

Part 1

Construction Tolerances

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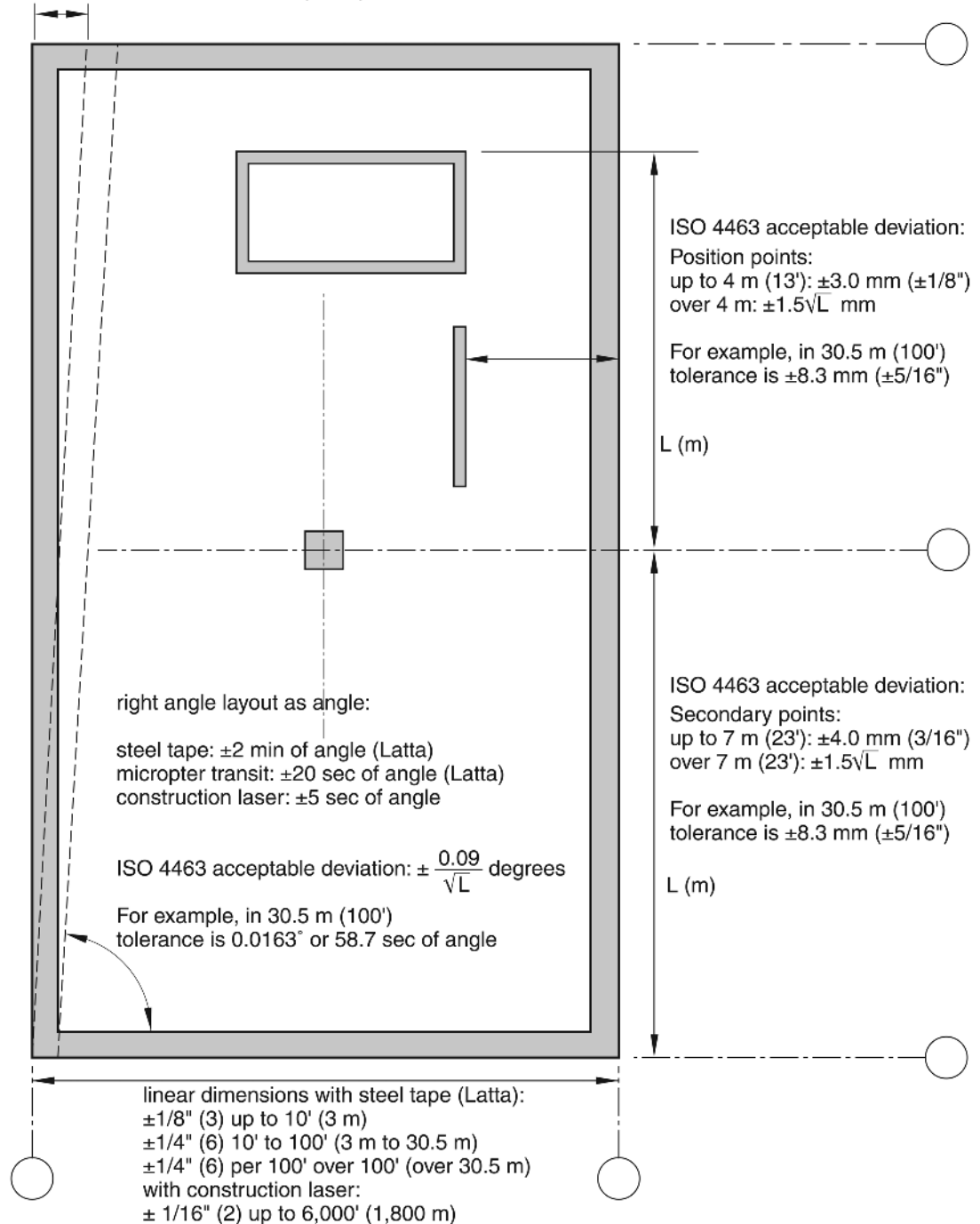
Figure 1–1 Horizontal building layout

right angle as offset:

steel tape: $\pm 3/4"$ (19) in 100' (30.5 m) (Latta)
 micropter transit: $\pm 1/8"$ (3) in 100' (30.5 m) (Latta)
 construction laser: $\pm 1/32"$ (0.74) in 100' (30.5 m)

ISO 4463 acceptable deviation: $\pm 1.5\sqrt{L}$ mm

For example, in 30.5 m (100')
 offset tolerance is ± 8.3 mm ($\pm 3/8"$)



Chapter 1

Building Layout and Sitework

1–1 Horizontal Building Layout

Description

One of the first sources of inaccuracies in building construction is the establishment of horizontal and vertical referencing systems for the layout of a building and subsequent marking of lines and benchmarks for horizontal and vertical dimensions as construction proceeds. Layout is dependent on the accuracy of the instruments used, as well as on environmental conditions and the skill of the people doing the layout. This section includes some of the horizontal layout accuracies possible with various instruments, assuming the surveyor uses a normal degree of skill. This section also gives accuracy standards given in three publications. Refer to sections on specific materials for industry standard tolerances for each specific material. Refer to Chapter 17 for more information on the accuracy of measuring instruments and methods of measurement.

With currently available surveying equipment, it is possible to lay out a building and monitor construction with a high degree of accuracy, in many cases much higher than is generally required for most construction. Because of this fact and because there are few standards for general building layout, the architect and engineer should clearly state in the specifications what tolerances are required, recognizing that higher degrees of accuracy generally will result in higher costs.

References

- Latta, J. K. "Inaccuracies in Construction," *Canadian Building Digest* 171, April 1975.
In *Canadian Building Digests*, 151–200 (Ottawa, ON: Institute for Research in Construction, National Research Council Canada, 1989).
- Model Standards of Practice* (Gaithersburg, MD: National Society of Professional Surveyors, 2003) www.acsm.net/nsps/modelstandards.html.
- NIST Handbook 44-2003*, Section 5.52 (Gaithersburg, MD: National Institute of Standards and Technology) <http://ts.nist.gov/ts/htdocs/230/235/h442003.htm>.
- Product literature: Faro Technologies, Inc. (www.faro.com), Leica Geosystems (www.leica-geosystems.com), Topcon Positioning Systems (www.topcon.com), and Trimble (www.trimble.com).
- ISO 4463-1, *Measurement Methods for Buildings—Setting Out and Measurement—Part 1: Planning and Organization, Measuring Procedures, Acceptance Criteria*, November 1 (Geneva, Switzerland: International Organization for Standardization, 1989).

Allowable Tolerances

Although there are no generally accepted standards that are widely used for building layout in the United States, one international standard and one U.S. model standard may be used to gauge what is realistically possible for most building construction and layout of site elements. These standards may be used to guide the development of specifications for individual building projects or to determine a reasonable standard in the absence of specific project requirements.

International standard ISO 4463-1, *Measurement Methods for Building—Setting Out and Measurement*, describes procedures for establishing a survey grid, relating it to a building site, and establishing building layout and control points based on property boundaries and major survey control points. It gives guidance on measurement methods and acceptance criteria (tolerances) for various stages of the process, which includes the primary system, the secondary system, and position points. The primary system is connected to the official control system (national, municipal, or other higher-order coordinate system) and normally covers the entire site. The secondary system is that structural or other grid reference system that is used for the erection of a particular building. Position points mark the location of individual elements in the building, both horizontally and vertically. The standard gives acceptance criteria for distance measurement, angle measurement, plumbing, and the establishment of levels. The ISO acceptance criteria are shown in Figure 1-1 for secondary and position points and in Figure 1-1.1 for primary positioning. For building construction, the accuracy of individual building layout (secondary points) and position points within a building are, in most cases, more important than the exact position of the building on the site. The acceptable values in ISO 4463-1 are for general layout and not specific materials. In this standard, the tolerance level is typically given in terms of the length being measured.

