Designation: D 6026 – 01^ε1

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

This standard is issued under the fixed designation D 6026; 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.

ε[1] NOTE—Section 6.1.2.3 was corrected editorially in August 2002.

1. Scope *

1.1 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, and are representative of the significant digits that should generally be retained. The guidelines do not consider material variation, purpose for obtaining the data, special purpose studies, or any considerations for the user's objectives; and it is common practice to increase or reduce significant digits of reported data to 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.

1.2 This practice accepts a variation of the traditional rounding method that recognizes the algorithm common to most hand-held calculators, see 5.2.3. The traditional rounding method (see 5.2) is in accordance with Practice E 29 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 of this document means only that the document has been approved through the ASTM consensus process.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 653 Terminology Relating to Soil, Rock, and Contained Fluids[2]

D 2905 Practice for Statements on Number of Specimens for Textiles[3]

D 4356 Practice for Establishing Consistent Test Method Tolerances[4]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[4]

E 344 Terminology Relating to Thermometry and Hydrometry[5]

E 456 Terminology Relating to Quality and Statistics[2]

E 833 Terminology of Building Economics[6]

IEEE/ASTM SI 10 Standard for Use of the International System of Units (SI): *The Modern Metric System* [4]

3. Terminology

3.1 *Definitions:*

3.1.1 For common definitions of soil and rock terms in this standard, refer to Terminology D 653.

3.1.2 *accuracy*, *n*—the degree of agreement of an individual measurement or average of measurements with an accepted reference value, or level. See Terminology E 344 - 97

3.1.3 *calculated value*, *n*—the resulting value determined by processing measured value(s) using an equation. See Practice D 4356 - 84(Reapproved 1996).

3.1.3.1 *Discussion*—In many cases the calculated value(s) is considered a determination value(s).

3.1.4 *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. See Practice D 4356 - 84(Reapproved 1996).

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

3.1.5.1 *Discussion*—In many cases the term "measured value(s)" is also referred to as "measurement value(s)". See Practice D 4356 - 84(Reapproved 1996).

[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.

Current edition approved Nov. 10, 2001. Published January 2002. Originally published as D 6026–96. Last previous edition D 6026–99.

[2] *Annual Book of ASTM Standards*, Vol 04.08.
[3] *Annual Book of ASTM Standards*, Vol 07.01.
[4] *Annual Book of ASTM Standards*, Vol 14.02.
[5] *Annual Book of ASTM Standards*, Vol 14.03.
[6] *Annual Book of ASTM Standards*, Vol 04.07.

***A Summary of Changes section appears at the end of this standard.**

3.1.6 *precision*, *n*—the closeness of agreement between independent test results obtained under stipulated conditions. See Terminology E 456 - 96.

3.1.6.1 *Discussion*—Precision depends on random errors and does not relate to the true or specified value.

3.1.6.2 *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.

3.1.6.3 *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.

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

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

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

3.1.8.2 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.

3.1.8.3 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.

3.1.8.4 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.

3.1.9 *test result*, *n*—the value obtained by applying a given test method, expressed as a single determination or a specified combination of a number of determinations. See Practice D 2905 - 91.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *sensitivity analysis*, *n*—a test of the outcome of an analysis by altering one or more parameters from an initially assumed value(s). See Terminology E 833 - 97b.

3.2.1.1 *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.

3.2.2 *variability analysis*, *n*—the determination of the variation in values within a given boundary condition(s)

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

4. Significance and Use

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

4.2 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 of the values.

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

5. Guidelines for Rounding Numbers in Calculating and Recording Data

5.1 *General Discussion*—Rounding data avoids 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 E 29.

5.2 *Rounding Numbers*—When a numerical value is to be rounded to fewer digits than the total number available, use the following procedure which is in accordance with Practice E 29 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

5.2.1 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.

5.2.2 The same rule applies when rounding a number with many digits to a number with a few digits as occurs when using a computer or calculator that displays the answer to a computation 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.

5.2.3 Calculators and computers, in general, do not follow all the rules given in 5.2, (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.

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

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

5.3.2 The number of significant digits given by a digital display or printout from an instrument should be greater than or equal to 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.

5.4 *Calculation of Measured Data*—When using measured values to produce a calculated value(s), avoid rounding of intermediate quantities. As far as practicable with the calculation device or data sheet/form used, or both, carry out calculations exactly as they occur (no reduced digits) and round the final value/result.

5.5 *Recording Data*—The recorded data should conform to instructions in the respective standards. For example, the computed water content values used in determining the liquid and plastic limits of a soil are recorded on the data sheet/form to the nearest 0.1 %, see Table A1.1. While the liquid and plastic limits are recorded, reported, or summarized to the nearest whole number and the percent designation is omitted.

