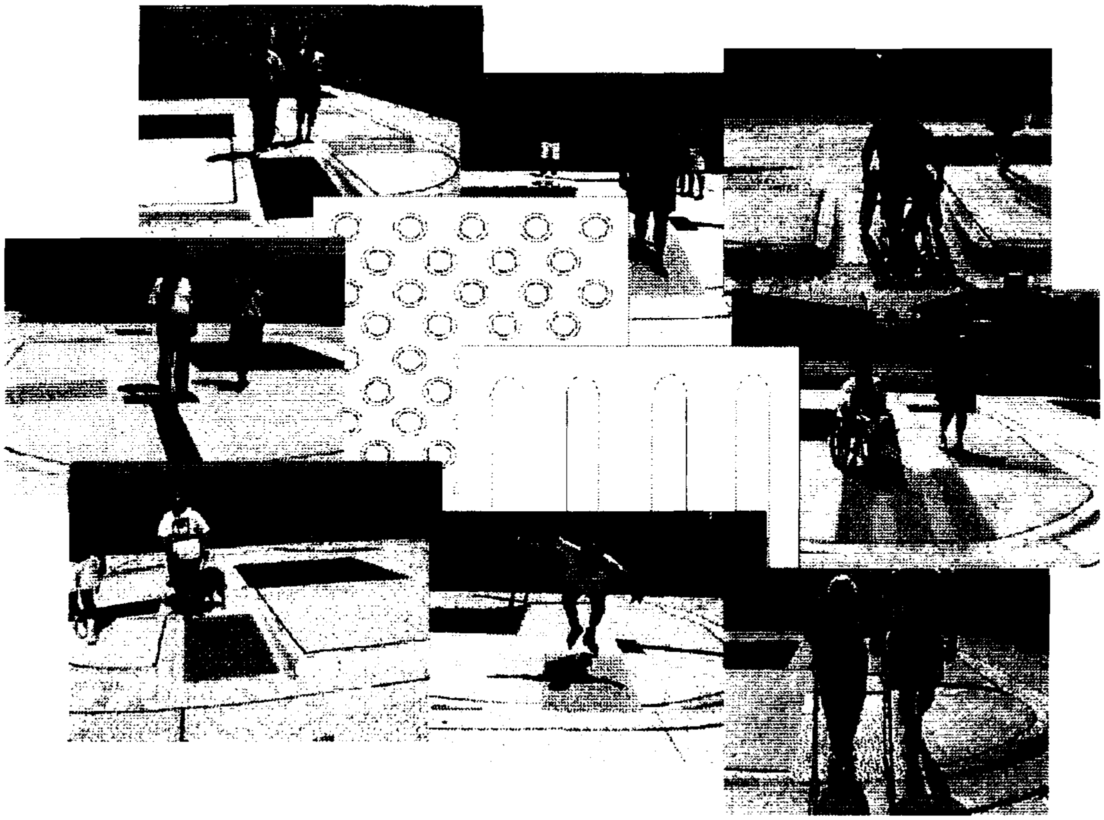
- Hughes, R.G. (1995). An Evaluation of Detectable Warnings in Curb Ramps: Mobility Considerations for the Blind and Visually Impaired. Chapel Hill, NC: University of North Carolina Highway Safety Research Center.

An Evaluation of Detectable Warnings in Curb Ramps: Mobility Considerations for the Blind and Visually Impaired



Draft Final Report (Task D)
"Evaluation of Surface and Audio Tactile Warnings"
Under R&D Contract
INTERSECTION DESIGN FOR NON-MOTORIZED TRAFFIC

Submitted to:
The Florida Department of Transportation (FDOT)
Safety Office

by
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The University of North Carolina at Chapel Hill
Highway Safety Research Center (HSRC)

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Preface

The present study was conducted under Task D, "An Evaluation of Surface and Audio Tactile Warnings," which was part of a larger R&D contract between the University of North Carolina Highway Safety Research Center (HSRC) at Chapel Hill, North Carolina and the Florida Department of Transportation. The title of the larger contract is "Intersection Design for Non-Motorized Traffic." Our special thanks to Mr. Dan Burden, State Ped/Bike Coordinator within the FDOT Safety Office, for his recognition that this research needed to be undertaken, not solely because of the pending ADA requirement, but because of his personal dedication to ensuring that the needs of all pedestrians are fully considered in the design of transportation facilities.

The conclusions and recommendations presented in this report are those of the author and not necessarily the Florida Department of Transportation. HSRC is grateful to the FDOT for its support of the present research and to the Orientation and Mobility instructors of the Florida School for the Deaf and Blind in St Augustine, FL and the Governor Morehead School for the Deaf and Blind in Raleigh, NC. The inputs provided by these individuals were invaluable in forming an understanding of the orientation and mobility problems of the blind and visually impaired pedestrian. Special appreciation goes to Mr. Jerry Stewart (Principal) and to the administration of the Florida School for the Deaf and Blind in St Augustine for permitting the construction of the experimental test facility on its grounds.

Special appreciation is also in order for the Florida Department of Transportation, both for funding the construction of the test facility and for the invaluable support provided by Doreen Joyner-Howard and the staff of the FDOT Regional Planning Office as well as the local FDOT maintenance support function in St Augustine. Mr. Dean Perkins from the FDOT design office in Tallahassee provided support both in the interpretation of ADA requirements and in ensuring that the detailed design of the test facility was consistent with established FDOT construction standards. We also want to recognize Mr. Jeff Williams in the Palatka district office for the excellent job he did in managing the actual construction phase of the test facility. Our thanks also go to Ms. Lydia Jetson and Ms. Leigh Matusick of the DeLand Sheriff's Office, to Mrs. Pat Greason in the FDOT Office of Safety in Tallahassee, and to Mr. Charles Houston and Mr. Milton Locklear from the FDOT Jacksonville office for their willingness to assist in the actual collection of data.

Acknowledgements

Special thanks to Mr. Larry Russel, Distributor/Owner of L&L Speciality Products in Daytona Beach, FL for providing the tactile warning materials used in the study as well as for their installation.

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An Evaluation of Detectable Warnings in Curb Ramps: Mobility Considerations for the Blind and Visually Impaired

Introduction

It has been reported (see Barlow, 1993) that blind individuals on occasion may fail to detect the presence of the sloped ramp used to facilitate wheel chair users' transition from the sidewalk to the street and, as a result, proceed unaware into the street and traffic as often as 35% of the time, according to Barlow. While data from a recent Access Board study (McAuley, et al, 1995) question that the frequency is this high, many blind pedestrians readily admit that they have, at one time or another, experienced the problem. It has been proposed under the Americans with Disabilities Act Accessibility Guidelines (ADAAG) that *detectable warnings*[1] be applied to the sloped surface of the curb ramp to warn blind and visually impaired pedestrians of the potential hazard.

The ADA recommendation for the use of tactile warnings in curb ramps has been put "on hold" until the Spring of 1996 pending further review and study. A comprehensive operational field evaluation on the use of truncated domes in curb ramps was commissioned by the Access Board. The study examined not only the performances of blind and visually impaired individuals as they came into contact with tactile warnings, but also the performances of other individuals having mobility limitations that might be affected be the use of tactile warnings in the ramp area (e.g, wheelchair users, those requiring the use of some type of support device such as a support cane, walker, etc.). The study was conducted by researchers from Virginia Polytechnic Institute and State University (VPI&SU). The VPI report also provides an excellent review of the literature in this area.

Concurrent with the Access Board study, the Florida Department of Transportation (FDOT) chose to pursue research of its own in order to better understand not only the operational effectiveness of tactile warnings but the key design and implementation issues associated with their use. As a precursor to this research, the University of North Carolina at Chapel Hill Highway Safety

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[1]A detectable warning is defined as a standardized surface feature build in or applied to walking surfaces or other elements to warn individuals with visual impairments of hazards along their path of travel.

Research Center (HSRC) was tasked, as part of its ongoing R&D contract support of FDOT ped/bike issues, to do two things: (1) to monitor the conduct of the Access Board study, and (2) based upon those observations, to design and conduct additional research focused on ADA compliance in the context of proposed improvement efforts in the Miami South Beach area. The key concern was whether or not strict compliance with the proposed tactile warning requirement would indirectly create mobility problems for other parts of the general pedestrian population, in particular the elderly.

Observation of the Access Board trials conducted in nearby Greensboro, NC and review of the draft VPI report on those trials provided the basis for the work reported here. While the Access Board study confirmed the results of earlier work showing that trunctated dome surfaces could be reliably detected by blind and visually impaired individuals, the study emphasized the need to deal with the larger problem; namely, the general lack of information available to the blind and visually impaired pedestrian, especially at intersections.

The present FDOT study sought to extend the findings of the Access Board study in several areas. First, the FDOT study examined the effect of variations (deviations from) the proposed ADA requirement calling for the tactile warning surface to be applied throughout the entire ramp area. The FDOT was particularly interested in evaluating the effect of selectively texturing only a portion of the ramp area in order to reduce the potential obstacle to wheelchair users or pedestrians with special mobility problems/needs. Second, the FDOT wanted to examine further the relative effectiveness of different tactile warning colors, in particular the use of yellow versus black.

Equally as important as its interest in the design and implementation issues surrounding the effective use of tactile warnings, the FDOT wanted to address the broader mobility issues of the blind and visually impaired traveler. In particular, the FDOT wanted to explore more fully the VPI/Access Board view that there is a general lack of reliable information for non-sighted pedestrians and how the general concept of Intelligent Transportation Systems (ITS) might be applied to correct that deficiency. Thus, a significant portion of the present effort sought to identify the relative value of different sources of information (as perceived by the blind and visually impaired pedestrian), the effect such information might have on increased mobility/travel (to include the intermodal and multimodal aspects of that travel) for such persons, and lastly a recommendation to pursue further the concept of a Pedestrian's Associate (PA) within the context of future ITS pedestrian applications.

The present study was thus not designed to be a simple systematic replication of the Access Board study on tactile warnings, but to extend those findings in such a way so as to place the ADA tactile warning recommenation in the context of the broader mobility issues of the blind and visually impaired individual. The study seeks to deal with *information*, not simply hazard warning, and argues that the notion of a Pedestrian's Associate (PA) represents a promising concept for bridging the gap between the goals and objectives of ITS and the special needs of the blind and visually impaired pedestrian.

METHOD

Subjects:

Subjects for the study included individuals recruited from the local area as well as individuals attending a weekend conference at the Florida School for the Deaf and Blind in St Augustine, FL. The primary groups of interest were those for whom the use of tactile warnings might prove to be a mobility aid (i.e, the blind and visually challenged pedestrian) and those with normal vision whose mobility might be negatively affected by the use of detectable warnings (e.g, those in wheelchairs or those dependent upon some type of support device such as a support cane or walker). In addition to the main groups of subjects shown in the table, a limited assessment was made of the effect of detectable warning surfaces on women wearing high heels; the effects upon those using roller blades; and those riding through the ramps on bicycles.

Group	*Number in Group*	*Male/Female*	*Age*
Totally blind-cane users	9	6 males/3 females	mean=44 (range 24-64)
Totally blind-dog users	4	1 male/3 females	mean=46 (range 40-59)
Partial vision-no support device/cane	4	4 males	mean=43 (range 34-53)
Wheelchair users	4	1 male/ 3 females	mean=41 (range 27-70)
Users of support devices	5	1 male/ 4 females	mean=77 (range 65-93)

Table I. Volunteer Subjects

Test Facility:

A special test facility was constructed under FDOT contract and supervision at the Florida School for the Deaf and Blind in St Augustine, FL. The 52 x 52 ft test facility provided a "simulated" walkway and adjoining street environment consisting of eight (8) individual curb ramps, and a separate 21 ft long sidewalk surface (width 3.75 ft) which terminated at each ramp. Ramps were constructed according to Florida DOT specifications with 1:12 slopes. Standard FDOT curb and gutter specifications were followed. A grassy area approximately 10 x 10 ft was located at the center of the facility in order to provide a surface that blind cane users could use for "shorelining." A 10 ft concrete, non-operational "street" formed the perimeter of the test facility. An overall view of the facility and its general dimensions are given in Figures 1 and

Figure 1. View of Tactile Warning Test Facility

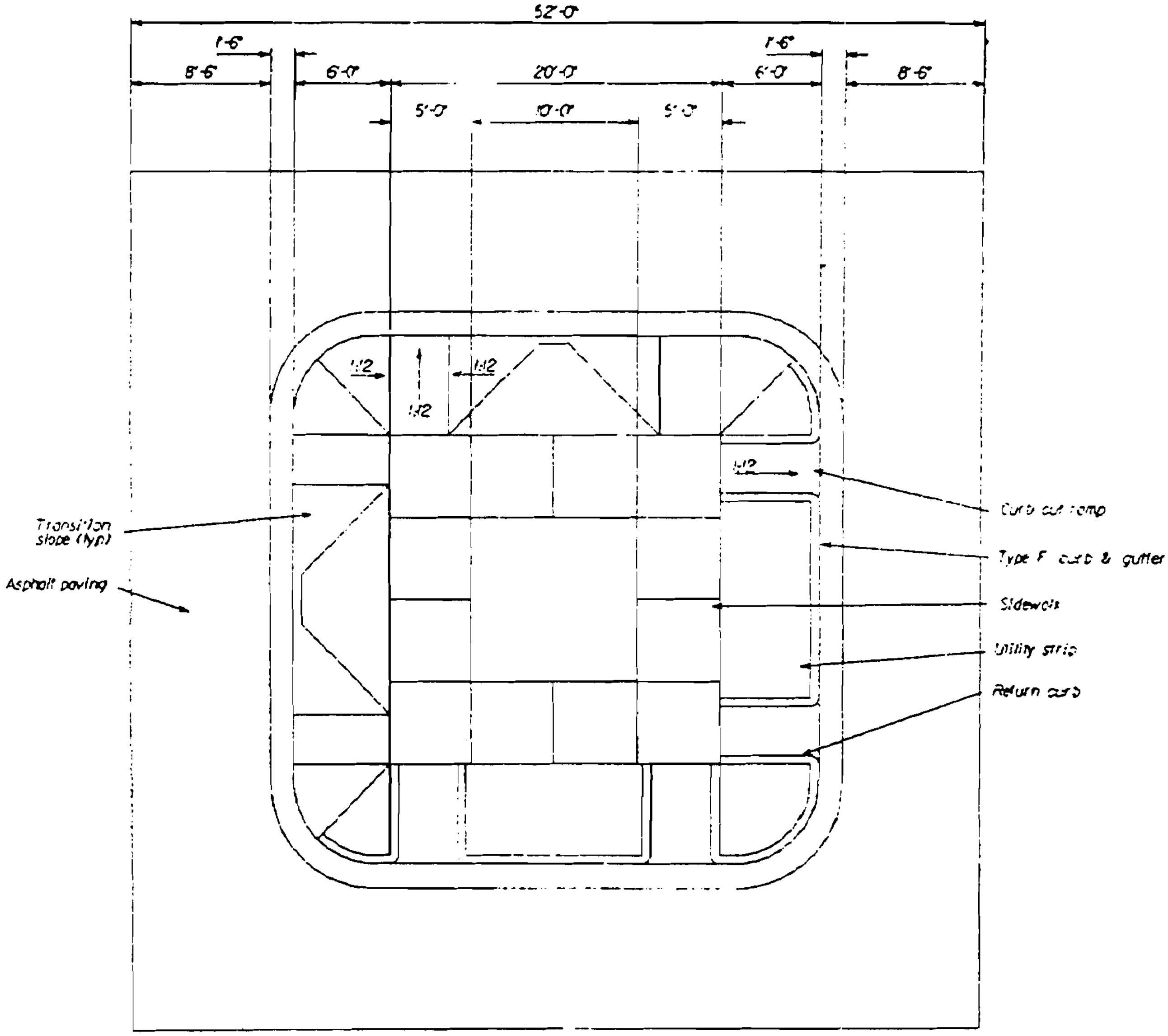


Figure 2. Dimensions of Test Facility Located at Florida School for the Deaf and Blind, St Augustine, FL

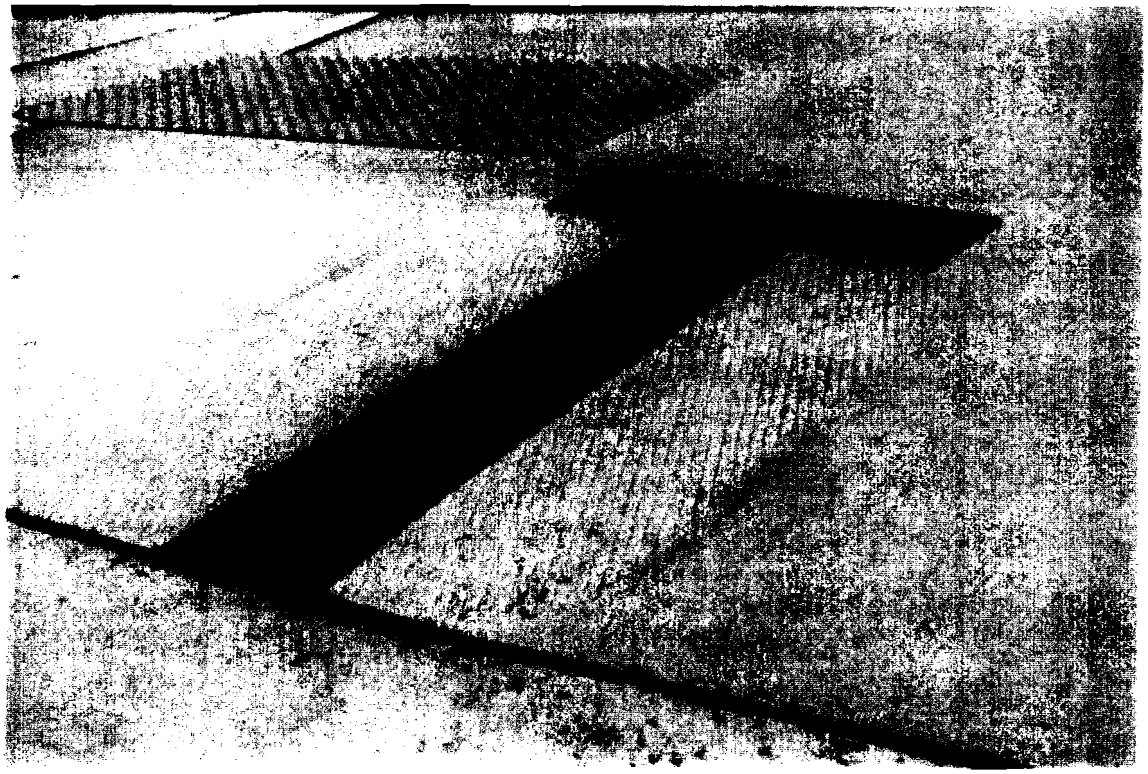


Figure 3. View of Ramp Number I.

Material.	Pathfinder Resilient Truncated Dome Pattern (12 inch tiles)
Color:	Black
Arrangement:	Truncated dome material installed so as to form a continuous 12 inch wide strip through the center of the ramp intersecting with a 12 inch wide strip of the same material across the top of the ramp. (Embedded surface texture in the concrete on which the truncated dome pattern is applied is not considered an integral part of the T-pattern being evaluated)

Rationale:

Possible Advantages

Minimizes truncated dome surface area (by approximately 56 percent) in terms of its potential as an impediment to wheel chair use, while maintaining detectable surface for the blind individual both at the top of the ramp as well as longitudinally down its center (the latter cue also providing some directional cuing advantage). Provides usable clear zones to either side of slope for unobstructed passage by those wearing non-traditional footware, or those simply desiring to the ramp but to wanting to avoid the tactile warning surface.

Possible Disadvantages

Reducing detectable surface area reduces the probability of early detection with the cane or underfoot.