For the structural grid or reference grid of a building, ISO 4463 suggests that a reasonable linear dimension tolerance can be ± 4.0 mm ($\pm \frac{3}{16}$ in.) for distances up to 4 m (13 ft.) and ± 1.5 mm for distances over 4 m (13 ft.), where L is the length in meters. For position points, ISO 4463 suggests that a reasonable tolerance can be ± 3.0 mm ($\pm \frac{1}{8}$ in.) for distances up to 4 m (13 ft.) and ± 1.5 mm for distances over 4 m (13 ft.) where L is the length in meters. These numbers are very close to the linear accuracies published by the Institute for Research in Construction (IRC) in 1975 (Latta).

For right angle layout, ISO 4463 suggests that a reasonable angular tolerance can be $\pm$ degrees, where L is the length in meters of the shorter side of the angle. In a 30.5-m (100-ft.) length, this translates to a tolerance of approximately 1 minute of angle (0.0163°). This is well within the accuracy standards of transits as well as construction lasers. Viewed in terms of an offset over a length of 30.5 m (100 ft.), ISO 4463 suggests an allowable tolerance of ± 8.3 mm ($\pm \frac{3}{8}$ in.). Again, this is well within the capabilities of a standard transit as published by the IRC in 1975 and is easily accomplished with construction lasers.

In the United States, the National Society of Professional Surveyors (NSPS) publishes model standards that are intended to be used as guidelines for those individual state associations, professional registration boards, state surveying agencies, and others who have the authority of set standards. Section D of these model standards is for construction layout surveys and the recommended positional accuracies are given in Table 1-2 in Section 1-6.

The NSPS standard for building offset stakes is ± 10 mm (0.03 ft.) for horizontal positional accuracy. Positional accuracy in this standard is given at the 95 percent confidence level. This means, for example, that if a 200-ft. (61-m) distance is measured 100 times, the measurement will be between 199.97 ft. and 200.03 ft. (60.09 m to 61.01 m) 95 times out of 100. Refer to Chapter 18 for a discussion of expressing the uncertainty of measurement.

Construction lasers and other electronic devices can measure distances, angles, and plumb with a high degree of accuracy. The exact accuracy level depends on the specific manufacturer's device, the calibration of the equipment, the conditions under which the equipment is used, whether or not a prism is employed, and, of course, the skill and diligence of the surveyor. Refer to Chapter 17 for a discussion of electronic distance measuring devices. The numbers given in Figure 1-1 are derived from several manufacturers' product literature and represent what can reasonably be expected when these devices are used correctly under ideal conditions.

While more precise construction laser equipment is commonly used for commercial construction, many contractors still use more traditional equipment for residential and small commercial projects. The expected degree of accuracy when using steel tapes and transits is also shown in Figure 1-1.

The dimensional accuracy for a 100-ft. (30.5-m) steel tape depends on the amount of sag, temperature, tension, and angle of use. The National Institute of Standards and Technology (NIST) sets tolerances for metal tapes as shown in Table 1-1. For typical situations and when sag is minimized, the tolerances shown in Figure 1-1 can be expected. If higher accuracy is required, a laser should be used or steel tapes with correction factors included for temperature and other variables.

Table 1-1 Maintenance and acceptance tolerances, in excess and in deficiency, for metal tapes

Nominal interval from zero, ft (m)Tolerance, in (mm)	
6 or less (1.8 m)	$\frac{1}{2}$ (0.8)
7 to 30, inclusive (2.1 m to 9.1 m)	$\frac{1}{6}$ (1.6)
31 to 55, inclusive (9.4 m to 16.8 m)	$\frac{1}{8}$ (3.2)
56 to 80, inclusive (17.1 m to 24.4 m)	$\frac{3}{16}$ (4.8)
81 to 100, inclusive (24.7 m to 30.5 m)	$\frac{1}{4}$ (6.4)
<i>Note: SI units added</i>	
<i>Source: NIST Handbook 44-2003, Section 5.52, Table 2</i>	

Right angles for many buildings, such as houses and small commercial structures, can be laid out with a steel tape measuring a 3:4:5 triangle. When greater accuracy is required, a transit or construction laser should be used.

Related Sections

- 1-2 Vertical Building Layout
- 1-6 Grading and Sitework
- 17-1 Measuring Devices
- 18-2 Expressing Uncertainty

Figure 1–2 Vertical building layout

Accuracy in plumbness: (Latta)

spirit level: $\pm 1/4"$ (6) in 10' (3 m)

plumb bob: $\pm 1/8"$ (3) in 10' (3 m)

transit: $\pm 1/8"$ (3) in 100' (30.5 m)

optical plumbing device: $\pm 1/16"$ (1.6) in 100' (30.5 m)

SmartTool: $\pm 1/32"$ (0.8) in 2' (600) or 0.1°

laser plumb: $\pm 1/32"$ (0.8) in 100' (30.5 m)

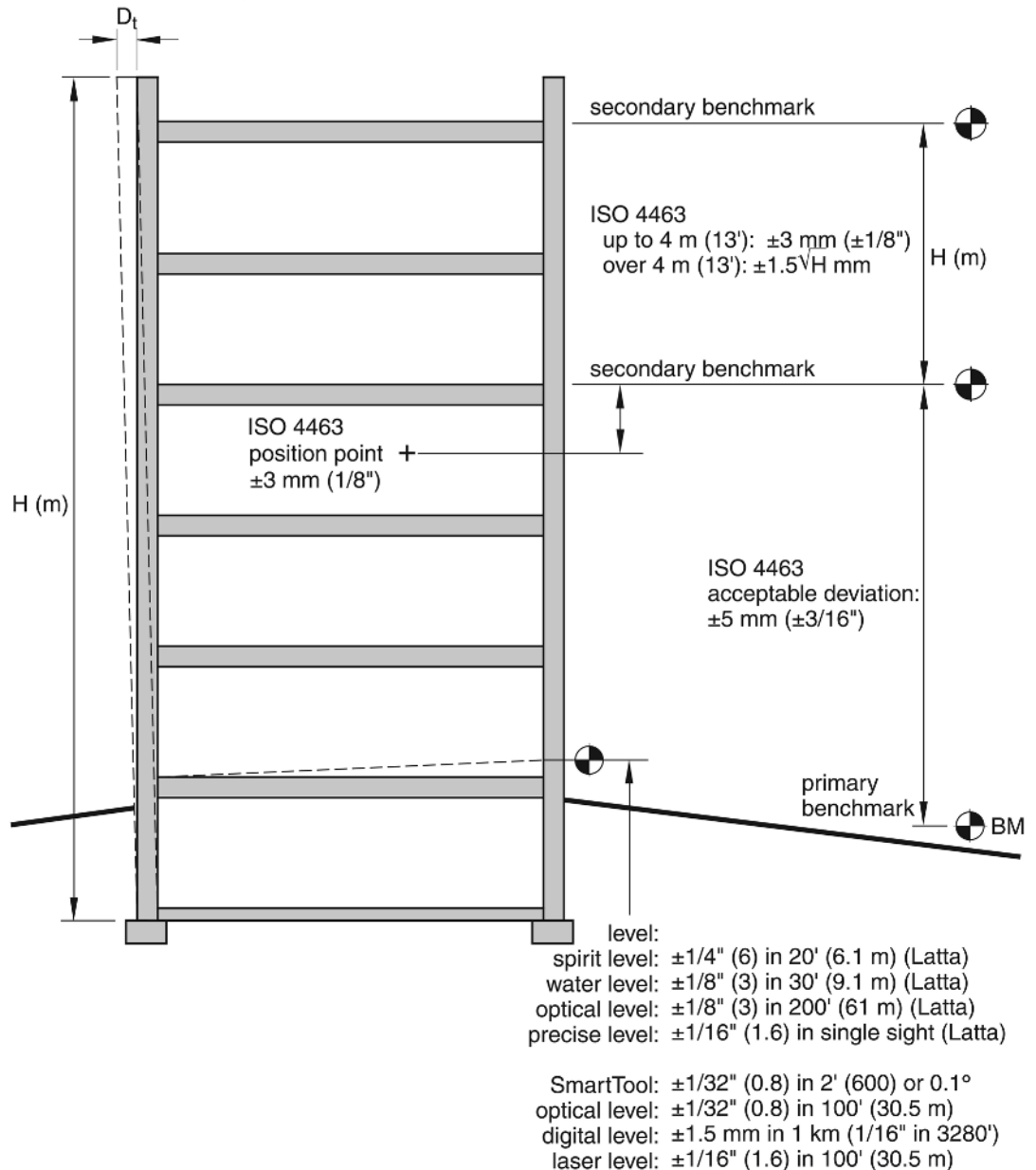
ISO 4463 acceptable deviation from plumb:

for heights up to 4 m (13'): $D_t = \pm 3 \text{ mm}$ ($\pm 1/8"$)

for heights greater than 4 m: $D_t = \pm 1.5\sqrt{H} \text{ mm}$

For example, in 30.5 m (100')

tolerance is $\pm 8.3 \text{ mm}$ ($\pm 5/16"$)



