From: Jim Gordon
To: Debbie Johnstone
Cc: Question and Answer - May 30th
Subject: June 6, 2022 5:03:11 PM Tactile
Date: Walking Surface.pdf
Attachments: image002.png
image003.png
image004.png

TACTILE WALKING SURFACE INDICATORS (TWSI)

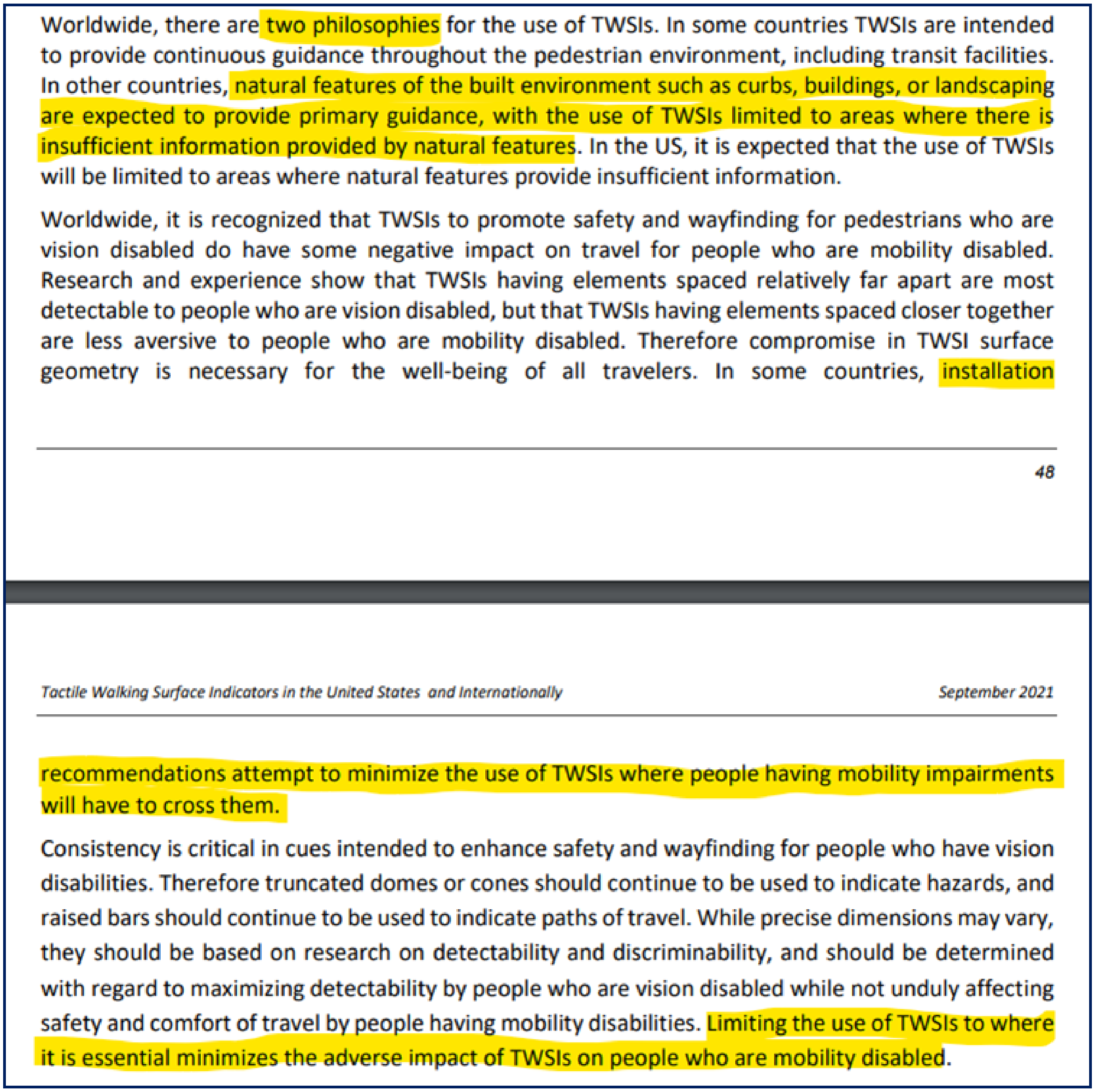
These strips (usually yellow) are installed to assist those with vision impairment. Unfortunately, others with mobility challenges sometimes find these installations problematic. Opinions on the usage of these
TWSI vary.

Published in **September 2021,** the report titled ***Tactile Walking Surface Indicators (TWSI) in the United States and Internationally*** has reviewed and examined the application of TWSI.

In Canada, TWSI specification and application standards generally refer to Canadian Access standards, *CSA B651-18 Accessible Design for the Built Environment* (2018), which is mandatory for all federal buildings and sites and is used as a model for accessibility standards in some provinces. The province of Ontario and the City of Toronto also have been advocates of the application of TWSI with detailed requirements.

The local municipality practices appear to be mixed: some are in (Vancouver, Coquitlam, Coquitlam, Maple Ridge, City of Langley) while some are not in application (Burnaby, Township of Langley, Surrey – limited the application to high traffic arterial/arterial intersections). Of note, TransLink is to install TWSI at every bus stop according to its announcement in December 2021**. White Rock staff is now limiting the installations of TWSI due to resident complaints and mixed opinions on their effectiveness compared to concerns.**

We share the summary & conclusion of the report in the screenshot below. The City may consider the highlight in yellow as a guide for the City's practice given the City's demographic texture consisting of the highest proportion of senior residents in Metro Vancouver (31% of White Rock residents over the age of 65, and 42% over 65 is projected by 2050). The report is attached for information.



Worldwide, there are two philosophies for the use of TWSIs. In some countries TWSIs are intended to provide continuous guidance throughout the pedestrian environment, including transit facilities. In other countries, natural features of the built environment such as curbs, buildings, or landscaping are expected to provide primary guidance, with the use of TWSIs limited to areas where there is insufficient information provided by natural features. In the US, it is expected that the use of TWSIs will be limited to areas where natural features provide insufficient information.

Worldwide, it is recognized that TWSIs to promote safety and wayfinding for pedestrians who are vision disabled do have some negative impact on travel for people who are mobility disabled. Research and experience show that TWSIs having elements spaced relatively far apart are most detectable to people who are vision disabled, but that TWSIs having elements spaced closer together are less aversive to people who are mobility disabled. Therefore compromise in TWSI surface geometry is necessary for the well-being of all travelers. In some countries, installation

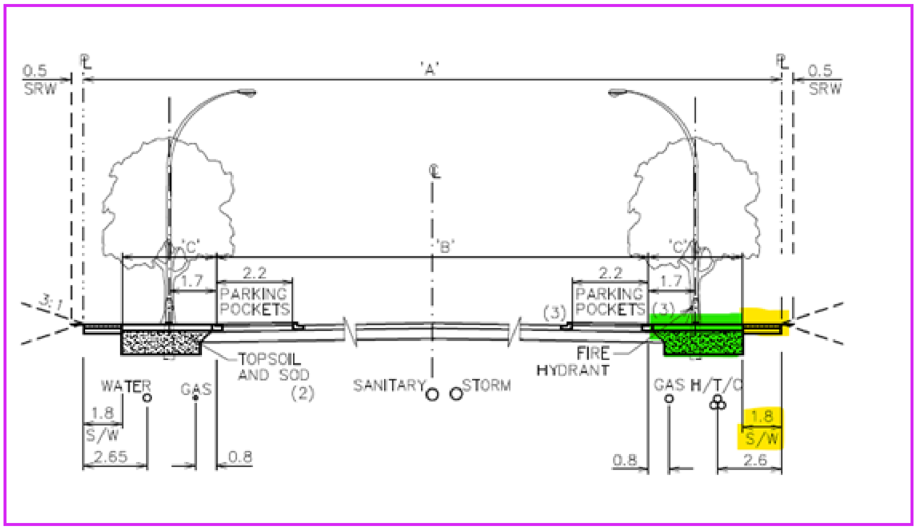
recommendations attempt to minimize the use of TWSIs where people having mobility impairments will have to cross them.

Consistency is critical in cues intended to enhance safety and wayfinding for people who have vision disabilities. Therefore truncated domes or cones should continue to be used to indicate hazards, and raised bars should continue to be used to indicate paths of travel. While precise dimensions may vary, they should be based on research on detectability and discriminability, and should be determined with regard to maximizing detectability by people who are vision disabled while not unduly affecting safety and comfort of travel by people having mobility disabilities. Limiting the use of TWSIs to where it is essential minimizes the adverse impact of TWSIs on people who are mobility disabled.

DRIVEWAY CROSSINGS

Concern was expressed that mobility challenged persons travelling on sidewalks could encounter difficulties traversing the driveway letdowns.

As shown in the screen shot below, the standard road configurations/ ideal solution should have a boulevard (variable width) /utility zone between the concrete barrier curb and the sidewalk to transition the grade (driveway letdown) so the sidewalk can remain flat; however, many urban roadways don't have sufficient road allowance to accommodate a boulevard.



In the absence of boulevard, an alternative is to install **rollover** curb rather than barrier curb to keep the sidewalk flat as there is no need for driveway letdown, however, the alternative may compromise the safety of sidewalks. Some examples can be found in the City of Surry as shown in the screenshot below, however, it is not the direction the City of Surrey is headed for. Otherwise, the sidewalk can hardly remain flat by the interruption of driveway letdown.

POLES AND OBSTRUCTIONS IN SIDEWALKS

Mitigation plan in general is to relocate the poles & obstructions out of sidewalk pending funding availability and can be accommodated in the operation/capital plan. In particular, it's challenging when hydro poles are involved while in long term, hydro poles should be eliminated with cables underground.

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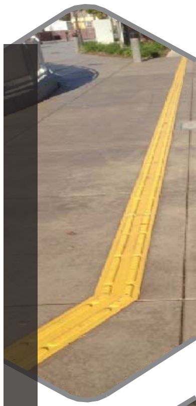

Tactile Walking Surface Indicators in the United States and Internationally

Research, Standards, Guidance, and Practice


Beezy Bentzen, Janet Barlow--Accessible Design for the Blind
Robert Wall Emerson--Western Michigan University
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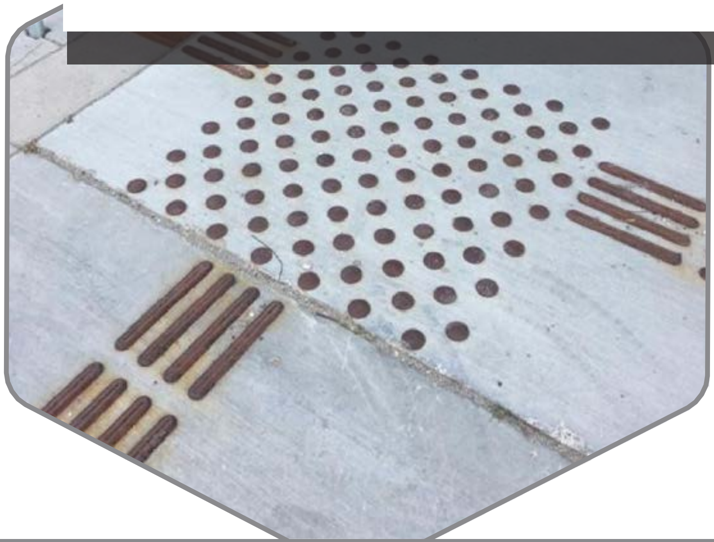
Published September 2021

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SEPTEMBER 2021

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Keywords:

blind, vision disabled, visually impaired, detectable warning, tactile walking surface indicators, TWSI, guidance surface, attention field, delineator surface, wayfinding

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ORGANIZATION OF THIS SYNTHESIS

This synthesis provides:

- Background information about early practice and research regarding tactile walking surface indicators (TWSIs).
- A broad description of current U.S. and international practice.
- Key US and international research on detectability, discriminability, and visibility of TWSIs in wayfinding applications.
- A discussion of international standards related to TWSIs, especially ISO 23599 Assistive products for persons with vision impairments and persons with vision and hearing impairments—Tactile walking surface indicators (ISO 2019).
- A discussion of national standards and practices, particularly pertaining to the U.S., Japan, Canada, Australia, New Zealand, the United Kingdom, Germany, Sweden, and Denmark.

Throughout this synthesis, dimensions are given as stated in the original standard or guidance (e.g., metric), followed by the opposite, equivalent measure (e.g., U.S. customary units.) Except when the source provides a specific conversion, this synthesis typically uses hard conversions for guidance and standards (e.g., 300 mm is shown as 12 inches, rather than 11.8 inches). Research results are converted with an equivalent number of significant digits.

EARLY PRACTICE AND RESEARCH RELATED TO TWSIS

For years, pedestrians who are visually impaired depended on curbs to indicate that they had reached a street (ANSI *A117.1-1961*). However, as early as 1961, the U.S. and other countries began installing curb ramps at crosswalks. Although these ramps improved mobility for persons using wheelchairs and other wheeled mobility devices, their installation resulted in the removal of an important cue for pedestrians who are visually impaired, without providing an alternative. Research in various countries considered various TWSI surfaces and surface configurations, with most settling on a combination of truncated domes and raised bar surfaces to provide guidance and information to pedestrians who are blind or visually impaired.

Raised bar surfaces vary in width from about 150 mm (6 inches) to 600 mm (24 inches). In some countries, raised bar surfaces are combined with truncated dome surfaces to form continuous paths of travel throughout regions in the built environment. For example, at both ends of a block, truncated domes may indicate where pedestrians who are visually impaired should begin and end street crossings. These block ends will be connected by raised bars, which are usually located in the center of the sidewalk. These indicators may be used in both indoor environments such as large public buildings, as well as outdoors and in the transit environment.

Early Japanese Practice and Research

To address the concerns, Japan began using TWSIs in the 1960s as wayfinding assistance for pedestrians who are visually impaired. Two patterns were designed to provide continuous paths of travel: (1) a surface of raised bars oriented in the direction of travel, and (2) raised or truncated domes indicating destinations, intersections, places of danger, or turns in a pathway defined by the guidance surface. These patterns worked jointly to assist persons with vision impairment; the raised-bar guidance surface along sidewalks led to crosswalks, while the locations of crosswalks were typically indicated by a domed or truncated dome surface.