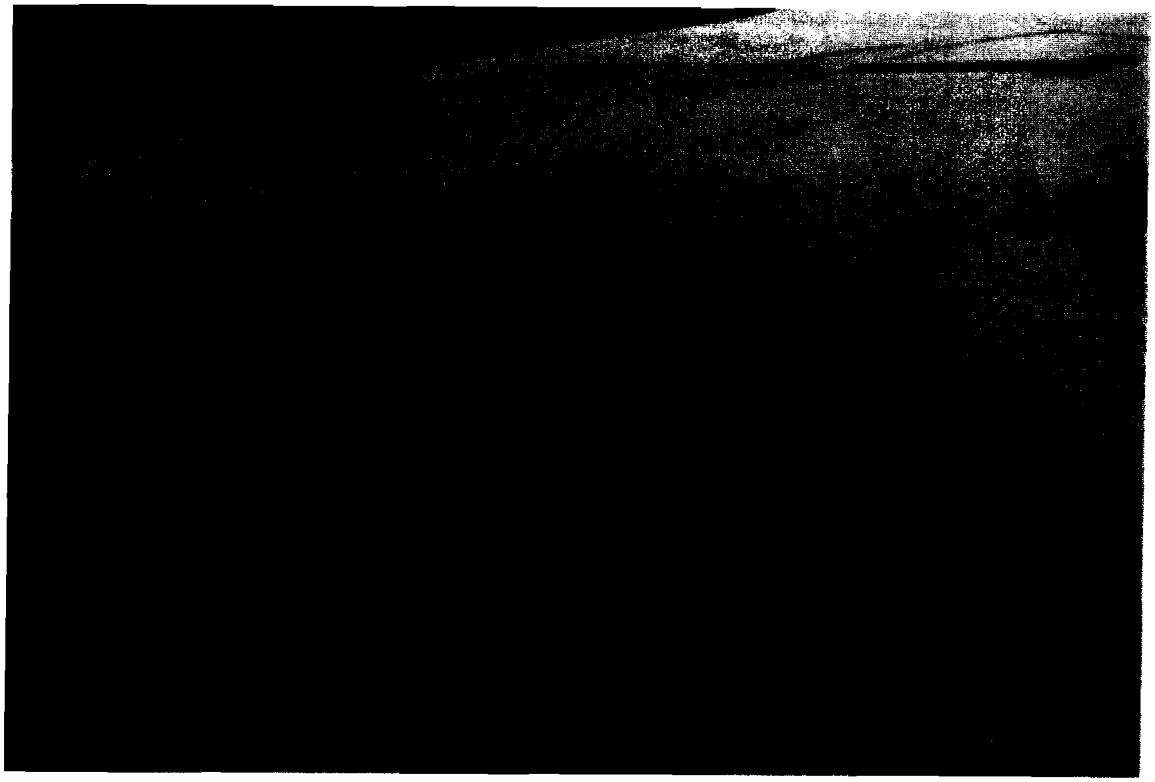


Figure 4. View of Ramp Number 2

Material:	Pathfinder Resilient Truncated Dome Product (12x12 inch sections)
Color:	Black
Arrangement:	Truncated dome pat tern placed in 12 in stip along top edge of ramp and extending along top edge of flare to the left of ramp. (The dark area in the ramp is due to unintentional differences in the shade of the cured concrete in what was originally a recessed area in the ramp before being filled to create present design).

Rationale:

Possible Advantages

Minimizes any obstacle to wheel chair users and those with mobility limitations that might be associated with negotiating a textured slope. Provides advanced warning of slope to visually impaired approaching both on and off-axis to the ramp. Retains desirable visual contrast and surface texture features.

Possible Disadvantages

Reduces overall detectable surface area by about 80% compared to texture throughout the main area of the ramp. Probability of detection is reduced. Possibility that the portion used to warn of the slope associated with the side flare will provide misleading directional cues.

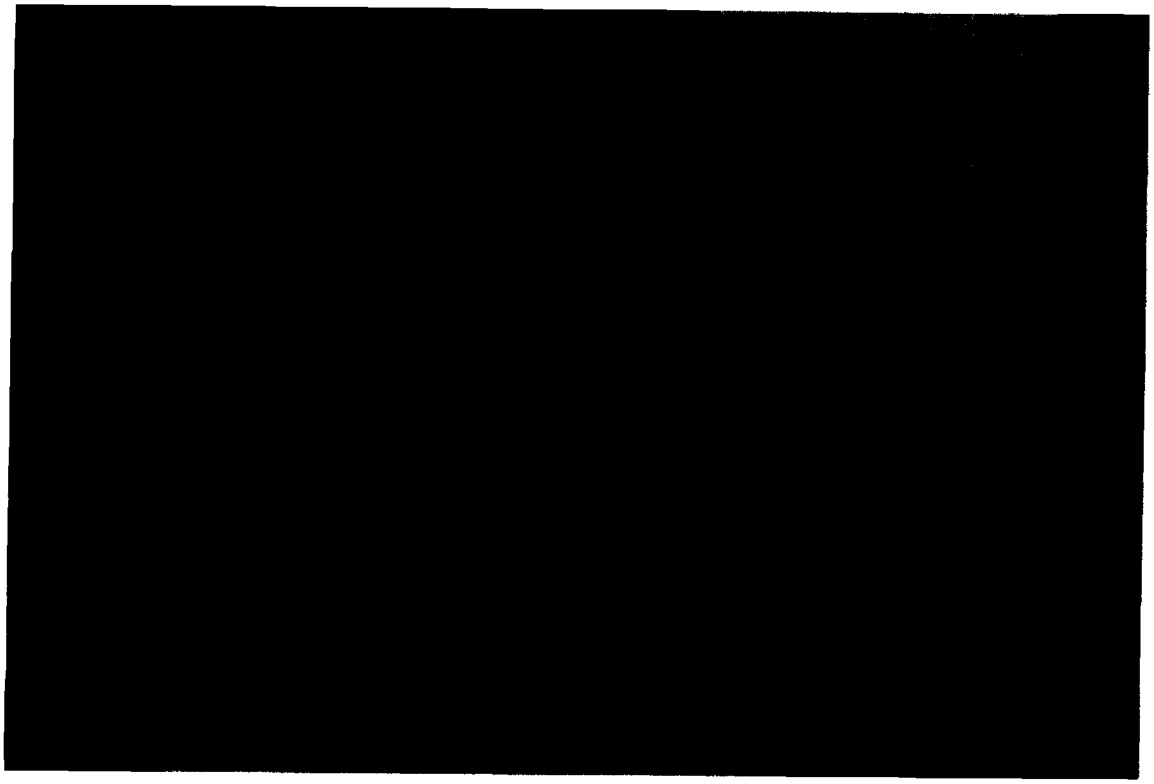


Figure 5. View of Ramp Number 3

Material: 12x12x2 inch BarTile[T] Reinforced Composite Truncated Dome Paver
Color: Red
Arrangement: 24 in wide strip running longitudinally through center of ramp from bottom to top of ramp.

Rationale:

Possible Advantages

Reduces problem for wheelchair users. Provides clear zones on either side of ramp allowing those needing or desiring to use the ramp to do so while avoiding the tactile warning surface. Provides approximately the same overall detectable surface area as the T-design but does so by concentrating it in the central portion of the ramp.

Possible Disadvantages

50% reduction in total detectable surface area compared to full ramp treatment lowers the probability that blind individual will physically contact the warning surface either with the cane or by foot. Red color more difficult to detect than yellow/orange by those with low vision. Consistent auditory signature dependent upon installation conditions.

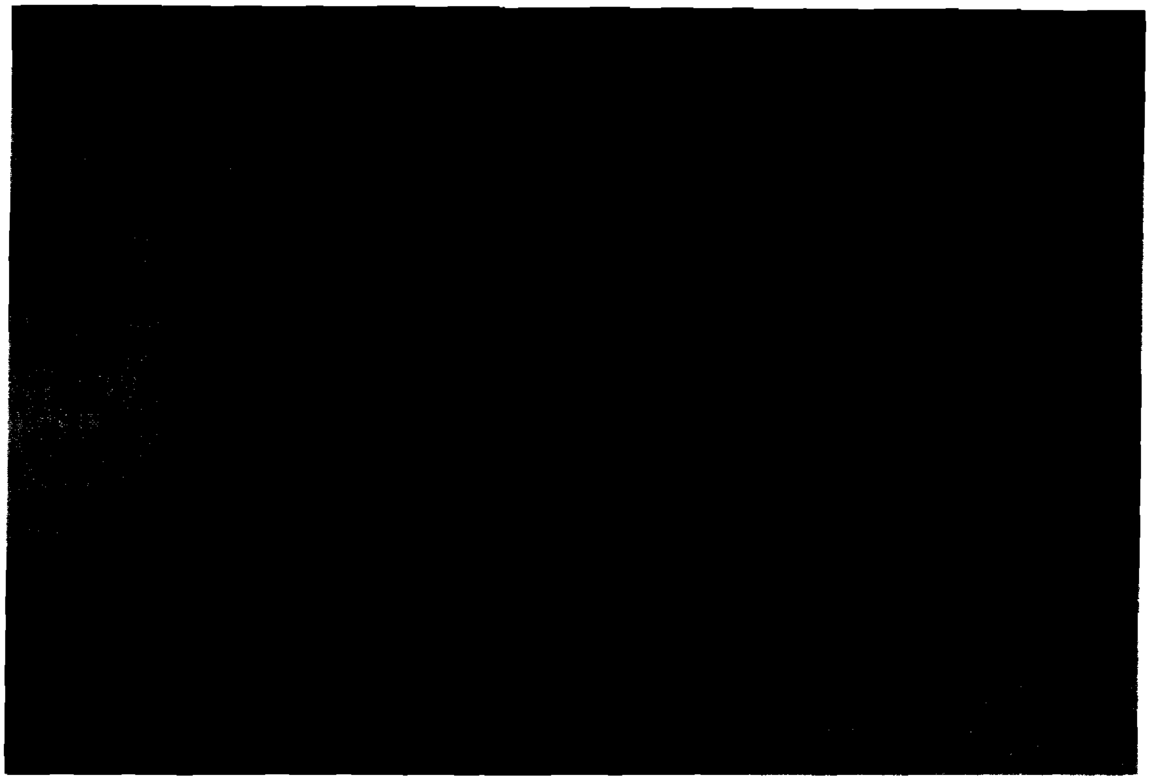


Figure 6. View of Ramp Number 4

Material:	Pathfinder Rigid Composite Directional/Bar Tile (12x12in sections)
Color:	Yellow/Orange
Arrangement:	Material installed to cover entire surface of ramp. Directional/bar pattern runs in longitudinal direction (i.e., same direction as ramp).

Rationale:

Possible Advantages

Full ramp coverage increases probability of detection. Lontitudinal pattern reduces impedance to wheel chair users. Rigid composite material provides better auditory signature/feedback than resilient material. Pattern provides directional cue. May be preferred over truncated dome pattern traditionally used for hazard warning.

Possible Disadvantages

Where truncated dome pattern is in used for hazard warning, use of directional pattern may be confusing and lead to incorrect response. Rigid composite material, originally designed for use on platform (i.e, flat) surfaces is more difficult to install in ramp area. No "clear zone" for those needing to use ramp but wanting to or needing to avoid tactile warning surface.

Figure 7. View of Ramp Number 5

Material:	Pathfinder Resilient Truncated Dome Pattern (12x12 in sections)
Color:	Yellow/Orange
Arrangement:	Three (3) 12in wide strips running longitudinally from top to bottom of ramp with 8in clear zones between each.

Rationale:

Possible Advantages

Provides large overall detectable surface area (approximately 75% of full ramp). Provides distinctive visual pattern for low vision individuals. Yellow/orange color provides high contrast and potential advantage under low light level conditions. Clear zones between warning surfaces allows clear passage for wheel chair users.

Possible Disadvantages

Reduced overall surface area of warning material may reduce likelihood of reliable detection by blind individuals. Greatly reduces the area of the ramp that can be used by those wanting to or needing to avoid tactile warning surface, especially if used in a return curb ramp design.

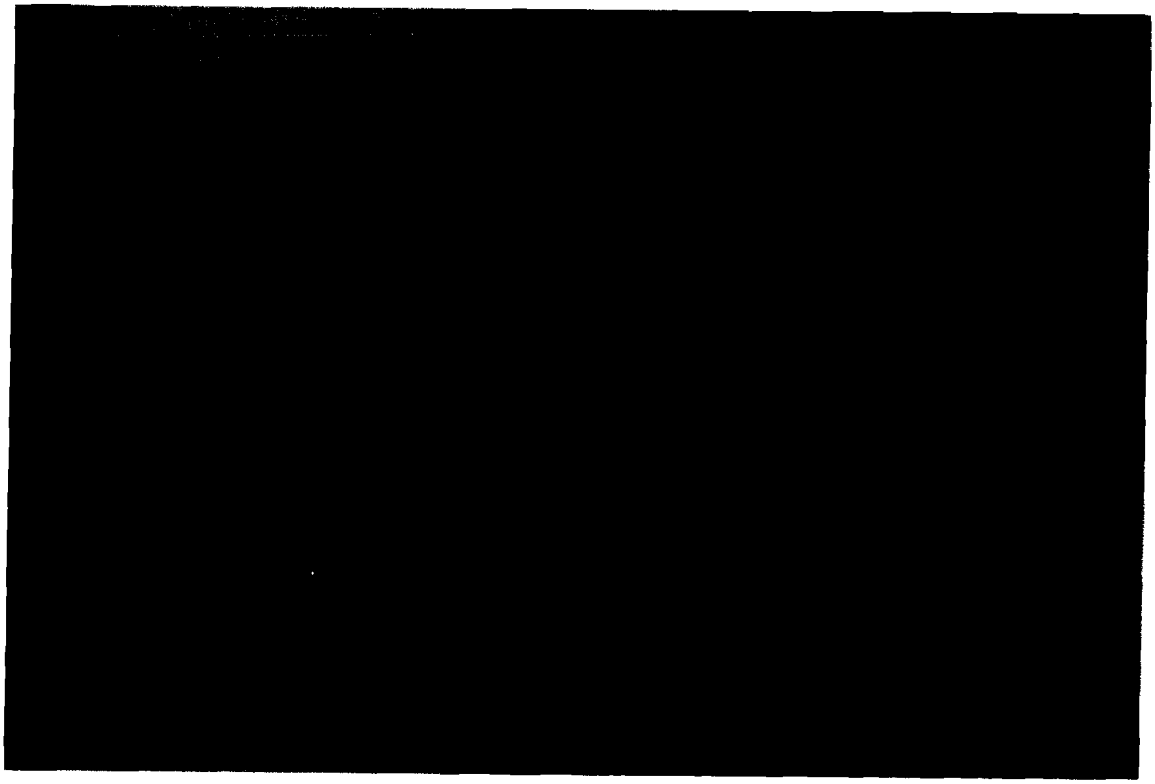


Figure 8. View of Ramp Number 6

Material:	Exposed Aggregate Surface (no detectable warning applied)
Color:	N/A
Arrangement:	Satisfies Florida DOT requirement for textured surface treatment

Rationale:

Possible Advantages

Eliminates any obstacle potential asociated with the use of tactile warnings on ramp surfaces. When used in conjunction with 1:12 slope, provides a detectable change in walkway slope that is detectable by vast majority of pedestrians. Avoids materials and maintenance costs associated with use of truncated domes or directional/bar materials.

Possible Disadvantages

Detectability of exposed aggregate surface less than truncated dome surface. More likely to be confused (in the absence of detectable slope) with frequently encountered surface conditions and irregularities. Not likely to be effective as a hazard warning for the blind independently of 1:12 or greater slope condition. Provides minimal visual contrast for use as a cue in locating ramp area.

Figure 9. View of Ramp Number 7

Material:	High Quality[T] Reinforced Truncated Dome Panels (2x3 ft)
Color:	Yellow
Arrangement:	Attached to ramp surface by metal fasteners so as to form a continuous 3x6 ft warning surface.

Rationale:

Possible Advantages

Yellow surface is preferred by those with low vision. Full ramp treatment maximizes probability of detection. Possible benefit under reduced illumination conditions. Rigid surface provides better, and more reliable, auditory signature/feedback than resilient material. Experience gained from use in transit (platform) applications.

Possible Disadvantages

Installation on irregular surface (ie., that found in most ramps) presents problem. Fasteners alone (without glue) are not effective installation technique. Poor attachment to surface generates feedback suggesting unstable surface. Distinct, but "unnatural," feedback results in low pedestrian preference. Hazard created by metal fasteners coming loose or heads shearing off. Exposed fasteners and fasteners superheated by sun are concern for users of guide dogs. Would also be problem for "shufflers" and those without shoes. Significant hazard to in-line skates (roller blades).

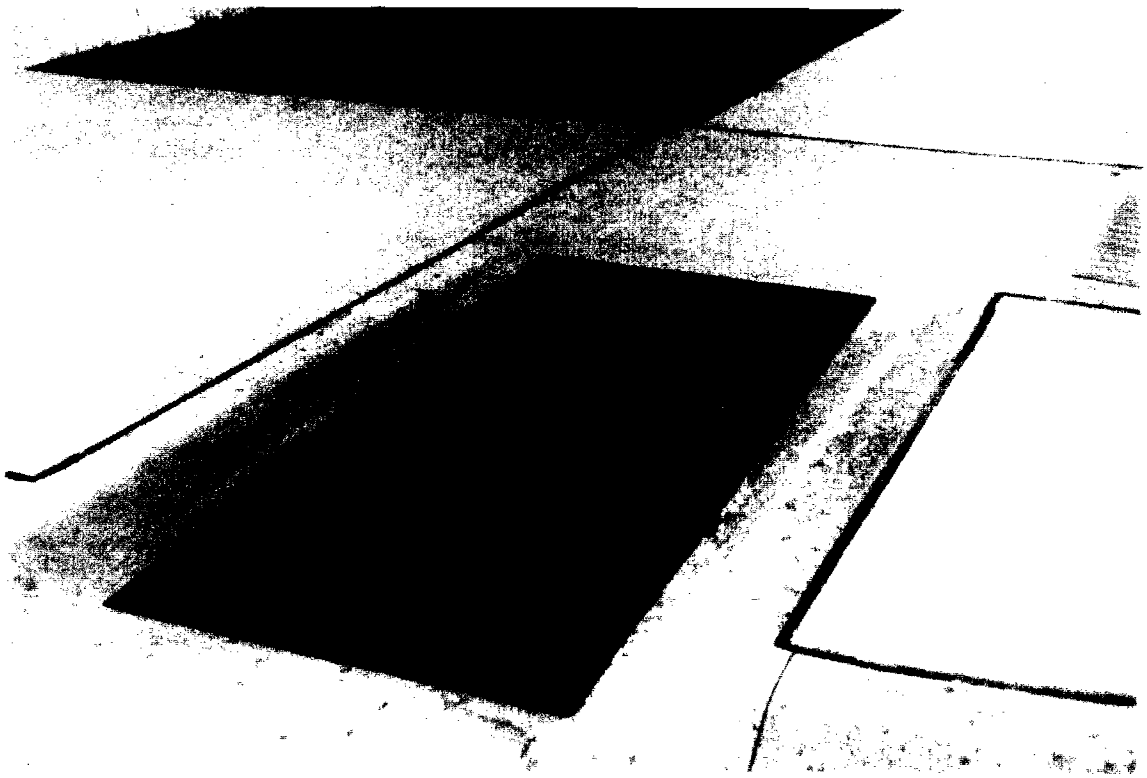


Figure 10. View of Ramp Number 8

Material:	Pathfinder Rigid Composite Directional/Bar Tile (12x12 sections)
Color:	Black
Arrangement:	Material installed to cover entire ramp. Directional/bar pattern installed perpendicular to (versus in-line with) pedestrian's direction of travel through ramp.

Rationale:

Possible Advantages

Full ramp installation maximizes probability of detection by cane contact or underfoot. Rigid composite material provides enhanced auditory/sound signature. When installed perpendicular to path of travel, is easily distinguished from same tile when used in-line as a hazard warning (e.g, ramp 4).