1-2 Vertical Building Layout

Description

After the horizontal form and dimensions of a building are established, the next source of inaccuracy is setting elevations, plumbing vertical elements, and maintaining levels. These are dependent on the accuracy of the instruments used as well as on environmental conditions and the skill of the people doing the layout. This section includes some of the layout accuracies possible in establishing elevations, plumb, and level with various instruments, assuming the surveyor uses a normal degree of skill.

The tolerances shown in other sections of this book for plumb and level for individual construction materials and assemblies are often more or less accurate than those shown in this section. Refer to individual sections for more specific information on industry standards for specific materials. Refer to Chapter 17 for more information on the accuracy of measuring instruments and methods of measurement.

References

- “Inaccuracies in Construction,” J. K. Latta, *Canadian Building Digest* 171, April 1975. In *Canadian Building Digests*, 151–200 (Ottawa, ON: Institute for Research in Construction, National Research Council Canada, 1989).
- Model Standards of Practice* (Gaithersburg, MD: National Society of Professional Surveyors, 2003) www.acsm.net/nsps/modelstandards.html.
- NIST Handbook 44-2003, Section 5.52 (Gaithersburg, MD: National Institute of Standards and Technology) <http://ts.nist.gov/ts/htdocs/230/235/h442003.htm>.
- Product literature: Faro Technologies, Inc. (www.faro.com), Leica Geosystems (www.leica-geosystems.com), Topcon Positioning Systems (www.topcon.com), and Trimble (www.trimble.com).
- M-D Building Products. SmartTool® digital inclinometer. www.mdteam.com
- ISO 4463-1, *Measurement Methods for Buildings—Setting Out and Measurement—Part 1: Planning and Organization, Measuring Procedures, Acceptance Criteria*, November 1 Geneva, Switzerland: International Organization for Standardization, 1989.

Allowable Tolerances

As with horizontal layout, there are no generally accepted standards for vertical layout. The numbers given in Figure 1-2 for tolerances are based on ISO 4463 and research done by the Institute for Research in Construction (Latta). However, with construction lasers and laser levels, optical levels, and digital levels, higher degrees of accuracy are possible. For example, some manufacturers’ digital levels can achieve an accuracy of ± 1.5 mm per kilometer if used according to the manufacturer’s recommendations. Single-measurement optical levels can be accurate to ± 0.8 mm in 30 m ($\pm 1/32$ in. in 100 ft.). The required tolerances should be clearly stated in the specifications based on the level of accuracy required by the project.

For less exacting applications, spirit levels and plumb bobs are often used for residential and small commercial buildings. The typical accuracies for these instruments are also shown in Figure 1-2.

For establishing slopes and checking for level, digital inclinometers are now commonly used. The accuracy for a digital inclinometer (SmartTool) is 0.1 degree (approximately $\pm\frac{1}{16}$ in. in 4 ft. or 1.6 mm in 1,200 mm). They are available in 2-ft. and 4-ft. lengths. Because local variations of flatness are possible, large slabs and ramps should be checked with a transit or construction laser to establish overall level or slope.

The NSPS standard for building offset stakes is ± 10 mm (0.03 ft.) for vertical positional accuracy. Positional accuracy in this standard is given at the 95 percent confidence level, as described in Section 1-1.

Related Sections

- 1-1 Horizontal Building Layout
- 1-6 Grading and Sitework
- 17-1 Measuring Devices
- 18-2 Expressing Uncertainty

1-3 Concrete Paving

Description

Concrete paving includes drives, parking surfaces, and other site paving. In many cases, tight tolerances for exterior paving for vehicles is not critical. However, when existing building and site elevations require minimum slopes for drainage (usually $\frac{1}{4}$ in. per ft. or 6 mm per 300 mm), the tolerances shown in this section should be specified. When ponding of water might create hazards in any situation, these tolerances should also be specified.

Industry Standards and Recommendations

ACI 117-06, *Specifications for Tolerances for Concrete Construction and Materials and Commentary* (Farmington Hills, MI: American Concrete Institute, 2006).

NCHRP Project 20-07/Task 167, *An Analysis of the Draft ADA Guidelines for Accessible Rights-of-Way*, David Kent Ballast, June (Washington, DC: Transportation Research Board, National Cooperative Highway Research Program, 2004).

Standard Specifications and Supplements (Washington, DC: American Association of State Highway and Transportation Officials, 1998)

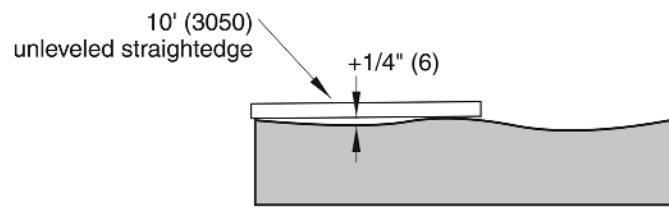
<http://fhwapap04.fhwa.dot.gov/nhswp/servlet/LookUpCategory>

UFGS Section 02752, *Portland Cement Concrete Pavement for Roads and Site Facilities*, and UFGS Section 02754, *Concrete Pavements for Small Projects*. Unified Facilities Guide Specifications, August 2004 (Washington, DC: National Institute of Building Sciences, 2004) www.ccb.org/docs/ufgshome.

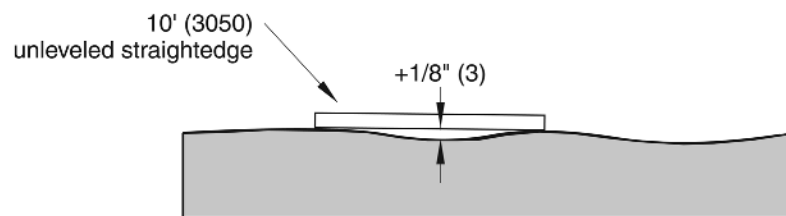
Allowable Tolerances

The only industrywide tolerances for paving on a construction site are published by the American Concrete Institute (ACI) as shown in Figure 1-3(a), (b), and (c). For highway work, state and local departments of transportation (DOTs) often give allowable tolerances in their model specifications or contract requirements. The tolerances by ACI are for vertical deviations of surfaces below an unlevel straightedge resting on high spots. Slope tolerances are not included in the ACI document.

