macro in Visual Basic® named GRADISTAT® that is an easy-to-use tool for users who are familiar with the management of spreadsheets; furthermore, Gallon and Fournier (2013) developed G2SD® which is a library for R™; the main advantage of G2SD® is that the code has been written for freely available software.

This paper presents the computer program SANDY©, a novel tool which allows the use of statistical analysis to determine the size distribution and the main textural properties of the sediment, using Matlab®. The functioning principles are based on data from a sieved sample of sediment taken from coastal and riverine environments.

The aim of this computational routine is to estimate the main percentiles and statistical parameters of the sediment sample. In the statistical analysis it is possible to define the parameters of the distribution with the Trask (1932), Inman (1952), Folk and Ward (1957), Kondolf and Wolman (1993) methodologies. The significant moments of the distribution function are computed with arithmetic, geometric and logarithmic procedures. SANDY© employs the Wentworth (1922) and ASTM (2011) scales to classify the sediment based on the skewness and kurtosis moments, and based on the Unified Soil Classification System (SUCS) it is possible to identify whether the sample is well or poorly sorted. SANDY© is an innovative code developed with a powerful programming tool (Matlab®), which is very easy to use and has many applications that can make the calculation of sediment sample parameters efficient.

In the first section of the paper general considerations related to SANDY© are provided. The next section describes the computational routine as well as its implementation process in Matlab®. In order to validate the results of the program, in the section of calibration and validation, the results of a RMSE and MSE analysis are given. As a case study, the characterization of sands in the Riviera Maya (Mexico) is presented. The characterization was carried out using the results that were obtained with the program SANDY©. In order to study the sediment, 107 sand samples were extracted from 35 measuring stations along the coast of the Riviera Maya; the sediment samples were subjected to field and laboratory analyses. SANDY© proved to be a great tool when estimating the textural sediment parameters

2. General considerations

SANDY© is a computer program that has been developed for coastal engineers, geologists, sedimentologists, coastal oceanographers and other professionals involved in projects related to sediment transport along coastal and river margins, where sand is the predominant beach material. SANDY© is a Matlab® script which allows the user to perform a size distribution analysis of sediment from a sieved sample of sand from a beach profile, the bed of a river, an estuary, the seafloor, or inland. The computation routine has been tested for Matlab® version 6.5 (R13) to version 9.0 (R2016a). Furthermore, the tool is programmed as a user function which does not require any special toolbox and requires only that Matlab® is installed on a personal computer with an Intel® Centrino® Duo or higher microprocessor. The user license is free and the script is available on the website for this paper (Appendix B).

In order to compute the sediment parameters, the computer program considers sediment and rock sizes ranging from large boulders to very fine sand (Table 1), hence only the results of the sieve technique are used as input data. Sieving is the most accurate method for the general analysis of sand and gravel. Sediments such as silts and clays should not be analyzed by the program. Moreover, countries such as France (AFNOR), Great Britain (BS) and the US (ASTM) have standard specifications regarding the wire