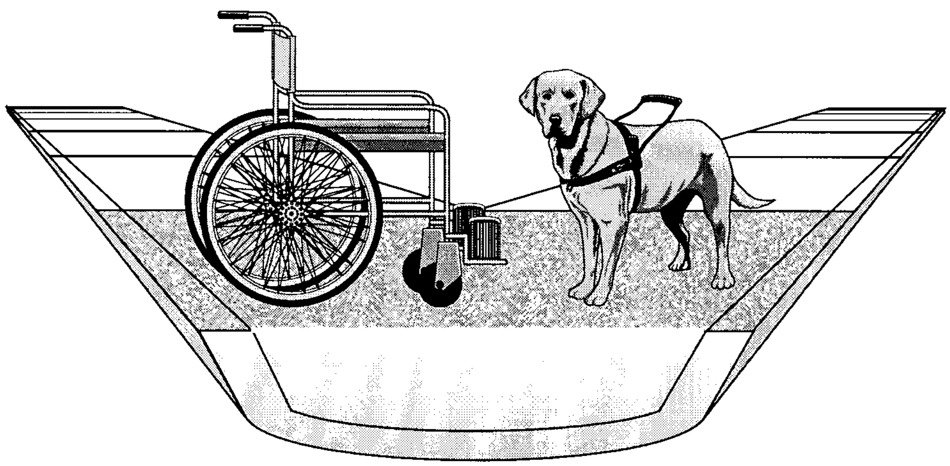
FINAL REPORT

AN EVALUATION OF DETECTABLE WARNING SURFACES FOR SIDEWALK CURB RAMPS



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16. Abstract

The 1991 Americans with Disabilities Act Accessibility Guidelines (ADAAG) required the installation of a detectable warning surface (raised truncated domes) on sidewalk curb ramps to alert visually impaired people to potential hazards. Although this requirement was later suspended until 1996, there has been much debate about whether visually impaired people need detectable warnings on ramps and, if so, whether domes are the best option. The Virginia Department of Transportation's (VDOT's) current standard requires an exposed aggregate (gravel mixed into concrete) surface on curb ramps. This study evaluated seven warning surfaces for their detectability by the visually impaired and their ease of maneuverability for the mobility impaired. Information about the performance characteristics of different ramp surfaces was also obtained by telephone survey of transportation officials in Virginia and 21 other states.

Test results for 52 visually impaired subjects indicated that the five domed surfaces were far more detectable than the aggregate surfaces; a majority of the totally blind subjects failed to detect the aggregates. Aggregate surfaces were clearly preferred by the six mobility impaired subjects, some of whom had notable difficulty maneuvering on the domed surfaces. Some visually impaired subjects made negative comments about the feel of the domed surfaces underfoot.

Survey results indicated that other states are requiring a variety of ramp surfaces, not all of which are detectable warnings. Some areas using domes reported considerable winter maintenance damage. No maintenance damage to aggregate was reported, but Virginia respondents reported other kinds of problems with its installation and use. Selection of a curb ramp surface involves numerous tradeoffs, most notably the tradeoff between high detectability for the visually impaired and maneuverability for the mobility impaired.

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In Cooperation with the U.S. Department of Transportation
Federal Highway Administration

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ABSTRACT

The 1991 Americans with Disabilities Act Accessibility Guidelines required the installation of a detectable warning surface (raised truncated domes) on sidewalk curb ramps to alert visually impaired people to potential hazards. Although this requirement was later suspended until 1996, there has been much debate about whether visually impaired people need detectable warnings on ramps and, if so, whether domes are the best option. The Virginia Department of Transportation's (VDOT's) current standard requires an exposed aggregate (gravel mixed into concrete) surface on curb ramps. This study evaluated seven warning surfaces for their detectability by the visually impaired and their ease of maneuverability for the mobility impaired. Information about the performance characteristics of different ramp surfaces was also obtained by telephone survey of transportation officials in Virginia and 21 other states.

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INTRODUCTION

The Americans with Disabilities Act (ADA), signed into law in July 1990, provided comprehensive civil rights protection to people with disabilities. Its implications are far-reaching: protection is provided in the areas of employment, public accommodations, state and local government services, transportation, and telecommunications.[1,2] The ADA mandates changes in the way many facilities are designed and constructed. One example in the transportation field is the requirement of accommodations for disabled people on almost all new pedestrian facilities. In some cases, modification of existing facilities may also be required.

Under Section 504 of the ADA, the Architectural and Transportation Barriers Compliance Board (Access Board) is required to issue guidelines to ensure that commercial establishments, public accommodations, and transit properties will be accessible to those with disabilities. These guidelines are intended to help the Departments of Justice and Transportation establish regulations for newly constructed and altered facilities. In January 1991, the Access Board published the Americans with Disabilities Act Accessibility Guidelines for Buildings and Facilities (ADAAG). Currently, these guidelines are mandatory only for public accommodations, transit properties, and commercial facilities. State and local governments currently have the option of following either ADAAG guidelines or the Uniform Federal Accessibility Standards (UFAS), developed in 1984. The Access Board stated, however, that it anticipates that the ADAAG will eventually be the **single** accessibility standard for the United States, encompassing all state and local government facilities as well as commercial ones.