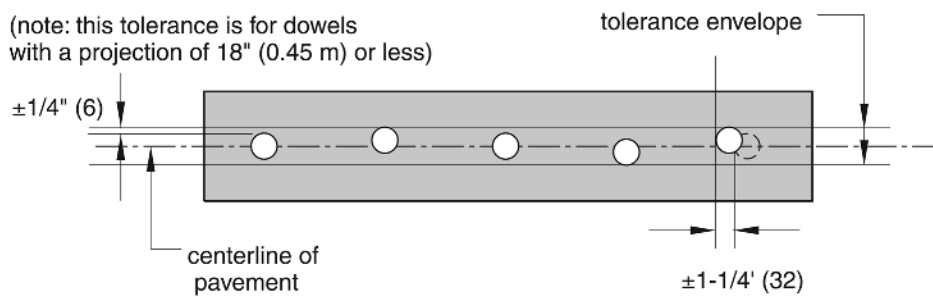
Guide specifications for concrete pavement published as part of the Unified Facilities Guide Specifications (UFGS) for military facilities state that roads and streets should have a tolerance of ± 5 mm ($\frac{3}{16}$ in.) in the longitudinal direction and ± 6.5 mm ($\frac{1}{4}$ in.) in

Figure 1-3 Concrete paving

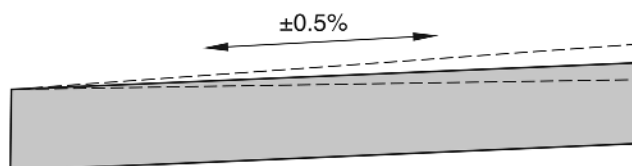
(a) mainline pavements in transverse direction (ACI)



(b) mainline pavements in longitudinal direction (ACI)



(c) lateral placement and alignment of dowels (ACI)



(d) suggested slope tolerance for concrete paving

the transverse direction when measured with a straightedge. Interestingly, in Section 02754, no length of straightedge is specified, and in Section 02752, a 4-meter (12-ft.) straightedge is required. For other surfaces, such as parking areas, the suggested tolerance is ± 6.5 mm ($\frac{1}{4}$ in.) in both directions.

A research report for the Transportation Research Board suggested an allowable slope tolerance for concrete of ± 0.5 percent, as shown in Figure 1-3(d). The same research report surveyed state and city departments of transportation and found that the allowable tolerances for roadway slope ranged from a low of 0 percent to a high of 5 percent, with an average of 0.6 percent. However, the suggested slope tolerance did not indicate the length over which the slope should be measured or in what locations slope should be measured. See Chapter 17 for discussions on measuring slopes and the flatness of surfaces.

For highway paving, the American Association of State Highway and Transportation Officials (AASHTO) publishes the AASHTO Standard Specifications and Supplements. In Section 501 for Portland Cement Concrete Pavement, the specifications require a surface test that limits surface defects to ± 5 mm under a 3-m straightedge placed at random locations. (Section 501 [L]1). This is very close to the commonly used $\frac{1}{4}$ -in. deviation under a 10-ft. straightedge.

When necessary, concrete road pavement, highway barriers, curbs and gutters, and sidewalks can be placed by specialized paving equipment with a high degree of precision. Slope tolerances of ± 0.13 percent can be achieved for roads and sidewalks using automated equipment guided by stringlines, lasers, or global positioning system (GPS) devices. They are made by a number of manufacturers. However, this equipment is commonly used only for very long runs of highways or sidewalks.

Related Sections

1-4 Asphalt Paving

1-5 Pedestrian Paving

1-7 Right-of-Way Construction

1-4 Asphalt Paving

Description

Asphalt paving includes drives and parking surfaces. Like concrete paving, asphalt paving tolerances are not always critical if sufficient slope is built into the paving for drainage. However, when a minimum drainage slope of $\frac{1}{4}$ in. per ft. (6 mm per 300 mm) is required, the tolerances shown in this section should be specified.

Recommendations

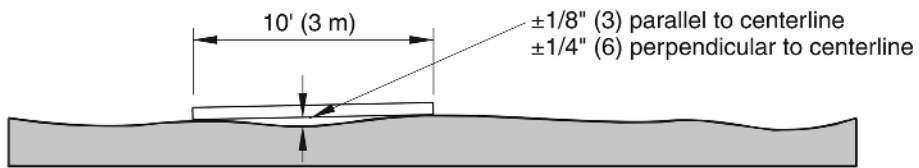
NCHRP Project 20-07/Task 167, *An Analysis of the Draft ADA Guidelines for Accessible Rights-of-Way*, David Kent Ballast, June (Washington, DC: Transportation Research Board, National Cooperative Highway Research Program, 2004).

SS-1: *Model Construction Specifications for Asphalt Concrete and Other Plant-Mix Types*, November (Lexington, KY: Asphalt Institute, 1984) Out of print.

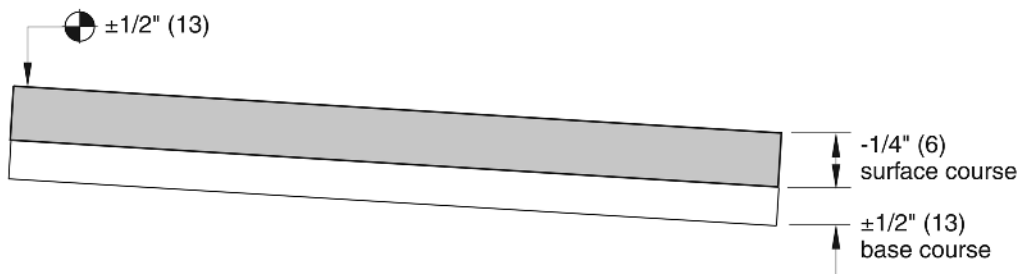
Standard Specifications and Supplements (Washington, DC: American Association of State Highway and Transportation Officials, 1998)

<http://fhwapap04.fhwa.dot.gov/nhswp/servlet/LookUpCategory>

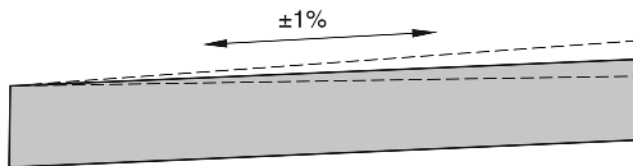
UFGS Section 02742, *Hot Mix Bituminous Pavement*. United Facilities Guide Specifications, August 2004 (Washington, DC: National Institute of Building Sciences, 2004) www.ccb.org/docs/ufgshome.

Figure 1–4 Asphalt paving

(a) flatness tolerances



(b) thickness and elevation tolerances



(c) suggested slope tolerance for asphalt paving

Allowable Tolerances

There are currently no industry tolerances for asphalt paving. The Asphalt Institute (AI) previously had tolerances as part of its *Model Construction Specifications*. This document is no longer in print and the Asphalt Institute no longer establishes tolerances. However, in the last edition of the printed volume, the recommended tolerances were $\pm\frac{1}{8}$ in. (3) parallel to the centerline of the compaction roller and $\pm\frac{1}{4}$ in. (6) perpendicular to the centerline as measured under a 10-ft. (3-m) straightedge. See Figure 1-4(a). These previously published tolerances suggest what one trade organization deemed reasonable.

The previous AI tolerances are consistent with suggested limits on surface smoothness published by AASHTO in its *Standard Specifications and Supplements*. In Section 401 for plant mix pavements, the AASHTO specifications give two methods for testing surfaces. The first method calls for surfaces to be tested with a 3-m (10-ft.) straightedge at random locations. Variations greater than 3 mm to 5 mm ($\frac{1}{8}$ in. to $\frac{3}{16}$ in.) are to be corrected.

Guide specifications for hot-mix bituminous pavement published as part of the Unified Facilities Guide Specifications (UFGS) for military facilities states that the unevenness of leveling and binder courses should not vary more than 6 mm in 3 m ($\frac{1}{4}$ in. in 10 ft.) and that unevenness of the wearing course should not vary more than 3 mm in 3 m ($\frac{1}{8}$ in. in 10 ft.).

Research done for the Transportation Research Board found that the state and city departments of transportation surveyed reported tolerances ranging from a low of $\frac{1}{8}$ in. in 10 ft. (3 mm in 3 m) to a high of 2 in. in 10 ft. (50 mm in 3 m) with an average of 0.37 in. in 10 ft. (9.4 mm in 3 m).

From these sources, it seems reasonable to expect a tolerance of $\pm\frac{1}{8}$ in. under a 10 ft. straightedge parallel to the centerline of the compaction roller and $\pm\frac{1}{4}$ in. under a 10 ft. straightedge perpendicular to the centerline. If smoothness is not critical, it is preferable to specify a tolerance of $\pm\frac{1}{4}$ in. (6 mm) in both directions.