5.5.1 If the number of significant digits or number of decimal places in the measured and calculated value(s) is not specified in the respective standard, then one may use the following approach. Use Table A1.1 to determine the number of significant digits or number of significant digits or number of decimal places in the calculated value(s). Using that value(s) and the rules of significant digits as described in Section 6, determine the required significant digits or number of decimal places for the measured value(s).

5.5.2 If a standard has a conflict between the measured and calculated value(s) related to significant digits or number of decimal places, then use the following criterion. The criterion specified for calculated value(s) should govern how the measured value(s) is determined and recorded.

6. Guidelines for Retaining Significant Digits in Calculating and Recording Data

6.1 Upon completion of mathematical calculations, use the following rules as guidelines to determine the proper number of significant digits or decimal places of rounded numbers.

6.1.1 The rule when multiplying or dividing is that the result shall contain no more significant digits than the value with the smaller number of significant digits. Examples include:

6.1.1.1 $11.38 \times 4.3 = 49$, since the factor 4.3 has two significant digits.

6.1.1.2 Determine the volume, *V*, of an object having a base area, *A*, of 28.48 in.^{2} and a height, *h*, of 6.12 in., $V = Ah = (28.48 \text{ in.}^2)(6.12 \text{ in.}) = 174$, the answer to three significant figures in agreement with the height measurement.

6.1.2 The rule when adding or subtracting data is that the number of decimal places in the result is the same as in the number containing the fewest digits following the decimal. Examples include:

6.1.2.1 $11.24 + 9.3 + 6.32 = 26.9$, since the last significant digit of 9.3 is the first following the decimal place, and 26.9 results by rounding the exact sum, 26.86.

6.1.2.2 $(926 - 923.4) = 3$.

6.1.2.3 $(926 - 923.4)\ x\ 11.38\ x\ 4.68/2.00 = 70$, not 69 or 69.2 since there is only one significant digit in the difference. This means, although there is a minimum of three significant digits in the input values, you could only record or expect to check the result to one significant digit. This is an important factor to consider when recording and checking a calculated value(s) that include a difference(s), see Note 1.

NOTE 1—Typical examples of calculated values which include a difference(s) are water content, void ratio, deformation, degree of saturation, and specific gravity.

6.1.3 The rules for logarithms and exponentials are: digits of $\ln(x)$ or $\log_{10}(x)$ are significant through the *n*th place after the decimal when *x* has n significant digits. The number of significant digits of e^x or 10^x is equal to the place of the last significant digit in *x* after the decimal. Examples include:

6.1.3.1 $\ln(3.46) = 1.241$ to three places after the decimal, since 3.46 has three significant digits.

6.1.3.2 $10^{3.46} = 2{,}900$ has two significant digits, since 3.46 is given to two places after the decimal.

6.1.4 When an exact count is used in a calculation with a number, the number of significant digits in the result is the same as the number of significant digits in the number. For example, the sum of two measurements was found to be 8.24 in. To find the average value, this sum must be divided by two. In this case, however, two is not a measurement but an exact count. Therefore, 8.24 in./2 = 4.12 in. Since 8.24 has three significant digits, the results also contain three significant digits.

6.1.5 To preserve accuracy in calculations using constants, or conversion factors with measured values, these non–measured values should retain at least one more significant digit than the measured number. For example, compute the inside circumference, *C*, of a mold having an inside diameter, *d*, of 6.025 in. The example calculation is:

$$C = \pi d = \pi \times (6.025) = (3.1416) \times (6.025) = 18.93 \text{ in.}$$

7. Guidelines for Applicability to Committee D-18 Standards

7.1 If the rounding method of Section 5 is to apply to all data in the standard, and if all numbers expressed in the standard are to conform to the guidelines for significant digits as described in Section 6, then a statement similar to the following should be included in the scope of the standard:

7.1.1 *All measured and calculated values shall conform to the guidelines for significantdigits and rounding established in Practice D 6026.*

7.2 If results are to be compared with specification limits, a statement similar to the following should be included in the procedure or report section of the standard:

7.2.1 *For purposes of comparing a measured or calculated value(s) with specified limits, the measured or calculated value(s) shall be rounded to the nearest decimal or significant digits given in the specification limits in accordance with the provisions of Practice D 6026.*

NOTE 2—In preparing this statement, the author might want to replace "measured or calculated value" with the appropriate name of that value(s) given in the standard

8. Keywords

8.1 data; data management; determination value; measurement value; recording data; rounding numbers; significant digits; test result

ANNEX

(Mandatory Information)

A1. Recommended Rounding for Processing Geotechnical Data

A1.1 See table below.