Possible Disadvantages

Pattern causes significant vibration for wheel chair users. Increases extent to which those using walker (especially those containing wheels) have to lift the device. Significant hazard to inline skates (roller blades). When installed in return curb ramp, those wishing or needing to avoid warning surface are forced to negotiate vertical curb (i.e, no clear zone provided). Can be obstacle for "shuffler." Bar pattern retains water on upper side causing possible ice/slipping problem in cold conditions.

2, respectively. Quantitative descriptions of the truncated dome and directional/bar materials are provided in Appendix A. Appendix B provides more detailed information on each of the particular products used in this evaluation.

The sloped area of each ramp was configured with a different detectable warning application "design." Figures 3-10 provide illustrations of the treatments applied to each ramp, descriptions of the tactile warning materials and their placements in the ramps, as well as an abbreviated discussion of the potential advantages and disadvantages of each. The primary rationale for selecting the designs used in the study was that each represented an attempt to provide a surface adequate in size and placement for effective detection by the blind individual either by use of the cane or by direct contact with the foot, while at the same time attempting to minimize any obstacle presented by the surface to those in wheelchairs or for those using various support devices (walkers, support canes, etc.). Illustrations of the tactile warning patterns/designs used in each of the eight ramps, as well as the rationale for each, are shown in Figures 3-10.

General Procedure

Each subject in the study first listened to a taped Informed Consent presentation, a written version of which is shown in Appendix C. Once consent for participation in the study was granted, each subject negotiated the eight curb ramps in the order that they are described in Figures 3-10. Subjects began each trial approximately 20-ft from the ramp and proceeded until they perceived that they had reached the street. Blind subjects were given minimal directional cues by the experimenter when necessary to ensure they would come into contact with the ramp area (see footnote). When subjects perceived they were at the street, each was then led into the street where they were asked to walk back (up) through the ramp area before stopping. Subjects then proceeded to the next ramp in the sequence. In most cases, blind and partially sighted subjects repeated the entire sequence of eight ramps. Wheelchair subjects and subjects with other mobility limitations generally negotiated each ramp only once. All trials were videotaped for future reference. Following the "performance" part of the study, all blind and partially sighted subjects (with the exception of those using guide dogs) responded to a series of prepared questions read to them by the experimenter. All answers and responses were recorded for later tabulation and analysis.

Note: It is clear that without such cues, a large number of trials would have resulted in subjects missing the ramp area entirely and coming into contact with the curb. Some number of these "missed approaches" were allowed in order to assess the likelihood that the raised curb was a sufficient cue to warn the individual that he/she had reached the street.

Results

Organization of the Results Section.

The results of the study are presented in two major sections.

Section 1: Provides a description of subject performances as a function of the different tactile warning "designs" and class of subject (i.e, blind/partially sighted; wheelchair user; individuals with various mobility limitations; blind subjects with guide dogs; and sighted individuals with non-traditional footwear).

Section 2: Summarizes subjects' responses to structured interview/survey items.

Section I. Performance Observations

Blind Cane Users.

We observed significant variation in subjects' use of the cane with respect to the area covered by a single sweep, the extent to which contact between the cane and the surface is intermittent or more continuous in nature, and the extent to which different individuals appear to rely upon information from the cane versus information from their feet for detection of variation/changes in surface conditions. Furthermore, these variations occur in conjunction with (not necessarily correlated with) individual gait and walking speed. There is thus no one prototypical "blind cane user." Our general observation of blind cane users in the present study was that directional orientation was a problem they shared in common. Even though the approach to the ramp was short and subjects were aligned with the ramp prior to the start of a trial, there was a high probability (without experimenter intervention) that subjects would arrive at the curb at some point other than the ramp, per se. In many cases, the experimenter had to provide mid course corrections to ensure that the blind subject came into contact with the ramp, since a failure to do so provided no data of interest in terms of tactile warning detection.

When the blind cane user did come into contact with the general ramp area, detection of the tactile warning surface was most likely to occur through initial contact with the cane. Frequently initial cane contact was with the raised edge/side of the tactile warning rather than the top. This seemed particularly true for those having a tendency to keep the cane in more or less continuous contact with the walkway surface. There were however cane users who, despite initial contact with the tactile warning being by way of the cane, reported initial contact being through the sensation underfoot.

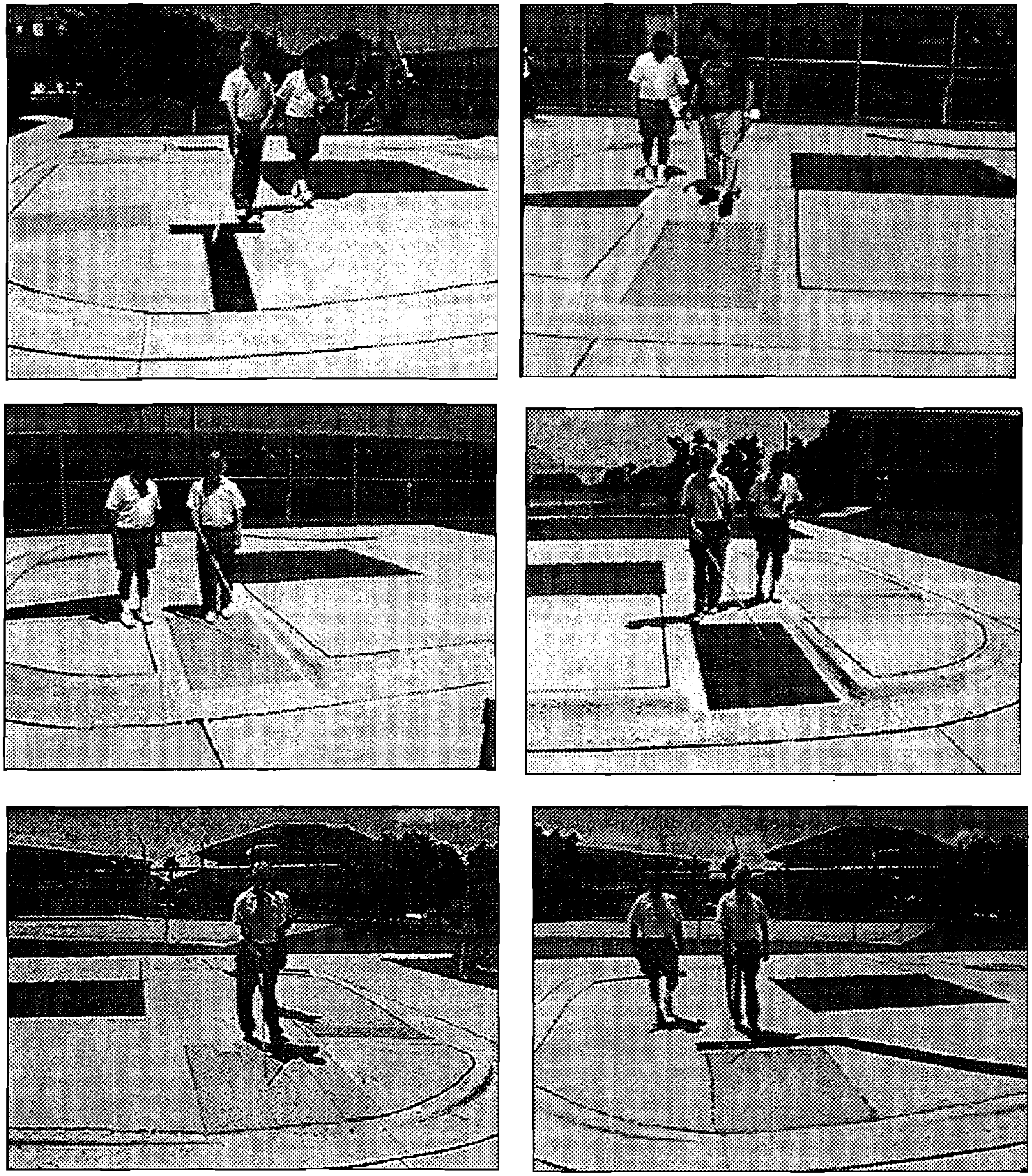


Figure 11. Cane Users

Imagery is reproduced from video tape used in data collection. Starting in upper left and moving clockwise, ramps are numbers 1, 4, 8, 2, 5, and 4 (see explanation in text).

The most reliable detection occurred in those situations where the entire ramp surface was covered by the tactile warning, and in those instances where the tactile warning was created using the rigid, composite materials (either the Pathfinder dome or diagonal/bar designs or the TacTile composite dome panels. The full composite ramp treatment seemed to accomplish two things: (1) increase the likelihood that the cane, regardless of technique, would come into contact with the tactile warning surface, and (2) provide a distinct auditory (sound) cue that the ramp area had been reached. Early detection with the cane alone was poorest for those treatments using "partial" coverage designs implemented with the resilient warning materials.

Visually Impaired (Partial Vision) Subjects.

Low vision subjects were effective in using the tactile warning signatures to locate the general ramp area and in using a combination of slope and tactile warning surface to detect the presence of the ramp. Those with reduced visual capabilities indicated clear preferences for the yellow and/or yellow-orange surfaces versus black. Subjects reported the black surfaces as being easily confused with shadows. In the case of the ramp containing the black directional/bar pattern installed perpendicular to the path of travel, one subject said that from a distance it presented the image of a grate/drain. Most subjects speculated that the yellow or yellow-orange surfaces would probably be more easily detected under low levels of illumination (the time of day when these subjects reported the most difficulty). No data were collected in the present study under reduced illumination levels.

One distinct performance aspect observed with low vision subjects was the tendency for the appearance of the tactile warning to unintentionally exert control over their path/direction of travel. In the case where the warning was placed at the top and middle of the ramp as well as where three sections were placed so as to allow a path for the wheelchair user, subjects tended to restrict their travel almost entirely to the textured areas of the ramp. The result was that subjects with generalized mobility limitations encountered an unintended problem with balance and lateral stability. This tendency to "follow the line" caused one subject, when negotiating the ramp where the tactile warning was placed at the top and alone the edge of one of the flared side slopes to actually "follow the line" in a direction that led the individual away from the ramp proper.

In short, the performances of the low-vision subjects in the present study appear to have been strongly influenced by the spatial/directional component of the partial ramp, tactile warning designs as well as by their color. The partial-ramp designs may present a problem for those low vision individuals for whom the requirement (perceived or real) to walk down a narrow path creates a lateral stability/balance problem. With respect to color, the present data show a clear preference on the part of low vision subjects for the yellow and yellow-orange color versus black, with speculation that the former may also be more effective under low levels of illumination.

Wheel Chair Users.

Wheel chair users ranging from those with motorized chairs to manual chairs. Motorized chairs included those ranging from full-size chairs with pneumatic tires, etc. to motorized "scooters." Included in this group was one blind wheel chair user with a cane. All subjects were observed negotiating the 8 different ramp conditions. The primary issues for wheelchair users were (1)directional control, (2) perceived stability, (3) effort, and (4) comfort/discomfort.

a. *Directional Control*. As one might suspect, directional control was easiest for those tactile warning configurations which minimized the amount of textured surface the individual had to cross in the chair (i.e., those configurations where the warning was in the center of the ramp only; in the center as well as the top of the ramp; at the top of the ramp only; and the design where the truncated dome pattern was "opened up" to provide an untextured path for the wheels of the chair to pass. Those ramps constituting a potential problem for the wheel chair user were (a) the rigid (*High Quality*[T]) composite dome surface, and (b) the Pathfinder Rigid Composite Directional/Bar Pattern laid perpendicular to the path of travel. There is some tendency on the truncated dome patterns for the smaller front wheels to be affected in terms of their ability to naturally track a straight line. It is certainly not possible for the wheel chair user to simply "coast" down the ramp on these designs without exerting directional control. Intermediate to these extremes in terms of facilitating directional control were (a) the Pathfinder Rigid Composite Directional/Bar pattern installed in line with the path of travel and (b) the 24 inch wide inlaid ceramic tile surface.

b. Perceived Stability. None of the surface configurations tested caused subjects to perceive there to be stability problems even though the vibration caused by some of the surfaces may have had an effect on comfort and a minor effect on directional control (front wheels). None of these effects, however, were significant enough to cause subjects concern for their basic stability while in the ramp. Ramp design (flare versus return curb) was more of a threat to the stability of wheel chair users than tactile warnings, per se. The return curb design posed problems to wheel chair users (especially the blind user) when approached off-axis; that is, when the ramp was approached from the side. The flared ramp design can also be problem when the blind wheel chair user is misaligned with the major portion of the ramp, resulting in an approach which takes him/her through the flare to the taper area of the curb to the left/right of the ramp proper.

c. *Effort.* Effort is irrelevant for the user of the motorized chair, other than the extent to which effective power control may be a problem for some small subset of the user population. We observed no "independent" users of non-motorized chairs (i.e., those accustomed to traveling without an aid) who could not travel up the ramp. While there were some reports of greater or lesser effort required for the different tactile warning designs, none were reported by subjects

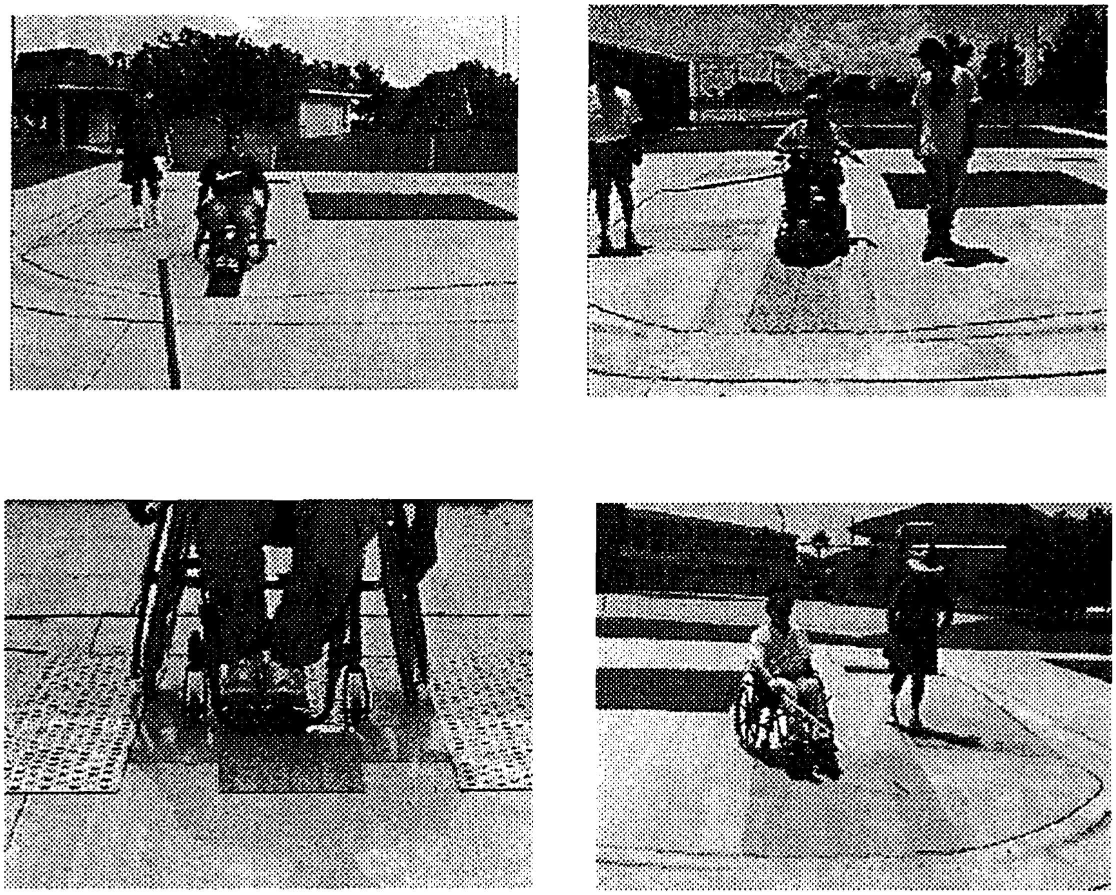


Figure 12. Wheel Chair Users

Imagery reproduced from video tape used in data collection. Shown here are ramp treatments intended to minimize resistance caused by surface texture. Beginning in upper left and moving clockwise, ramps are 2, 3, 5, and 5. See text for further explanation of treatments.

as being insurmountable in terms of effort.

d. *Comfort/Discomfort.*. While subjects clearly responded to the different sensations produced in crossing the different surface textures, none reported significant discomfort. To the extent that vibration may be related to ones perception of discomfort, the worst condition was the Directional/Bar tiles installed perpendicular to the path of travel. The second most aggressive surface was the Rigid Composite Dome material. These two treatments constituted the most significant impact on vibration and directional control.

Support Device Users

Support Canes and Walkers. As with wheel chair users, the chief interest here lay in evaluating any real or perceived negative impact to personal mobility, perceived safety, etc. . . in essence, the same criteria used to assess the impact(s) of tactile warning applications on the wheel chair user. Our observations did not reveal problems for persons in this group. For the one individual we observed using a walker with wheels (casters) on front, the TacTile composite dome surface and the Pathfinder Composite Directional/Bar pattern laid perpendicular to the path of travel did not permit free use of the casters, but rather caused the user to lift and reposition the walker with each step. This was more of a problem for the directional/bar pattern than for the truncated dome pattern. For the wheeled walker, those patterns which minimized the textured area of the ramp and/or provided clear zones for the path of the wheels caused the least problem.

Users with Physical Limitations to Mobility but Who Travel Without the Aid of A Support Device.

These individuals generally moved very slowly, but without incident as they negotiated the different ramp treatments. Effort, stability, and comfort/discomfort were not reported to be negative factors although personal preferences were noted for particular materials/designs. It is worthwhile to point out here that there was an observed tendency in older women subjects with physical mobility limitations to point out problems with lateral stability for the Pathfinder Composite Directional/Bar pattern (i.e., a feeling that their foot had an increased tendency to roll to the side when standing on the raised bar portion of the surface).

Blind Individuals Using Guide Dogs.

We had the opportunity to observe a number of blind and visually impaired individuals who regularly traveled with the aid of a trained guide dog. The interest here lies with the behavior of the dog as it approached the tactile warning with its owner. With few exceptions, guide dogs were observed to either lead their owner around the tactile warning or to halt when coming into contact with it.

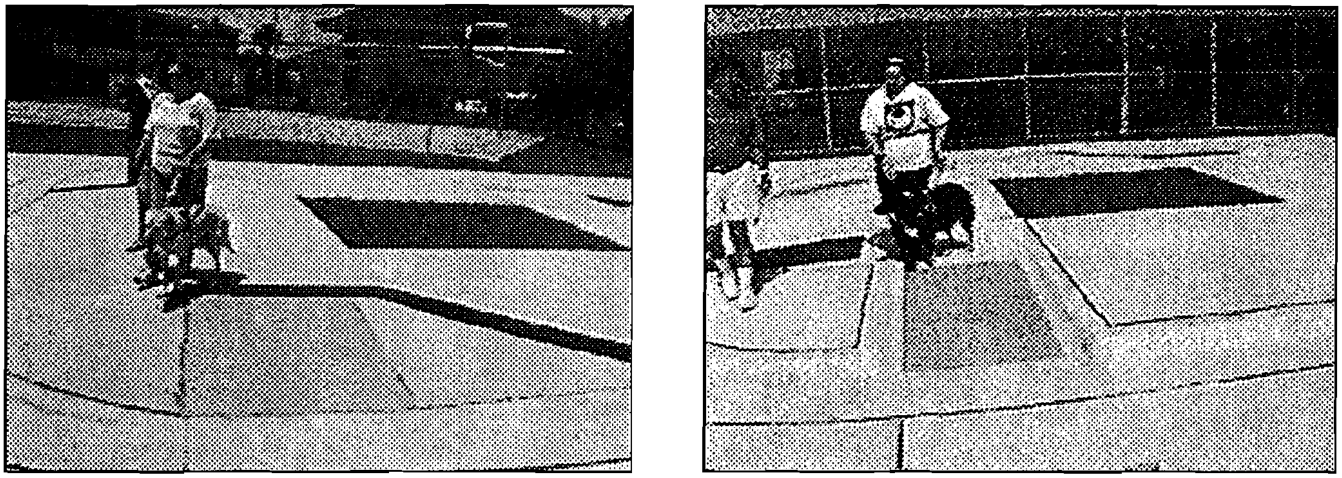


Figure 13. Guide Dogs Users

Imagery reproduced from video tape used in data collection. Shown is the typical reaction of guide dogs to the placement of detectable warnings in the curb ramp; i.e., dogs either halted at top of ramp or led owner around the ramp to a point on the curb.