These tactile paths were quickly considered necessary by planners and architects in Japan because they allowed pedestrians who were visually impaired to travel independently, and they became widely used throughout the country (Murakami et al., 1982). Most of the early Japanese warning surface domes were arranged in a square pattern, were about 5 mm (0.2 inch) high, and were separated from one another by about 65 mm (2.6 inches) on center. Meanwhile, the guidance surface bars were typically parallel, rounded or flat-topped; were also about 5 mm (0.2 inch) high; and were typically separated by about 65 mm (2.6 inches) on center. The Japanese TWSIs were typically some shade of yellow. However, no specifications for these surfaces, nor standards for where and how they should be installed, existed in Japan until 1985. As a result, the dimensions and locations used for installations varied widely (Shimizu et al. 1991).

The uses for these various "Braille blocks," referred to as dot tiles and bar tiles, were described by Murakami et al. (1982) and the first Japanese standard for both the dot tiles and bar tiles was issued in 1985 (Ibukiyama, et al., 1985). Today, both developed and developing parts of Asia use a design similar to Japan's for pedestrians who are visually impaired, and many countries worldwide use some variation of the raised bar guidance and truncated domes although the size and method of installation varies.

Early U.S. Practice and Research

In contrast, the focus in the U.S. has been directed toward establishing highly detectable surfaces for use as warnings at curb ramps or transit platform edges. In 1980, *ANSI Standard A117.1-1980* required "tactile warnings" at locations without a defined boundary between pedestrian and vehicular ways, at the top of stairs, and at reflecting pools. The TWSI was required to be standardized within a building or site and could consist of exposed aggregate concrete, raised strips, or grooves.

A number of research efforts conducted during the 1980s sought to identify a sufficiently detectable surface for curb ramps and transit platform edges (Aiello and Steinfeld 1980; Pavlos, Sanford, and Steinfeld 1985; Templer and Wineman 1980; Templer, Wineman, and Zimring 1982, Peck and Bentzen 1987). None of the tactile warning surface options required by *ANSI A117.1-1980* were found to be highly detectable. Research in the early 1980s indicated that a surface's resilience, as well as the sound it produced when tapped with a long cane, appeared to enhance detectability regardless of surface texture, although this finding was not consistently confirmed in later research (Bentzen et al. 1993). The only highly detectable surfaces suitable for use on curb ramps or transit platforms were found to be textures comprised of truncated domes, similar to the Japanese dot tiles, and raised, rounded bars similar to the Japanese bar tiles (Peck and Bentzen 1987).

The truncated dome surface was standardized as a warning in the *Americans with Disabilities Act (ADA) Accessibility Guidelines* (U.S. Access Board 1991) and became required at transit platform edges as well as at "hazardous vehicular areas," the most common of which were curb ramps. The term used for the truncated dome surface in the U.S. is a "detectable warning surface" (DWS). The surface dimensions for these DWS were determined by Peck and Bentzen's (1987) testing on the single truncated dome surface. The dome height was 0.2 inch (0.5 cm); the diameter was 0.9 inch (2.3 cm), presumably measured at the base, although the standard was ambiguous on this; and the center spacing was 2.36 inches (59.9 mm). Additionally, a DWS was required to differ from adjoining surfaces revolving door entrances; at the boarding door locations of transit stops; throughout railway and other transportation facilities; and at kiosks or locations where additional wayfinding information, such as a tactile maps, can be found. In some countries, installations of truncated dome surfaces at street crossings are aligned perpendicular to the direction of travel on the associated crosswalk, with the intention of providing a good cue for alignment (establishing a heading) for crossing.

Philosophies for Installing TWSIs

Internationally, there are two different philosophies for the use of TWSIs, which impact where and how TWSIs are installed. The prevailing philosophy in Japan and other Asian countries is that TWSIs should provide continuous paths of travel throughout the built environment. The continuous paths commonly use guidance surfaces installed in the center of sidewalks that are bounded by buildings, landscaping, or curbs. In contrast, the prevailing philosophy in North America, most of Europe, Australia, and New Zealand is that TWSIs should use existing features of the built environment and should be installed only where there is insufficient information for guidance.

Use on Sidewalks

Figure 1 shows a combination of a raised bar guidance surface and a truncated dome DWS. The guidance surface provides bars oriented parallel to the crossing direction, indicating the location of a mid-block crossing. The DWS indicates the end of the safe pedestrian way. Variations on this scheme are common internationally.

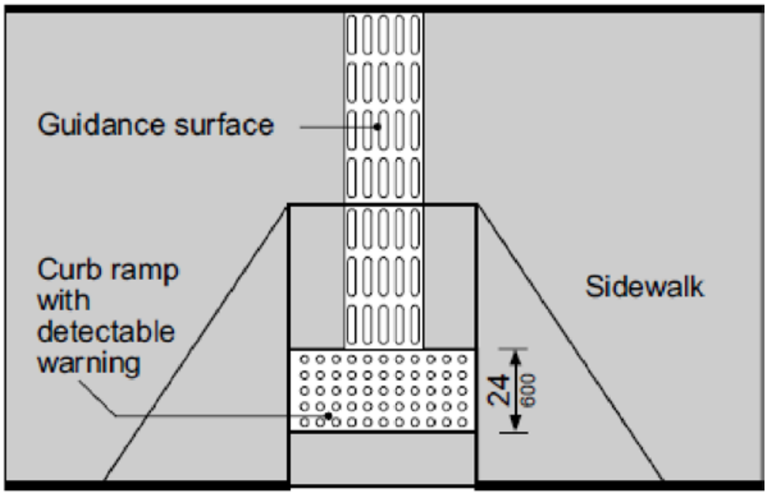


Figure 1. A raised bar guidance surface and a truncated dome DWS as commonly used together to indicate the location of a street crossing.

In the U.S., truncated domes are placed at or very near the bottom of curb ramps and at the edges of other hazardous vehicular ways, such as blended corners and cut-through islands, to provide precise information about the location of the junction between the pedestrian and vehicular ways (curb line). Given that information, pedestrians in the U.S. then decide how close or far from the street they wish to wait to cross. In other countries, it is more common for truncated domes to be set back a short distance from the curb line with the intention of keeping pedestrians who are visually impaired farther away from traffic.

In countries other than the U.S., truncated domes are often used to indicate crossing locations for pedestrians who are visually impaired; these crossings may or may not be at curb ramps. Truncated domes may be placed alongside or a short distance away from curb ramps because truncated domes at curb ramps have some effect on other travelers, including those with mobility impairments and those pushing or pulling wheeled objects such as strollers or luggage. Additionally, pedestrians who are visually impaired do not require curb ramps and may not prefer them.

Use on Transit Platforms

In the U.S., truncated domes are placed at the edge of the platform. Safety managers representing U.S. rail rapid transit agencies, who were advisors to the research reported in Peck and Bentzen (1987), recommended placing the warning surface at the platform edge. It was desired to encourage all travelers to stay at least 24 inches (60 cm) from the platform edge, but not to decrease the effectiveness of the platforms, some of which were very narrow. It was anticipated that if the warning was set back from the platform edge, some passengers would use the smooth surface between the platform edge and the rough warning surface as a “highway” to move down the platform.

On transit platforms outside the U.S., some setback from the edge of the platform is usually provided between the platform edge and either the truncated domes or raised bars that run the length of the platform. In many countries, high-speed trains that do not stop at all stations pass boarding platforms. Air currents from fast trains may pull waiting passengers toward the platform edge as the trains pass. It is therefore considered unsafe for passengers to wait close to the platform edge.

International Standardization

An international standard, *ISO 23599:2012 Assistive products for persons with vision impairments and persons with vision and hearing impairments—Tactile walking surface indicators*, was published in 2012 after about 15 years of work. It was revised with minor editorial corrections in 2019 as ISO 23599:2019. Because the process of producing this standard was so long, being interrupted twice for lack of consensus, by the time the standard was completed, countries participating in its development had each implemented somewhat different systems. As a result, the technical specifications for the attention and guidance surfaces and the methods and locations of installations varied by country. Consequently, the standard’s technical specifications for attention fields and guidance surfaces allow for wide variation, and ISO 23599:2019 only provides general principles for installation.

There was consensus that:

- TWSIs should be easily detected from surrounding surfaces, both under foot and by use of a long cane.
- TWSIs should be easily discriminated from one another, both under foot and by use of a long cane.
- TWSIs should be highly visible to travelers with reduced vision.
- TWSIs should not adversely impact other travelers any more than necessary.
- TWSIs should be 4–5 mm (0.16–0.20 inch) high for good detection, especially in outdoor environments where walking surfaces are not uniformly smooth.

RESEARCH ON TWSIS SINCE THE 1990S

This section summarizes TWSI-related research that has occurred since the development of the 1985 Japanese TWSI standard and the 1991 *ADA Accessibility Guidelines*. This research has addressed the detectability and discriminability of TWSIs, visibility of TWSIs, the use of TWSIs for wayfinding and for delineating between pedestrian and cycle sides of separated bicycle lanes at sidewalk level, and the effect of TWSIs on travel by persons with mobility impairments.

United States

Effects of TWSIs on Pedestrian Safety

Research in the U.S. subsequent to Peck and Bentzen (1987) confirmed the high detectability of a truncated dome surface but did not test varying the surface dimensions for optimal effectiveness (Bentzen and Myers 1997; Hughes 1995; McGean 1991; Mitchell 1998; O'Leary, Lockwood, and Taylor 1996; Peck et al. 1991; Tijerina, Jackson, and Tornow 1994). According to multiple studies by different investigators, a truncated dome depth of 24 inches across the surface and in the direction of travel was sufficient to enable stopping without stepping beyond the surface on approximately 90% of trials by participants who were blind (Bentzen and Myers 1997; Hughes 1995; Mitchell 1998; O'Leary, Lockwood., and Taylor 1996; Peck et al. 1991; Peck and Bentzen 1987; Tijerina, Jackson, and Tornow 1994).

The installation of a 24-inch (60-cm) wide strip of the truncated dome surface at transit platform edges resulted in decreased platform edge falls, not only for transit users who were visually impaired, but for all users (McGean 1991). Installation of detectable warnings on curb ramps improved detection of the street when pedestrians who were blind approached the curb ramps (Hauger et al. 1996).

Visual Contrast of TWSIs

It is important that TWSIs be highly visible so they can be readily seen and effectively used by people who have low vision and who do not travel using a long cane or other travel aid. Because there is considerable variability in color (hue) perception amongst people with vision disabilities, high luminance contrast is the most reliable way to achieve high visibility.

Bentzen, Nolin and Easton (1994a) assessed the visibility of six DWS paired with three adjoining materials, brushed concrete, coarse aggregate and black Pirelli tile, indoors, under fluorescent illumination. Twenty-seven participants who reported that they had enough vision to tell where light was coming from but were unable to reliably see transit platforms in interior stations, were asked to stand on the adjoining surface and report whether they could or could not see a DWS in front of them at distances of 4 feet (1.22 m) and 8 feet (2.44 m). Half of the time the surface in front of them resembled the surface on which they were standing. All pairs having luminance difference of 40% or greater were detected on at least 90% of trials, with no significant difference between pairs. Detection of only the lowest contrast pair was significantly less (25% of trials). However luminance contrast did not predict participants' subjective choice of which surface had the best contrast. Federal yellow (Pantone 109u) was preferred both when it was combined with coarse aggregate (contrast 65%), and when it was combined with brushed concrete (40%).

Jenness and Singer (2006) investigated the visibility of 13 DWS paired with 4 adjoining surfaces outdoors, during midday hours. Fifty participants who reported that they had difficulty seeing the boundary between sidewalks and streets viewed each combination from a starting distance of 26 feet (7.92 m) on the adjoining surface, and walked toward the DWS until they were confident that they could see a DWS, to determine detection distance. On some trials, there was no DWS. Participants then viewed each DWS from 8 feet (2.44 m) and were asked to describe the color or pattern of the DWS. Finally, they rated the conspicuity of each DWS on a five-point scale. DWS in most sidewalk combinations were visible from 8 feet (2.44 m), but they were less likely to be seen from 26 feet (7.92 m). About 95% of participants were able to see DWS from 8 feet (2.44 m) when luminance contrast was equal to or greater than 70%. Combinations having at least 60% contrast were visible at 8 feet (2.44 m) to 92% of participants. An exception was dark DWS on a dark sidewalk, which were minimally visible despite having moderately high luminance contrast. The researchers recommended that any standard luminance contrast for DWS have a minimum reflectance for the lighter of the two surfaces. Yellows and orange-reds resulted in highest detection, and lighter colors were more visible than darker colors. The researchers recommended that if a standard color or colors were desired, federal yellow would be a good choice when used with dark colored adjoining surfaces, and brick-red would be a good choice when used with light colored adjoining surfaces.

Wayfinding Applications of TWSIs

Scott et al. (2011a) compared six tactile cues for crossing alignment. The cues were installed on plywood ramps in an empty parking lot in such a way that the orientation of the cues relative to the slope of the ramp could be systematically varied.

- A ramp slope alone.
- A tactile arrow on an accessible pedestrian signal.
- A returned curb.
- Two raised, flat-topped bars parallel to the intended direction of travel.
- Two similar raised bars perpendicular to the intended direction of travel.
- A DWS in which the bottom two rows of truncated domes were replaced by a single raised bar that was perpendicular to the direction of travel. This surface was tested on plywood curb ramps in an outdoor laboratory.

The raised bars were all 1.28 inch (32.5 mm) wide at the base and 0.19 inch (4.8 mm) high. In the two conditions in which two parallel raised bars were oriented either parallel or perpendicular to the intended travel direction, the two bars were spaced 3.0 inches (76 mm) apart, on center.

The two surfaces that resulted in the most accurate alignment, even when the surfaces were not aligned with the ramp slope, contained bars that were perpendicular to the intended direction of travel on the crosswalk. Bars aligned parallel to the direction of travel on the crosswalk (a common arrangement internationally) resulted in significantly less accurate alignment. In a subsequent, unreported experiment, using the same plywood ramps, the same researchers investigated the accuracy of alignment with DWS, and found alignment to be significantly less accurate with DWS than with raised bars oriented perpendicular to the intended direction of travel (personal communication from A. Scott, 2012).

Figure 2 depicts examples of the plywood ramps used for testing alignment based on the six different cues (Scott et al. 2011a). Each cue could be turned so that it was or was not oriented to indicate travel in the same direction as the ramp slope. Figure 2(a) shows a person taking a direction from bars perpendicular to the intended direction of travel. Figure 2(b) shows a person who has taken a direction from bars parallel to the intended direction of travel.

(a) Bars perpendicular to intended travel direction (b) Bars parallel to intended travel direction

Figure 2. Examples of surfaces used for testing by Scott et al. (2011a).

