INTERNATIONAL

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Standard Practice for Using Significant Digits and Data Records in Geotechnical Data[1]

This standard is issued under the fixed designation D6026; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 Using significant digits in geotechnical data involves the processes of collecting, calculating, and recording either measured values or calculated values (results) or both. This practice is intended to promote uniformity in recording significant digits for measured and calculated values involving geotechnical data.

1.2 ~~This practice is intended to promote uniformity in recording significant digits for measured and calculated values involving geotechnical data.~~ The guidelines presented are industry ~~standard,~~standard and are representative of the significant digits that should ~~generally be retained.~~ be retained in general. The guidelines do not consider material variation, the purpose for obtaining the data, special purpose studies, or any considerations for the user's ~~objectives;~~objectives, and it is common practice to increase or reduce significant digits of reported data to be commensurate with these considerations. ~~It is beyond the scope of this practice to consider significant digits used in analysis methods for engineering design.~~

~~1.1.1 Using significant digits in geotechnical data involves the processes of collecting, calculating, and recording either measured values or calculated values (results), or both.~~

1.3 It is beyond the scope of this practice to consider significant digits used in analysis methods for engineering design.

1.4 This practice accepts a variation of the traditional rounding method that recognizes the algorithm common to most hand-held ~~calculators,~~ calculators and computers, see ~~5.2.3~~6.2.3. The traditional rounding method (see ~~5.2~~6.2) is in accordance with Practice E29, ASTM Manual 7, or IEEE/ASTM SI 10.

~~1.3 *This practice offers a set of instructions for performing one or more specific operations. This document cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of this practice may be applicable in all circumstances. This ASTM standard is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without consideration of a project's many unique aspects. The word "Standard" in the title means only that the document has been approved through the ASTM consensus process.*~~

NOTE 1—Calculators and computers often present and use many digits in their output and calculations, which may not all be significant. It is the responsibility of the programmer and user to make sure that the measured and calculated values are handled, interpreted and reported properly using these guidelines.

1.5 *This practice offers a set of instructions for performing one or more specific operations. This document cannot replace*

[1] This practice is under the jurisdiction of ASTM Committee D18 on Soil and Rockand is the direct responsibility of Subcommittee D18.91 on Standards Development and Review.

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*A Summary of Changes section appears at the end of this standard education or experience and should be used in conjunction with professional judgment. Not all aspects of this practice may be applicable in all circumstances. This ASTM standard is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without consideration of a project's many unique aspects. The word "Standard" in the title means only that the document has been approved through the ASTM consensus process.

1.6 This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D653 Terminology Relating to Soil, Rock, and Contained Fluids
D2435/D2435M Test Methods for One-Dimensional Consolidation Properties of Soils Using Incremental Loading
D4186/D4186M Test Method for One-Dimensional Consolidation Properties of Saturated Cohesive Soils Using Controlled-Strain Loading
E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E344 Terminology Relating to Thermometry and Hydrometry
E456 Terminology Relating to Quality and Statistics
E833 Terminology of Building Economics
IEEE/ASTM SI 10 Standard for Use of the International System of Units (SI): *The Modern Metric System*
MNL7 ASTM Manual 7 on Presentation of Data and Control Chart Analysis

3. Terminology

3.1 *Definitions:*

3.1.1 For common definitions of soil and rock terms in this standard, refer to Terminology D653.

3.1 *Definitions*—For common definitions of soil and rock terms in this standard, refer to Terminology D653.

3.2 This terminology standard contains many definitions that are applicable to this standard in a grouping named Measurement Grouping. These terms are: accuracy, bias, estimation, meaningful number/digit or significant number/digit, observation/observed value or data point/recorded value, precision, resolution or readability, sensitivity, signal noise or noise.

3.3 Other definitions that are relevant to this topic of data management or presentation or both are given below.

3.4 *Definitions of Terms Specific to This Standard:Definitions:*

3.2.1 *accuracy*—the closeness of agreement between a test result and an accepted reference value. (See Terminology E456.)

3.2.2 *calculated value, n*—the resulting value determined by processing measured value(s) using an equation.

3.2.2.1 *Discussion*—

In many cases the calculated value(s) is considered a determination value(s).

3.2.3 *determination value, n*—the numerical quantity calculated by means of the test method equation from the measurement values obtained as directed in a test method.

3.2.4 *measurement value, n*—the resulting value determined by measuring a dimension, quantity, or property.

3.2.4.1 *Discussion*—

In many cases the term "measured value(s)" is also referred to as "measurement value(s)".

3.4.1 *precision, significant digit/number/figure, n*—the closeness of agreement between independent test results obtained under stipulated conditions. (See Terminologyany of the integers one through nine and zeros except leading zeros and E456 – 08.)some trailing zeros.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

3.4.1.1 *Discussion—*
Precision depends on random errors and does not relate to the true or specified value.Zero is a significant digit if it comes between two non-zero integers.