Where the dog leads its owner around the tactile warning (and ramp) to a spot on the curb it perceives as safe, there is no significant consequence to this behavior. However, on a number of occasions, the dog's avoidance of the tactile warning and ramp resulted in the dog either leading its owner to the adjacent ramp or literally in circles; in either event, serving to disorient the blind individual. In some cases, the dog's perception of the tactile warning and ramp in the distance caused the dog to prematurely halt well in advance of the ramp leading its owner to think he/she had reached the street (assuming the absence of cues to the contrary). It was clear that with some experience (both on the part of the dog and its owner) the owner could cause the dog to move through the ramp (in essence, to learn that the tactile warning was not a hazard itself). Dogs seemed to experience no difficulty in negotiating any of the materials used. Concern, however, was expressed by owners for the TacTile composite material and the means by which metal fasteners were used to attached it to the surface. Over the short period of the study, a number of fasteners were already observed to be pulling out of the surface with at least one head having broken off from the rest of the fastener. Owners expressed obvious concern for the danger of this method of attachment in terms of both the dog injuring its paws on exposed and/or broken fasteners as well as the possible danger associated with stepping on exposed fasteners exposed to high temperatures and sunlight.

Users with Non-Traditional Footwear.

Recreational Roller Blade Users.

Our observations of a female roller blade user (approximately 10 hrs/wk as a cross-training activity) indicated that tactile warnings in curb ramps are incompatible with the use of roller blades. Our subject fell in the ramp containing the inlaid composite dome surface, as well as in the two ramps using the Pathfinder Rigid Composite Directional/Bar material. In those ramps where the tactile warning material was only partially applied allowing room to either step over the material or to maneuver around it, the subject reliably attempted to do so. . . but in so doing increased the difficulty of coming to a controlled stop at the edge of the street. It is our general observation that braking on roller blades is a difficult task, one which does not transfer directly from prior experience in roller skating. Traveling through the curb ramp for the person not skilled in braking only serves to increase the speed at which they approach (or are propelled into) the street. The best course of action as suggested by the performance of our subject is to come to a controlled stop at the vertical curb area and to step down into the street.

Women with High Heels

A staff member of the FDOT Regional Planning Office in St Augustine served as our subject with high heels. While perhaps the best index of a safety hazard would in this case be an observed incident (for example, a fall or clear loss of balance), perhaps a secondary measure (in the absence of falls) might be

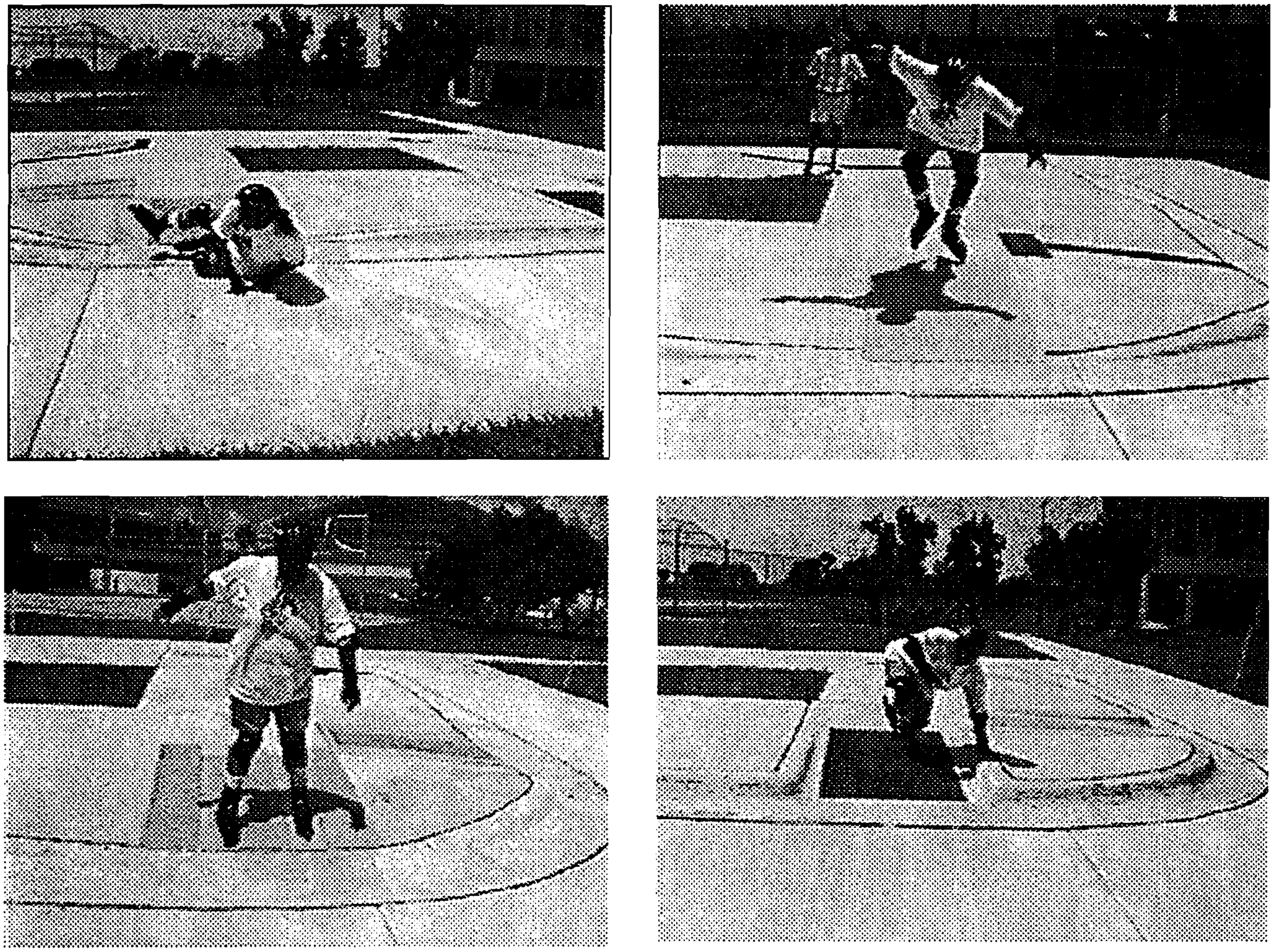


Figure 14. Roller Blade User

Imagery reproduced from video tape used in data collection. Pictures show obvious problems for users of in-line skates (roller blades) associated with tactile warning surfaces in curb ramps.

a clear sense of hesitancy and caution on the part of the individual being observed. While our FDOT subject did not fall, trip, or otherwise exhibit any major overt problems while negotiating the different tactile warning designs, her behavior clearly indicated a heightened sense of caution and hesitation, which we interpreted to be associated with a "perceived" sense of risk. When questioned whether she would choose to avoid walking over such areas if she encountered them naturally, she said "Yes." However, while tactile warning surfaces may be perceived by women with heels as a potential risk, their presence in ramps need not present an obstacle to their mobility, since those capable of wearing heels are in all likelihood also capable to negotiating the vertical curb section without significant problem. Those individuals "needing" to use the ramp because of some mobility limiting condition are, in most cases, not likely to be wearing heels.

Section 2. Responses of Blind and Partially Sighted Subjects to Interview and Survey Questions

After participating in the performance portion of the study, all blind and partially sighted subjects took part in a structured interview which involved both ratings and a number of open-ended response items. Items were intended to solicit their reaction to the various tactile warning materials and placement alternatives as well as to the (perceived) effectiveness of the tactile warning concept in general.

This portion of the study was also an attempt to pursue further the suggestion of the VPI/Access Board study that more emphasis be placed on the overall "information" environment in which the blind pedestrian operates. The questions sought to do that both in terms of the restricted context of the intersection problem, per se, as well as for the broader intermodal and multimodal context in which travel occurs.

Through items meant to identify what information was critical to effective mobility for the blind and partially sighted pedestrian, we sought to introduce the concept of Intelligent Transportation Systems (ITS) and how the notion of applying technology that creates a more informative travel environment might be applied to pedestrians with special needs, such as the blind.

The following represents the major findings from the interview and survey portions of the study:

Issue: ***What is the perceived safety benefit associated with tactile warnings?***

In response to the question, "*How much do you think that the presence of tactile warning materials in the wheelchair ramps at intersections will increase your safety as a pedestrian?*" subjects responded as follows:

- 6 of 10 responded, "*significant effect on safety*"
- 3 of 10 responded, "*moderate effect on safety*"
- 1 of 10 responded, "*little or no effect on safety*"

Table 2
The Perceived Safety Benefit of Tactile Warnings

Issue: ***How important are tactile warnings relative to other pedestrian "improvements?"***

When asked to choose between tactile warnings and other pedestrian "improvements,"

- subjects chose tactile warnings over improved surface conditions, fewer manmade obstacles along route, and better definition of crossing locations almost 80% of the time, but
- chose traffic signals sensitive to the need for additional crossing time 4:1 over tactile warnings in curb ramps.

Table 3
The Relative Value of Tactile Warnings
Versus Other Pedestrian "Improvements"

Issue: Will tactile warnings increase the mobility of the blind or visually impaired pedestrian?

With respect to whether the presence of tactile warnings would increase the mobility of the blind and/or visually impaired pedestrian,

- 6 of the 10 subjects reported they would be *more likely to take additional trips on foot*
- all (10 of 10) reported they *would travel more places by foot if they felt safer at intersections.*

Table 4
The Perceived Mobility Benefit of Tactile Warnings

Issue: To what extent are intersections perceived to be a major problem for the blind pedestrian?

- 9 of 10 reported that there were intersections that they now avoided because they (the intersections) provided *insufficient information* to cross safely.
- All subjects indicated they would travel more places by foot if they felt safer *at intersections.*

Table 5
Information, Intersections, and Mobility
for the Blind and Partially Sighted Pedestrian

Issue: Why are some intersections more difficult than others for the blind?

With respect to those factors which added to the blind or visually impaired pedestrian's perception of the difficulty associated with some intersections, subjects pointed out the following. Responses were given in terms of a l-to-10 scale where a "l" indicated very little or no relationship to difficulty and a "10" indicated that the factor was a major contributor to difficulty. Listed in order of perceived difficulty from high to low.

Factor	*Rated Difficulty*
Absence of clear signal when it is safe to cross	9.11
Sound of traffic unreliable cue (i.e., low volume conditions such as in rural or suburban environment)	8.33
Multiple lanes and no pedestrian "refuge" island (i.e., ., protected median area)	8.25
Not enough time to cross	8.22
Vehicles turning right on red	8.00
Edge of roadway not well defined	7.22
Hard to maintain direction and orientation while crossing	5.78

Note: The two most important factors relate to the blind pedestrian's *need for additional information.*

Table 6
Factors Associated with the
Blind and Partially Sighted Pedestrians' Perceived Difficulty
of Intersections

Issue: What information is critical to detecting the wheelchair ramp?

With respect to the problem of the blind or visually impaired pedestrian failing to recognize the presence of the wheelchair ramp, subjects reported the following:

- 9 of the 10 blind or visually impaired subjects reported that they had personally experienced walking through the wheelchair ramp at intersections without recognizing its presence
- 8 out of those 9 indicated that the major factor was an inability to discriminate a change in *slope*.

Table 7
Subjects' Experience with Failure to Perceive Slope

Issue: Does the truncated dome surface provide a cue that is distinct from normal surface irregularities?

When asked whether they thought it might be possible to confuse the truncated dome surface with other surface irregularities normally encountered while walking,

- 6 of the 10 subjects indicated they thought the truncated dome surface provided a distinct cue easily discriminated from other surface irregularities while
- 4 of the 10 reported the possibility of failing to recognize the tactile warning surface was distinctly different.

Note: In the present study, the effectiveness of the truncated dome warnings is confounded by the effectiveness of the 1:12 slope which was detected by all subjects, even in the absence of any tactile warning.

Table 8
Perceived Potential for Confusing Surface Textures

Mobility: Going Beyond the Immediate Issue of Tactile Warnings for Curb Ramps

The blind and visually impaired subjects in the study were asked additional questions which sought to address the issue raised by the VPI/Access Board study regarding how to better meet the information needs of blind and visually impaired pedestrians at intersections. From a mobility standpoint, the issue is one which clearly goes beyond concerns for tactile warning surfaces and ramp design.

To address the general issue of "information" pertinent to the increased mobility of the blind pedestrian, subjects were asked to rate the perceived benefit of various types of information that might be provided by the pedestrian environment. Further questions were presented which sought to explore how that information might be presented. The various classes of information and the perceived benefit associated with each are given below. Subjects used a 1-10 scale, where "1" represented *no benefit* and where a "10" represented a *significant benefit.*

Capability	*Perceived Benefit*
Capability for dialing "911" in case of emergency and providing responders with accurate location of current position	8.78
Information on present location relative to major buildings, street address, etc.	8.22
While on a bus, a capability to receive information about bus's current location, next stop, and estimated arrival time at ones destination	8.22
Self-contained capability to call taxi and to give current location	7.78
Directions to desired destination and suggested travel times by different modes (e.g., on foot, by bus, taxi, etc.)	7.22
Directions to nearest bus stop needed for reaching desired destination	6.78
Direct of travel (north, east, south, west)	6.33

Note: *Spatial orientation and the ability to accurately know ones current location/position are common to each of the above.*

Table 9
The Perceived Importance of Potential Types of Information to the Blind and/or Partially Sighted Pedestrian

Information and Intermodal Access

Blind and visually impaired subjects were asked additional questions dealing with their access to necessary information pertinent to the effective use of other modes of travel (e.g., transit and taxi). As before, each question asked the blind or visually impaired respondent to judge the extent to which various sources of information and/or their traditional means of communication posed problems for them as travelers. Responses were given on a 1-10 scale where a "1" indicated *no problem* and where a "10" indicated a *major problem*.

Area of Information/Communication	*Rating*
Knowing when the next bus is coming	8.88
How to tell one bus from another at the point where you want to board	8.57
Locating the bus stop if it is not one that you are already familiar with	7.50
Knowing when the bus is approaching the place where you want to get on	7.00
Locating an empty seat once on the bus	4.25
Physically getting on/off the bus	2.75

Table 10
Information and the Effective Use of Transit
by Blind and Visually Impaired Individuals

With respect to the effective use of public transit (the bus), blind individuals reported little or no difficulty in physically getting on/off the vehicle, but being almost totally dependent upon other persons and/or the driver(s) for other key spatial (location) and temporal (schedule) information. While it is important not to underestimate the value of other individuals (e.g., riders, vehicle operators/drivers, etc.) as a source of information, they are sources that may not always be present or be willing/able to provide accurate information in a form that the blind individual can comprehend. It should also be pointed out that several of these information categories are problems not only for the blind individual but for sighted individuals as well.

With respect to factors having a bearing on the blind or visually impaired individual's ability to utilize taxi service (apart from cost), subjects in the present study were asked to judge the extent to which each of the following contributed to the difficulty of taxi use. Ratings were made using the same 1-10 scale, where a "1" indicated *little or no problem* and a "10" indicated a *major problem.*

Problem Area	*Rating of Difficulty*
If not at home or work, having to locate a phone to contact taxi company	8.33
Knowing that I had been taken to the location that I had requested.	8.11
Being able to quickly and accurately communicate my location to dispatcher	8.00
Feeling that I would be safe riding in taxi	7.56
Feeling confident I was being taken to my location by the most direct route	7.11

Table 11
Information and the Effective Use of Taxi Service by Blind and Visually Impaired Individuals

Expanding the Information Available to the Blind/Visually Impaired Pedestrian: Design and Implementation Alternatives

The notion of making additional information available to blind and visually impaired pedestrians was pursued through subjects' responses to several open-ended questions which were intended to address subjects' preferences for different implementation approaches.

We began this line of inquiry by asking subjects to consider the possibility of an intersection that could "talk" (i.e., actually speak versus simply provide various auditory cues/signals). If such an intersection were possible, we said, what information would you want it to provide (i.e., to the blind or visually impaired pedestrian)? If addition to what information would they like we also questioned them about the static versus "dynamic" nature of the information (e.g., information about actual traffic speeds and volumes versus information such as "normally heavy traffic" or pedestrian signals present versus information on actual real time phase of the signal). We also sought to address how such information might be presented in a way that would not call attention to the presence of a visually handicapped individual.

Subjects were intrigued by the idea of an intersection, which through an ability to monitor its current operation and status, could actually communicate dynamic information to a blind pedestrian, information that would normally be available to a sighted pedestrian without any special provision (e.g., information about intersection geometry/number of lanes, presence/absence of protected median, phase of traffic and/or pedestrian signals, etc.). At least one subject was familiar with such limited audible/vocal capabilities at intersections. Based upon information provided by her as to the particular location of such a capability (Palatka, FL) we visited the site. Our observations and comments are discussed separately in this report (see Appendix).

The Pedestrian's Associate (PA): A Step Beyond Current Geographically-Fixed Concepts of Audible 'Warnings'

We tried to take subjects one step further; that is, to have them consider the possibility that such *information need not be limited to intersections,* per se, or that information (including travel information of a broader scope) could only be obtained at these locations. We had them consider the concept of a portable device (a "Pedestrian's Associate," if you will) that would contain a range of capabilities such as those in Table 12.

The Pedestrian's Associate (PA)

- A continuous capability (through GPS, or otherwise) to know its own location.
- A capability to transmit its location (coordinates) to another receiver(s) capable of recognizing it.
- A capability to transmit voice (e.g., cellular phone capability) with an automatic dial function enabling the blind individual to call selected numbers without dialing.
- An internal digital map of the local area that would permit the individual to receive information about his/her position relative to some other location or destination (assuming a capability to enter the latter).

Table 12
The Concept of a Pedestrian's Associate (PA)

The Pedestrian's Associate (PA)-Continued

- An ability to query the device for relational information (e.g., distance/time from present location to destination by mode of travel (e.g., by foot, transit, taxi, etc).
- Information about nearest bus stop for traveling to that location; time for next bus; ability to communicate with bus/driver once at the site to be aware of rider with special needs, etc.).
- Capability for use while using other modes of travel such as transit, taxi, etc.

Table 12-Continued
The Concept of a Pedestrian's Associate (PA)

Subjects were led in a discussion of such capabilities (irrespective of cost, technologies involved, etc.) simply to see whether there was any perceived benefit associated with a capability whereby real time system information could be made available to blind and visually impaired pedestrians.

At least one subject recognized the similarity of such a capability to the Advanced Traveler Information System (ATIS) concept being pursued under the Intelligent Transportation System (ITS) program. The ideas here are a direct extension of the ATIS concept to the area of pedestrian application, and in particular, to the information requirements of the blind and visually impaired pedestrian. Applications of portable, digital communications and information system concepts are already a part of the Minnesota GUIDESTAR program. Most of the information however is related to providing information pertinent to traffic and transit operations as opposed to travel purely on foot. Since the Minnesota program has no requirement for use by the blind or visually impaired traveler, unique user interface/display issues associated with a blind user (e.g., speech generation vs visual displays) are not being addressed, at least to my knowledge. Current capabilities are also limited in terms of how much onboard/local computing the system can handle. Present systems simply use cellular communication to interact with a central processor/host which tracks traffic conditions, transit operations, etc. There are a number of similar design issues for the development and application of fixed location *kiosks* being developed largely for the display of real time transit information.