Based on the results of Scott et al. (2011a, 2011b), Bentzen et al. (2017) installed a temporary guidance surface prototype of raised bars at six non-corner crossings. The purpose of this study was to determine whether such a surface could aid wayfinding at crossings where there is otherwise insufficient detection and alignment information for pedestrians who are blind. The surface was installed across the width of the sidewalk and beside the DWS to indicate the location of the crosswalk and to provide a cue for alignment (see Figure 3). The bars of the guidance surface were oriented perpendicular to the direction of travel on the crosswalk. The dimensions and spacing of the bars were the same as in the previous laboratory research (Scott et al. 2011a). When used in other countries to indicate the location of crosswalks, the raised bar guidance surface typically orients the bars parallel to the direction of travel on the crosswalk. Because Bentzen et al. (2017) were interested in identifying a surface that could aid with both crosswalk detection and pedestrian alignment, they oriented the raised bars perpendicular to the direction of travel on crosswalks. This decision was based on prior research in both the U.S. (Scott et al. 2011a, 2011b) and Japan (Takeda et al. 2006) that found that direction-taking from raised bars perpendicular to the intended direction is more accurate than direction-taking from raised bars parallel to the intended direction.

Figure 3. Photo of a guidance surface with raised bars perpendicular to the direction of travel across the crosswalk (Bentzen et al. 2017).

Without the guidance surface, research participants who were blind passed crosswalks without detecting them on 17.9% of trials and aligned in a heading that would have resulted in crossing completion outside of the crosswalk on 47.9% of trials. The prototype guidance surface resulted in reducing passing the crosswalk without detecting it to 2.4% and decreased headings that would have resulted in crossing completion outside the crosswalk to 22.7% (both statistically significant).

Negotiability of TWSIs

US research has evaluated the safety and negotiability of truncated dome and raised bar surfaces for travelers with mobility impairments. In research by Peck and Bentzen (1987), two potential warning surfaces that were equal in detectability were installed on transit platform edges. The two surfaces used were truncated domes and a prototype surface of raised bars that were semi-circular in cross-section. Twenty-four research participants with various mobility impairments using various travel aids were asked to travel across and along the two surfaces and to initiate turns. Both surfaces were oriented parallel to an elevated transit platform edge. No mobility impaired participants judged that either surface would seriously impair their travel on transit platforms; there were nine spontaneous responses indicating that one or both surfaces would be helpful in travel.

Bentzen et al. (1994b) videotaped 40 participants with mobility impairments navigating 6-foot (1.8-m) long ramps (slope 1:12) with nine different truncated dome surfaces and one brushed concrete surface. Participants were asked to travel up and down each ramp, stopping, starting, and making a turn on the ramp. Video raters observed minimal evidence of increased effort, slipping, stability loss, or wheel or tip entrapment on this challenging task. Participants reported minimal negative effects of truncated domes relative to the brushed concrete surface.

In other research, Hughes (1995) had nine people with mobility impairments travel up and down eight ramps, each with different tactile surfaces including truncated domes. No individuals were reported or observed to have problems with directional control, stability, effort, or discomfort that would have altered their ability to travel safely.

Additionally, Hauger et al. (1994) had 30 participants with mobility impairments travel up and down curb ramps with and without truncated domes. A majority felt safer, had better traction, and were more stable on ramps having truncated domes than on concrete ramps. Forty-four percent of participants said it required less effort to navigate the ramps with detectable warnings than the concrete curb ramps, while 23% said the reverse.

Lee (2007) examined the effects of 24 in (600 mm) deep DWS on curb ramps, compared with a ramp with no DWS, on 21 individuals with mobility impairments who used either manual or power wheelchairs. The dome diameter was relatively small (.9 inch; 22.9 mm), and center spacing relatively large (2.4 inches; 61 mm). Half of the trials on a ramp having DWS were on a ramp having truncated domes aligned in the direction of ramp slope, and half of the trials were on a ramp on which the domes were aligned diagonal to ramp slope. Analysis of both video data and subjective questions showed that the DWS did not compromise safety of participants. Some participants judged that surfaces with truncated domes promoted better traction than the concrete ramp. Performance on the ramp having domes aligned with the direction of slope was slightly better than on the ramp having diagonally aligned domes.

Bentzen et al.(2019a) investigated the effects of crossings of a raised bar guidance surface installed perpendicular or parallel to the direction of travel on the sidewalk on 38 participants with mobility impairments who used a variety of mobility aids. Crossing either orientation of bars caused some increase in effort and instability for more than half of participants. Effort was somewhat greater on average for all participants when crossing bars perpendicular to their travel direction, but stability was also better, on average, for wheelchair users when crossing bars oriented perpendicular to their travel direction. There was low incidence of any slipping of feet or mobility aids, and low incidence of trapping of wheels or cane/crutch/walker tips. A significant majority of participants expressed their preference for crossing bars oriented parallel to their travel direction.

TWSIs as Delineators for Separated Bicycle Lanes at Sidewalk Level

Bentzen et al. (2019b) studied three potential delineators for separated bicycle lanes at sidewalk level. The potential surfaces, selected on the basis of previous research in the UK (see below), were a 12 inch wide continuous raised trapezoid (0.75 inches high), and 12 inch and 24 inch wide installations of relatively wide flat-top bars and of a “corduroy” surface of narrower bars spaced more closely together. Thirty-one VI participants detected all 5 surfaces in addition to DWS, a total of 6 times each, from 90° and 25° approaches, with mean detection accuracies better than 90% for all surfaces (no significant differences). The long white cane intruded into the cycle track significantly less frequently with 24” wide surfaces. In a counterbalanced manner, participants also briefly stepped onto each surface 8 times, each time identifying it as “domes,” “bars,” or “trapezoid.” They identified the trapezoid significantly better (mean rate of correct identification = 98.8%) than all other surfaces. A majority of VI participants preferred the trapezoid. Thirty participants with a variety of mobility impairments, using a variety of aids, crossed each surface 4 times with little significant difference from the DWS in effort, instability, and discomfort or pain. No surface was found to be a barrier to crossing. The trapezoidal surface was recommended as the delineator, although the 24" FTBs also performed very well.

The decision to recommend the trapezoidal surface as the delineator instead of the FTBs was based on the following factors: 1) it was more highly identifiable; 2) it was preferred by a majority of participants who were visually impaired; 3) it required ½ the right-of-way to install; 4) it required ½ the amount of material (lower cost); 5) it was considered to "look more like a barrier"; and 6) it was distinctly and identifiably different than FTBs, which are commonly used as a guidance surface.

Japan

An extensive body of research on detectability of TWSIs has been conducted in Japan. After it had been found that dot tiles and bar tiles were often mistaken for each other (Murakami et al. 1991), Japanese researchers carried out an extensive research program to determine the optimal dimensions for both guiding (bar tiles) and warning (dot tiles) surfaces to ensure that they would be readily detected and readily discriminated from one another. To the best of our knowledge, these research efforts (National Institute of Technology and Evaluation 1998, 2000; Sawai, Takato, and Tauchi 1998) are the only ones to systematically vary the dimensions of the raised elements and the spacing between them.

Under-foot discriminability tests for nine bar tile patterns, all of which varied in the size and spacing of the raised elements, found that the six tiles having bar widths between 18 and 35 mm (0.7–1.4 inch) (measured at the top surface of the bar) and bar spacing of either 75 or 86 mm (3.0 or 3.4 inch) (on center) were highly detectable and statistically equivalent. The three surfaces with the same range of bar widths, but only 50-mm (2.0-inch) spacing, were significantly less detectable and discriminable. The same principle held true for dot tiles—surfaces having truncated domes that were closer together were less detectable and discriminable than surfaces having the raised dots farther apart.

The height of the raised surfaces was also varied in these tests, with heights of 2.5, 5.0, 7.5, and 10 mm (0.10, 0.20, 0.30, and 0.39 inch) tested. About 15% of participants were unable to detect 2.5-mm (0.10-inch) high surface elements, while nearly all participants detected and correctly identified 5.0-mm (0.20-inch) high surface elements. This research was the basis for the Japanese standard *JIS T 9251 Dimensions and patterns of raised parts of tactile walking surface indicators for blind persons* (2001).

Subsequent research in Japan found that the standard dot and bar tile patterns are also highly detectable and discriminable by use of the long cane (Mitani et al. 2007). Furthermore, Fujinami et al. (2005) confirmed that dot tiles 300 mm (12 inches) deep in the crossing direction, as was common on Japanese transit platforms at the time, enabled some research participants who were blind to detect them and stop without stepping beyond the surface, but that a depth of 600 mm (24 inches) was necessary to enable all participants to detect the tiles and stop without stepping beyond them.

Concern that dot and bar tiles as high as 5 mm (0.2 inch) can sometimes cause tripping or discomfort for people with mobility impairments led to research on under-foot detectability of dot tiles less than the standard 5-mm (0.2-inch) height and truncated domes less than the standard 12-mm (0.47-inch) diameter. The research revealed that the detection rate was 95% for truncated domes only 2.3 mm (0.09 inch) in height, regardless of the top diameter; diameters of 6, 9, and 12 mm (0.24, 0.35, and 0.47 inch) were tested (Nakamura et al. 2008). Further research on under-foot detectability and bar tile direction recognition found that raised bars as low as 2.4 mm (0.09 inch) resulted in accuracy and confidence equal to bars 5 mm (0.2 inch) in height (Nakamura, Nishioka, and Suemitsu 2009). According to subsequent research (Nakamura, et al. 2011), when the raised surface height was 3.0–4.5 mm (0.12–0.18 inch) and the top diameter was 6–12 mm (0.24–0.47 inch), the under-foot discriminability of the change from bar tiles to dot tiles was greater than 99% regardless of the top diameter and height, but participants' confidence in detecting the difference was low for textures below 3.9 mm (0.15 inch) in height.

Takeda et al. (2006) examined the effect of raised bars aligned perpendicular versus parallel to the intended heading on direction-taking by participants who were visually impaired. Their results matched those of Scott et al. (2011a); accuracy was significantly better when participants used the perpendicular bars to establish a heading than when they used the parallel bars.

United Kingdom

Research on TWSIs in the U.K. began in the early 1990s (Gallon 1992; Gallon and Fowkes 1992; Gallon, Oxley, and Simms 1991; Gallon et al. 1992; Savill et al. 1996). This extensive research program identified seven different detectable and discriminable tactile surfaces that could be used to convey various meanings. The research confirmed that when participants who were visually impaired were familiarized with the seven surfaces, they were able to remember what meaning each surface was intended to convey. Table 1 identifies the surfaces identified, along with their meaning and application. Extensive guidance was published on the use of each surface (U.K. Department of the Environment, Transport and the Regions 1998).

Table 1. Tactile Surfaces Developed Through U.K. Research

Surface	Meaning	Application
Parallel rows of truncated domes (referred to as flat-topped blisters)	Pedestrian crossing point	Applied in red to indicate the location of controlled (signalized) crossings or in buff or another contrasting color to indicate the location of uncontrolled crossings
Corduroy consisting of raised, rounded bars	Hazard warning	Used at the tops and bottoms of stairs, at the bottom of ramps leading to on-street light rapid transit platforms, and/or at level crossings at rail platforms
Offset rows of truncated domes (flat-topped blisters)	Off-street platform edge warning	Used along edges of all types of off-street rail platforms, set back from the edge
Rows of lozenge shapes	On-street platform edge warning	Applied at the edges of on-street light rail transit platforms
Raised flat-topped bars 35 mm (1.4 inch) wide, running in the direction of pedestrian travel	Guidance path	Used in pedestrian areas, including transit stations, where there is no traditional guidance such as a curb, landscape or building line.
Resilient, matte-finish, slip-resistant surface without raised texture elements	Information surface	Precedes an amenity such as a ticket office, entrance to a civic destination, an ATM, or a toilet room
Raised bar, trapezoidal in cross-section, with base surface 150 mm (6 inches) wide	Delineation between pedestrian and cycle sides of shared cycle paths	Applied along the entire length of shared pedestrian/cycle paths at the same level

Researchers in the UK investigated TWSIs for delineators between separated bicycle lanes (SBLs) at sidewalk level. Williams (1987) identified a continuous raised trapezoidal surface, 150 mm (5.9 in.) wide at the base, and either 12 mm (0.47 in.) or 20 mm (0.79 in.) in height, that was detectable and usable by pedestrians with VI as a delineator between bicycle and pedestrian sides of a SBL. In 1998, a 20 mm (0.79 in.) high trapezoid became the recommended delineator for sidewalk level SBLs in the UK (*5*), although a 12 mm (0.47 in.) high trapezoid was permitted.

Subsequent research by Childs et al. (*2010*), Savill et al. (*1997*), and research commissioned by Guide Dogs for the Blind (*Testing proposed delineators to demarcate pedestrian paths in a shared space environment: Report of design trials conducted at University College London Pedestrian Accessibility and Movement Environment Laboratory (PAMELA)* 2008), together included 24 potential surfaces (varying in surface geometry, width, and orientation of the geometry) for use as delineators for SBLs or for guidance in shared streets. They confirmed the detectability of the trapezoid at 20 mm (0.79 in.), but not at 12 mm (0.47 in.). Two other surfaces were also highly detectable, a guidance surface of 35 mm (1.38 in.) wide bars raised 5 mm (0.20 in.), and a surface dubbed “corduroy,” which consisted of rounded bars, 2 mm (0.08 in.) wide at the base, and 6 mm (0.24 in.) high. The three surfaces were all found to be crossable by people with mobility impairments.

Sweden

Research found that a sinusoidal surface was preferred over a raised bar surface due to it being more highly detectable and easier to follow when using a long cane (Ståhl, Almén, and Wemme 2004). The sinusoidal surface was less likely to cause the long cane to “stick” and was preferred by more participants. However, it was minimally detectable under foot and not highly discriminated from truncated domes.

Research on the detection of truncated dome warning surfaces when using a long cane in a natural pedestrian environment (Ståhl et al. 2010) found that the most detectable surface out of four tested had truncated domes with a bottom diameter of 30 mm (1.2 inch), a top diameter of 25 mm (1.0 inch), and a center-to-center spacing of 70 mm (2.8 inch). These were the largest truncated domes that were tested. This surface was detected on 100% of trials. All four surfaces tested had a height of 5 mm (0.2 inch). Detection was not improved by preceding the surface with a curb, and detection was equal with surface lengths of 1000 mm and 1500 mm (40 and 60 inches), but detection was more difficult when the truncated dome surface was preceded by a cobblestone walkway rather than a smooth walkway.