3.4.1.2 *Discussion—*
The measure of precision usually is expressed in terms of imprecision and computed as a standard deviation of the test results. Less precision is reflected by a larger standard deviation.Zeros, after a decimal point and leading the first nonzero digit of a number, indicate the order of magnitude only and are not significant digits. For example, the number 0.0034 has two significant digits.

3.4.1.3 *Discussion—*
Zeros trailing the last nonzero digit for numbers represented with a decimal point are significant digits. For example, 4.00 and 4.01 have three significant digits.

3.4.1.4 *Discussion—*
"Independent test results" means results obtained in a manner not influenced by any previous result on the same or similar test object. Quantitative measures of precision depend critically on the stipulated conditions. Repeatability and reproducibility conditions are particular sets of extreme conditions.The significance of trailing zeros for numbers represented without the use of a decimal point can only be identified from a knowledge of the source of the value.

3.2.6 *rounding, n*—the process of reducing the number of digits in a number according to rules relating to the required accuracy of the value.

3.2.7 *significant digit*—any of the integers one through nine and zeros except leading zeros and some trailing zeros.

3.2.7.1 Zero is a significant digit if it comes between two non-zero integers.

3.2.7.2 Zeros leading the first nonzero digit of a number indicate the order of magnitude only and are not significant digits. For example, the number 0.0034 has two significant digits.

3.2.7.3 Zeros trailing the last nonzero digit for numbers represented with a decimal point are significant digits. For example, 4.00 and 4.01 have three significant digits.

3.2.7.4 The significance of trailing zeros for numbers represented without use of a decimal point can only be identified from knowledge of the source of the value.

3.4.2 *sensitivity analysis, n*—a test of the outcome of an analysis by altering one or more parameters from an initially assumed value(s). (See Terminologyor initial test E833 – 09a.)value(s).

3.4.2.1 *Discussion—*
Sensitivity analyses are often related to the design process, but not exactly applied in that design process. A sensitivity analysis might include how measured shear strength or hydraulic conductivity varies with molding water content and percent compaction.or percent compaction, or both.

3.4.3 *test result, n*—the value obtained by applying a given test method, expressed as a single determinationmeasurement or a specified combination of a number of determinations.measurements, calculations, or any combination.

3.4.4 *variability analysis, n*—the determination of the variation in values test results or property values (index or engineering) within a given boundary condition(s) condition(s).

3.4.4.1 *Discussion—*
A variability analysis might include how a given property varies with depth.

3.5 Data Processing Grouping, the following four definitions cover how one should cover the collection or processing of test data.

3.6 *Definitions:*

3.6.1 *measurement or measured value, n*—the act or process of quantifying a physical measurement; such as time, acceleration, dimension (length, diameter, depth, and circumference), force, mass, pressure, and velocity. This process would also include in many test methods the calculation of basic quantities which do not require any judgment, such as water content, void ratio, density, unit weight, stress, and strain. See *read or reading* and determination.

3.6.1.1 *Discussion—*
A typical example is: "Measure and record the height, diameter, and mass of the test specimen and calculate its density, in accordance with the requirements specified in this standard. or simply state Measure the density or water content." However, in

some standards, the apparatus specified internally makes the necessary measurements and calculations and displays a test result(s), such as a nuclear gauge. In such cases, an example is: "Measure and record the total density and water content using a nuclear gauge meeting the requirements specified in the apparatus section of this standard."

3.6.2 *read or reading(s), n*—the act or process of quantifying an instrument(s); such as dial gauge, burette, multimeter, transducer, or data acquisition system. See observation/observed value or data point/recorded value, mentioned above in 3.2.

3.6.2.1 *Discussion—*
A typical example is: "Read and record the dial gauge measuring the change in the height of the test specimen during consolidation at time intervals and meeting the requirements specified in this standard." For usage of a data acquisition system: "Read and record, at intervals specified in this standards the transducer's measuring the applied axial force, axial displacement, and cell pressure applied to the test specimen along with the internal pore-water pressure in the test specimen."

3.6.3 *calculation or calculated value, n*—the act or process of using an equation which converts a measured value(s) into another define quantity, without interpolation.

3.6.3.1 *Discussion—*
Some examples being: converting diameter to area or diameter and height to volume, or mass, height, and diameter to density.

3.6.4 *determine or determined value, n*—the act or process of quantifying measured or calculated or both value(s) into another value(s) that requires judgment based on education, training, or experience.

3.6.4.1 *Discussion—*
A simplified example is: "Determine the preconsolidation stress based on the test results from a consolidation test (either Test Method D2435/D2435M or D4186/D4186M)."

4. Summary of Practice

4.1 The user follows a set of guidelines that allow making decisions and actions that promote uniformity in the retention, rounding, and recording of significant digits for measured and calculated values involving geotechnical data.

4.2 The programmer and user make sure that the numbers are handled, interpreted, and reported accordingly for any specific requirements and caveats in the geotechnical standard for which the data were obtained.