General Discussion

With Respect to Tactile Warnings, Per se

The results of the present study corroborate the basic findings of the study conducted by Virginia Polytechnic Institute in the summer of 1995 for the Access Board so far as the essential detectability of tactile warnings using the truncated dome pattern. Tactile warning effectiveness and subjects' ability to detect the ramp without tactile warnings are confounded in the present study inasmuch as (a) detection of the tactile warnings in the present study was always in conjunction with the presence of a 1:12 sloped surface in the ramp, and (b) the 1:12 ramp area was reliably detected by subjects in the present study in the absence of any tactile warning. Data, however, are available from the study of tactile warnings in transit platform (flat) applications which clearly support their detectability. Thus, the first source of confounding in the present study is not critical.

Data, however, are still needed which address the extent to which failures to detect the sloped area of wheelchair ramps are associated with slopes less than the 1:12 design standard recommended by the Florida DOT and others. In the absence of such definitive data, it would seem reasonable to recommend that the highest priority be given to the application of tactile warnings in ramps with slopes less than 1:12, which would include those non-sloped (i.e., flat) areas defining the transition between safe walk areas and areas constituting a hazard to the blind or visually impaired pedestrian (e.g., the frontage area of many businesses in shopping malls where there is no elevation change (step down) between the sidewalk and traffic area. Such conditions present an extended high risk area for blind and visually impaired individuals. The "convenient" access which these conditions provide sighted customers moving from the store area into the parking lot area itself creates a hazard to motorists who must be on the constant lookout for individuals along the entire frontage of the business.

Use of Color/Contrast.

The proposed ADA requirement for the use of tactile warnings recommends the warning surface provide a high degree of contrast with the surrounding surface on which it is placed. It has therefore been assumed by many that the optimum condition would therefore be for the tactile warning to be black. The results of the present study strongly suggest that for those individuals with low vision yellow is highly preferred over black for detectability (note: for the totally blind individual, color is an irrelevant cue). Yellow may also prove to be more detectable under low light level conditions. Additionally, yellow is traditionally associated with warnings. For those with low vision, black surfaces may be confused with shadows; a misperception that becomes more likely as dirt and debris accumulates on the surface of the tactile warning making it even less distinct from its background.

Compensation for Wheelchair Users.

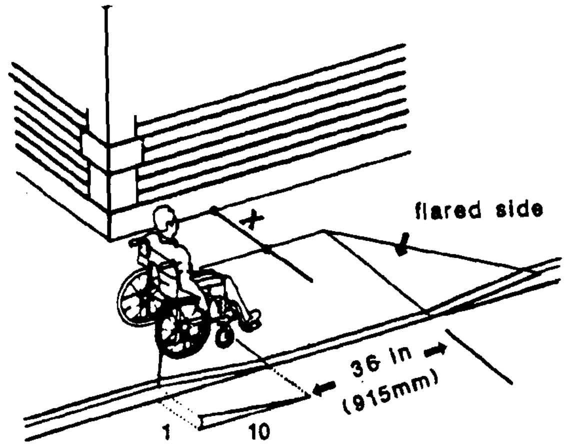
The present study demonstrated that while it is possible to deviate from the recommended full ramp coverage in order to increase the ease of use by wheelchair subjects, doing so has the effect of reducing the detectable surface area available to the blind cane user. The present study also showed that placements involving narrow tactile warning surfaces down the center of the ramp and/or along the edges of the ramp may unintentionally lead the visually impaired pedestrian to assume a restricted path of travel. For those with balance and/or stability problems, this unintentional restriction in the acceptable path of travel may create an unnecessary problem.

Use of "Directional" Patterns for Warnings.

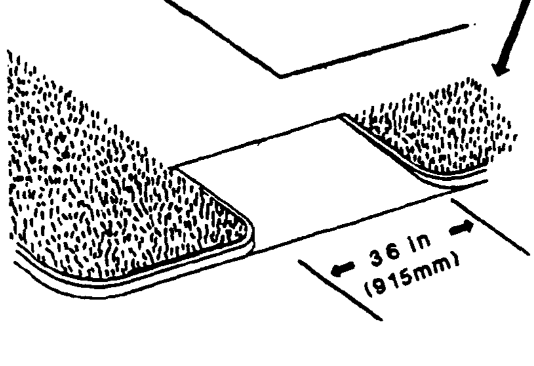
While surfaces using longitudinal patterns have traditionally not been recommended for warning subjects of hazardous areas, the FDOT opted in the present study to evaluate their use as a hazard warning in curb ramps. The pattern, when applied with the texture running along the path of travel, was highly rated by most blind and visually impaired subjects as well as most wheelchair subjects. Associated with this preference was the fact that the application in the present study was yellow and the pattern was formed from the harder composite Pathfinder material which provided a more distinct auditory cue when contacted with the cane. The only drawback however was the comment received from several of the older female subjects who reported some degree of lateral imbalance associated with a tendency for the foot to roll off the raised longitudinal portion of the pattern. These individuals reported no similar sensation when walking on the truncated dome surface. Applying the longitudinal texture perpendicular to the path of pedestrian travel (Figure 10) proved to be generally undesirable for most subjects, especially for wheelchair users. Placement of the directional pattern perpendicular to the path of travel also creates a potential obstacle for the "shuffler" or individual who lifts his/her foot less than the height of the raised pattern. Such placement also aggravates the problem for those in high heels. Additionally, when the pattern was "flooded," water was slow to drain from the upper side of the raised strips, suggesting a possibility for the creation and retention of ice under freezing conditions as well as the accumulation of dirt and debris under normal operating conditions.

Ramp Design: Returned Curb Versus Flared Sides.

Two of the eight ramps (Ramps number 3 and 8) were created with a returned curb design versus the more common situation where the sides of the ramp are flared (see Figure 16), creating a sloped approach to the ramp when approached off-axis. The returned curb design proved to be less desirable, especially when approached off-axis by the blind traveler, with the worst case being for the blind individual in a wheelchair approaching the ramp off-axis. The returned curb design also significantly reduces the room for maneuvering in the ramp for the wheelchair user. Additionally, the returned curb ramp design creates a change in elevation along the path of travel that presents a potential obstacle for sighted travelers in terms of an abrupt lateral change in surface elevation.



(a) flared sides



(b) returned curb

Figure 15
Ramps with "Flared" and "Returned Curb" Designs
(from Earnhart and Simon, 1987)

While the flared design creates a much larger sloped surface with some potential for orientation problems for the blind pedestrian, the area, if properly sloped, should be easily detected and, assuming the adequacy of other physical cues and the directional sound of traffic, problems should be minimal.

Auditory Cues/Feedback from Tactile Warnings.

Based upon the results of the present study, it is our opinion that any auditory feedback value associated with the tactile warning materials in the present study is minimal and is incapable of serving as a reliable cue for the blind or visually impaired pedestrian. This is certainly the case when considering the ambient noise level associated with the environment of most intersections. The only surface treatment in the present study which produced a distinct auditory cue upon contact was the composite Pathfinder sheet material. Given the inadequate installation of this material in the ramp, it cannot be determined whether its auditory/sound properties were the result of the material itself or its poor installation.

This is not to say in any way that audible cues do not or cannot constitute a significant source of information for the blind or visually impaired pedestrian if implemented properly. Color in conjunction with visual contrast and surface texture were clearly the more prominent and reliable cues used by subjects in this study.

Interaction Between Tactile Warnings and Irregular Footwear.

With respect to the effects of tactile warnings on those wearing footwear designed especially for fashion (e.g., high heels) or recreation (e.g., roller blades), there is cause for concern. Our general observation from the Access Board study as well as from observations conducted informally in the local area is that women with heels will generally avoid the ramp area with tactile warnings applied. Our FDOT "heeled subject" when required to walk over each of the designs used in the present study displayed noticeable hesitancy when crossing the material. . . definitely a departure from "normal" walking behavior. Those placements which minimized the tactile warning surface area and which permitted the subject in heels to basically "step over" (otherwise avoid) the tactile surface caused the least problem. Roller blade users need to be advised in ramps where tactile warnings have been applied should be prohibited since such use, according to our observations, is clearly associated with a high probability of falling upon contact.

With Respect to the Larger Mobility Issues of the Blind and Visually Impaired

Subjects' responses to the interview and survey items confirm the position expressed by VPI in the Access Board study, namely, that many of the problems encountered by blind and visually impaired pedestrians are associated with the requirements of a "low cue" environment. The intersection is not the only part of the blind pedestrian's environment where the lack of cues poses a significant mobility limitation. The survey/interview questions in the present study were an attempt to pinpoint more specifically those areas where the lack of cues exerts a significant limitation on a blind individual's travel behavior.

The blind or visually impaired person's level of access to mass transit options can be greatly affected by a lack of real time information; such things as information about where the bus stops, information needed in order to distinguish the bus he or she is waiting for from other buses arriving at the same stop, information about ones location while en route, etc. Many of the same information constraints affect the blind individual's effective use of taxi/cab service. Given the difficulty of multimodal travel, the blind individual's mobility remains limited largely to familiar, local destinations that can be reached on foot. The bottom line is that mobility for the blind and visually impaired need not be defined in terms of the local boundaries of visual familiarity. When we design for an informative environment, we are designing not only for the blind and other individuals handicaps, we are designing for all.

When designing for the blind pedestrian, not only must we consider *what* information is needed but how to "display" or make available the information. The notion of the audible pedestrian signal (see Appendix C) is a good idea, but one needs to ask the question of how the blind pedestrian is supposed to know the intersection has such a capability and how he/she is supposed to access it. Mounting a button and an accompanying sign on a pole provides an obvious cue to a sighted individual, but does little for the blind pedestrian. Even for the sighted person, such simple things as ensuring that the placement of signs supports ones intuitive understanding of the spatial relationships between the sign, its geographical reference, and the nature of the pedestrian behavior required to produce some desired action.

Recommendations

Regarding the (Pending) ADA Requirement for Tactile Warnings

1. A 1:12 slope in the ramp provided for wheel chair users at curbs can be reliably detected by most blind and visually impaired pedestrians. The extent to which the addition of tactile warnings to these sloped surfaces improves detection of the ramp area is counteracted by the negative, but not necessarily harmful, effects such surfaces create for persons with other forms of mobility limitation (e.g., wheel chair use, use of support devices, etc.).

2. Where the use of tactile warnings in ramps is used to augment the blind or visually impaired pedestrian's ability to detect the ramp surface (such as where the slope is less than 1:12), the present data suggest that

    a. a surface with a demonstrated ability for reliable detection by pedestrians be applied on the *full surface* of the ramp,

    b. strong preference be given to the *use of yellow or yellow/orange surfaces* (versus black) for improved detection by low vision individuals both in daylight and under low levels of illumination,

    c. that the rigid composite material, or material with similar auditory feedback/signature, be used where the underlying surface contour permits a secure application, preferably without a requirement for the use of metal fasteners,

    d. that "partial coverage" applications be avoided which may on occasion cause unintended orientation problems for the blind and low vision pedestrian,

    e. that consideration be given for the development and evaluation of "mixed" patterns (see Figure 17a and b)) which, in principle, can provide a surface design that optimizes the benefits of both the truncated dome and directional/bar patterns.

    f. that any widespread application of tactile warnings be associated with a public information/education program having among its objectives the following:

        (1) the need for special training for guide dogs and their users to avoid behavior on the part of the dog that might disorient its user.

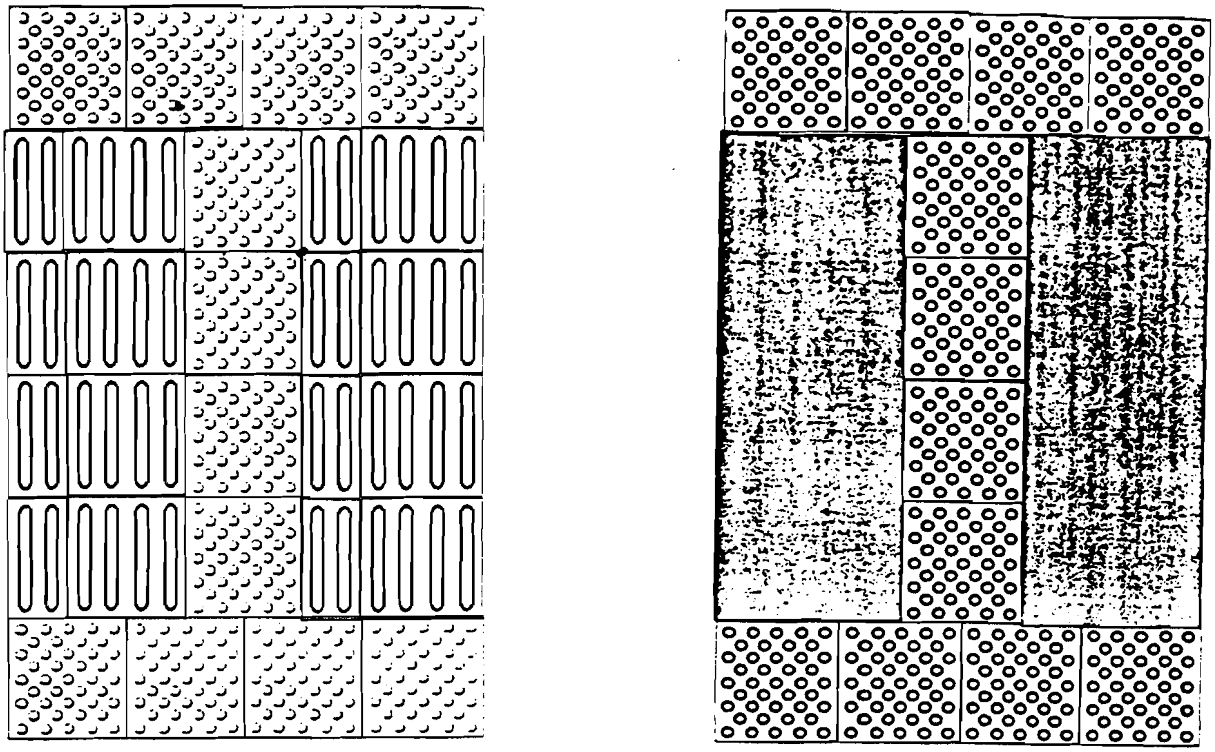


Figure 16

Examples of "Mixed" Texture Patterns in Same Ramp

Figure 11a and 11b show examples of tactile warning patterns which combine positive features associated with the different treatments in the present study. Both patterns provide full ramp coverage. The pattern in Figure 11a provides truncated dome surfaces at the top and bottom of the ramp and along the centerline of the ramp. Portions of the ramp to the left/right of the central truncated dome area use the directional/bar pattern. Recommended color is yellow/orange. Choice of resilient versus rigid composite material is dependent upon installation requirements and desirabilty of enhanced auditory signature/feedback for blind cane user. The pattern in Figure 11b also provides for full ramp coverage and like the pattern in Figure 11a utilizes truncated dome surfaces both at the top and bottom of the ramp as well as along the centerline. The pattern differs in that the areas to the left/right of the centerline section contain neither directional bars nor truncated domes but instead are a continuation of the same resilient or composite material used elsewhere in the ramp without the raised surface features. Recommended color throughout the pattern is yellow/orange. The same considerations apply to choice of resilient or rigid composite material.

(2) a warning/advisory to women in high heels that reasonable caution should be exerted when proceeding through a textured curb ramp, with the recommendation that those not requiring use of the ramp because of physical or mobility limitations cross at the curb and not through the ramp.

(3) that those using the sidewalk while wearing in-line skates (roller blades) avoid use of wheelchair ramps (in particular, those with tactile warnings) due to a high likelihood of falling and increased difficulty in stopping prior to entering the street.

g. that "returned" curb designs not be used where they permit off-axis approaches to the curb ramp.

Regarding Efforts to Improve the Low-Cue/Information Nature of the Environment for Blind and Visually Impaired Pedestrian

1. Recommend efforts to develop and evaluate audible forms of cuing for the blind and visually impaired pedestrian that will accomplish the following:

(a) Provide for both spatial orientation and directional cues in/around intersection environments that are widely recognized as difficult for the blind and visually impaired. (At a minimum, the capability should provide current location, direction of travel, name of street and name of nearest intersection along path of travel, etc.)

(b) Provide an effective "interface" for the blind and/or visually impaired pedestrian. Characteristics of the interface should include:

(1) Capability for recognizing/detecting the presence of a blind and/or visually impaired pedestrian (such as through a pedestrian-activated signal received by the system).

(2) Capability for communicating directly to the blind or visually impaired individual requesting the information without drawing undue attention to that individual as having special needs (e.g., through a small concealed earphone, etc.)

c. Provide a means for communicating such information beyond the immediate environment of the intersection, per se.

d. Provide a means for travel planning that would include at a minimum: real time position information, times to selected destination . .. by mode, modality options, location of nearest mass transit (e.g., bus, subway, etc.) stop; schedule and time of arrival of next vehicle, etc. (In essence, a "Pedestrian's Associate (PA)" similar in function to the Advanced Travel Information System (ATIS) concept being developed under ITS largely for driver use, but

portable, interactive with a natural speech response capability and simplified input format suitable for use by a blind individual, and oriented principally to the integrated use of walking, bicycling, and/or transit modes of travel.

e. **Integrated communications (e.g., cellular phone) and auto-dial capability for increased personal security of pedestrians.**

The Bottom Line

- Tactile warnings placed in curb ramps represent a reasonable means for increasing the blind or visually impaired pedestrian's ability to detect the sloped ramp provided for wheel chair users where slope alone, the sound of traffic, and other factors do not provide reliable sources of information.

- Where such other sources of information are available and provide the blind or visually impaired pedestrian with reliable cues, the addition of tactile warnings is redundant. The cost effectiveness of redundancy is beyond the scope of this report.

- Where tactile warnings are warranted because of the low-cue nature of the pedestrian curb/ramp environment, a yellow or yellow-orange color will enhance detection by those with low vision and generate fewer misperceptions than the use of black warning surfaces.

- Treatment of the full ramp surface is advisable to ensure a high probability of detection.

- Consideration should be given to the use of "mixed" patterns such as those recommended in Figure 12 in order to optimize the unique benefits of each of different surface textures.

- Audible signals/warnings/advisories, etc. can be an effective means of communicating needed spatial (orientation, location, etc.) and temporal (schedule) information to pedestrians if certain basic design considerations are kept in mind;

    - ensuring that the information communicated to the traveler is "intuitive" and does not mislead or disorient the individual because of incorrect associations/expectations

    - ensuring that the design considers how one is to be aware of the presence of the audible capability and the location or means of activating it

    - ensuring that the interface does not draw undue attention to those relying upon it; and ideally provides the individual with an ability to select or tailor the specific information that he/she needs.

- The audible interface is viewed as a critical feature of a proposed "Pedestrian's Associate" (PA) capability that would provide a real-time ATIS-like capability for pedestrians having significant implications for not only increasing the intermodal/multimodal travel options of blind and visually impaired pedestrians, but the options of the sighted community as well.

- The PA capability is conceived of as an important means by which the information and technology oriented philosophy of Intelligent Transportation Systems (ITS) might be applied to pedestrians.

References

Barlow, J., and Bentzen, B.L. Cues blind travelers use to detect streets. (Draft report), American Council of the Blind. 1993.