Germany

Prior to 2011, a sinusoidal surface was used as a direction indicator in Germany. However, it was found to be minimally detectable, especially under foot (Behling 2008, Böhringer 2003, Böhringer 2007). In 2001, 25 different TWSIs from Germany and Europe were tested by more than 60 people who are blind. (Böhringer 2003, Böhringer 2007) This research considered the type of cane tip, as well as slip resistance. Through this testing, truncated domes and raised bars of varying dimensions were all found to be more detectable and discriminable from one another than sinusoidal surfaces.

France

Langevin et al. (2013) conducted research in Paris on ability to locate and align with street crossings with and without the aid of TWSIs. The research involved 22 travelers with vision disabilities who used long canes for assistance. These individuals crossed streets twice at eight locations, including crossings that were perpendicular to the direction of travel on the crosswalk and crossings that were oblique. At half of the crossings, raised bar guide strips consisting of eight raised bars, each 60 cm (24 inches) wide, were installed across the full width of the sidewalk, terminating at truncated dome surfaces which were placed about 60 cm (24 inches) back from the curb line at the crossing. The raised bars were oriented parallel to the direction of travel on the associated crosswalk.

In this study, crossings having raised bar guide strips were located significantly more successfully than those without guide strips. In addition, perpendicular crossings were identified significantly more accurately than oblique crossings. The findings also determined that crossing alignment was not significantly different for crossings having TWSIs (with bars aligned with the direction of travel across the crosswalk).

Participants were also asked to locate a bus stop that was indicated using the same raised surfaces as the street crossings. While most were successful in locating the destination, subjective data indicated that the participants were unable to determine that it was a bus stop.

Canada

Canadian researchers tested the detectability of truncated dome surfaces under snow (Ratelle, Zabihaylo, and Gresset 1997; Ratelle et al. 1995). The tested surfaces were similar in texture but different in color and material composition. Detectability was approximately equal when the surfaces were dry or covered with a light layer of snow (Landry et al. 2010). The researchers hypothesized that snow on darker-colored surfaces would melt more readily, increasing detectability, but this was not the case, and guidance surfaces were difficult to follow when snow-covered. Field tests of varying materials concluded that only high-density materials such as cast iron and solid steel offered enough strength to be used where snow removal was required (Couturier and Ratelle 2010).

Landry et al. (2010) investigated the effectiveness of 300-mm (12-inch) wide raised bar guidance surfaces. Two T-shaped arrangements were tested, with one having a 600-mm (24-inch) square of truncated domes (i.e., an attention field) at the intersection, and the other not having it. Participants were asked to travel L-shaped routes. The study found that the truncated dome attention field did not provide any benefit in indicating the place to turn.

INTERNATIONAL STANDARDS

CEN/TS 15209:2008 Tactile Paving Surface Indicators Produced from Concrete, Clay and Stone

This standard, published by the European Committee for Standardization (CEN), was the first international standard for the dimensions of TWSIs. It specified dimensions for the geometry of the various types of tactile paving units used in the 30 participating countries at that time. A variety of geometries were in use, but in general, surfaces that had linear elements served as guidance, and surfaces with discrete elements served as warnings or indicators for particular elements in the environment. In this standard, regular domes, flat-topped domes, flat-topped pyramids or cylinders, and lozenge shapes were described. Additionally, six types of raised bar surfaces were specified. The bars could be rounded, flat topped, or trapezoidal. Two grooved surfaces, flat or trapezoidal, were also specified. The height (or depth), width, and spacing of elements were also specified and could vary widely.

ISO 23599:2019 Assistive products for persons with vision impairments and persons with vision and hearing impairments—Tactile walking surface indicators

As described previously, this standard was first adopted in 2012 and revised with editorial corrections 2019. By the time this standard was finalized in 2012, most of the countries contributing to its development were already recommending or requiring the provision of tactile pathways in some situations, most notably in rail transit stations. All of the participating countries were also using some type of raised dome or truncated dome surface arranged on a square grid as a warning surface, as was required in the U.S., and almost all of the countries using guidance surfaces were using a surface composed of raised bars. In all countries except the U.S., the dome or truncated dome texture was being used together with raised bars, not only as a warning, but also as an “attention pattern” to indicate intersections, turns in travel paths, and locations of landmarks of interest (e.g., bus stops, elevators, and tactile maps) (personal communication from B. Bentzen, participating in the working group for this standard as the U.S. technical expert). In the U.S., however, the use of the truncated dome surface was and is intended to designate the end of a pedestrian way and the beginning of a vehicular way.

The specifications for the ISO23599 standard’s attention and guiding patterns offer considerable latitude to participating countries in specifying the dimensions of TWSI elements. According to the standard, truncated domes should be arranged in a square grid of domes positioned parallel or diagonal to the principal direction of travel. The domes may be integrated into a unit or discretely applied to the walking surface, and they must differ in luminance from the surrounding walking surface. The diameter of the truncated domes (or truncated cones) is related to the spacing between the raised elements; in general, smaller elements can be closer together than larger elements while still being distinguishable from the raised bars. On the other hand, larger elements closer together result in less vibration for people using wheeled mobility aids such as wheelchairs or rollator walkers. The truncated domes should be 4–5 mm high (0.16–0.20 inch), and the combinations shown in Table 2 are acceptable.

Table 2. Top diameter and corresponding spacing of truncated domes or cones in ISO 23599:2019.

Top diameter of truncated domes or cones	Center spacing
12 mm (.47 in)	42-61 mm (1.65-2.40 in)
15 mm (.59 in)	45-63 mm (1.77-2.48 in)
18 mm (.71 in)	48-65 mm (1.89-2.56 in)
20 mm (.79 in)	50-68 mm (1.97-2.68 in)
25 mm (.98)	55-70 mm (2.17-2.76 in)

Likewise, specifications for raised bars provide a relationship between the width of the bars and the space between them. Narrower bars may be closer together than wider bars, while remaining highly detectable and discriminable from truncated domes, but wider bars closer together will result in less vibration for people using wheeled mobility aids. The combinations in the following table are acceptable. Similar to truncated domes, bars should be 4–5 mm high (0.16–0.20 inch), and the bars may be together in a unit or discrete bars may be applied to the walking surface. Raised bars should also differ in luminance from the surrounding walking surface. The standard also permits the use of a surface comprised of sinusoidal ribs instead of raised bars.

Table 3. Top width and corresponding spacing of axes of flat-topped elongated bars in ISO 23599:2019.

Top width of flat-topped elongated bars	**Center spacing**
17 mm (.67 in)	57-78 mm (2.24-3.07 in)
20 mm (.79 in)	60-80 mm (2.36-3.15 in)
25 mm (.98 in)	65-83 mm (2.56-3.27 in)
30 mm (1.18 in)	70-85 mm (2.76-3.35 in)

ISO 23599.2019 has specific requirements for luminance contrast of TWSIs. Luminance contrast between TWSIs and the surrounding surface must be greater than 30% using the Michelson Contrast formula where the TWSIs are integrated into paving modules of uniform color. However, luminance contrast must be greater than 50% where discrete elements are used to form TWSIs. The standard recognizes that there will be locations where it is not possible to achieve the required luminance contrast, and requires a continuous adjoining band of compliant contrast for a minimum width of 100 mm (4 inches).

Because of the considerable differences in where and how TWSIs were being used in participating countries, the standard's guidance regarding exactly where and how TWSIs should be installed is minimal, but there are a few standards regarding effective width and depth and some guidance regarding location (setback) in relation to hazards. Attention patterns must have a minimum effective width and depth (in the direction of travel) of 550 mm (22 inches). Note that the "minimum effective width and depth" are measured from the outer edges of the raised elements such as truncated domes or bars, and do not include the additional margin that is part of any paving surface that includes a TWSI. A surface of truncated domes having an effective width of 22 inches is roughly comparable to a 24 inch paver having truncated domes, depending on the diameter and spacing of the domes. When attention patterns are used to indicate a hazard, they must extend the full width of the hazard, and it is recommended that they be set back at least 300 mm (12 inches) from the hazard. Guiding patterns must have a minimum effective width of 250 mm (10 inches)—roughly comparable to a 12 inch paver. However, where a guidance pattern must be detected by travelers approaching from an angle, the minimum required width is 550 mm (22 inches)—roughly comparable to two 12 inch pavers. Furthermore, a minimum clear path of 600 mm (24 inches) must be provided on both sides of a guiding pattern. The standard contains an appendix with illustrations of a variety of installations.

The experience of technical experts in the ISO standardization process and comments on the draft standard indicated that wider bars were sufficiently detectable by pedestrians who are visually impaired and were less aversive to travelers with mobility impairments. Recorded comments also recognized that TWSIs sometimes cause tripping, slipping, loss of mobility aid control, and pain for people with mobility impairments. Therefore, the comments recommend utilizing some compromise between maximizing detectability for pedestrians with visual impairments and minimizing discomfort or decreasing safety for travelers with mobility impairments.

ISO 21542:2011 Building construction – Accessibility and usability of the built environment

This standard is a broad international accessibility standard that was developed simultaneously with *ISO 23599:2012* and is specific to TWSIs. Appendix A of *ISO 21542:2011* contains technical specifications for TWSIs which are nearly the same as those in *ISO 23599:2019*. According to this standard, rounded bars, flat-topped bars, and sinusoidal ribs are permitted as guidance surfaces, in addition to rounded or truncated domes. *ISO 21524:2011* requires TWSIs where no other clues in the built environment indicate the path to a destination.

STANDARDS, GUIDANCE, AND PRACTICE BY COUNTRY

United States

ADA Guidelines and Standards

The 1991 *Americans with Disabilities Act Accessibility Guidelines (ADAAG)* (U.S. Access Board 1991) had very narrow specifications for DWS. Truncated domes were required to be .2 inches (5 mm) in height from the base surface, .9 inches (23 mm) in diameter (presumably at the base, though this is not specified), and 2.35 inches (60 mm) apart, on center. They were required on the full width and depth of curb ramps, at the boundary of hazardous vehicular areas ("where walking surfaces are not separated by curbs, railings, or other elements between the pedestrian and vehicular areas"), at edges of transit platforms, and at reflecting pools.

The rather precise technical specifications for DWS in the Americans with Disabilities Act Accessibility Guidelines (1991) were broadened as follows in the Americans with Disabilities Act Accessibility Guidelines (2010) (2010 ADA Standards). DWS were required only at transit platforms.

- 705 Detectable Warnings
    - 705.1 General. Detectable warnings shall consist of a surface of truncated domes and shall comply with 705.
        - 705.1.1 Dome Size. Truncated domes in a detectable warning surface shall have a base diameter of 0.9 inch (22.8 mm) minimum and 1.4 inches (35.56 mm) maximum, a top diameter of 50 percent of the base diameter minimum to 65 percent of the base diameter maximum, and a height of 0.2 inch (5.1 mm).

- 705.1.2 Dome Spacing. Truncated domes in a detectable warning surface shall have a center-to-center spacing of 1.6 inches (40.6 mm) minimum and 2.4 inches (61.0 mm) maximum, and a base-to-base spacing of 0.65 inch (16.5 mm) minimum, measured between the most adjacent domes on a square grid.
- 705.1.3 Contrast. Detectable warning surfaces shall contrast visually with adjacent walking surfaces either light-on-dark or dark-on-light.

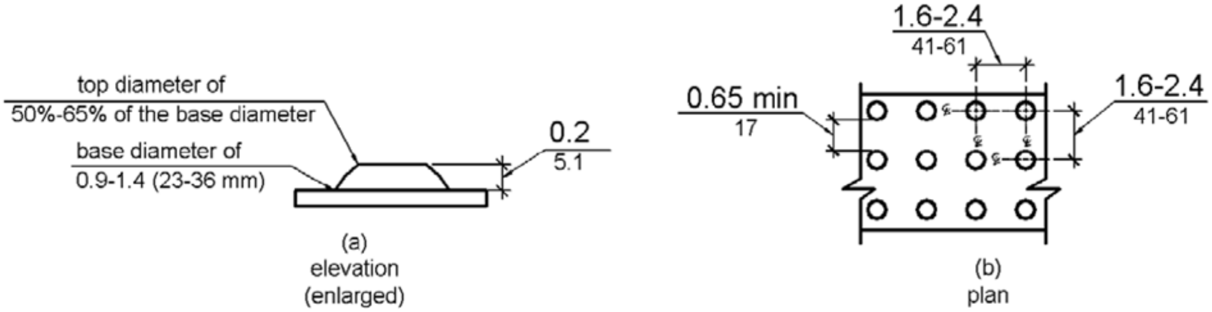


Figure 705.1 The size and spacing of truncated domes

The only guideline for the installation of DWS in 2010 ADA Standards specifies how they are to be placed at the edge of transit platforms:

- 705.2 Platform Edges. Detectable warning surfaces at platform boarding edges shall be 24 inches (610 mm) wide and shall extend the full length of the public use areas of the platform.

The Department of Justice (DOJ) 2010 ADA standards (DOJ, 2010) apply to all facilities covered by the ADA, except public transportation facilities, which are subject to Department of Transportation (DOT) (USDOT, 2006) standards.

The two standards are the same with regard to the dimensions of the truncated dome surface and the requirement for visual contrast, but the DOT standard requires truncated domes on curb ramps as well as at the edges of transit boarding platforms (USDOT 2006). Barlow and Bentzen (1995) presented strong evidence that pedestrians with little or no vision are at great risk of unknowingly stepping into a street if they approach via a curb ramp, while Hauger et al. (1994, 1996) demonstrated that the risk could be considerably reduced by installing detectable warnings on curb ramps. The DOT standard is as follows (USDOT 2006):

- 406.8 Detectable Warnings. A curb ramp shall have a detectable warning complying with 705. The detectable warning shall extend the full width of the curb ramp (exclusive of flared sides) and shall extend either the full depth of the curb ramp or 24 inches (610 mm) deep minimum measured from the back of the curb on the ramp surface.

Specifications for the DWS in the *Proposed Accessibility Guidelines for Pedestrian Facilities in the Public Right-of-Way* (U.S. Access Board 2011) (*Proposed PROWAG*) are the same as in the 2010 ADA

Standards. Advisory notes permit small variations in truncated dome geometry in locations where they are arrayed radially, and rows of domes are required to be aligned perpendicular to the grade break between the ramp run and the street so that pedestrians who use wheelchairs can "track" between the domes. The DWS alignment is not intended to indicate the direction of travel on the associated crosswalk; instead, a DWS is provided at the grade-break to indicate the end of the pedestrian way.

