Initiative on Dimensional Tolerances in Construction
Surface Compliance Design Issues
By David Ballast, AIA, CSI, March, 2007

Tolerances and measurement methods of surfaces have been ongoing issues among architects, building owners, and others when trying to meet the dimensional requirements of the ADA Accessibility Guidelines (ADAAG).

Although the ADAAG states that all dimensions are subject to conventional industry standard tolerances, in many instances there are no standard tolerances for the various accessible elements mentioned in the ADAAG. In addition, ADAAG does not address the question of how measurements should be taken to verify compliance.

This paper discusses some of the design issues involved with surface tolerances and measurement from the standpoint of the designer. Other papers discuss usability by disabled persons and constructability issues from the viewpoint of the contractor. The design issues discussed in this paper fall into three broad categories:

(1) the language of measurement, which includes current measurement units, tools and protocols,
(2) construction tolerances, which includes existing industry tolerances and suggested tolerances, and
(3) communicating needs, which includes the current and suggest methods of using drawings, specifications, and other means to clearly define design intent.

The language of measurement

Units of measure

In the United States the inch-pound system of is still the predominant method used for construction measurement. The SI system is used for federal construction, military work, and for work done outside of the U.S. Because both units are included in ADAAG, conversion is not necessary. Units of length are generally in feet, inches, and fractions of an inch for most architectural and interior design work and in feet and decimals of a foot for civil engineering work. Millimeters and meters are used when the SI system is employed.

Angles and slope are expressed in many different ways in architectural and landscape design. For slopes and angles in the inch-pound system designers use percent (feet per 100 feet), ratio (e.g. 1:12), inches per foot, degrees, and inches per 12 inches (for roof slope). These different methods can cause confusion, errors, and create some difficulty in converting one unit to another.

For surface smoothness and planarity, the traditional system has been to describe the amount of variation from a true plane within a certain distance, such as 1/4 inch under a 10-foot straightedge. Newer electronic devices make it possible to express and measure planarity more precisely, such as with the F-number system.

The expression of measurement

Expression is how a measurement is stated, whether it is a design requirement or a measurement of an existing physical element. How a value is stated may imply, but doesn't always, a certain amount of accuracy. For example, saying something is 2.5568 feet long implies a precise instrument was used to take a measurement very accurately. Saying the same thing is "two and one-half feet long" implies the measurement is approximate.

In the way most construction measurements are expressed, the number may or may not indicate the accuracy of the measurement. For example, in most construction work, writing or saying an item is 6 feet, 4 inches long could mean it is very close to that length, say within 1/16 inch, or that the measurement has been rounded off to the nearest inch and the measurement is only within about one half inch of the stated value. In the architectural and construction industries there is no standard way, on a typical basis, of designating the precision of a measurement when the feet and inch system is used.

When using SI units the situation is less ambiguous. Because it is standard practice in the construction industry to use either millimeters or meters for design dimensions and most tape measures and other instruments are graduated in millimeters, a measurement in millimeters, especially if it ends in a non-zero number, implies an accuracy of ±0.5 mm. If meters are being used the position of the decimal point (if any) indicates (or should indicate) the precision based on significant figures as discussed in the next section.

One of the problems with using fractional units in construction is that fractions are expressed to the nearest "reduction" even though the measurement might have been made more accurately. For example, a measurement expressed as 4-3/4 inches could mean the item was measured as 4-12/16 inches with the fraction reduced or that it was measured to the nearest quarter of an inch so the accuracy is ±1/8 inch rather than ±1/32 inch.

Significant figures

Significant figures in a number are all the non-zero digits, any zeros between them, and any trailing zeros to the right of the decimal place. Significant figures can be used to express a desired degree of accuracy or to imply an uncertainty in measurement. However, they can only be used with decimal numbers. They cannot be extended to fractional measurements like 1/4 inch, based on current practice, which is to reduce fractions. 1/4 inch could be expressed as 4/16 to indicate that the nearest sixteenth of an inch was the accuracy, but this would take a change in industry standard practice. Another way to do the same thing would be specifically indicate with a dimension the tolerance required. For example, 6'-4" (±1/8"). Converting a fraction to a decimal would be problematic.

For slopes, the use of percent or angles as units allows decimals to indicate accuracy or uncertainty, but "fractions of an inch per foot" does not.

Rounding

Rounding is the reduction of the significant digits in a number while trying to keep it value similar. Generally, rounding is performed one of two ways.

(1) If the last digit is between 1 and 4 the next to the last digit remains as is. If the last digit is between 5 and 9, the next to the last digit is increased by 1.

(2) Similar to the first method except than when the last digit is 5 the next to the last digit is increased by 1 if it is an odd number; otherwise, the next to the last digit is left even. This is sometimes known as the "round to even" method and attempts to eliminate bias that results when 5 is always rounded up.

The National Institute of Standards and Technology, in its Handbook 44, Section 10.2, gives general rules for rounding-to-even as described above in addition to other guidelines. The NIST Handbook 44, Section 10.4 also gives rules for rounding common fractions. The rules are applied to the numerators of the fractions that have, if necessary, been reduced to a common denominator. If the numerator is less than one-half, then drop, if more than one-half, then add. If the numerator is exactly one-half, then round to the nearest even numerator in the round-off fraction. For example, rounding off a 3/8 inch measurement to the nearest quarter inch would be ½" because it is between ¼ inch and 2/4 inch and the numerator in the 2/4 is even.

However, 5/8 inch would be rounded down to ½ inch because the numerator in 2/4 is even, rather than the odd numerator in ¾ inch.

Metric and metric conversions

No direct conversions from English units to SI units are required because both units are given in ADAAG. However, most of the dimensions given in accessibility guidelines have been derived from research conducted in English units. In addition, metric equivalents currently incorporated in ADAAG do not conform to transportation industry practices. The Access Board has proposed a conversion table when converting from English units to the SI equivalent that includes rounding of the metric equivalent.

English

(inch/feet) Metric Rounding Tolerance
(inches x 25.4, rounded to mm/m)
< ½ inch   nearest tenth of a millimeter
½ inch to < 3 inches   nearest millimeter

3 inches to < 10 feet   nearest 5 millimeters

10 feet to ~ 33 feet   nearest 10 millimeters (where conversion is less than 10 000 mm)

~ 33 feet and greater   nearest meter (where conversion equals or exceeds 10 000 mm)