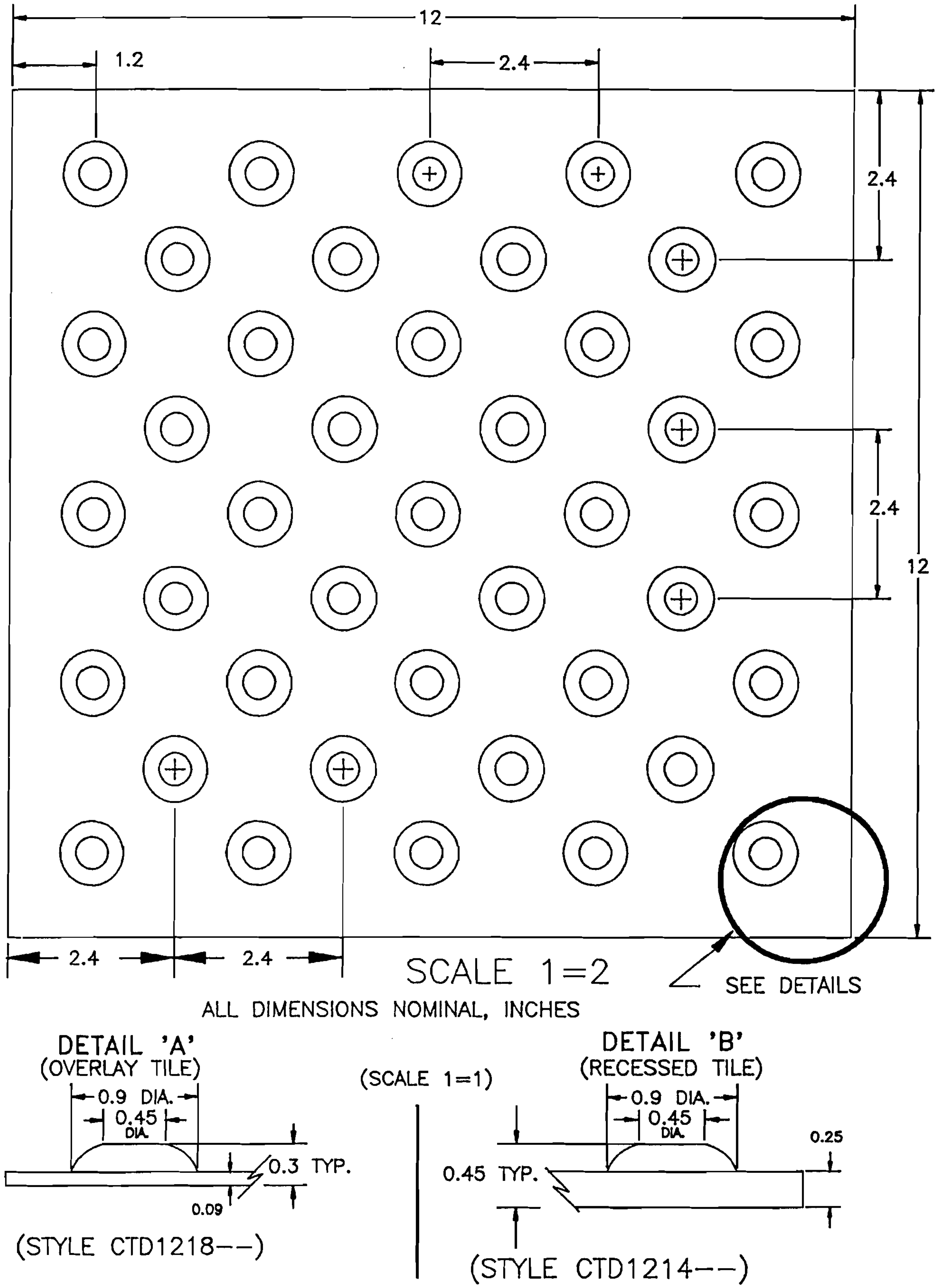
Earnhart, G., and Simon, L. Accessibility for Elderly and Handicapped Pedestrians (Final Report). FHWA-IP-87-8. US Department of Transportation -Federal Highway Administration, Safety and Implementation Division, McLean, VA October 1987.

McAuley, W.J., Hauger, J.S., Safewright, M.P., and Rigby, J.C. The Detectable Warnings Project (Phase 1 Executive Summary). Center for Gerontology, Virginia Polytechnic Institute and State University, Blacksburg, VA, January 1995.

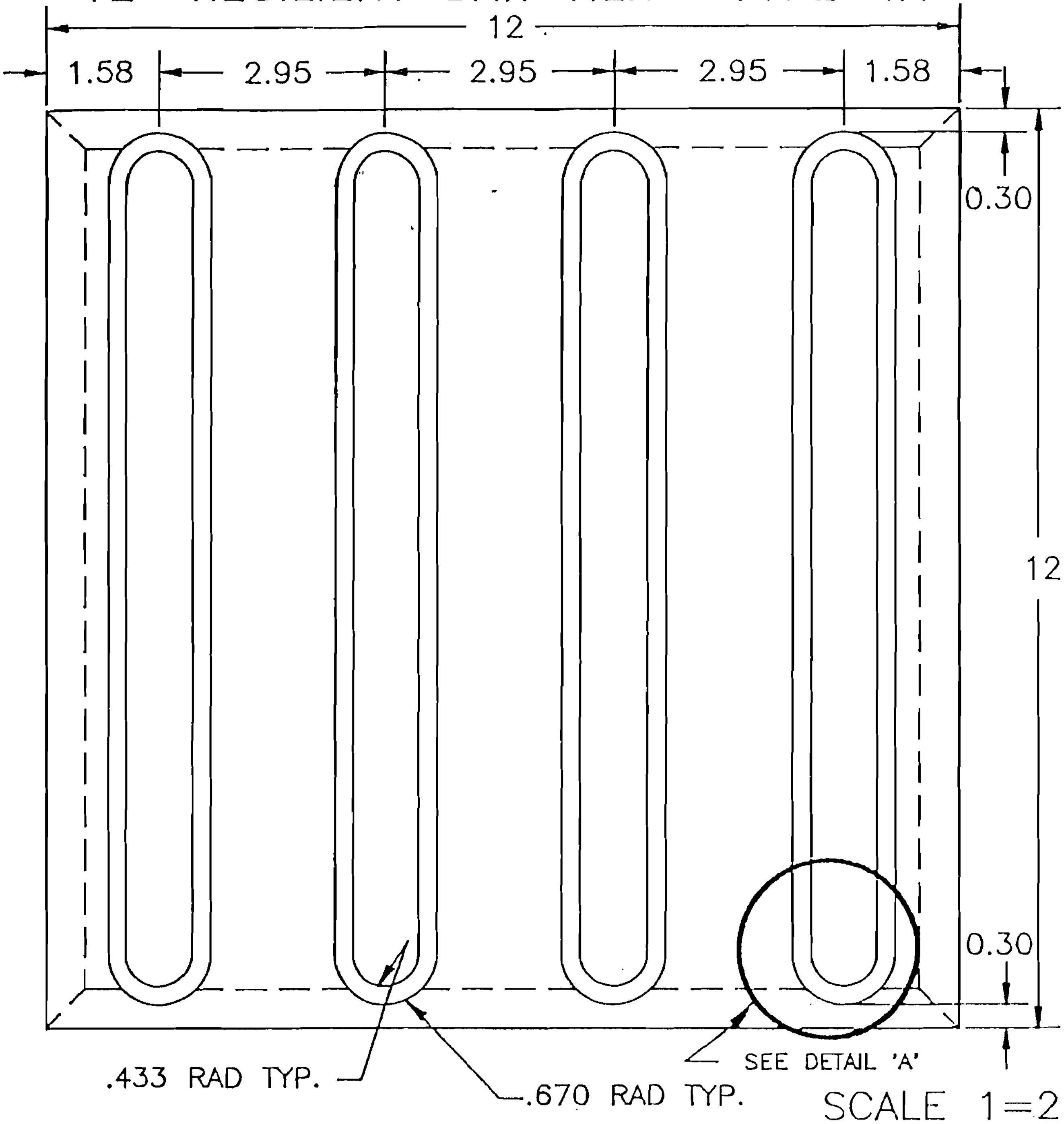
Appendix A

Specifications for Truncated Dome and Directional/Bar Patterns

PATHFINDER™
12" COMPOSITE DOT TILE--TYPE 1A

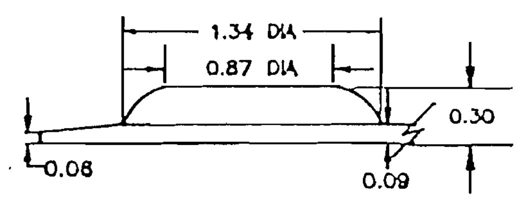


PATHFINDER™
12" RESILIENT BAR TILE--TYPE 4A



SCALE 1=2

ALL DIMENSIONS NOMINAL, INCHES



DETAIL 'A' (SCALE 1=1)
(STYLE RTB1218--)

NOTE

Resilient Tiles are 11-1/2" Square,
Composite Tiles are 12" Square

Appendix B

Product Descriptions

SPECIFICATIONS FOR PATHFINDER COMPOSITE TILE

I. SCOPE

The scope of this specification covers the requirements for detectable warning surfaces which, when installed as specified, conform with Section 4.29 of the Americans With Disabilities Act (ADA) 1990 and California State Accessibility Standards (Title 24 CAC). The use of these tiles is restricted and reserved for hazard detection.

FUNCTION

The tile provides multiple sensory signals of sight, sound, and touch.

FORM

The tiles are supplied in four basic forms and made of synthetic composite.

TYPE I The Type I Dot or Warning Tile consists of a flat surface with:

- A. 41 raised, truncated domes in accordance with Diagram 1A;
- B. 13 raised, truncated domes in accordance with Diagram 1B;
- C. 380 raised, truncated domes in accordance with Diagram 1C.

TYPE II The Type II Bar or Direction Tile consists of a flat surface with:

- A. 4 raised parallel bars in accordance with Diagram 2A.

II. GENERAL REQUIREMENTS

A. MATERIAL

The material shall be a fiber reinforced polymer bonded composite.

B. MECHANICAL PROPERTIES

Property	Nominal Values	Test Method
Specific Gravity	2.0	ASTM D 792
Tensile Strength (psi)	5000	ASTM D 638
Ultimate Elongation %	1.25	ASTM D 638
Rockwell E Hardness	70 minimum	ASTM E 18-93
Compressive Strength	15,000 PSI	ASTM D 695
Impact Resistance	No Cracking	ASTM D 3029

C. PHYSICAL PROPERTIES

Property	Nominal Values	Test Method
Chemical Resistance	No Dissolution	ASTM D 1038
Stain Resistance	No Stain	ASTM D 2299
Water Absorprion	less than .35%	ASTM C 373-88
Coefficient of Friction	0.8	ASTM C 1028
Abrasive Wear	>350	ASTM C 501
Flame Spread	<25	ASTM E 84
Smoke Developed	<450	ASTM E 84
Weatherability 500 hrs. xenon arc exposure	No Cracking, Crazing, Change in Color	ASTM G 26-90

D. DIMENSIONS

The tile shall conform to the dimensions as seen in Diagrams 1A, 1B, 1C and 2A.

E. COLOR - FEDERAL STANDARD #595A

Yellow	33538
Red	31302
Black	37038
Earthtone	31090

III. ADHESIVE PROPERTIES

A. Urethane sealants and adhesives shall comply with ASTM C 920-79 Standard Specifications for Elastomeric Sealants.

B. The modified epoxy adhesive shall meet the requirements of California Specification 8040-21M-09 for standard set epoxy adhesive for pavement markers.

IV. PACKING

Each box of tiles shall be marked with product number, type, color and lot number.

V. INSTALLATION

Installation must comply with the pre-qualified instructions and procedures supplied by manufacturer.

HIGH QUALITY

TACTILE SYSTEMS

DESIGNERS • FABRICATORS

TAC TILE SPECIFICATIONS

DOME GEOMETRY: In accordance with ADA Regulations; Part IV, Sec. 4.29.2. Raised truncated domes with a diameter of nominal 0.9 in., a height of nominal 0.2 in., and a center-to-center spacing of nominal 2.35 in.

SIZES: Tiles are available in 4'x2'x1/8", 4'x2"x3/8", 4'x2' paver tile.

MATERIAL: A glass and carbon reinforced composite which is colorfast and U.V. stable.

FASTENERS: Fasteners shall be sleeve anchors, 1/4"x1-3/8" with a minimum pull-out capacity of 1613 psi.
Fasteners shall have a flat, round, head which has a wedge-type countersink and allow for one component bolt removal and refastening within installed sleeve component without disturbance of any kind to substrate.

ADHESIVE: (OPTIONAL) As manufactured by Bostik.

TEST RESULTS:

TEST	RESULT	METHOD
Accelerated Weathering	No deterioration	ASTM G 23 (500 Hours)
Chemical Resistance	No Dissolution	ASTM 1308
Flexural Strength	20,450 psi	ASTM C 293
Tensile Strength	17,000 psi	ASTM D 638
Compressive Strength	15,000 psi	ASTM D 695
Hardness, Rockwell R	119	ASTM D 785
Freeze/Thaw/Heat	No Disintegration	ASTM C 1026 (5 cycles)
Impact Resistance	No cracks	ASTM D 3029
Flame Spread Index	10	ASTM E 84
Slip Resistance	0.88 (neolite,wet/dry)	ASTM C 1028
Stain Resistance	No Stain	ASTM D 2299
Wear Resistance	0.023 inches	ASTM D 658 (60 sec.)
Water Absorption	.23%	ASTM D-570
Abrasion Resistance	621	ASTM C 501
Izod Impact Resistance	773 J/m	ASTM D256

Appendix C

Volunteer Consent Form

YOUR CONSENT TO PARTICIPATE

I have read, or have had read to me, the above description of the FDOT Detectable Warning Study and I understand it. All my questions have been answered to my satisfaction and I understand that any future questions I may have will also be answered. I understand that I am free to withdraw this consent and discontinue participation in this study at any time.

I agree to participate and acknowledge that I have received a copy of this form.

____

Signature Date

____

Please <u>print</u> your name here

The above named person has been given an opportunity to have his/her questions answered.

____

Signature of Researcher Date

Appendix D

Questionnaire/Survey Forms

FLORIDA DOT DETECTABLE WARNING STUDY

Subject's ID **Male/Female Age**

Date Participated in Study: **(Paid Volunteer) or (Conference Participant)**

Condition:

Totally Blind/Cane User	**Visually Impaired Uses Cane or Support Device**
Wheelchair User	**Visually Impaired Uses No Support Device**

Number years with disability:

Other Known/Reported "Mobility" problems: (Describe below)

Subject ID: Date Participated:

Questions for Wheelchair Users

(These are to be answered after each ramp when collecting the performance data)

1. How much of a problem did this particular design have on your ability to negotiate the ramp with respect to:

	little or no problem (N)	somewhat of a problem (S)	a major problem (M)
being able to control the direction of my chair			
the effort/force required to move up the ramp			
discomfort going over surface			
concern for chair turning over			
ability to "maneuver" while on the ramp			

RECORD IN APPROPRIATE CELL IN TABLE BELOW

SEQUENCE NUMBER ONE FOR WHEEL CHAIR SUBJECTS

RAMP NUMBER	APPROACH LENGTH	*control* *N,S,M*	*effort* *N,S,M*	*comfort* *N,S,M*	*stability* *N,S,M*	*maneuver* *N,S,M*
1	LONG					
2	SHORT					
3	SHORT					
4	LONG					
5	SHORT					
6	LONG					
7	LONG					
8	SHORT					

General Observations:

Subject ID: Date Participated:

Questions for Wheelchair Users

(These are to be answered after each ramp when collecting the performance data)

1. How much of a problem did this particular design have on your ability to negotiate the ramp with respect to:

	little or no problem (N)	somewhat of a problem (S)	a major problem (M)
being able to control the direction of my chair			
the effort/force required to move up the ramp			
discomfort going over surface			
concern for chair turning over			
ability to "maneuver" while on the ramp			

RECORD IN APPROPRIATE CELL IN TABLE BELOW

SEQUENCE NUMBER TWO FOR WHEEL CHAIR SUBJECTS

RAMP NUMBER	APPROACH LENGTH	*control* *N,S,M*	*effort* *N,S,M*	*comfort* *N,S.M*	*stability* *N,S,M*	*maneuver* *N,S,M*
8	LONG					
7	SHORT					
6	SHORT					
5	LONG					
4	SHORT					
3	LONG					
2	LONG					
1	SHORT					

General Observations:

2. I'm going to read you a list of things that may cause you varying amounts of difficulty when crossing intersections? I'd like for you to indicate the degree of difficulty on a 10-pt scale where a "I" is no difficulty and where a "I0" is a high degree of difficulty.

A. a vertical curb with no wheelchair ramp present

"no difficulty" **"significant difficulty"**

1	2	3	4	5	6	7	8	9	10

B. Overly steep slope of the wheelchair ramp when one is present

"no difficulty" **"significant difficulty"**

1	2	3	4	5	6	7	8	9	10

C. loss of traction in the ramp

"no difficulty" **"significant difficulty"**

1	2	3	4	5	6	7	8	9	10

D. transition through the gutter pan area (i.e, "getting stuck" in gutter)

"no difficulty" **"significant difficulty"**

1	2	3	4	5	6	7	8	9	10

E. physical effort required to make it over the crown in the road

"no difficulty" **"significant difficulty"**

1	2	3	4	5	6	7	8	9	10

F. having adequate time to cross before signal changes

"no difficulty" **"significant difficulty"**

1	2	3	4	5	6	7	8	9	10

G. ramps that are oriented diagonally rather than perpendicular to the street that you are trying to cross.

"no difficulty" **"significant difficulty"**

1	2	3	4	5	6	7	8	9	10

3. If it were possible for the blind pedestrian to do equally well with less than the full ramp covered with the detectable warning surface, which condition would you prefer:

a. detectable warning material on entire surface

b. detectable warning material placed so as to allow area for the wheels of my chair to pass freely.

c.- detectable warning at top of ramp only (on flat portion before the ramp)

FLORIDA DOT DETECTABLE WARNING STUDY

Subject's ID **Male/Female Age**

Date Participated in Study: **(Paid Volunteer) or (Conference Participant)**

Condition:

Totally Blind/Cane User	Visually Impaired Uses Cane or Support Device
Wheelchair User	Visually Impaired Uses No Support Device

Number years with disability:

Other Known/Reported "Mobility" problems: (Describe below)

Questions to Ask Visually Challenged Subjects Prior to Collecting Performance Data

Capability for Independent Travel for Visually Challenged Subjects

1. How often do you travel beyond where you live (your home) without the assistance of a companion or guide?

never	sometimes	often

2. If answer to first question was "sometimes" or "often", then ask. . .

" When you travel beyond your immediate home environment, how often do you use the following forms of transportation?"

Bus

never	sometimes	often

Paratransit

never	sometimes	often

Taxi

never	sometimes	often

3. When you travel on foot (i.e, as a pedestrian), how likely is it that your trip will require that you do each of the following?

a.	**cross a street where there is traffic in one direction only**	**almost never**	**sometimes**	**often**	**almost always**
b.	**cross a street where there is traffic in two directions**	**almost never**	**sometimes**	**often**	**almost always**
c.	**cross at an intersection where there is a traffic signal**	**almost never**	**sometimes**	**often**	**almost always**
d.	**cross at an intersetion where there is no traffic signal**	**almost never**	**sometimes**	**often**	**almost always**

4. What do you consider the biggest obstacle to your independent travel? I want you to use a 10 point scale wehre a "l" is not important and a "10" is extremely important.

a. *EMBARRASSMENT ABOUT MY PHYSICAL LIMITAT IONS*

"Not Important" *"Extremely Important"*

1	2	3	4	5	6	7	8	9	10

b. *LACK OF INFORMATION TO ORIENT EFFECTIVELY*

"Not Important" *"Extremely Important"*

1	2	3	4	5	6	7	8	9	10

c. *RISK OF BEING INJURED IN ACCIDENT*

"Not Important" *"Extremely Important"*

1	2	3	4	5	6	7	8	9	10

d. *FEAR FOR PERSONAL SAFETY*

"Not Important" *"Extremely Important"*

1	2	3	4	5	6	7	8	9	10

e. *ACCESSIBILTY TO OTHER MODES OF TRANSPORTATION (E.G, BUS, TAXI, ETC.)*

"Not Important" *"Extremely Important"*

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*

Subject ID: **Date Participated:**

SEQUENCE NUMBER ONE

RAMP NUMBER	APPROACH LENGTH	First Contact: Curb(C) or Ramp (R)	If Ramp, Detected first by Spt Device(SD) or Foot(F)	Regardless, Action Taken: Stopped (S) or Continued (C)
1	LONG			
2	SHORT			
3	SHORT			
4	LONG			
5	SHORT			
6	LONG			
7	LONG			
8	SHORT			

General Observations:

Subject ID: **Date Participated:**

SEQUENCE NUMBER TWO

RAMP NUMBER	APPROACH LENGTH	Contacted Curb (C) or Ramp (R)	If Ramp, Detected first by Spt Device (SD)or Foot (F)	Action Taken: Stopped (S) or Continued (C)
8	LONG			
7	SHORT			
6	SHORT			
5	LONG			
4	SHORT			
3	LONG			
2	LONG			
1	SHORT			

General Observations:

Questions for Visually Challenged Subjects
(After Collecting Performance Data)

Read: *Now that you have experienced the use of detectable warning surfaces on curb ramps, we would like to have you answer the following questions:*

1. How much do you think that the presence of tactile warning materials in the wheelchair ramps at intersections will increase your safety as a pedestrian?

little or no effect on safety	moderate effect on safety	significant effect on safety

2. We would like to know how important you think tactile warnings are relative to other "improvements" that could be made for pedestrians? I'm going to give you some choices. You tell me which you would choose.