The variation of actual elevation from spot elevations shown on the drawings should be within $\pm\frac{1}{2}$ in. (13 mm). See Figure 1-4(b). This is consistent with the Asphalt Institute's former recommendations as well as the specification language in the UFGS specification and research done for the Transportation Research Board.

For thickness tolerances, the UFGS specification states that the maximum allowable deficiency at any point should not be more than 6 mm ($\frac{1}{4}$ in.) less than the stated thickness. Previous master specifications suggested a base course thickness tolerance of $\pm\frac{1}{2}$ in. (13 mm). Both the previous Asphalt Institute's model specifications and UFGS specification state that the average thickness should not be less than the thickness stated on the drawings and in the specifications.

There are no industry-standard slope tolerances for asphalt pavement, although the AASHTO *Standard Specifications and Supplements* specify that asphalt pavers be set to maintain the transverse slope at ± 0.1 percent.

The research report for the Transportation Research Board suggested an allowable slope tolerance for asphalt roadways of ± 1 percent, as shown in Figure 1-4(c). The same research report surveyed state and city departments of transportation and found that the allowable tolerances for asphalt roadway slope ranged from a low of zero percent to a high of 5 percent, with an average of 0.83 percent. As with concrete pavement, the suggested slope tolerance did not indicate the length over which the slope should be measured or in what locations slope should be measured. See Chapter 17 for discussions on measuring slopes and the flatness of surfaces.

Related Sections

- 1-3 Concrete Paving
- 1-5 Pedestrian Paving
- 1-7 Right-of-Way Construction

1–5 Pedestrian Paving

Description

This section includes paving of concrete, asphalt, and concrete steps. For safety reasons, pedestrian paving should be constructed to close tolerances to avoid ponding and freezing of water; to prevent water buildup, which could damage the paving; and to drain water away from the building and other important site structures. This is especially important because pedestrian paving is normally shown at low slopes, from $\frac{1}{4}$ in. per ft. (6 mm per 300 mm) to $\frac{1}{2}$ in. per ft. (13 mm per 300 mm). There are currently no industry tolerances for concrete pavers, brick pavers, stone, or wood walkways.

Industry Standards and Recommendations

ACI 117-06, *Specifications for Tolerances for Concrete Construction and Materials and Commentary* (Farmington Hills, MI: American Concrete Institute, 2006).

NCHRP Project 20-07/Task 167, *An Analysis of the Draft ADA Guidelines for Accessible Rights-of-Way*, David Kent Ballast, June (Washington, DC: Transportation Research Board, National Cooperative Highway Research Program, 2004).

SS-1: *Model Construction Specifications for Asphalt Concrete and Other Plant-Mix Types*, November (Lexington, KY: Asphalt Institute, 1984) Out of print.

Allowable Tolerances

Tolerances for pedestrian paving are shown in Figure 1-5. The tolerance for concrete sidewalk flatness is based on an ACI standard, which is $\pm\frac{1}{4}$ in. in 10 ft. (± 6 mm in 3,050 mm). There are no ACI standards for slope deviation, but a Transportation Research Board report suggested a slope tolerance for concrete sidewalks of ± 1 percent for running slopes and ± 0.5 percent for sidewalk cross-slopes.

Tolerances for concrete steps are also based on ACI standards and are $\pm\frac{3}{16}$ in. (5 mm) for riser height and $\pm\frac{3}{16}$ in. (5 mm) for tread width as shown in Figure 1-5(b). The International Building Code allows a $\frac{3}{16}$ -in. (9.5 mm) variation between the highest and lowest extremes of risers and treads within any flight of stairs. The *Americans with Disabilities Act Accessibility Guidelines* (ADAAG) only states that treads and risers must be of uniform dimension.

Tolerances for asphalt walks are based on the Asphalt Institute's previous model specifications, which are no longer published. However, as with asphalt paving, it suggests what one trade organization deemed reasonable. The Transportation Research Board report suggested a slope tolerance for asphalt sidewalks of ± 1 percent for running slopes and ± 0.5 percent for asphalt sidewalk cross-slopes as shown in Figure 1-5(c).

There are no standard tolerances for brick, concrete unit pavers, stone paving, or wood walks, so if these are critical they should be specified based on the requirements of the project.

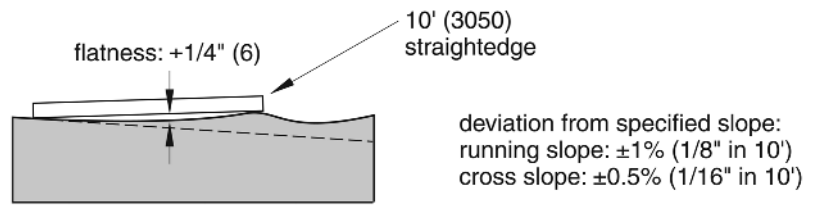
Related Sections

1–3 Concrete Paving

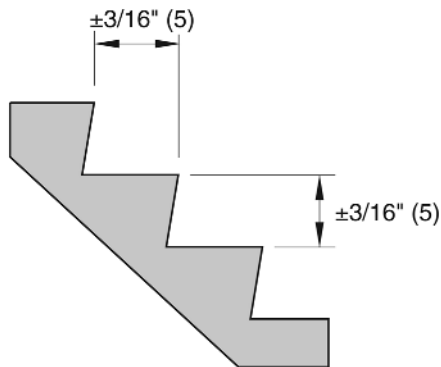
1–4 Asphalt Paving

1–7 Right-of-Way Construction

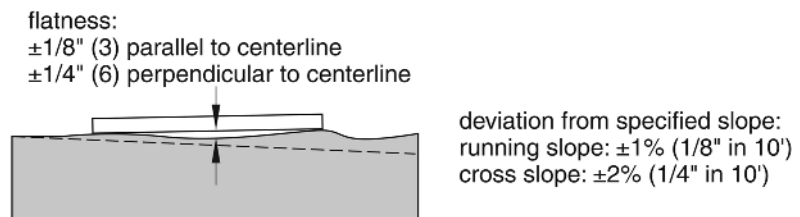
Figure 1–5 Pedestrian paving



(a) concrete sidewalks



(b) concrete steps



(c) asphalt walks

1-6 Grading and Sitework

Description

Although grading tolerances are not always critical, they can affect drainage away from a building, the appearance of ground cover material at the building line, and the final appearance of finish landscaping. Because of its nature, soil grading cannot be very accurate and is subject to the skills of the people grading as well as natural forces such as rain, snow, and freeze-thaw cycles. This section includes some of the various recommended tolerances for grading.

Industry Recommendations

ISO 4463-1, *Measurement Methods for Buildings—Setting Out and Measurement—Part 1: Planning and Organization, Measuring Procedures, Acceptance Criteria*, November 1 (Geneva, Switzerland: International Organization for Standardization, 1989).

Model Standards of Practice; Section D, NSPS Model Standards for Construction Layout Surveys (Gaithersburg, MD: National Society of Professional Surveyors, 2003) www.acsm.net/nsps/modelstandards.html.

2005 *Minimum Standard Detail Requirements for ALTA/ACSM Land Title Surveys* (Washington, DC: American Land Title Association /American Congress on Surveying and Mapping, 2005) www.acsm.net/ALTA2005.pdf.

UFGS Section 02730, *Earthwork*. United Facilities Guide Specifications, October 2004 (Washington, DC: National Institute of Building Sciences, 2004) www.ccb.org/docs/ufgshome.

Landscape Specification Guidelines, 5th ed. (Rockville, MD: Landscape Contractors Association, 2000).

SPECTEXT® Section 02211, *Rough Grading*, July (Baltimore: Construction Sciences Research Foundation, 1989).

SPECTEXT Section 02923, *Landscape Grading*, July (Baltimore: Construction Sciences Research Foundation, 1989).