Recommended Rounding for Processing Geotechnical Data[A]

Geotechnical Property	Common Units: SI	Common Units: Inch-Pound	Expressed to Nearest Decimal or Significant Digits[B]
Index and Related Properties			
Atterberg Limits			Nearest whole unit in %
Density, total/moist and dry	g/cm^3, Mg/m^3, kg/m^3	$slugs/ft^3$, lbm/ft^3[C]	3 or 4 significant digits[D]
Effective particle diameter	mm	in.	2 or 3 significant digits
Percent passing (gradation)	%	%	Nearest 0.1
Percent/Relative Compaction	%	%	Nearest 0.1
Relative density	%	%	Nearest 0.1
Specific gravity			3 significant digits
Unit weight, total/moist and dry	kN/m^3	lbf/ft^3	3 or 4 significant digits
Void ratio or porosity			2 or 3 significant digits
Water content	%	%	Nearest 0.1[E]
Engineering and Related Properties			
Angle of shear resistance	degrees	degrees	Nearest 0.1
Axial strain	%	%	3 significant digits[F]
Coefficient of consolidation	m^2/s, m^2/day, m^2/y	ft^2/day, ft^2/y	2 significant digits
Cohesion	kN/m^2, kPa	psi,ksf	2 significant digits
Compression indexes	ratio of (Δe, $\Delta \epsilon_a$, $\Delta \epsilon_V$) to (Δstress or Δlog stress)		2 or 3 significant digits, but ≤4 decimal places
Hydraulic head	cm or m of H_20	in. or ft of H_20	3 significant digits
Hydraulic conductivity	m/s, m/day, m/y	ft/day, ft/y	2 or 3 significant digits
Moduli	kN/m^2, kPa	psi, ksf	3 significant digits
Percent consolidation	%		Nearest 0.1
Pore pressure parameters			3 significant digits[F]
Preconsolidation stress	kN/m^2, kPa	psi, ksf	2 significant digits
Stress or pressure	kN/m^2	psi, ksf	3 siginificant digits[F]
Velocity	m/s	ft/s	3 significant digits

[A] The significant digits and nearest decimal places presented in this table are not directly related to the precision with which the data can or should be applied in design or other uses, or both. How one applies or transmits the results obtained using standards under the jurisdiction of ASTM Committee D18 on soil and Rock are usually not within their scope, unless specified otherwise. However, it is common practice to use fewer significant digits in design and transmittal of data than given above.

[B] For studies involving a specialized application(s), more significant digits or decimal places might be required than recommended above. Since there is such diverse application of sensitivity studies, a range of significant digits is given in some cases.

[C] This unit should not be used in standards under the jurisdicition of ASTM Committee D18 on Soil and Rock, because Committee D18 has decided to use the gravitational system of inch-pound units; i.e. a pound represents a unit of force not mass.

[D] If four significant digits are required, the dimensions of specimens have to be measured to four significant digits; i.e., typically to the nearest 0.01mm or 0.001 in. In addition, if the total density is calculated based on a dry density and water content, the dry density requires four significant digits and the water content (not in percent) to three decimal places.

[E] Recording the water content to the nearest 0.1 percent yield four significant digits in the calculation of one plus the water content (not in percent),even if the water content is greater than 99.9 percent.

[F] At the start of loading, there might not be enough significant digits to have the prescribed significant digits in the calculated value(s). However, it is acceptable practice to record those calculated values with fewer than the number of significant digits given above without being in nonconformance with this practice

SUMMARY OF CHANGES

In accordance with Committee D18 policy, this section identifies the location of changes to this standard since the 1999 edition that may impact the use of this standard

(1) Reworded 1.2.

(2) In 5.2, changed the procedure given for rounding numbers so they would be in accordance with Practice E 29 and IEEE/ASTM SI 10, that is the traditional rounding method which only rounds up odd digits followed by a five, while even digits stay the same (2.55 to 2.6 or 2.45 to 2.4).

(3) In 5.2.3, reworded to state that the use of calculators or computers, which always round up a number followed by a 5 (2.45 to 2.5) shall not be regarded as nonconforming with this practice.

(4) In Table A1.1, for coefficient of consolidation and hydraulic conductivity changed the recommended SI units of cm^2/s and cm/s to m^2/s and m/s, respectively. In addition, for coefficient of consolidation the SI unit of m^2/day was added and the

abbreviation for year was corrected from “yr” to “y”.