-OR-

smoother walking surface	*tactile warnings in curb ramps*
fewer man-made obstacles along the path	*tactile warnings in curb ramps*
better definition of where to cross	*tactile warnings in curb ramps*
traffic signals sensitive to need for additinal time	*tactile warnings in curb ramps*

3. If tacticle warning surfaces were available everywhere, would you be more likely to take more trips on foot?

yes	no

4. Are there any intersections that you now avoid because they have insufficient cues for safe crossing?

yes	no

5. True or False: I would travel more places by foot if I felt safer at intersections

True	False

6. I would travel more places by foot if I felt safer at those points where I have to cross the street.

True	False

7. The widespread use of detectable warnings at intersections would contribute more than anything else to my feeling of safety at crossing sites.

True	False

Dealing with Ramps

1. To the best of your knowledge, have you ever walked through a wheelchair ramp at the corner and failed to realize that you had reached the edge of the street?

Yes	No

If yes,

2. Tell me which of the following is generally true when this happens:

   a. I cannot tell that the slope of the sidewalk had changed.
   b. There is no traffic signal at the intersection
   c. At the time, I am not able to rely on the sound of traffic to tell when to cross (i.e, quiet, no cars coming)

3. Are you aware that some wheelchair ramps are oriented perpendicular to the street you are trying to cross and some are oriented at an angle (that is, pointing to the middle of the intersection?)

yes	no

4. A ramp can have different orientations to the street. A "projected" ramp points to the middle of the intersection. Others are perpendicular to the street you are about to cross. Do you depend upon the orientation of the ramp to the street in order to orient yourself or do you move to a section on the curb where you can "square off? or both?

   a. Use orientation of ramp
   b. Use raised curb to "square off"
   c. both (if both, which is the most reliable cue?)

orientation of ramp	raised curb

5. Has you reliance on the orientation of the ramp ever caused you to have a problem when crossing at an intersection?

yes	no

Confusion of truncated dome surface with other surfaces

1. Do you think that it might be possible to confuse the truncated dome surface with other surfaces you normally encounter while walking?

yes	no

2. If it were not possible to place this type of warning material in all curb ramps, at what types of intersections would it benefit you the most? That is, under what conditions do you think the presence of the material would provide you some additional safety?

CHARACTERISTICS OF DIFFICULT INTERSECTIONS

Say: *"Now we want you to think about intersections more broadly, not just in terms of detectable warnings."*

I want you to think of those intersections that you think of as being the most difficult to cross. I want you to tell me to what extent each of the following is a problem for you has on that difficulty. Use the 1-10 scale like you did before where "I" is *no problem* and where "I0" is a *major problem*.

(a) Not Enough Time to Cross

"No Problem" ***"Major Problem"***

1	2	3	4	5	6	7	8	9	10

(b) The absence of a clear signal when it is safe to cross

"No Problem" ***"Major Problem"***

1	2	3	4	5	6	7	8	9	10

(c) Hard to maintain direction and orientation while crossing

"No Problem" ***"Major Problem"***

1	2	3	4	5	6	7	8	9	10

(d) Edge of roadway is not well defined

"No Problem" ***"Major Problem"***

1	2	3	4	5	6	7	8	9	10

(e) Intersections with vehicles turning right on red

"No Problem" ***"Major Problem"***

1	2	3	4	5	6	7	8	9	10

(f) Multiple lanes with no pedestrian "island" in the middle

"No Problem" ***"Major Problem"***

1	2	3	4	5	6	7	8	9	10

(g) Intersections where sound of traffic cannot be used as a reliable cue

"No Problem" ***"Major Problem"***

1	2	3	4	5	6	7	8	9	10

The Perfect Intersection for the Blind Pedestrian

If you could design what, for you as a blind pedestrian, would be the perfect intersection conditions, what would it be like? (open ended)

Unique Needs/Improvements for Visually Challenged Pedestrians

Most "improvements" beneficial to the blind pedestrian are also beneficial to the sighted pedestrian. Are there any improvements that would be considered "unique" for blind or visually challenged pedestrians?

Helping without calling attention to those needing help

While most persons with physical limitations appreciate an environment that supports their special needs, they don't want to be singled out as needing help. What are some ways that the pedestrian environment can be made more helpful to blind travellers without drawing undue attention to them?

Talk-to-Me

If the intersection could somehow "talk," what information would you want it to provide you as you approached?

(e.g, how many lanes, safe haven in middle, direction of traffic, traffic light/heavy, street names, direction of my travel (NESW), location of bus stop, signal/no signal, phase of the signal, etc.)

Making Intersections more "informative" - Implementation Considerations

In terms of making intersections more "informative" for visually challenged pedestrians, here are some implementation possibilities. We would like to know which ones you think are best.

1. The intersection provides information out loud to all who approach.

2. Intersection provides information out loud only when there is a blind or visually challenged pedestrian present.

3. Blind or visually challenged pedestrians can receive information "privately" through an earpiece similar to that worn by hearing impaired individuals.

4. Blind or visually impaired pedestrians can select when they want information and what particular information they want.

If cost were not a factor, would you prefer such a device (call it a "pedestrian's associate") to some form of tactile (e.g, braile) information display whose position at the intersection you would have to locate (e.g, on a pole) and which was unable to give you current, real time information (e.g, could give you street names, but not the current traffic conditions)?

-OR-

Pedestrian's Associate	Tactile Display

Such a device might provide other sources of information in addition to that provided at intersections. I'm going to give you some examples. I'd like you to to tell me how much benefit you think each would have for the blind or visually challenged pedestrian. Use the I0-point scale that you are now familiar with using where a "I" is no benefit and a "I0" is a significant benefit.

a. present location relative to major buildings, street address, etc.

"no benefit" *"significant benefit"*

1	2	3	4	5	6	7	8	9	10

b. direction of travel (north, east, south, west)

"no benefit" *"significant benefit"*

1	2	3	4	5	6	7	8	9	10

c. directions to desired destinatations and suggested travel times by different modes of travel (on foot, by bus, by taxi, etc.)

"no benefit" *"significant benefit"*

1	2	3	4	5	6	7	8	9	10

d. directions to nearest bus stop for reaching location

"no benefit" *"significant benefit"*

1	2	3	4	5	6	7	8	9	10

e. self-contained capability to call taxi and to give current location

"no benefit" *"significant benefit"*

1	2	3	4	5	6	7	8	9	10

f. capability to dial "911" in case of emergency and to provide emergency providers with current location.

"no benefit" *"significant benefit"*

1	2	3	4	5	6	7	8	9	10

g. if on a "smart bus," a capability to receive information about bus's current location, next stop, and estimated time to reach your desired location

"no benefit" *"significant benefit"*

1	2	3	4	5	6	7	8	9	10

The Use of PublicTransportation by the Visually Challenged

1. Do you ever use public transportation (i.e, the bus)?

yes	no

2. If you use the bus, or have ever considered using the bus, to what extent do you consider each of the following to be a problem for the visually challenged traveller? Use the same 1-10 point scale that you used before, where a "l" means no problem and where a "10" means a major problem.

a. *locating the bus stop if it is not one that I am already familiar with.*

1	2	3	4	5	6	7	8	9	10

b. *knowing when the next bus is coming*

1	2	3	4	5	6	7	8	9	10

c. *how to tell one bus from another at the point where I want to get on.*

1	2	3	4	5	6	7	8	9	10

d. *boarding (getting on/off) the bus*

1	2	3	4	5	6	7	8	9	10

e. *locating a seat after getting on the bus.*

1	2	3	4	5	6	7	8	9	10

f. *being able to know when the bus is approaching the place where you want to get off.*

1	2	3	4	5	6	7	8	9	10

Questions on Use of Taxi

1. Do you ever use a taxi other than when you are somewhere you can use the phone and have it meet you at your location?

yes	no

2. To what extent are each of the following importantl to you in terms of improving your ability to use the taxi as a form of transportation? (aside from cost). Use the 1-l0 scale like you did before where "l" is of little or no help and where "l0" is of significant help.

a. Not having to be at a phone to call (i.e., having a portable phone that I could carry with me)

"not important" *"very important"*

1	2	3	4	5	6	7	8	9	10

b. Being able to quickly and accurately communicate my location to the taxi company

"not important" *"very important"*

1	2	3	4	5	6	7	8	9	10

c. Feeling that I would be safe riding in a taxi

"not important" *"very important"*

1	2	3	4	5	6	7	8	9	10

d. Feeling confident that I was being taken to my location by the most direct route.

"not important" *"very important"*

1	2	3	4	5	6	7	8	9	10

e. Being able to know that I had been taken to the location that I had requested.

"not important" "very important"

1	2	3	4	5	6	7	8	9	10

Appendix E

Evaluation of Palatka Audible Pedestrian Crossing Signal

Appendix

Comments on the Palatka, FL Audible/Vocal Pedestrian Crossing Signal at the Intersection of SR 19 and St Johns Road

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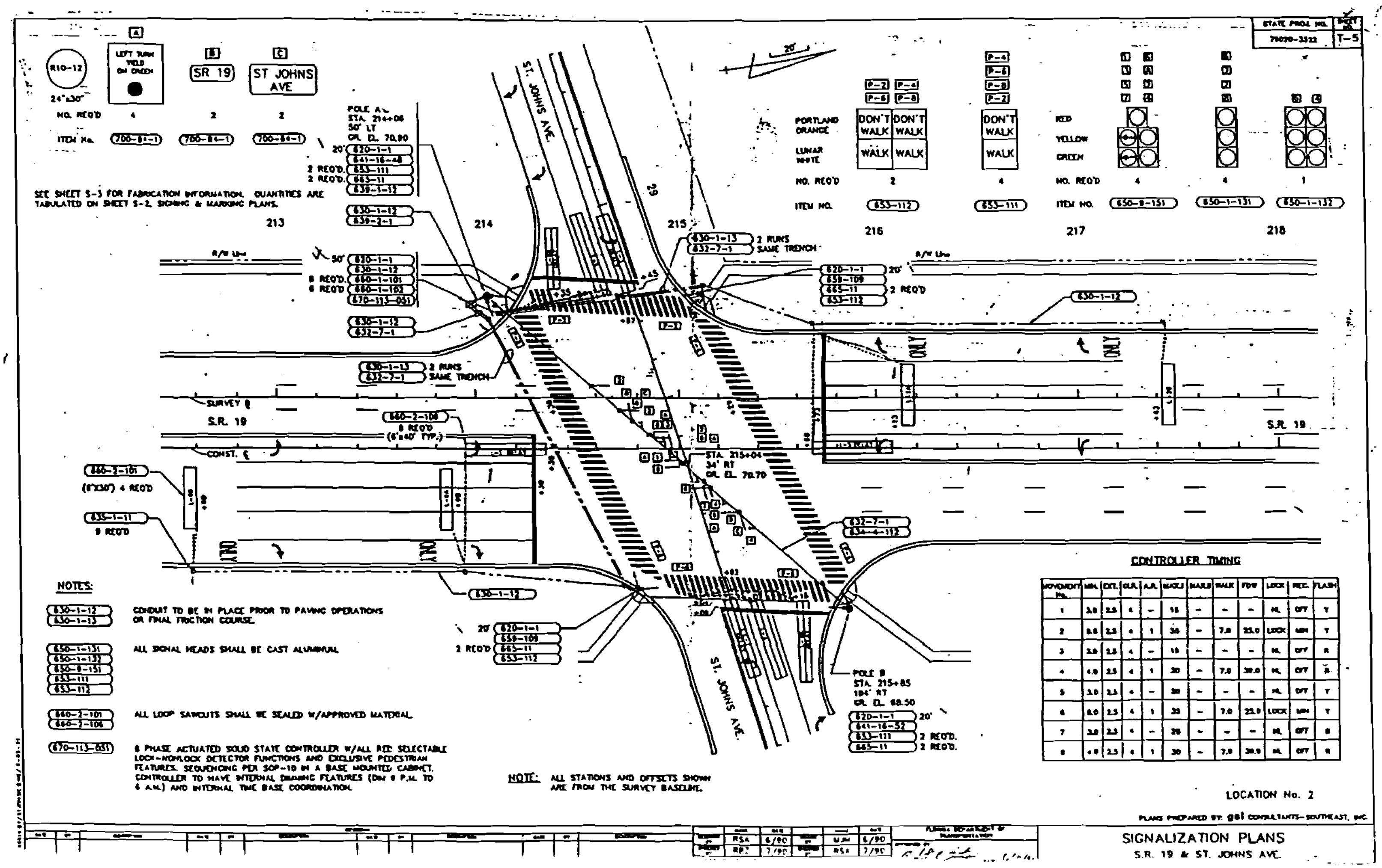
The principal HSRC investigator on the FDOT tactile warning study and a representative of the FDOT Safety Office in Tallahassee assigned to the study traveled to Palatka, FL to observe the operation of an audible/vocal pedestrian signal at the intersection of SR 19 and St Johns Road. A recommendation that we take a look at the installation came from one of the subjects in the study when prompted by the survey item, "if an intersection could talk, what information would it provide to you as you approached?"

SR 19 is a busy, multi-lane facility with two lanes of traffic in either direction separated by a turn lane (see diagram). St Johns Rd is basically a two-lane facility upstream and downstream from the intersection but flares to a dual left turn configuration at the intersection. There is no median or pedestrian refuge island on either facility. Traffic volumes on both facilities are heavy with a high percentage of trucks. Ambient noise during the period we observed was very high.

The audible/vocal pedestrian crossing signal operates in conjunction with pole-mounted, illuminated *walk, don't walk* displays and pole-mounted pedestrian-activated push button devices used to request the crossing signal. Mounted directly above the push button is a printed sign saying "Push button to cross SR 19" or. . . St Johns Road." There is no feedback to the pedestrian that pushing the button has effectively communicated to the system his/her desire to cross. Perhaps most confusing was the manner in which these signs were mounted in relationship to the crossing which each commanded. As one walked along St Johns Rd in the direction of SR 19 (with the intention of crossing SR19), the sign displayed immediately in front of the pedestrian reads "Push button to cross St Johns Rd." Without any independent knowledge of which road is which, the natural tendency would be for the pedestrian to assume that the sign applies to the cross street which he/she has just approached. If the pedestrian were blind, the audible signal saying that it is not safe to cross would result in that individual crossing the active lane of traffic. In this case, the button and sign applying to SR 19 is located on the opposite side of the pole out of the individual's direct field of view; and given that the walkway did not extend on both sides of the pole, an individual in a wheelchair would have go in the grass to reach a point that the sign could even be read. In short, the spatial orientation of the sign and its message are not logically correlated with the action that the pedestrian would normally expect to take.



Intersection of SR 19 and St Johns Road

While observing, two teenage boys approached walking along St Johns Rd approached the intersection with the intention of crossing SR19. We asked if they frequently used this intersection and whether or not they had used it both before and after the installation of the audible pedestrian signal. Both had before/after familiarity with the intersection. When asked if they thought the audible signal was effective in terms of making it easier to cross this major intersection, both said yes. Their behavior however questioned the effectiveness of the device. As they approached the intersection, they pressed the button under the sign "push button to cross St Johns Rd" (rather than the button for SR 19 which was hidden from view on the other side of the pole). And then without waiting for the walk signal, proceeded to cross against the flow of traffic.

With respect to the audible and vocal elements of the message, a good job was done in trying to differentiate commands for the two separate crossing messages. For example, the message for SR 19 and St Johns Rd each used a different voice (male/female) and the audible signal which followed each was also differentiated (chirp vs beep).

The problem is that the verbal portion of the messages are hard to understand, especially the high ambient noise environment of this busy intersection. Furthermore, the walk phase of the signal b begins with the *onset* of the verbal message. When the verbal message terminates, the remainder of the "*walk*" phase is signaled by the presence of the audible beep or chirp (about two beeps/chirps) after which time the signal changes to a flashing "*don't walk*", a change which, of course, cannot be detected by the blind pedestrian. The remainder of the crossing phase is not correlated with any audible cue, such that the pedestrian has no way of knowing the time remaining before the light changes.

The problems are problems with implementation and not problems that are inherent to the use of audible/verbal messages. Some simple "fixes" might include the following:

1. Mount the information (signs) providing instructions as to the role of each push button so that they are correlated intuitively with the direction of the crossing to which they apply. A sign directly in front of a pedestrian as he/she approaches a cross street will be assumed to apply to that street. To ensure that the pedestrian relates the message with the appropriate crossing, consider placing an arrow on the sign pointing in the direction of the crossing controlled by that button. Assume that pedestrians will interpret a sign that is directly in front of them at a cross street as applying to that street. If the sign is not intended to apply to the street immediately ahead of

them, then use the arrow to point to the left or right. Arrows pointing straight up (indicating straight ahead) are confusing and should be avoided. Ensure that all signs and their controllers, regardless of the crossing to which they apply, are both visually and physically accessible to the pedestrian.

2. Consider changing the verbal message from one that simply says you now have the signal to cross xx-road to one that says "cross xx-road now" followed immediately by "you have x-seconds to cross." Keep the message short so that valuable crossing time is not reduced by the time it takes to process the message before responding. Also consider continuing the use of the audible cue during the safe crossing phase. As currently implemented, once the verbal message ends and the two brief audible tones are sounded, there is no further auditory cuing as to the phase of the crossing signal. At a mi minimum, there needs to be signal for when it is safe to begin and a different signal for "complete crossing but don't begin if you haven't already started." Audible cuing needs to be used not only to "initiate" the desired pedestrian behavior, but to continuously guide it as well.

3. Attempt to provide the pedestrian some feedback that his/her pressing the button beneath the sign has been recognized by the system. At a minimum, provide some type of feedback (vibratory or auditory would work best for blind individuals as well as for sighted individual under lighting conditions when visual confirmation of button pressing might go unnoticed. One might also consider having the system feedback include the time to the next crossing signal; e.g., "safe to cross in x-seconds, please wait."

4. While the present situation is fine for sighted individuals who are capable of locating the push button for affecting the signal change, the question arises as to how a blind or visually impaired pedestrian would, with no prior experience at this particular intersection, know that there was a button to control the pedestrian crossing phase; and even if he/she did, how would that person physically "find" the button?

There are probably other "fixes" that would work equally well. Our suggestions are based upon a very hurried and cursory observation of the intersection and the operation of the audible crossing signal in place at the time. Whatever, it is important that the pedestrian crossing signal. . .whether audible, verbal, visual, etc. provide a cue to the pedestrian that is (1) unambiguous as to its meaning/direction, (2) requires minimal processing time (i.e., can be quickly responded to), 3) utilizes written messages/instructions whose spatial orientation is logically correlated with the locus of the desired pedestrian behavior, and (4) which provides continuous (not simply onset) cuing to effectively guide the behavior during the entire crossing cycle.

Signal installed for blind persons

BY DIANE RODGERS
Daily News

As part of a statewide pilot program, a pedestrian signal for blind persons has been installed at Highway 19 and St. Johns Avenue.

The signal was installed about two months ago by the Department of Transportation.