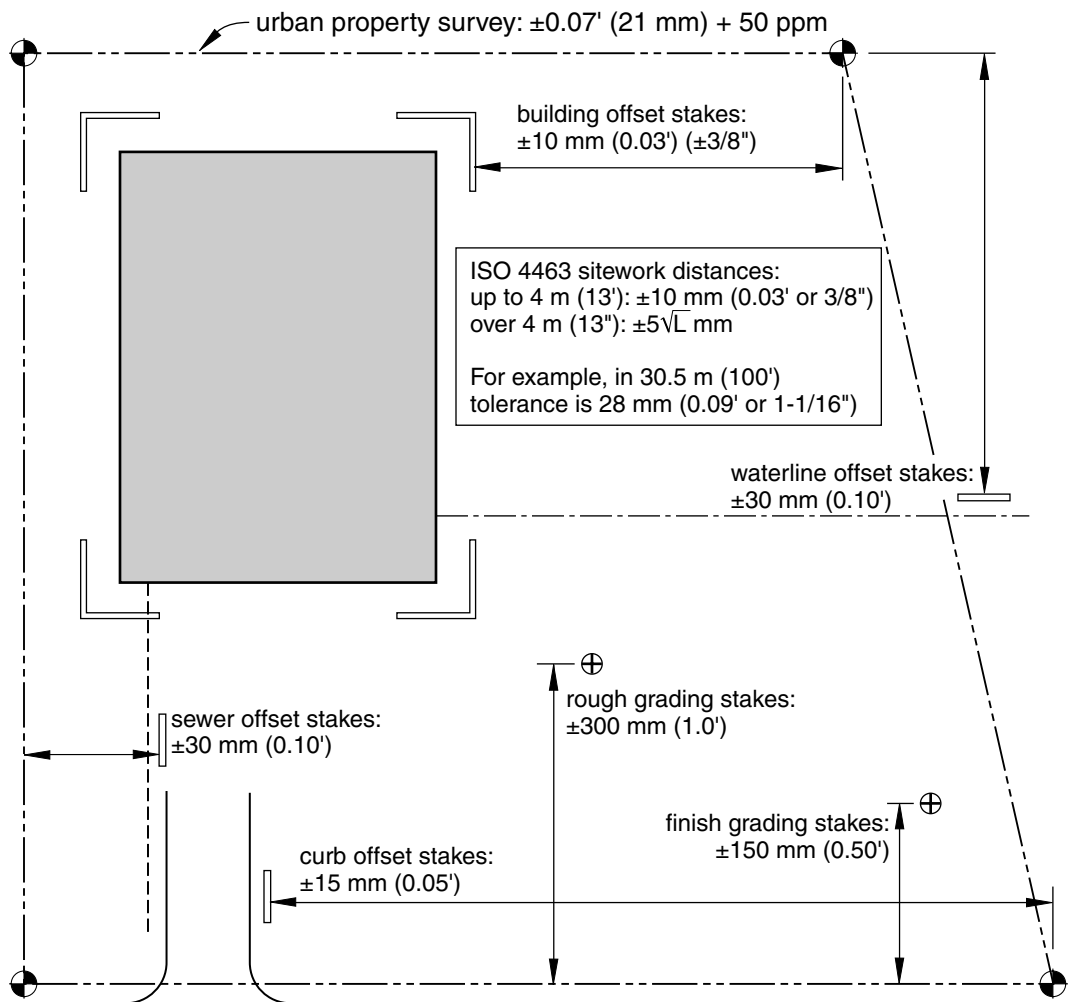
Allowable Tolerances

There are several sources for recommended tolerances for rough and finish grading as well as the horizontal position of various elements on a building site. The National Society of Professional Surveyors publishes the *Model Standards of Practice*, which includes guidelines for the horizontal and vertical relative positional accuracy of stake placement to mark the location of proposed fixed works. These are shown in Table 1-2 and in Figure 1-6.

In addition, the NSPS Model Standards includes accuracy standards for property surveys based on the intended use of the land. These are shown in Table 1-3.

Another U.S. standard is the *Accuracy Standards for ALTA/ACSM Land Title Surveys*, published by the American Land Title Association (ALTA) and the NSPS as a member organization of the American Congress on Surveying and Mapping (ACSM). This standard is used by professional surveyors for the execution of property surveys (land boundaries). It allows a relative positional accuracy for measurements controlling land boundaries on ALTA/ACSM land title surveys of 0.07 ft. (20 mm) plus 50 parts per million (ppm). The NSPS *Model Standards of Practice* adopts this standard for its classification of urban surveys.

Guide specifications for earthwork published as part of the Unified Facilities Guide Specifications (UFGS) for military facilities states that the degree of finish for graded

Figure 1–6 Grading and sitework

(a) Sitework positional accuracy (NSPS)

NSPS:

Rough grading stakes: ± 60 mm (0.20')Finish and subgrading stakes: ± 15 mm (0.05') or $5/8"$

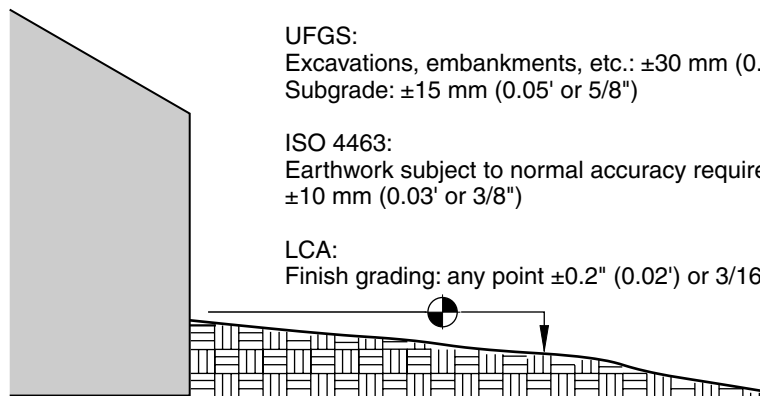
UFGS:

Excavations, embankments, etc.: ± 30 mm (0.1' or $1-3/16"$)Subgrade: ± 15 mm (0.05' or $5/8"$)

ISO 4463:

Earthwork subject to normal accuracy requirements:
 ± 10 mm (0.03' or $3/8"$)

LCA:

Finish grading: any point $\pm 0.2"$ (0.02') or $3/16"$ (5 mm)

(b) Grading elevations

areas be within 30 mm (0.1 ft. or 1 $\frac{3}{16}$ in.) of the grades and elevations shown. Requirements for subgrade preparation call for elevations to not vary more than 15 mm (0.05 ft. or $\frac{3}{16}$ in.) from the established grade and cross section.

The *Landscape Specification Guidelines*, published by the Landscape Contractors Association, suggests the landscape contractor not proceed with final work until the finish grading of topsoil has been uniformly graded to within 0.2 in. (about $\frac{3}{16}$ in. or 5 mm).

International standard ISO 4463-1 gives general allowable deviations for sitework distances and elevations regardless of the site element being placed. These are also shown in Figure 1-6.

There are other recommended tolerances for rough and finish grading. Previous SPECTEXT master specifications suggested the topsoil be within $\frac{1}{2}$ in. (13 mm) of specified elevations. For rough grading, SPECTEXT master specifications suggested a tolerance of ± 0.1 ft. or 1 $\frac{3}{16}$ in. (30 mm).