The standard for installing DWS on curb ramps is considerably more complex in *Proposed PROWAG.*

> R305.2.1 Perpendicular Curb Ramps. On perpendicular curb ramps, detectable warning surfaces shall be placed as follows:
>
> 1. Where the ends of the bottom grade break are in front of the back of curb, detectable warning surfaces shall be placed at the back of curb.
> 2. Where the ends of the bottom grade break are behind the back of curb and the distance from either end of the bottom grade brake to the back of curb is 1.5 m (5.0 ft) or less, detectable warning surfaces shall be placed on the ramp run within one dome spacing of the bottom grade break.
> 3. Where the ends of the bottom grade break are behind the back of curb and the distance from either end of the bottom grade brake to the back of curb is more than 1.5 m (5.0 ft), detectable warning surfaces shall be placed on the lower landing at the back of curb.

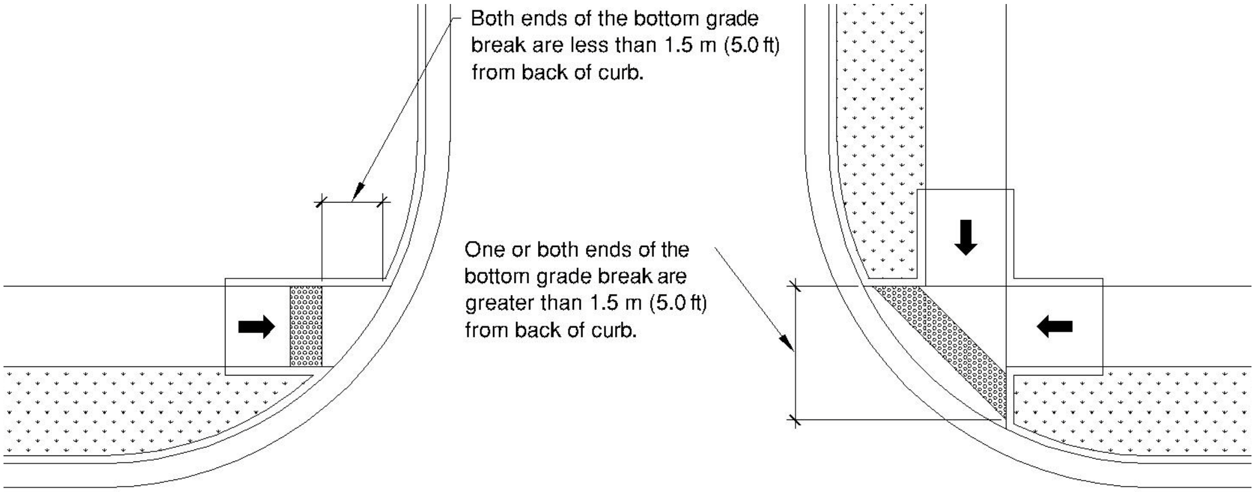
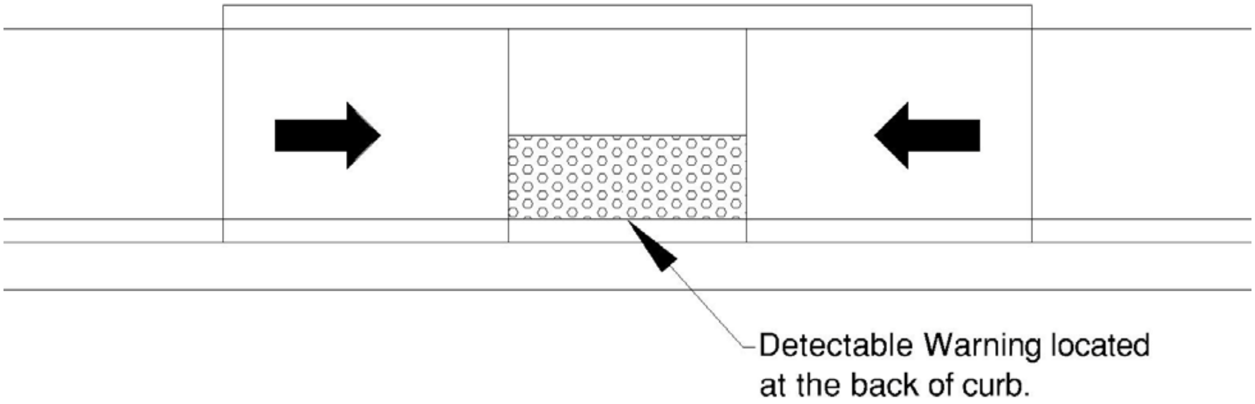


Figure R305.2.1 Perpendicular Curb Ramps

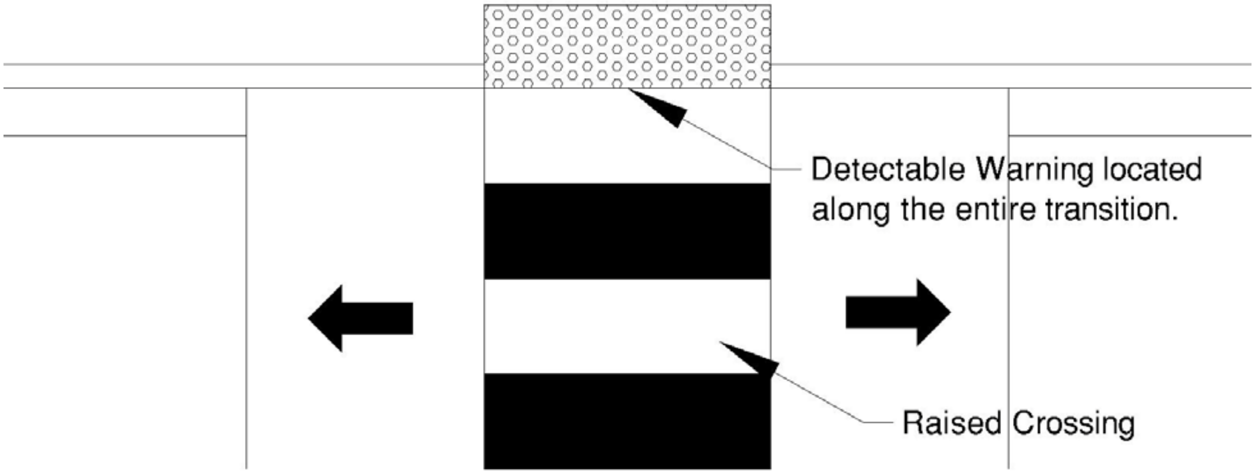
R305.2.2 Parallel Curb Ramps. On parallel curb ramps, detectable warning surfaces shall be placed on the turning space at the flush transition between the street and sidewalk.

Figure R305.2.2 Parallel Curb Ramps

R305.2.3 Blended Transitions. On blended transitions, detectable warning surfaces shall be placed at the back of curb. Where raised pedestrian street crossings, depressed corners, or other level pedestrian street crossings are provided, detectable warning surfaces shall be placed at the flush transition between the street and the sidewalk.



a) Blended Transition for Sidewalks



b) Blended Transition for Raised Crossing

Figure R305.2.3 Blended Transitions

R305.2.4 Pedestrian Refuge Islands. At cut-through pedestrian refuge islands, detectable warning surfaces shall be placed at the edges of the pedestrian island and shall be separated by a 610 mm (2.0 ft) minimum length of surface without detectable warnings.

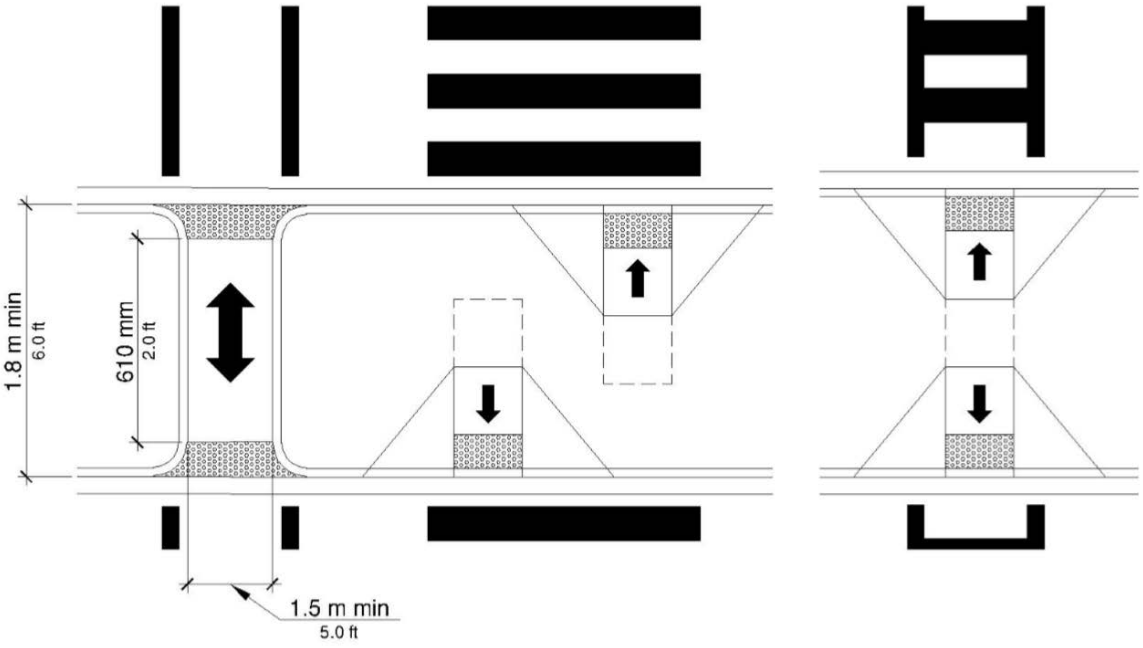


Figure R305.2.4 Pedestrian Refuge Islands

R305.2.5 Pedestrian At-Grade Rail Crossings. At pedestrian at-grade rail crossings not located within a street or highway, detectable warning surfaces shall be placed on each side of the rail crossing. The edge of the detectable warning surface nearest the rail crossing shall be 1.8 m (6.0 ft) minimum and 4.6 m (15.0 ft) maximum from the centerline of the nearest rail. Where pedestrian gates are provided, detectable warning surfaces shall be placed on the side of the gates opposite the rail.

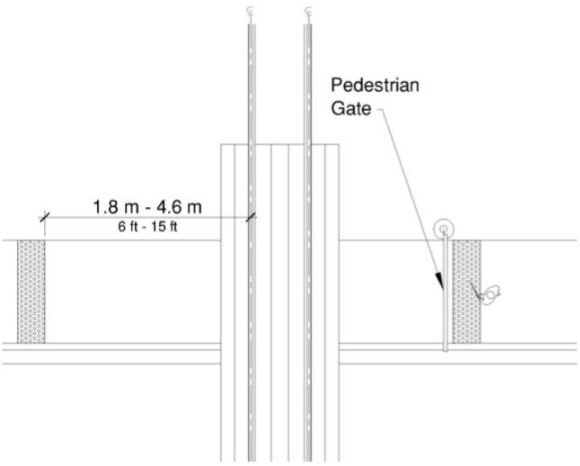


Figure R305.2.5 Pedestrian At-Grade Rail Crossings

R305.2.6 Boarding Platforms. At boarding platforms for buses and rail vehicles, detectable warning surfaces shall be placed at the boarding edge of the platform.

> R305.2.7 Boarding and Alighting Areas. At boarding and alighting areas at sidewalk or street level transit stops for rail vehicles, detectable warning surfaces shall be placed at the side of the boarding and alighting area facing the rail vehicles.

Guidance Surface Practice

National standards for guidance surfaces do not exist in the U.S. Their current use is not widespread and surfaces and installations differ widely. The most commonly used surface seems to be raised bars that are within the width and spacing standardized in ISO 52399:2019, but the width of the raised bar guidance surface itself is often less than the minimum specified in that standard.

However, FHWA's publication *Accessible Shared Streets – Notable Practices and Considerations for Accommodating Pedestrians with Vision Disabilities* (Elliott, J. et al. 2017) says "Directional indicators [raised bars] should not be used to define the edge between exclusive pedestrian space and vehicular lanes (bicycle or motor vehicle) but rather to delineate the path for through pedestrian travel. They also should not be used for aesthetic or general edging purposes as this could confuse the meaning".

Detectable Warning Surface Practice

As of 2019, DWS are routinely installed at curb ramps in new or altered construction (see Figure 4), although not all installations meet the precise geometry specified in the *Proposed PROWAG*. DWS at blended transitions and pedestrian refuge islands are less consistently present or precisely positioned. All rail properties in the U.S. have installed DWS at most or all platform edges and installation of DWS at the remaining rail platforms is planned.

Photo: B. Bentzen.

Figure 4. A DWS located at a curb ramp and a level crossing in Portland, OR.

In the US, truncated dome DWS are used at curb ramps and hazardous vehicular ways simply to indicate locations where there is a potential of failing to detect the limit of the pedestrian way. These surfaces are not required elsewhere, nor are they intended for additional uses such as marking transit boarding areas.

Truncated dome DWS have not been intended to indicate a place from which pedestrians who are blind or who have low vision should cross. However, they are now being used in some areas with shared streets to indicate preferred crossing locations. Many travelers who are visually impaired do not choose to begin crossing from curb ramps. They may have better information for establishing a heading for crossing (aligning), and the crossing distance may be shorter if they cross from the curb beside a curb ramp. In the U.S., truncated domes are not intended for aligning because U.S. research has shown that pedestrians who are blind or who have low vision are not able to align accurately with truncated domes (A. Scott personal communication 2013).

At U.S. rail transit stations, truncated domes 24 inches (600 mm) deep, in the direction of crossing, are placed at platform edges. When the U.S. standard was being developed, input from rapid rail property safety managers indicated that the detectable warning should be along the edge of the platform, in the same location that was typically marked in a contrasting color, indicating that waiting passengers should not stand in this area. Safety managers were concerned that placing the detectable warning farther from the platform edge would encourage passengers to wait farther back, effectively reducing the platforms' carrying capacity, especially for the narrow platforms that were common in older systems. They were also concerned that by causing most people to wait farther from the platform edge, some passengers would use the space between the detectable warning and the platform edge as an "expressway" where they could quickly walk down the platform, although they would be too close to the edge. From the perspective of passengers who are visually impaired, an area of the platform along the edge that did not have truncated domes seemed ambiguous. Therefore, the location of the platform edge was indicated and travelers were left to decide how close to the warning they wished to stand.