5. Significance and Use

5.1 The guidelines presented in this practice for retaining significant digits and rounding numbers may be adopted by the using agency or user. ~~Generally, their~~ Their adoption should generally be used ~~for calculating~~to calculate and ~~recording~~record data when specified requirements are not included in a standard.

5.2 While this practice originated when most geotechnical data were manually collected and recorded on data forms, tables, or into computers, the use of digital acquisition, calculations, and reporting of data has become more common. When calculators and computers are used for data collection, the significant digits may not meet the requirements specified in this standard. Nevertheless, their use shall not be regarded as nonconforming with this practice.

5.3 The guidelines presented herein should not be interpreted as absolute rules but as guides to calculate and report observed or test data without exaggerating or degrading the ~~accuracy~~precision of the values.

5.3.1 The guidelines presented emphasize recording data to enough significant digits or the number of decimal places to allow sensitivity and variability analyses to be ~~performed, see~~ performed.~~3.2.~~

6. Guidelines for Rounding Numbers in Calculating and Recording Data

6.1 *General Discussion*—Rounding data ~~avoids~~avoid the misleading impression of precision while preventing the loss of information due to coarse resolution. Any approach to retention of significant digits of necessity involves some loss of information; therefore, the level of rounding should be selected carefully considering both planned and potential uses for the data. (See Practice E29.)

6.2 *Rounding Numbers*—When a numerical value is to be rounded to fewer digits than the total number available, use the following procedure ~~which is~~ shown in Table 1~~accordance with~~, per Practice E29, ASTM Manual 7 on Presentation of Data and Control Chart Analysis, or IEEE/ASTM SI 10:

~~When the first digit beyond the last place to be retained is:~~	~~The digit in the last place retained is:~~	~~– Examples~~
~~<5~~	~~unchanged~~	~~2.445 to 2.4~~
~~>5~~	~~increased by 1~~	~~2.464 to 2.5~~
~~Exactly 5~~	~~increased by 1 if it is odd unchanged if it is even~~	~~2.55 to 2.6 or 2.45 to 2.4~~
~~5 followed only by zeros~~	~~same as above for exactly 5~~	~~2.5500 to 2.6 or 2.4500 to 2.4~~

6.2.1 The rounded value should be obtained in one step by direct rounding of the most precise value available and not in two or more successive rounding steps. For example, 89 490 rounded to the nearest 1000 is at once 89 000. It would be incorrect to round first to the nearest 100, giving 89 500 and then to the nearest 1000, giving 90 000.

6.2.2 The same rule applies when rounding a number with many digits to a number with a few ~~digits as~~ digits. This typically occurs when using a computer or calculator that displays the ~~answer to a computation~~ computed answer as ten or more digits, and the answer is to be recorded to a few digits. For example, the number 2.34567 rounded to two significant digits would be 2.3.

6.2.3 Calculators and computers, in general, do not follow all the rules given in ~~5.2~~6.2, (that is, only rounding up odd digits followed by a five, while even digits stay the same (2.55 to 2.6 or 2.45 to 2.4)) and generally always round up. Recognizing the widespread use of calculators and computers that always round up, their use shall not be regarded as nonconforming with this practice. When carrying out computer calculations, do not perform intermediate rounding. Computations performed with spreadsheets or computer programs hold real numbers in double precision, about 17 digits, so concern about rounding during computation is largely unnecessary. Rounding of calculator and computer values is done when reporting the test result after all calculations have been completed. See Note 1.

6.2.4 The numbers to be reported are rounded at the end of calculations to the appropriate number of significant digits, not prior to the calculations. (See ~~5.4~~6.4.)

6.3 *Recording Measured Data*—When recording measured values, as in reading marks on a burette, ruler, or dial, record all ~~digits~~ known digits exactly, plus one digit, which may be uncertain due to estimation.

6.3.1 When the measuring device has a vernier scale, record the last digit from the vernier.

6.3.2 The number of significant digits ~~given~~displayed by a digital display or printout from an instrument should not be greater ~~than or~~than, but equal to the precision of the sensor to which it is connected. ~~Care should be taken not to record digits beyond the precision of the sensor, however. For example, using a pressure transducer with the precision of 1 kPa should not be read to the nearest 0.1 kPa because the readability of the output instrument displays more digits.~~ However, most digital apparatus record and/or display digits that are affected by "noise." Therefore, there needs to be some form of documentation specifying which digits are meaningful/significant. For example, one could tape over displayed digits that are not meaningful or in the heading of tabulated data, one could write/type "1st four digits are sufficient."

TABLE 1 Procedures and Examples of Rounding to Two Significant Digits

When the first digit beyond the last place to be retained is:	The digit in the last place retained is:	– Examples
<5	unchanged	2.445 to 2.4
>5	increased by 1	2.464 to 2.5
Exactly 5	increased by 1 if it is odd unchanged if it is even	2.55 to 2.6 or 2.45 to 2.4
5 followed only by zeros	same as above for exactly 5	2.5500 to 2.6 or 2.4500 to 2.4