Related Sections

1-5 Pedestrian Paving

1-7 Right-of-Way Construction

1-7 Right-of-Way Construction

Description

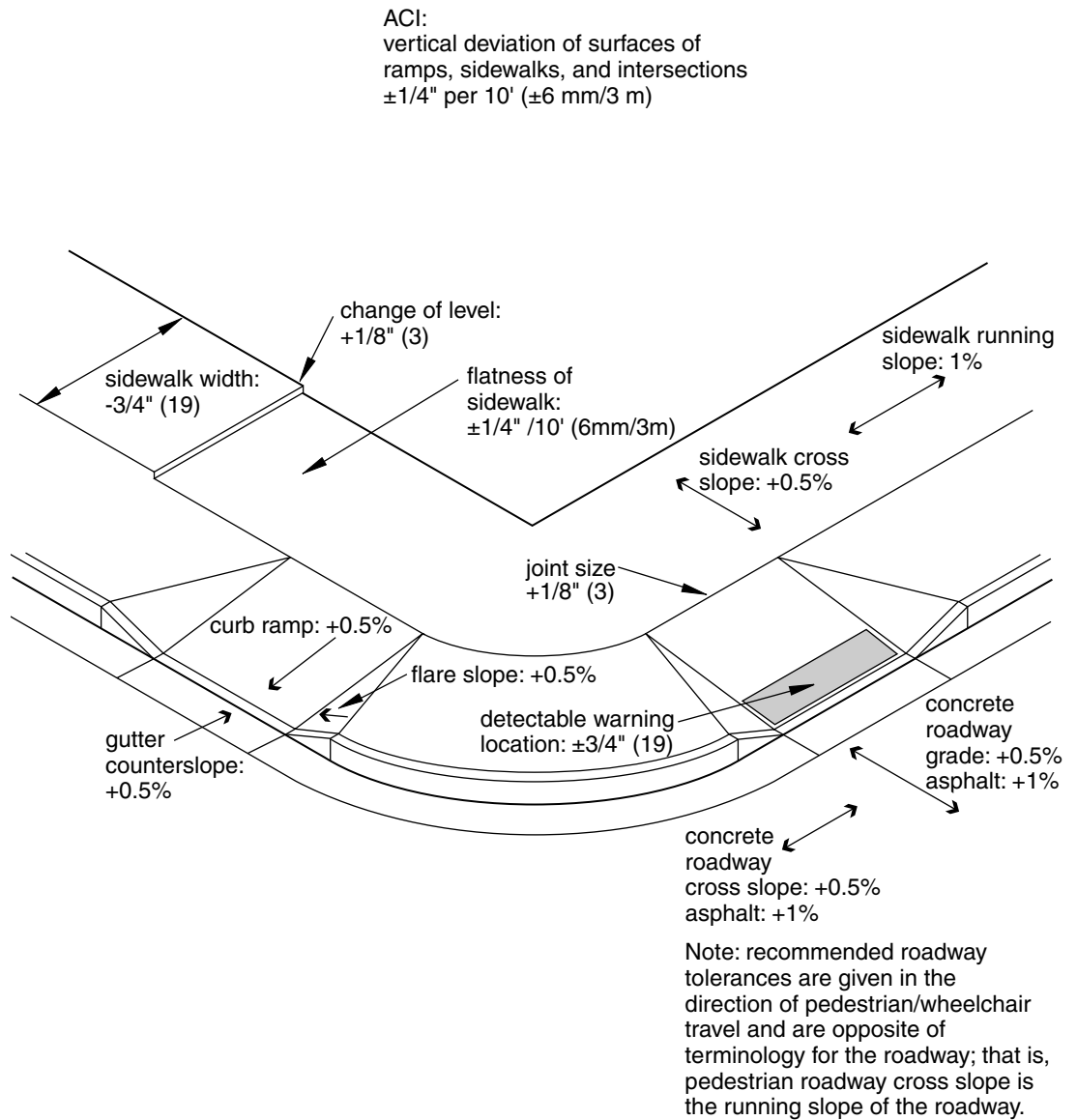
Right-of-way construction consists of streets, highways, sidewalks, curb ramps, bus stops, and other structures that are accessible by the public outside the borders of private property. The Federal Highway Administration (FHWA), AASHTO, and state and local departments of transportation (DOTs) all have standards for various components of right-of-way construction, but few have standards for tolerances. In most cases the tolerance standards relate to roadway smoothness, surface flatness of sidewalks, and curb alignment. Allowable deviations from dimensions and slopes on design drawings and in specifications are typically left to the discretion of the field inspector of the local DOT.

In most cases, tolerances are not a critical part of right-of-way construction, given the nature and use of the construction and the variables related to climate exposure, maintenance, and the heavy wear and tear that exterior elements are subjected to. Where tolerances *are* becoming an increasingly important issue is in the area of accessibility for disabled users.

At this writing, the U.S. Access Board had issued revised draft guidelines for accessible public rights-of-way, but they had not been issued as a final rule, nor had the Department of Justice adopted them as law. In the meantime, current right-of-way construction that is funded wholly or in part with federal monies is subject to requirements of various existing federal laws and generally makes reference to the technical requirements of the current ADAAG. Individual state laws may also apply. In addition, most local and state departments of transportation have requirements and guidelines for accessibility to meet ADA guidelines.

The draft guidelines for rights-of-way as well as the revised ADAAG both state that “all dimensions are subject to conventional industry tolerance except where the requirement is stated as a range with specific minimum and maximum end points.” (Section R103.1.1 of the draft rights-of-way guidelines and Section 3.2 of the revised ADAAG and). However, the advisory in the revised ADAAG states that where a requirement is a minimum or maximum dimension that does not have two specific minimum and maximum end points, tolerances may apply.

Figure 1-7 Right-of-way construction



Note: suggested tolerances, not industry standards. See text.

Table 1–2 Relative positional accuracies

Site elements	Horizontal positional accuracy		Vertical positional accuracy	
	mm	ft	mm	ft
Rough grading stakes	±300	±1.0	±60	±0.02
Subgrade red head stakes	±150	±0.50	±15	±0.05
Finish grade blue top stakes	±150	±0.50	±15	±0.05
Building offset stakes	±10	±0.03	±10	±0.03
Sewer offset stakes	±30	±0.10	±10	±0.03
Waterline offset stakes	±30	±0.10	±30	±0.10
Hydrant offset stakes	±30	±0.10	±15	±0.05
Street lights	±60	±0.20	±30	±0.10
Curb offsets	±15	±0.05	±10	±0.03

Positional accuracy is given at the 95 percent confidence level

Source: Used with permission from National Society of Professional Surveyors

Table 1–3 Relative positional accuracies for land title surveys

Classification of survey	Acceptable Relative Positional Accuracy
Urban	0.07 ft (21 mm) plus 50 ppm
Suburban	0.13 ft (40 mm) plus 100 ppm
Rural	0.26 ft (79 mm) plus 200 ppm

Positional accuracy is given at the 95 percent confidence level

ppm: parts per million

Source: Used with permission from National Society of Professional Surveyors

There are very few industry standard tolerances for right-of-way construction. Although tolerances exist for architectural construction, it is not generally appropriate to apply these to exterior work.

Industry Recommendations

Accessible Rights-of-way: A Design Guide, November (Washington, DC: U.S. Architectural and Transportation Barriers Compliance Board, 1999).

ACI 117-06, *Specifications for Tolerances for Concrete Construction and Materials and Commentary* (Farmington Hills, MI: American Concrete Institute, 2006).

Americans with Disabilities Act and Architectural Barriers Act Accessibility Guidelines, July 23 (Washington, DC: U.S. Architectural and Transportation Barriers Compliance Board, 2004) www.access-board.gov/ada-aba/index.htm

NCHRP Project 20-07/Task 167, *An Analysis of the Draft ADA Guidelines for Accessible Rights-of-Way*, David Kent Ballast, June (Washington, DC: Transportation Research Board, National Cooperative Highway Research Program, 2004).