Figure 5 shows a DWS located at the edge of a high-level platform in Seattle. The photo also shows a sinusoidal surface intended to indicate the location of a train door and a unique artistic guidance surface intended to aid travelers who are visually impaired in traveling down the length of the platform. Figure 6 shows a DWS located at the edge of low-level platform in Seattle.

Photo by B. Bentzen.

Figure 5. DWS and guidance surfaces at a high-level train platform in Seattle.

Photo by B. Bentzen.

Figure 6. DWS at a low-level train platform in Seattle.

In recent years, guidance surfaces have been installed at a number of transit properties, including in and around some bus and rail stations. Most of these installations use a raised bar surface, but the surface geometry, surface width, and installation locations vary. Figure 7 shows a 6-inch (150-mm) wide raised bar guidance surface at a bus stop at the Warm Springs BART station in Fremont, CA. Figure 8 shows 6-inch (150-mm) wide raised bar guidance surfaces at a bus stop at De Anza College in Cupertino, CA.

Photo by B. Bentzen.

Figure 7. Guidance surface at a bus stop in Fremont, CA.

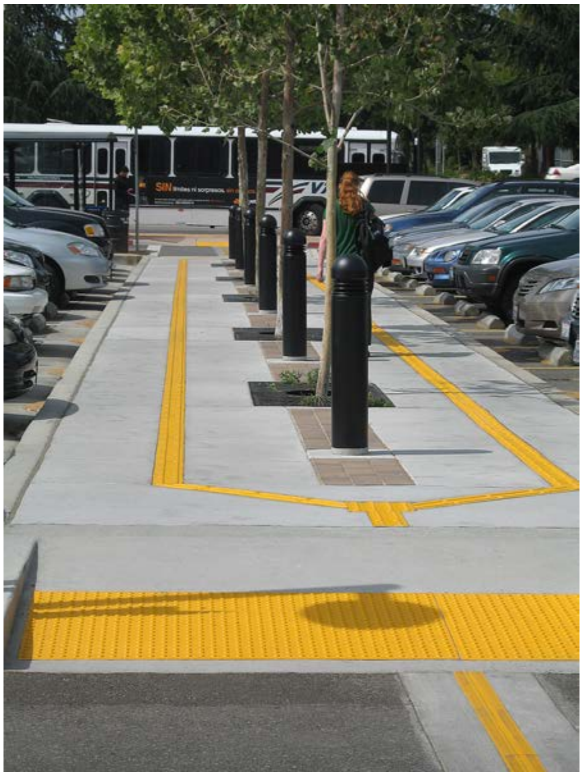


Photo courtesy of Armor Tile.

Figure 8. DWS and guidance surfaces at a bus stop at De Anza College, Cupertino, CA.

Figure 9 shows a 24-inch (600-mm) wide raised bar guidance surface in the parking garage at the Pleasanton BART station in Pleasanton, CA. Figure 10 shows a 6-inch (150-mm) wide raised bar guidance surface installed by Caltrain in Santa Clara, CA.

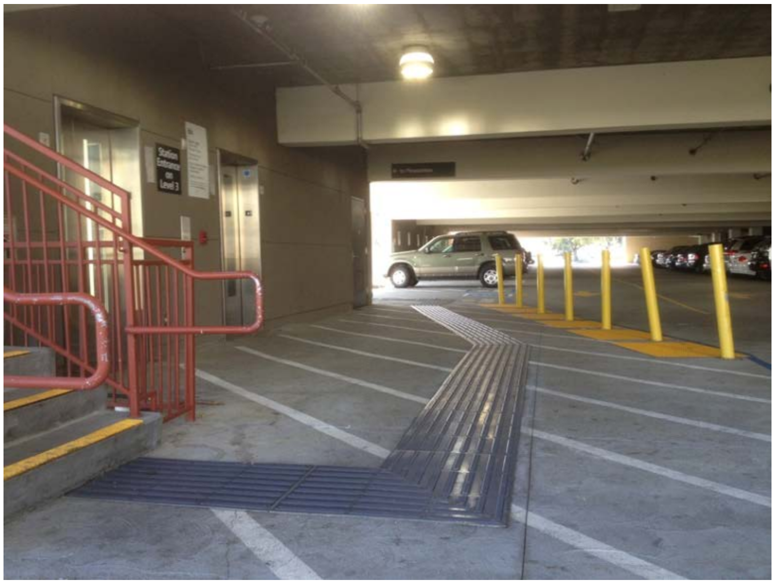


Photo courtesy of Armor Tile.

Figure 9. Guidance surface in a transit station parking garage in Pleasanton, CA.

Photo courtesy of Armor Tile.

Figure 10. Guidance surface at a commuter rail station in Santa Clara, CA.

Some cities have installed unique TWSIs for special purposes. Figure 11 and Figure 12 show attempts in two different cities to provide a tactile alignment cue after pedestrians who are visually impaired reported having difficulty aligning to cross at blended, large radius corners. Two strips of thermoplastic marking were installed perpendicular to the crosswalk travel direction. This installation may have worked for the individual requesting it after he became familiar with where to look for the two bars, but it never became a widely used solution. This cue has not been evaluated for detectability by pedestrians who are visually impaired, nor negotiability by travelers with mobility impairments.

Photo by J. Barlow

Figure 11. A blended corner with detectable warnings preceded by thermoplastic strips intended to provide alignment information.

Photo by B. Bentzen.

Figure 12. Angled tactile bars installed at an apex curb ramp, at angles perpendicular to the direction of travel on each of the crosswalks served by the curb ramp.

Guidance surfaces are also being installed to aid wayfinding by travelers who are visually impaired at shared streets and shared bicycle/pedestrian facilities at the same level. Again, the surface geometry, surface width, and installation location varies (Elliott et al. 2017). Figure 13 shows a 6-inch (150-mm) wide guidance surface comprised of two raised bars used in Seattle to delineate between the pedestrian and cycle areas in a sidewalk-level shared bikeway. A 24-inch (600-mm) deep area of a DWS indicates where pedestrians are intended to cross the bikeway. Figure 14 shows a 12-inch (300-mm) wide delineator strip of methyl methacrylate (MMA) being installed as a central delineator on a shared bicycle lane at sidewalk level in Seattle.

Photo B. Bentzen.

Figure 13. Guidance surfaces delineating bicycle and pedestrian areas and crossings in Seattle, WA.

Photo courtesy of D. Chang.

Figure 14. Installation of a guidance surface in Seattle, WA.

Japan

Standard

JIS T 9251 (2001) specifies the geometry of both truncated domes and raised bars for use as TWSIs. The top diameter of truncated domes is 12 mm (0.47 inch), the base is 22 mm (0.87 inch), and the spacing between truncated domes is 55–60 mm (2.17-2.36 inch) on center. The width of the top surface of raised bars is 17 mm (0.67 inch), the base is 27 mm (1.06 inch), and the center spacing is 75 mm (2.95 inch). The height of both truncated domes and raised bars is 5.0 mm (0.2 inch).

The Foundation for Promoting Personal Mobility and Ecological Transportation (2002) published an Addendum to the "Guidelines to improve barrier-free access for public transport passenger facilities," which provides guidance for installing TWSIs in transportation facilities, particularly rail stations with elevated platforms. It recommends that raised bar guidance be provided from an entrance point, through the ticket gates, to the boarding platform. Along the way, branching paths are to be provided to elevators, toilets, ticket windows, ticket vending machines, and tactile Braille displays. It also notes that truncated domes are to be provided at the tops and bottoms of stairs, ramps, and escalators, as well as along boarding platform edge drop-offs and at the ends of platforms. Truncated domes should be used at decision points where guidance paths intersect or turn. Along platform edge drop-offs, a line of truncated domes should extend the full length of the platform, placed 80 to 100 cm (32 to 40 inches) back from the drop-off, unlike in the U.S., where the DWS is placed at the drop-off. The width of Japan's truncated dome lines is not specified or indicated in drawings, but they appear to be approximately 30 cm (12 inches); in comparison, in the U.S., they are required to be 24 inches (60 cm) wide. Japanese raised-bar guidance appears to be approximately 30 cm (12 inches) wide wherever it is used, and truncated dome attention fields at corners and intersections of raised-bar guidance appear to be approximately 60 cm (24 inches) square.

There is no Japanese standard for TWSIs in public rights-of-way.

Practice

Both truncated dome attention fields and raised bar guidance surfaces are ubiquitous throughout Japan, but installations vary somewhat in dimension and material composition. Truncated domes are increasingly installed as areas of discrete "buttons," while raised bars are also seen as paths of discrete parallel bars rather than as pavers with raised bars``. TWSIs are used indoors in some public buildings as well as outdoors. Despite the universal use of TWSIs placed on the full length of high-level train platforms, the frequency of platform-edge falls remains a concern (Akatsuka, Kuskami, and Sato 1999; Fujinami 2005; Okhura et al. 1995, Shimizu et al. 2001; M. Tauchi, personal communication 2008). As a result, additional TWSIs have been added on some platforms, most commonly consisting of a raised bar preceding the domes or a guiding pattern prior to the platform edge. It is common, especially during times of high platform usage, to see travelers standing or walking on the domes/guiding pattern and between the domes/guiding pattern and the platform edge (personal observation, B. Bentzen 2008) (see Figure 15).

Photo by B. Bentzen.

Figure 15. Travelers walking along platform edge, between domes and drop-off.

When guiding patterns are used on sidewalks, they always lead to crossings. At mid-block crossings, guiding patterns extend across the sidewalk, with raised bars oriented parallel to the crossing direction, leading to the attention field preceding the crossing (see Figure 16). At all crossings, there is an area of truncated domes placed at, or a short distance from, the curb line.

Photo by B. Bentzen.

Figure 16. A guidance surface and attention field at a mid-block crossing in Japan.

TWSIs are commonly used to indicate the path toward and the location of specific destinations such as bus stops, tactile maps, and elevators, as illustrated in Figure 17.

Photo by B. Bentzen.

Figure 17. Guidance surfaces and attention fields used to aid in locating a bus stop.

Canada

Standards and Guidance

Ontario

The first accessibility standard in Canada, the *Accessibility for Ontarians with Disabilities Act* (Province of Ontario 2005), was passed by the province of Ontario and implemented through the *Integrated Accessibility Standards* (Province of Ontario 2011). This provincial standard requires TWSIs at curb ramps, depressed curbs, and the tops of stairs. TWSIs are specified very loosely as required to have raised tactile profiles and high tonal contrast with the adjacent surface. In all of the three locations where they are required, they must be 610 mm (24 inches) deep in the direction of travel, and at curb ramps and depressed curbs, they must be set back between 150 and 200 mm (6 and 9 inches) from the curb edge. In all usage, they must extend the full width of the hazard. Jurisdictions have the flexibility to determine specifications for TWSIs based on “best practice” or their own studies (Access Ontario 2014).

Canadian Accessibility Standard

CSA B651-18 Accessible design for the built environment (2018) is mandatory for all federal buildings and sites and is used as a model for accessibility standards in some provinces. It includes technical specifications for TWSIs and standards for their use. Truncated domes are to be used as attention fields, and raised bars are to be used as direction indicators. Both are required to be 4–5mm (0.16–.20 inch) in height and must differ in luminance from the surrounding surface. Yellow is preferred for truncated domes but not required. However, yellow may not be used for raised bars. Dimensions of truncated domes and raised bars have a wide range, corresponding to that in *ISO 23599:2019*.

Truncated domes, wherever they are used, shall be 600–650 mm (24–26 inches) deep in the direction of travel. Truncated domes are required on curb ramps, where they are set back from the curb line 300–350 mm (12–14 inches), unlike in the U.S., where DWS are required to be placed at the curb line. As in the US, the truncated domes are not used as direction indicators. They are required at transit platforms having a drop-off, where they shall be adjacent to the drop-off, as in the US. Truncated domes are required at pedestrian refuge islands and medians, both those that have curb ramps, and those that are cut through. They are also required at the top of stairs, at reflecting pools, at turns, and at decision points. Truncated dome attention indicators must also be used along accessible pedestrian routes that are not separated from vehicular routes by curbs, railings, or other barriers.

Directional indicators are required in large open-floor areas, such as malls and transit terminals, where they lead from the entrance to major destinations. Where they indicate a route to follow, they should be between 250 and 300 mm (10 and 12 inches) wide. Where they are installed across a path of travel to indicate a facility, such as the location of a crossing, they should be between 600 and 650 mm wide (24 and 26 inches). Wherever used, they must have a clear space at least 600 mm (24 inches) on each side.

Canadian practice varies widely between provinces. Two examples are shown below. Figure 19 shows a 600-mm (24-inch) deep truncated dome attention field placed along a blended curb in Toronto. It follows the curve of the curb. Figure 18. shows TWSIs indicating a path of travel to the top of a staircase in Mississauga, Ontario. The truncated domes and raised bars are discrete elements. Truncated domes indicate turns or decision points, as well as the top of the stairs.

Photo by Lesley MacDonald

Figure 18. DWS along a blended curb in Toronto.

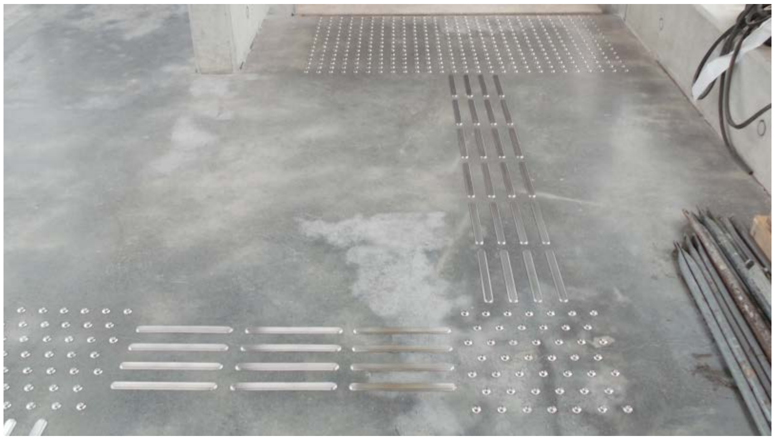


Photo courtesy of Armor Tile.

Figure 19. Guidance surfaces and DWS leading to a staircase in Mississauga, Ontario.