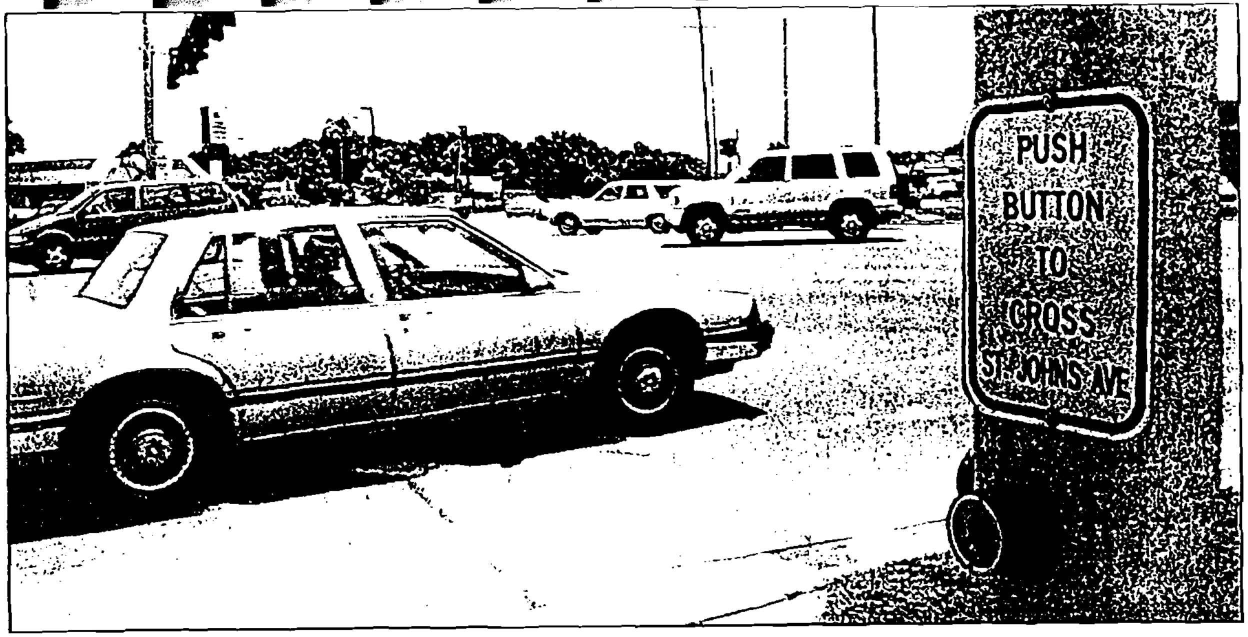
The DOT spent about $5,000 for materials and the county installed it, said Gina Busscher of the DOT's Lake City office.

She said signals were installed in several places in the state to test their effectiveness in assisting blind or sight-impaired residents.

Palatka and, specifically, the Highway 19 intersection were chosen because of efforts by Mary Ann Lightfoot, a blind woman who attends classes at St. Johns River Community College and uses the intersection periodically.

Lightfoot of Interlachen

See SIGNAL on Page 7A



PETER WILLOTT / Daily News

A pedestrian signal for blind persons has been installed at Highway 19 and St. Johns Avenue.

Signal

Continued from Page 1A

said she battled local agencies and the DOT to get the audible signal.

"It's important for their safety," she said.

She said the signal also helps sight-impaired residents.

"The sound gives them clearance," she said.

Lightfoot said she will continue to fight for more audible signals in Palatka. There are many sight-impaired residents at Frank George Apartments in Palatka, she added. Signals are needed near the apartments, the courthouse and the city police station.

"I think it's great," County Administrator Gary Adams said. "It's a great service."

Adams said there are several blind and sight-impaired residents who will benefit, but it can help everyone.

"The sound makes people more aware," Adams said.

The intersection is surrounded by traffic-intense businesses, he said.

The audible will help anyone trying to cross the six-lane highway amid the confusion, he said.

The county spent $250 on installation.

When the signal changes and it is OK to walk, a verbal message sounds telling the pedestrian the "walk" signal is activated.

The devise begins to beep, meaning it is OK to step down from the curb.

When the beeping stops, it does not mean the signal is going to change, but it is unsafe for pedestrians on the sidewalk to start crossing the intersection.

Another nearby test site is in Daytona Beach near a blind school.

There is also a signal in St. Augustine, but it has been there several years.

Busscher said the department will test the system for one year. If it is determined effective, the department will install more.

Even if it is not effective, the department is encouraging the county to continue maintaining the Highway 19 signal.

Appendix F

The Detectable Warnings Project (Final Executive Summary)

THE DETECTABLE WARNINGS PROJECT

Phase I Executive Summary

FINAL

January, 1995

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EXECUTIVE SUMMARY

I. Background

The Detectable Warnings Project (Phase I) was sponsored by the Access Board, and performed by the research team of the Center for Gerontology, College of Human Resources, at Virginia Polytechnic Institute and State University. The project was concerned with issues involving the use of detectable warnings in pedestrian areas.

A detectable warning is defined by the Access Board to be a standardized surface feature built in or applied to walking surfaces to warn individuals with visual impairments of a hazard on a circulation path. In particular, the term "detectable warning" is used to refer to a pattern of raised, truncated domes which can be detected by a cane or under foot. This pattern was identified by previous research as having high detectability, and being easy to distinguish from other surfaces. This type of detectable warning was adopted as a standard and required at curb ramps and hazardous vehicular areas by the ADA Accessibility Guidelines (ADAAG) in 1991. Curb ramps, short ramps cutting through a curb, have been and continue to be installed at intersections of pedestrian and vehicular ways to provide wheelchair users and others with mobility impairments with a means to cross a curb line. Hazardous vehicular areas refer to sites where pedestrian walks cross or adjoin vehicular ways and the pedestrian and vehicular areas are not separated by curbs, railings or other barriers. For example, strip shopping centers and hotels may have vehicular driveways that adjoin walkways at entrances. If there is no curb separating the pedestrian and vehicular area, a detectable warning would have to be provided.

Subsequent to issuance of the ADAAG, a number of interested organizations and individuals expressed a desire for further study of the need for detectable warnings. The Access Board agreed that these issues warranted further investigation, and initiated a Notice of Proposed Rulemaking to temporarily suspend the requirement until additional research could be undertaken. Although detectable warnings have been proposed for use in a variety of interior and exterior applications, this project was limited in its consideration to the use of detectable warnings at curb ramps and at hazardous vehicular areas.

II. Review of state and international requirements for detectable warnings and review of research literature

The research team undertook a survey of national and state guidelines and standards for detectable warnings at curb ramps and hazardous vehicular areas. Some jurisdictions, including Japan, Australia, Britain, Wisconsin and Massachusetts require or recommend tactile surfaces at curb ramps which provide directional information as well as a detectable surface. Japan and

Australia, (and California in transit applications) use truncated domes in combination with truncated bars. Britain recommends an orthogonal grid of truncated domes which, unlike the American pattern of staggered domes, have a directional aspect. Massachusetts, Wisconsin, Texas and the Republic of South Africa specify the use of tactually and visually contrasting surfaces at intersections without requiring the use of truncated domes or domes augmented by bars. Two jurisdictions require detectable warnings at some curb ramps, but not others. California requires tactile surfaces when the curb ramp slope is less than 1:15. Wisconsin requires tactile surfaces on perpendicular curb ramps (i.e., those which are perpendicular to the street and in the line of travel), but not at diagonal curb ramps (i.e., those which cut at an angle to the line of travel, generally 45 degrees).

The research also undertook a review of research literature. Since 1980, there have appeared some thirteen research articles reporting human subject research related to detectable warnings. As a result of these tests, mostly carried out under controlled conditions, truncated domes have emerged as a favored detectable warning surface. Most recently, field research has begun to include the study of detectable warnings within the context of specific built environments, and thus to consider the interactions of the traveler with both a curb ramp and other cue-producing elements in the built and social environment. Most prior research has an embedded assumption that detectability and uniqueness of surface are the most important elements of a detectable warning in any application context. The research reported here was, in part, designed to test that assumption.

III. Research Objective

The overall goal of this research was to investigate (1) the need for and effectiveness of detectable warnings at curb ramps and (2) to determine whether detectable warnings at curb ramps and at hazardous vehicular areas are a barrier to other pedestrians. Toward this end, the research team worked to gather evidence through the following activities:

IV. Research Activities

The research team undertook four sets of activities to address the research objectives:

(1) Investigate whether or not curb ramps at intersections create barriers for blind pedestrians. Particular attention was given to the cues travelers use to detect and safely cross an intersection with curb ramps.

Two separate tests were conducted in different order over the same course of twelve intersections. The first test, was a controlled test with a measurable dependent variable. Participants were instructed to locate an intersection and stop. The evaluator asked the participant what cues were used to detect the street and measured the distance from the curb line to the point where the participant stopped.

In the second test, participants were instructed to cross the intersection according to their usual means of travel. The measure of effectiveness was the travelers' success at crossing the intersection, as judged by five evaluators using videotapes of the events and by the participants' response to a series of questions. To ensure a balance of perspectives, the five evaluators included one member of the research team, two orientation and mobility instructors, and two persons who are family members of independent blind travelers.

These tests were conducted at 12 curb ramps in Roanoke, Virginia by cane users who had no useful residual vision and who were self-reported experienced travelers. There were 25 participants in the first test and 23 participants in the second test.

(2) Investigate the practices of blind pedestrians crossing intersections with and without detectable warnings to determine whether the presence of detectable warnings on curb ramps made any difference to the traveler in detecting the intersection.

The methodology used in this test was the same as the second test in Roanoke, Virginia. This test was conducted at 10 curb ramps in Greensboro, North Carolina with 70 persons with different degrees of visual impairments.

(3) Investigate whether detectable warnings at curb ramps or at hazardous vehicular areas introduced a hazard to persons with mobility impairments and other pedestrians.

Two tests were conducted at different locations. The first test concentrated on intensive exposure to 30 persons using mobility aids at curb ramps with and without detectable warnings in Greensboro, North Carolina. In the second test, 1700 members of the general population were observed at hazardous vehicular areas at 3 retail establishments in Virginia and North Carolina.

(4) Conduct focus groups to gather qualitative information to supplement the quantitative data and provide more in-depth understanding of the perceptions of the test participants regarding the research questions.

All test routes employed in items 1-3 above, were along public rights-of-way in downtown locations. In each case, blind travelers walked an "unfamiliar" route. Routes were unfamiliar in that they were chosen by the research team. In some cases, the travelers were generally familiar with the test area.

V. Major Findings

Are Blind Travelers Able to Detect Intersections with Curb Ramps?

- Blind travelers process a combination of cues providing information about the built and social environment to detect and cross intersections. Skillful travelers do not and will not rely on a single cue. Having detected a cue that may mean an intersection is at hand, travelers typically seek one or possibly more confirming cues. The most important cues, because they are the most reliable, are detection of a curb edge, of a slope which may be a curb ramp, of traffic sounds, and the end of a building line or "shoreline". Other cues which are often used are texture changes or counter slopes at the street, street poles, the sides of curb ramps, and seams between a curb ramp and the street. This finding is consistent with prior research, although detection of a curb edge was of substantially higher importance to our regional sample.

- In the Roanoke test, of 300 approaches to intersections with curb ramps, blind travelers stopped before entering the street 253 times (84%) and entered the street 47 times (16%). In 10 of these 47 cases (3%), travelers walked more than five feet into the street before stopping.

Blind travelers most often entered the street by walking down a curb ramp (38 events, or 18% of the 216 cases where travelers walked down the ramp). Travelers also entered the street by stepping off the curb (8 events, or 12% of the 65 cases when the curb ramp was not encountered). One traveler entered the street after encountering the curb ramp, avoiding it, and then stepping over the curb (1 event, or 5% of the 19 cases where the curb ramp was detected but avoided).

- When travelers entered the street by stepping off the curb, in none of the nine instances did the traveler proceed more than five feet into the street. In contrast, those who entered the street from a curb ramp detected the intersection within five feet of the curb line in 28 cases out of 38, and in 10 cases travelers proceeded more than five feet into the intersection. These 10 cases occurred at perpendicular curb ramps, and nine of which were at curb ramps with a low slope. From these results, we can infer that the experience of stepping off the curb, and/or other cues such as the slope of the street, indicated the presence of the intersection.

Does the Orientation of the Curb Ramp Affect the Ability of Blind Travelers to Detect Intersections?

- Blind travelers were more successful in detecting intersections at diagonal curb ramps than at in-line curb ramps. Out of 100 approaches to the four diagonal curb ramps, travelers proceeded down the curb ramp 39 times (39%). Thirty five travelers (90%) stopped before the street. Four travelers (10%) entered the street. Out of 200 approaches to eight in-line curb ramps, travelers proceeded down the curb ramp 177 times (89%). One hundred forty three travelers (81%) stopped before the street. Thirty four travelers (19%) entered the street. Of those who entered, ten did not stop within five feet of entering the street.

- Curb ramps are less detectable when they are in-line with the path of travel. Curb ramps that are encountered at an angle (oblique) to the path of travel are more detectable.

- Although diagonal curb ramps were detected more readily than in-line curb ramps at intersections, researchers observed that in the absence of other cues such as traffic noise, or a building line, some travelers would follow the alignment of diagonal curb ramps into the middle of an intersection. Although this can occur whether or not travelers intercept the curb ramp, it appeared to happen more often for those travelers using oblique curb ramps (diagonal ramps in particular), those with poor travel skills, and those traveling within a "cue-poor" environment.

Does Curb Ramp Slope Affect the Ability of Blind Travelers to Detect Intersections?

- Of the perpendicular and diagonal curb ramps, nine had slopes of 1:20 (low slope) and three had slopes of approximately 1:10 (steep slope).

- Of 216 approaches down a curb ramp, blind travelers entered the street 38 times. Thirty five of these events occurred at a 1:20 sloped curb ramp; nine did not stop within five feet of the curb. Only three travelers entered the street from a 1:10 slope, one of whom did not stop.

What Elements Contribute to a Successful Crossing of an Intersection?

- The measure of effectiveness for crossing intersections with curb ramps was the evaluation of blind travelers by five knowledgeable observers using videotapes of the crossings.

An excellent crossing was one where the blind traveler crossed from one side to the other within the area of the crosswalk, or immediately parallel and close to it.

A good crossing was one where the traveler may have strayed from the narrow crosswalk area but otherwise made an unremarkable crossing.

A successful crossing was one where the traveler made it across the street, but not without some problem or unusual event or behavior (e.g., departing at a large angle at the crosswalk or returning to the curb after entering the crosswalk).

An unsuccessful crossing resulted if the traveler failed to cross from one side to the other.

- There was no discernible pattern of differences reflected in the scores of our small group of evaluators. According to all reviewers, participants made good to excellent crossings 82 to 93% of the time, and made at least successful crossings 93 to 97% of the time. Evaluators rated from three to seven percent of the crossings as unsuccessful.

- An unsuccessful crossing can occur at any intersection, but the design of the intersection appears to contribute to the rate of unsuccessful crossings. Any traveler can experience a flawed crossing, though the rate of unsuccessful crossings decreases with an increase in travel skills. Curb ramps do not play a role in all unsuccessful crossings, but in these tests, they were involved in about half of the unsuccessful crossings. Most often, the alignment of the curb ramp with the curb and the street and how the participants aligned themselves for the crossing was the most important problem. All five evaluators found that a higher proportion of excellent crossings were made at perpendicular curb ramps than at intersections with diagonal curb ramps. Overall, 93% of crossings at diagonal curb ramps were rated successful or better while 97% of crossings at perpendicular curb ramps were rated successful or better.

This finding contrasts with the test of ability to detect intersections. Although intersections with diagonal curb ramps are generally easier to detect, if the diagonal curb is encountered and used by a blind pedestrian, it is more likely to result in an unsuccessful crossing. However, by the exercise of good mobility skills and consideration of other cues in the environment of the intersection, blind travelers are usually able to adjust their behavior during the course of crossing an intersection to successfully complete the crossing.

Are Detectable Warnings Needed by Blind Travelers in Crossing Intersections?

- The presence of a detectable warning on the departing curb ramp did not have a major impact on the quality of crossing.

About the same number of crossings were judged excellent by all evaluators. However, all evaluators found that a higher proportion of unsuccessful crossings occurred at curb ramps without detectable warnings. Blind travelers encountered curb ramps with detectable warnings slightly more often than those without detectable warnings (79% vs. 71%).

Three evaluators thought the result of the encounter had a positive effect on the crossing more often when the curb ramp included a detectable warning (45% vs. 38%). However, the degree of positive effect cannot be completely determined because in the absence of detectable warnings, travelers were able to rely on other cues.

- Out of 700 crossings, there were 34 crossings that two or more evaluators rated as unsuccessful. Unsuccessful crossings occurred at every type of intersection and every combination of type, slope, and approach (straight crossing or turn). In only 14 of the 34 cases of unsuccessful crossings, did the traveler use the curb ramp. In the other 20 cases, the curb ramp itself was not a direct factor, although its placement relative to other elements in the intersection may have been a contributing factor at certain intersections. Unsuccessful crossings occurred in the presence and absence of detectable warnings. However, four projected intersections with perpendicular curb ramps accounted for 71% of unsuccessful crossings. The biggest problem in crossing intersections in this test was disorientation at unfamiliar, projected intersections, where cues were lost - such as shorelines, or where cues had unusual meanings - such as the long curb line between curb ramps, the returned curb line at the base of the projection, and the change in texture in the sidewalk due to decorative brick.

- The overall rate of unsuccessful crossings was 4.9%. Blind travelers who are experienced travelers are going to make the large majority of crossings successfully whether or not detectable warnings are installed.

Are Additional Cues Needed at Intersections?

- Blind travelers are most likely to enter the street in the absence of reinforcing cues. Among the important situations are: absence of traffic and traffic sounds; the absence of a building or shoreline; the gradual slope on a curb ramp; and the failure to detect a curb edge to the side of the curb ramp. The need for additional cues at intersections is context dependent. Moreover, the context is complex, including both elements of the built environment (i.e., curb ramp slope) and of the social environment (i.e., amount of traffic) and the travel skills of the individual. Moreover, these elements are interactive. For example, a gradual slope may not be a problem in the presence of a building line or a high volume of traffic. But in their absence, the combination of variables may create a need for a reinforcing cue, recognizable in the context of an intersection, which can increase cue density, especially in a low cue environment.

Do Detectable Warnings Introduce Additional Barriers to Persons Who Use Mobility Aids?

- Paired comparison testing of curb ramps with and without detectable warnings found that a significant majority of the 30 participants using mobility aids found the detectable warning surface superior to smooth concrete because it offered superior traction. However, a sizable minority of people who had balance, stability and related gait problems and who used braces, canes and crutches found the detectable warning surface to be discomforting on sloped surfaces.

Do Detectable Warnings Introduce Additional Barriers to the General Population?

- Of the 1700 observations at three retail stores with concrete detectable warnings, there were few negative impacts. There was a tendency for objects to fall off of shopping carts, especially the lower rack. Objects fell off of seven carts out of 141. In all cases, the shoppers replaced the object and continued without apparent concern. Objects seemed to fall off of lightly loaded carts. Gurneys with larger wheels did better than shopping carts with narrow wheels.

- Several elderly pedestrians were observed to slow down while traversing the detectable warning surface. At all sites, most people ignored the surface.

VI. Recommendations for Further Research

- Provide advisory information regarding the need for additional cues at some intersections and the ability of detectable warnings to meet that kind of need in the appendix of ADAAG.

- Conduct research at hazardous vehicular areas and other sites where detectable warnings may be warranted because of the absence of other cues such as building shoreline, adjacent curb edge, and predictable traffic patterns.

- Conduct research to reconsider the use and design of detectable warnings at curb ramps from the perspective of multiple cues, especially as related to low cue-environments.

- Conduct research to identify a technology which can provide both location cues and orientation information at existing curb ramps, especially curb ramps which are diagonal, at an odd angle to the destination on the other side of a street, or that are located in a low cue environment.

- Conduct research to determine the interaction of degree of slope verses the length of the slope surface as they interact with the use of a cane.

- Alignment of the curb ramp at an intersection impacted the ability to detect and cross intersections. Conduct research on the effect of in-line and oblique curb ramp designs.