Figure 1–7.1 Right-of-way construction

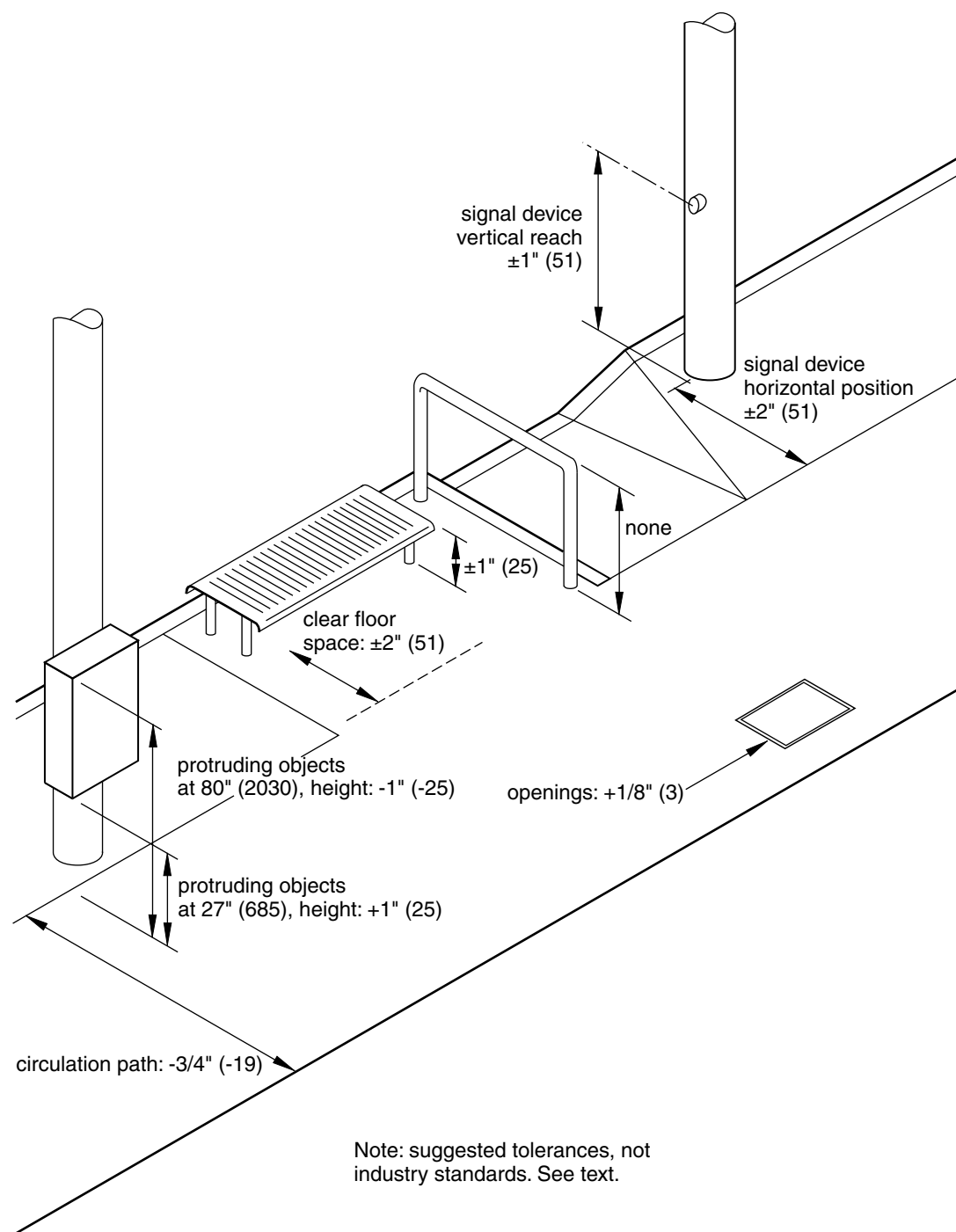


Table 1–4 Recommended tolerances for right-of-way construction

Element surveyed	Final suggested tolerance
Roadway grade (cross slope)-Concrete	+0.5%
Roadway grade cross slope (running grade)-Concrete	+0.5%
Sidewalk running slope	+1%
Sidewalk cross slope	+0.5%
Flatness (smoothness) of sidewalks	$\pm \frac{1}{4}''/10'$ (± 6 mm/3 m)
Curb ramp slope, main ramp	+0.5%
Curb ramp, flare slope	+0.5%
Curb ramp gutter counterslope	+0.5%
Widths of sidewalks and other paving	$\pm \frac{3}{4}''$ (± 19 mm)
Elevation points of construction	$\pm 0.5''$ (± 13 mm)
Concrete joint size	$+\frac{1}{8}''$ (3 mm)
Concrete stairs (riser and tread)	$\pm \frac{1}{8}''$ (± 3 mm) riser, $\pm \frac{1}{4}''$ (± 6 mm) tread
Placement of detectable warning surfaces	$\pm \frac{3}{4}''$ (± 19 mm)
Installation of metal handrails and guardrails	$\pm \frac{1}{2}''$ (± 13 mm)
Horizontal placement of poles, controls, signs, etc.	$\pm 2''$ (± 50 mm)
Vertical placement of handrails, controls, signs, etc.	$\pm 1''$ (± 25 mm) None for handrail height.
Street furniture—horizontal placement	$\pm 2''$ (± 50 mm)
Street furniture—vertical placement	$\pm 1''$ (± 25 mm)
Size of gaps at rail crossings	$\pm \frac{1}{4}''$ (± 6 mm) light rail and passenger train tracks
Flushness of surfaces at rail crossings	$\pm \frac{1}{4}''$ (± 6 mm)
Asphalt roadway grade	+1%
Asphalt roadway grade cross slope	+1%
Asphalt sidewalk running slope	+1%
Asphalt sidewalk cross slope	+0.5%
Asphalt flatness (smoothness) of sidewalks	$\pm \frac{1}{4}''/10'$ (± 6 mm/3 m)
Asphalt curb ramp slope, main ramp	+0.5%
Asphalt curb ramp, flare slope	+0.5%
Asphalt curb ramp gutter counterslope	+0.5%
Asphalt widths of sidewalks and other paving	$\pm \frac{3}{4}''$ (± 19 mm)
Asphalt elevation points of construction	$\pm \frac{1}{2}''$ (± 13 mm)
Change of level	$+\frac{1}{88}''$ (± 3 mm)

Source: An Analysis of the Draft ADA Guidelines for Accessible Rights-of-Way

Publication No. FHWA-EP-01-027, *Designing Sidewalks and Trails for Access, Part II of II: Best Practices Design Guide*, Beneficial Designs, Inc. (Washington, DC: U.S. Department of Transportation, Federal Highway Administration, 2001).

Revised Draft Guidelines for Accessible Public Rights-of-Way, November 23 (Washington, DC: U.S. Architectural and Transportation Barriers Compliance Board, 2005)
www.access-board.gov/prowac/draft.htm.

Allowable Tolerances

The only industry standard tolerances for right-of-way construction are for mainline pavements, ramps, sidewalks, and intersections published by the ACI. Refer to Section 1-3 for ACI paving tolerances. For ramps and sidewalks, ACI tolerances state that the vertical deviation of a surface as measured below an unlevelled 10-ft. (3-m) straightedge shall not exceed $\frac{1}{4}$ in. (3 mm).

In the publication, *Designing Sidewalks and Trails for Access, Part II of II: Best Practices Design Guide*, it is suggested that curb ramps be specified at 7.1 percent ± 1.2 percent tolerance. This is intended to give a maximum slope of 8.33 percent (1:12) as required by the ADAAG.

For specific tolerances for highway and road smoothness, the local DOT responsible for construction should be consulted.

There are currently no industry standards for other tolerances of the various elements that are part of right-of-way construction. The recommendations given in this section are based on a report summarizing research conducted for the National Cooperative Highway Research Program of the Transportation Research Board. For this research, state and city departments of transportation were surveyed to determine if they had standards for tolerances and if not, what they believed were reasonable tolerances for the items listed in the questionnaire. Additionally, recently completed right-of-way construction was measured to determine if actual construction met the requirements of the ADAAG and if not, how close actual construction came to meeting the requirements. The information was evaluated to determine what could reasonably be expected of right-of-way construction using today's standard construction techniques, tools, equipment, and work crews. Requirements by individual state or local departments of transportation may vary.

Some of the suggested tolerances developed by the author of this report are shown in Figures 1-7 and 1-7.1 and detailed in Table 1-4. These are not endorsed by the Transportation Research Board.

Related Sections

1-3 Concrete Paving

1-4 Asphalt Paving

1-5 Pedestrian Paving

20-4 Tolerances and Accessibility