Australia and New Zealand

Australia/New Zealand Standard

AS/NZS 1428.4.1 2009 Australian/New Zealand Standard: Design for Access and Mobility. Part 4.1: Means to Assist the Orientation of People with Vision Impairment—Tactile Ground Surface Indicators provides standards, guidance, and advisory notes. According to this standard, TWSIs should be installed to provide guidance or warning of an obstruction or hazard in any location where insufficient alternative or "natural" tactile cues exist. There is no intention to create a continuous path of travel.

In Australia and New Zealand, the term "Tactile Ground Surface Indicators" (TGSIs) is used instead of TWSIs. The dimensions of these "warning TGSIs" comprised of truncated cones and "guiding TGSIs" comprised of raised bars are tightly specified. Raised elements are relatively large and spaced relatively closely with minimal tolerance. The truncated cones have a top diameter of 25 mm (1 inch) and a base diameter of 35 mm (1.4 inch) with a center spacing of 50 mm (2 inches). Raised bars are required to have a top width of 25 mm (1 inch) and a base width of 35 mm (1.4 inch), with a center spacing of 75 mm (3 inches). Both types of surfaces are required to have the top surface no more than 4–5 mm (0.16–0.2 inch) above the base surface.

Truncated cones in a square arrangement are used to indicate hazards or decision points, while raised flat-topped bars are used to indicate paths of travel, including locations of pedestrian crossings and transit stops. Hazards at which truncated cones are used include locations where pedestrians and vehicles are at the same grade, such as curb ramps, blended curbs, or cut-through islands. They are also used at the tops and bottoms of stairways, ramps, escalators, and moving walkways, and where there are hazards within the circulation space or adjacent to a continuous accessible path of travel. A setback is required between all grade changes and hazards and where pedestrian ways join roadways at grade. Directional surfaces are used to indicate the location and direction of some pedestrian crossings on railway platforms, passenger wharves, bus stops, and light rail stops. Truncated cones 600 to 800 mm (24 to 32 inches) square indicate direction changes and intersection locations in a guiding path. TGSIs may be integrated into an applied surface or incorporated as discrete elements (truncated cones or raised bars).

Truncated cones used on curb ramps must be oriented so the edge farthest from the curb line is perpendicular to the direction of crossing, in order to serve as a cue for alignment. However, truncated cones are not required at all curb ramps. Curb ramp slope is permitted to be steeper in Australia and New Zealand than in the U.S. Slopes of 1:8 are permitted and common, while curb ramps are required to have slopes no steeper than 1:12 in the U.S. *AS/NZS 1428* does not require truncated cones at crossings where the slope of the curb ramp is 1:8.5 or greater because it is assumed that pedestrians who are visually impaired will readily detect the presence of such steep curb ramps, using the presence of the curb ramp to indicate a crossing location and the direction of the slope to indicate the crossing direction. Where the slope is less than 1:8.5, truncated cones require a minimum width of 1000 mm (40 inches), a setback from the curb line of 300 mm (12 inches), and a depth of 600–800 mm (24–32 inches) in the direction of travel. In addition, if the top of the curb ramp is less than or equal to 3000 mm (120 inches) from the building line, aligned with the building line, and aligned with the direction of travel on the crosswalk, truncated cones are not required.

The text of the standard notes that TGSIs can adversely affect travel by pedestrians with physical disabilities and recommends application in such a way that tactile indicators are minimized on the sloping surface of curb ramps. Truncated cones do not extend all the way across curb ramps and are sometimes located beside curb ramps to indicate a crossing location other than the curb ramp. Where raised bars are used to indicate the location of a crossing, they never extend down a ramp slope to join the truncated cones.

At some crossings, curb ramps are “dual-entry” with a width of at least 2000 mm (80 inches). These “dual-entry” curbs require a truncated cone warning for a width of 1000 mm (40 inches) on just one side, leaving the other side for travelers using wheeled mobility aids. Dual-entry crossings require a 300-mm (12-inch) wide path of the raised bar surface leading across the sidewalk from the building line to the top of the curb ramp, but the directional surface does not extend down the curb ramp to join the truncated domes.

Practice

TGSIs are widely used throughout Australia. The photos below show examples of installations in public rights-of-way. Figure 20 shows a raised-bar guidance strip across the sidewalk at a roundabout. The guidance strip does not extend down the curb ramp to the truncated cone warning, and the warning surface is at an angle to the curb line so that the edge farthest from the curb line is perpendicular to the crosswalk. Figure 21 shows TGSIs across a cut-through splitter island in Melbourne. Truncated cones aligned with the direction of travel on the associated crosswalk are at each side of the island and connected by a path of raised bars.

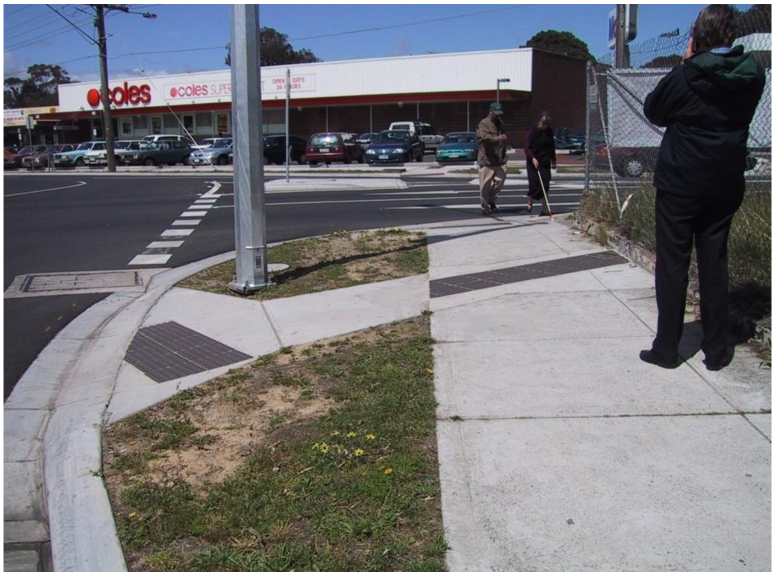


Photo by B. Bentzen.

Figure 20. TGSIs at a roundabout crosswalk in Australia.

Photo courtesy of Armor Tile.

Figure 21. TGSIs across a splitter island in Melbourne, Australia.

Figure 22 shows a guidance pattern of raised bars across a sidewalk in New Zealand which indicates the location of a mid-block crossing at a bulb-out. There is an attention field of truncated cones near the curb line. Figure 23 shows attention fields oriented perpendicular to the crossing directions in Auckland, New Zealand. One attention field is comprised of discrete elements, while the other is an integrated surface.

Photo by B. Bentzen.

Figure 22. TGSIs at a bulbed-out mid-block crossing in New Zealand.

Photo by B. Bentzen.

Figure 23. Attention fields oriented perpendicular to the crossing direction in Auckland, New Zealand. **One attention field is comprised of discrete elements, while the other is an integrated surface.**

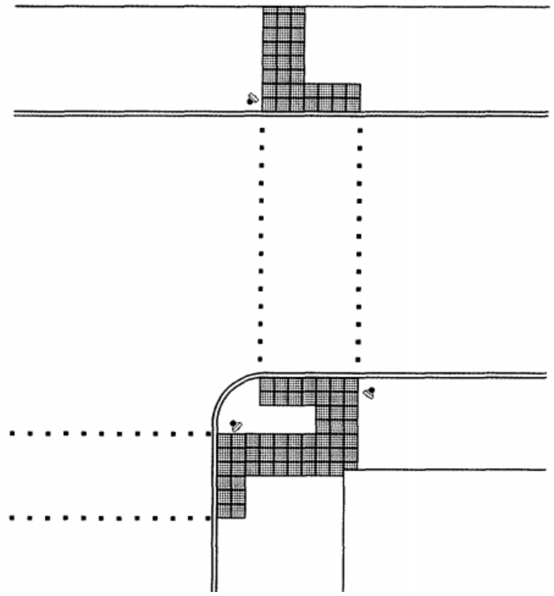
United Kingdom

Guidance

There is no standard requiring TWSIs in the U.K., but extensive guidance is provided in *Guidance on the use of Tactile Paving Surfaces* (UK Department of the Environment, Transport and the Regions 1998). The installation of tactile paving surfaces is recommended for new construction, repairs, and alterations to pedestrian areas. Detailed guidance is provided on the dimensions and installation of each of seven surfaces for various purposes (see the U.K. section of ***Research on TWSIs since the 1990s,*** above); all but two of these surfaces are variations on truncated domes and raised bars.

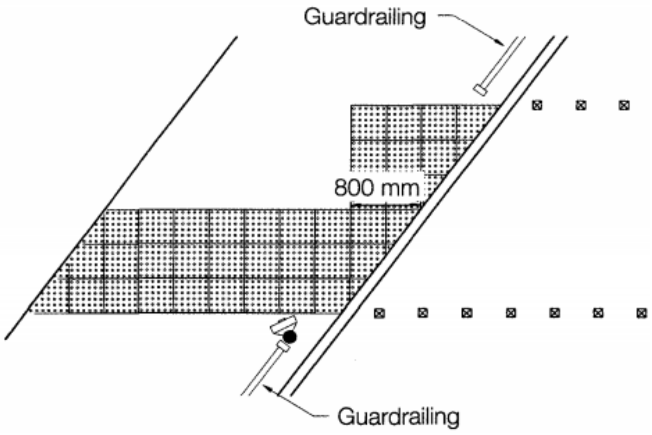
Blister (truncated dome) paving is used at signalized crossings. The blisters should be 5 mm (0.2 inch) high, have a 25-mm (1- inch) base diameter, and have a 66-mm (2.6-inch) center spacing. Red blister paving should be installed at the curb line for the full width of the bottom of the curb ramp, which is as wide as the pedestrian crossing. In locations where the crossing is in the direct line of travel, such as corners, the blister surface should be 1200 mm (48 inches) deep (in the direction of travel); at all other signalized crossings, the depth should be 800 mm (32 inches). The back edge of the blister surface should be perpendicular to the direction of travel on the crosswalk, which may not necessarily be parallel to the curb line. This design is intended to provide a cue for alignment. A “stem” of blister surface, 1200 mm (48 inches) wide, should extend from the curb line to the opposite side of the sidewalk or to the building line, as an aid for locating crossings. To assist with alignment, this stem should be oriented in the direction of travel across the crosswalk and should lead to the pushbutton.

Figure 24 from *Guidance on the use of Tactile Paving Surfaces* shows two crossings at a T-shaped intersection— a corner having two crosswalks, and a mid-block crossing from the stem of the T. The mid-block crossing is a simple L-shape. The blister paving at the corner where two crossings intersect is nearly Z-shape. Figure 25 shows one end of a mid-block crossing in which the crosswalk is not perpendicular to the sidewalk. The stem goes diagonally across the sidewalk in line with the crossing direction. The rest of the blister paving is triangular and always extends at least 800 mm (32 inches) back from the curb line with no setback.



Source: *Guidance on the use of Tactile Paving Surfaces* (UK Department of the Environment, Transport and the Regions 1998)

Figure 24. Layout of tactile paving surfaces at a T-intersection.



Source: *Guidance on the use of Tactile Paving Surfaces* (UK Department of the Environment, Transport and the Regions 1998).

Figure 25. Layout of tactile paving surfaces at a mid-block crossing not perpendicular to the sidewalk.

At uncontrolled crossings, the blister paving should be buff-colored or another color that contrasts from the adjoining paving, but not red. The minimum depth of the blister paving should be 800 mm (32 inches) from the curb line. There is no stem across the crosswalk to help in locating these crossings.

Raised bars of slightly different dimensions are used as warnings in specific situations and for guidance. The surface used for guidance paths has flat-topped bars 35 mm (1.4 inches) wide at the base with center-to-center spacing of 80 mm (3.2 inches). It is used sparingly.

Practice

TWSIs more-or-less complying with *Guidance on the use of Tactile Paving Surfaces* (UK Department of the Environment, Transport and the Regions 1998), such as the blister surface controlled crossings (see Figure 26), have been installed in many locations throughout the U.K. during the last two decades. However, in the last several years, numerous jurisdictions have departed from the guidance, making all blister paving gray and omitting the stem at signalized crossings. The Department for Transport issued *Interim changes to the Guidance on the use of Tactile Paving Surfaces* in 2015, which were intended to simplify the TWSI system and make it more usable. Organizations of and for the blind had not been extensively consulted and quickly filed objections to the *Interim Changes*, causing the interim changes to be dropped (RNIB response to “Interim changes to the Guidance on the use of Tactile Paving Surfaces”, 2015; RNIB – DfT Consultation on Tactile Paving 2015).

Photo by B. Bentzen.

Figure 26. Red blister paving leading to two crossings at a corner.

C. Thomas, the Director of Access Design Solutions UK Ltd (January 2018), indicated that although there has been some use of all of the TWSI types that were recommended in *Guidance on the use of Tactile Paving Surfaces* (1998), most pedestrians who are visually impaired differentiate the surface textures by context rather than surface geometry.

Germany

Standard

The national German standard, *DIN 32984* (2011) *Bodenindikatoren im öffentlichen Verkehrsraum* (Floor Indicators in Public Space), was revised in 2018 (*Draft DIN 32984*, 2018-06). This standard is recommended practice, which becomes a regulation once it is incorporated into local building regulations. The final standard may differ from the draft referred to in this document.

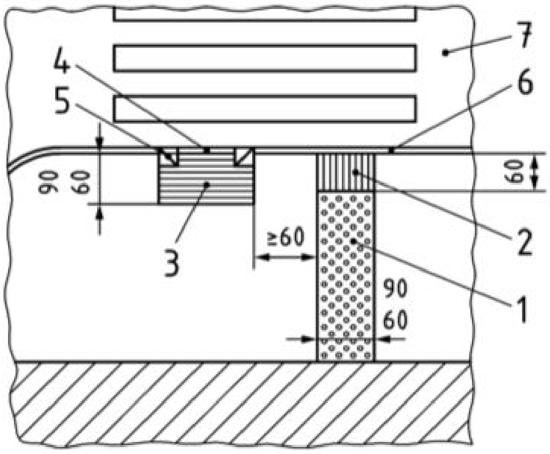
In Germany, raised bars are generally used for guidance and truncated domes for an indication of a decision point or hazard, but some installation designs are unique to Germany. Raised bars are only used on sidewalks where natural guidelines are lacking. Prior to 2011, the German standard included a sinusoidal guidance surface, but by 2011, the sinusoidal surface had been found to be minimally detectable by and useful for pedestrians with vision disabilities (Behling 2008; Böhringer 2003).

With the 2018 standard, there is considerable latitude in dimensions of truncated domes and raised bars, and the dimensions are different for interior versus exterior applications. For indoor applications, the TWSIs shall be 3–4 mm (0.12–0.16 inch) high, while for exterior applications, they shall be 4–5 mm (0.16–0.20 inch) high. Larger-diameter truncated domes with larger center-to-center spacing are required outdoors compared to indoors. Wider raised bars are permitted outdoors, but the center-to-center spacing must be less than indoors. Luminance contrast must be high, and where TWSIs are installed on a rough base surface, a 60-cm (24- inch) wide smooth walking surface is required on each side. Turns or intersections in raised bar guidance paths are marked by 90-cm (3.5-inch) square areas of truncated domes.

In *DIN 32984* (2011), crossings were to be marked with a combination of truncated domes and raised bars. A 60-cm (24-inch) wide strip of truncated domes was required to be placed across the sidewalk, leading to a raised bar surface behind the curb line with bars oriented parallel to the direction of travel on the crosswalk. Curbs at crossings were to be 3 cm (1.2 inch) in height. However, it was found that curbs this high were an obstacle to persons traveling with the aid of wheelchairs or rollator walkers, and pedestrians who had vision disabilities did not reliably detect these curbs because they were too low. Therefore, the *Draft DIN 32984*(2018-06) recommends separate crossing points for travelers who have vision disabilities and travelers using wheelchairs or rollator walkers, although they are both within the width of the associated crosswalk. This concept was originally proposed by Böhringer (2007).

In *Draft DIN 32984* (2018-06), the curb at crosswalks should be 6 cm (2.4 inches) high where pedestrians who are visually impaired are intended to cross, tapering to a minimum of 0 cm for a distance of 1 m (39 inches) (i.e., no elevation difference) to facilitate crossing by people using wheelchairs or rollator walkers. At signalized crossing locations intended for pedestrians who are visually impaired, a 60-cm (24-inch) wide strip of truncated domes should extend across the sidewalk, terminating in a 60-cm (24-inch) wide area of raised bars oriented parallel to the direction of travel on the crosswalk and extending for a distance of ≥90 cm (≥36 inches) behind the curb line. The raised bars are intended to be used to establish a heading across the crosswalk. Where there is no curb, there should be a 60-cm (24-inch) wide area of raised bars at the curb line, oriented parallel to the curb line, indicating that it is not the intended location for pedestrians with visual impairments to cross. At unsignalized crossings, which are deemed less safe for pedestrians with vision disabilities, the strip of truncated domes across the sidewalk should terminate 60 cm (24 inches) before the raised bar guidance surface.

Figure 27 depicts Figure 12b from *Draft DIN 32984(2018-06)*, showing the arrangement of TWSIs for crossing at a signalized location where a wide crosswalk has a portion of the curb lowered to street level (#4, to the left in the drawing). This lowered curb is preceded by a 60–90 cm (24–36 inch) deep rectangle of raised bars perpendicular to the direction of crossing (#3), indicating to pedestrians who are blind that this is not where they are intended to cross. The portion of the curb where pedestrians who are blind are intended to cross (#6, to the right in the drawing) is 3–6 cm (1.2–2.4 inches) high. A 60–90 cm (24–36 inch) wide strip of truncated domes is placed across the sidewalk to indicate the location where pedestrians who are blind are intended to cross (#1). This strip terminates at the curb line with a 60-cm (24- inch) deep field of raised bars oriented parallel to the direction of crossing (#2).



Source: Draft DIN 32984(2018-06).

Figure 27. Layout of crossing point for pedestrians with visual disabilities adjacent to a curb ramp.

The standard is illustrated with abundant and detailed examples of how TWSIs should be used in various situations, including at different types of street crossings, at various types of transit facilities, along bike paths, to various facilities, around obstacles, and indoors.

Practice

Sinusoidal wave surfaces are still commonly seen in some locations in Germany, despite their deletion from the standard in 2011. Germany is a federal state, and many states have their own accessibility standards that sometimes differ from the national standard. Therefore, TWSIs vary significantly throughout the country. The city of Bamberg (2014) published a well-illustrated guide to DIN 32984, *Bodenindikatoren im öffentlichen Raum: Leitfaden zur praktischen Anwendung der DIN 32984*. Figure 28 is an illustration from this guide, depicting truncated domes across a sidewalk to indicate the location of a crossing. Raised bars along the curb line are oriented parallel to the crossing direction.

Source: City of Bamberg (2014).

Figure 28. Use of TWSIs to indicate a crossing location.

Sweden

Guidance

Sweden does not have technical standards for TWSIs. However, well-illustrated guidance is available in *Enklare utan hinder* (Simpler without barriers) (National Board of Housing 2005). The guidance offers solutions for providing accessibility to public spaces for travelers with orientation problems (including visual impairment) or other disabilities. The Planning and Building Act of 1 July 2001, Chapter 17, requires that public spaces in new construction and alterations be accessible but does not provide technical standards. Swedish philosophy regarding provision of accessibility recommends that elements commonly used in an environment should provide good information for orientation. For example, a pathway of smooth pavers in a cobblestone sidewalk or landscaping beside a path of travel can be followed to a destination or a decision point. It recognizes, however, that some built environment features provide insufficient wayfinding information for travelers with impaired vision. A variety of TWSIs which provide additional orientation information in various jurisdictions are shown and described in the guidance. Jurisdictions or properties may use any system that they believe works to provide accessible orientation information.

Practice

Because there is no technical standard and because a variety of TWSIs are provided as examples, there is wide variation in application of TWSIs in Sweden. Although truncated domes are sometimes used as a warning surface or decision point indicators, smooth surfaces are the more common decision point indicators. A path of raised bars is sometimes used for guidance, but paths comprised of a sinusoidal surface with the ridges oriented in the direction of travel are more commonly seen. Decision points, such as turns and street crossings, may be indicated by an area of truncated domes.

Denmark

Standards and Guidance

The Danish accessibility standard, *DS ISO 21542:2012 Bygningskonstruktion – Tilgængelighed til og anvendelighed af det byggede miljø* (Building construction — Accessibility to and utility of the built environment), is based on *ISO 21542:2011*. It includes an Annex A (informative): Tactile walking surface indicators (TWSIs). (See above for a discussion of the differences between *ISO 21542:2012* and *ISO 23599:2019*.)

In addition, comprehensive guidance for TWSIs is provided in the handbook *Færdselsarealer for alle* (Travel areas for all) (Danish Road Directorate 2017), accompanied by abundant diagrams and photos of TWSI use in a variety of situations, including shared spaces and shared bike lanes. The Danish philosophy for installation of TWSIs is similar to that of Sweden; that is, TWSIs are recommended where there are no natural guidelines in the built environment (Danish Society for the Blind 2015). This guidebook describes and illustrates TWSIs of three types used in combination with one another: truncated dome attention fields, raised bar guiding lines, and raised bar directional fields. The three types of TWSIs were not included in either *DS ISO 21542:2012* or *ISO 23599:2019,* but recommended dimensions for attention fields and guiding lines are identical to those in *ISO 23599:2019*. Attention fields should have a depth of 900 mm (36 inches) in the direction of travel, but they may be a minimum of 800 mm (32 inches) deep. Thus, Danish attention fields are required to have a greater depth than the minimum 550 mm (22 inches) required by *ISO 23599*. Furthermore, dimensions for raised bar directional fields are not prescribed, but appear in illustrations to have wider flat-topped bars, spaced closer, together than the bars for guiding.

Guiding lines may have either three or four raised bars, resulting in an effective width of between 141 mm (5.54 inches) and 210 mm (8.27 inches). Unlike attention fields, even the maximum width for guiding lines is less than the 250-mm (10-inch) effective width specified in *ISO 23599:2019.* Directional fields are also comprised of raised bars as specified in *ISO 23599:2019*, but installations are wider than those for guiding lines. It is recommended to increase the effective width of the raised bar surface where it is important that the bars be detected from different directions of approach. This follows the concept of *ISO 23599:2019* that recommends that the effective width of guiding lines should be greater where travelers need to detect guiding lines from different angles of approach. In this case, the minimum width required by *ISO 23599:2019* is 550 mm (22 inches).

Attention fields should be used at intersections of guiding lines or where guiding lines turn at more than 45 degrees. Attention fields should also be used at street crossings where they are usually placed perpendicular to the direction of any associated guiding line or direction field and should be at least 300 mm (12 inches) back from the vehicular way.

At hard-to-find crossings, such as at roundabouts and channelized turn lanes, installation of 800 to 900 mm (32 to 36 inch) wide direction fields across sidewalks are recommended to help in locating the crossings. The direction fields lead to one end of the associated attention field near the curb line and are oriented with the bars parallel with the direction of travel on the crosswalk (see Figure 29).

Source: Danish Road Directorate (2017).

Note: The line of small pavers on the left side of the guidance surface is not standard.

Figure 29. Example guidance and warning surfaces at a signalized intersection in Viborg, Denmark.

Practice

The organization of people in Denmark who are blind or who have low vision, the Dansk Blindesamfund (Danish Society for the Blind), published a guidebook for making the environment accessible to Danes who are visually impaired, titled *Tilgængelighed for blinde og svagsynede* (2015). This guidebook is consistent with *Færdselsarealer for alle* (Danish Road Directorate 2013), and repeatedly emphasizes the use of common features in the built environment for guidance, such as pavement edges; rows of small, rough-surfaced, cut-stone pavers; or landscaping, rather than added guidance features such as attention fields, guiding patterns, or directional fields. The geometry and appearance of existing guiding patterns are quite varied.

Figure 30 illustrates TWSIs indicating an intersection of two shared streets in Fredensborg, Denmark. The guiding pattern is a single line of short raised bars. The intersection of guiding patterns is indicated by a large rectangle of truncated domes. Figure 31 shows a location where the base walking surface is concrete for most of its length and the guiding pattern is four bars wide and composed of individual elements. Where the base walking surface changes to pavers, the guiding pattern changes to pavers with four raised bars. At the intersection of guiding patterns, a rectangle of truncated domes composed of individual elements is used.

Photo by B. Bentzen.

Figure 30. Guidance pattern used at intersection of two shared streets in Fredensborg, Denmark.

Photo by B. Bentzen.

Figure 31. Change in guidance surface material with a change in the base walking surface.

Figure 32. shows a shared street where the guiding pattern is red pavers with four raised bars contrasting nicely with the adjoining flat, gray, concrete pavers. At the intersection of the guiding patterns, a large rectangle of truncated dome pavers is the same color as the flat pavers. Figure 33. shows a mid-block curbside bus stop, where a small rectangle of the Danish direction field, comprised of raised bars perpendicular with the direction of travel along the sidewalk, leads to a similarly sized warning surface set back from the curb.

Photo by B. Bentzen.

Figure 32. Non-contrasting attention field at the intersection of two guiding patterns.

Photo by B. Bentzen.

Figure 33. Guidance and warning surfaces used at a bus stop.

SUMMARY AND CONCLUSIONS

Worldwide, with few exceptions, truncated domes or cones are used to warn vision disabled pedestrians of hazards in the line of travel, and raised bars oriented in the direction of travel are used to provide guidance, but there is wide variability in the dimensions and spacing of the raised elements, and where they are used. However, in most countries it is accepted that:

- TWSIs should be easily detected from surrounding surfaces, both under foot and by use of a long cane.
- TWSIs should be easily discriminated from one another, both under foot and by use of a long cane.
- TWSIs should be highly visible to travelers with reduced vision.
- TWSIs should not adversely impact other travelers any more than necessary.
- TWSIs should be 4–5 mm (0.16–0.20 inch) high for good detection, especially in outdoor environments where walking surfaces are not uniformly smooth.

The US has a standard for the dimensions of DWS, which permit a good deal of latitude in dome diameter and spacing, which is based on repeated US research confirming detectability both under foot and by use of a long cane. It is well established that DWS 24 inches (600 mm) deep, in the direction of travel, enable detection and stopping without going beyond the DWS on at least 90% of approaches. There are requirements for their use at boarding platform edges and at curb ramps (ADA Standards for Transportation Facilities, 2006), and more specific guidance for use on different kinds of curb ramps, at pedestrian refuges and at rail crossings in Proposed PROWAG. However, there is no US standard for a guidance surface, and no research to identify combinations of truncated dome DWS and raised bar guidance surface dimensions that are readily discriminated from one another.

Many countries have standards or guidance specifying luminance contrast between TWSIs and surrounding surfaces, and some specify a particular hue. ISO 23599.2019 has minimum values for luminance contrast for TWSIs, and recommends a particular formula and measuring techniques. The most common color is yellow. There is increasing use internationally of discrete elements, truncated domes or bars, to form TWSIs. ISO 23599.2019 recognizes this trend, and requires that TWSIs comprised of discrete elements require greater contrast to achieve high visibility than TWSIs that are integrated into modular surfaces that are uniform in color. US standards for visual contrast specify simply “light-on-dark or dark-on-light.”

Worldwide, there are two philosophies for the use of TWSIs. In some countries TWSIs are intended to provide continuous guidance throughout the pedestrian environment, including transit facilities. In other countries, natural features of the built environment such as curbs, buildings, or landscaping are expected to provide primary guidance, with the use of TWSIs limited to areas where there is insufficient information provided by natural features. In the US, it is expected that the use of TWSIs will be limited to areas where natural features provide insufficient information.

Worldwide, it is recognized that TWSIs to promote safety and wayfinding for pedestrians who are vision disabled do have some negative impact on travel for people who are mobility disabled. Research and experience show that TWSIs having elements spaced relatively far apart are most detectable to people who are vision disabled, but that TWSIs having elements spaced closer together are less aversive to people who are mobility disabled. Therefore compromise in TWSI surface geometry is necessary for the well-being of all travelers. In some countries, installation recommendations attempt to minimize the use of TWSIs where people having mobility impairments will have to cross them.

Consistency is critical in cues intended to enhance safety and wayfinding for people who have vision disabilities. Therefore truncated domes or cones should continue to be used to indicate hazards, and raised bars should continue to be used to indicate paths of travel. While precise dimensions may vary, they should be based on research on detectability and discriminability, and should be determined with regard to maximizing detectability by people who are vision disabled while not unduly affecting safety and comfort of travel by people having mobility disabilities. Limiting the use of TWSIs to where it is essential minimizes the adverse impact of TWSIs on people who are mobility disabled.

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