Among the provisions of the ADAAG is a requirement for detectable warning surfaces on sidewalk curb ramps. Curb ramps provide sloping access to a street or parking lot from a sidewalk or other pedestrian path. These ramps are sometimes called "curb cuts" because the concrete curb line is interrupted wherever a ramp is constructed to make travel easier for those for whom a dropoff could be hazardous. Although curb ramps are typically regarded as an accommodation for wheelchair users, they are also used by visually impaired people. For the visually impaired, curb ramps represent a potentially hazardous location; if a ramp goes undetected, a visually impaired person may be unaware that he or she is entering a vehicular way. The ADAAG provisions state: "A curb ramp shall have a *detectable* warning . . . [it] *shall extend* the full width and depth of the curb ramp."[3] Warning surfaces are also required at other hazardous vehicular ways, at transit platform edges, and around the edges of reflecting pools. The ADAAG defines a detectable warning surface as a "standardized surface feature built in or applied to walking surfaces or other elements to warn visually impaired people of hazards on a circulation path."[3]

The ADAAG requires a specific type of warning surface on curb ramps: raised truncated domes with either a light-on-dark or a dark-on-light visual contrast. Section 4.29.2 describes the required surface:

> [It] shall consist of raised truncated domes with a diameter of nominal 0.9 in. (23 mm), a height of nominal 0.2 in. (5 mm) and a center-to-center spacing of nominal 2.35 in. (60 mm) and shall contrast visually with adjoining surfaces, either light-on-dark, or dark-on-light.
>
> The material used to provide contrast shall be an integral part of the walking surface. Detectable warnings used on interior surfaces shall differ from adjoining walking surfaces in resiliency or sound-on-cane contact.[4]

These guidelines became law in July 1991, when the Department of Justice issued regulations referencing the ADAAG.

The UFAS guidelines for curb ramp surfaces are less specific, stating simply that surfaces must be ". . . stable, firm and slip resistant."[5] A third set of standards exists: those of the American National Standards Institute (ANSI). ANSI's 1986 standards required detectable warning textures on curb ramps; exposed aggregate (gravel mixed into concrete) and detectable tile were among the acceptable textures. Exposed aggregate is made by washing away some of the surface cement paste from the gravel embedded in the concrete. In July 1992, however, the ANSI Committee on Accessibility, which is responsible for these guidelines, voted to delete the requirement for warning textures on curb ramps.[6]

In the December 21, 1992, *Federal Register*, the Access Board announced that it was suspending further rulemaking on detectable warning surfaces until January 1995.[7] Then, on April 12, 1994, the Access Board, Department of Justice, and Department of Transportation temporarily suspended the requirements for detectable warnings at curb ramps, hazardous vehicular areas, and reflecting pools until July 26, 1996.[8] In making these announcements, the Access Board cited its concerns about the safety of warning surfaces and its desire to evaluate the results of research in progress. In effect, state and local government agencies will not hear anything from the federal government about required curb ramp surfaces before mid-1996 at the earliest. In the interim, state and local governments must make their own judgments about the curb ramp surface that will best meet the sometimes conflicting needs of people with varied disabilities.

In March 1992, the Virginia Department of Transportation's (VDOT) desire to be proactive in addressing the needs of disabled persons led to the revision of the state curb ramp surface standard from a broom finish concrete to exposed aggregate. At that time, exposed aggregate met both the UFAS and ANSI guidelines. VDOT chose not to require raised truncated domes based on input from its Advisory Committee for Program Accessibility. In the Committee's judgment, research supporting this choice was insufficient and domes could present installation, maintenance, and safety problems. Since 1992, VDOT has received numerous requests from municipalities wanting to use ramp surfaces other than exposed aggregate. For example, some localities would prefer to use red paver bricks to maintain the aesthetic character of historic areas. Virginia Beach officials have had complaints from barefoot pedestrians that the exposed aggregate is very uncomfortable to walk on. Comments from VDOT residencies and contractors highlight the difficulty of installing the exposed aggregate surface with consistent results. Environmental conditions greatly affect the operation of the concrete retardant used to achieve the exposed aggregate surface, thereby making each installation unique and requiring some expertise to achieve the desired result. Installation of exposed aggregate surfaces can also be very time-consuming.

PURPOSE AND SCOPE

Since the Access Board will not issue guidelines for detectable warning surfaces on curb ramps built by state and local governments until at least 1996, and since studies conducted on this subject are limited, the Virginia Transportation Research Council (VTRC) was asked to undertake a study evaluating alternative ramp surfaces, with an initial emphasis on identifying the surface preferences of visually impaired Virginians.

The purpose of this project was to evaluate seven alternative curb ramp surfaces for their detectability by the visually impaired and their ease of maneuverability for the mobility impaired. This study is intended to be a first step in determining the optimum state standard. Since VDOT officials requested a quick response, long-term maintenance questions could not be addressed. However, information on maintenance experience with various surfaces was obtained by survey research methods.

Ultimately, Virginia's decision on which curb ramp surface to require has potentially tremendous financial consequences for the state and municipal governments. In VDOT's accessibility video, *Implementing the Americans with Disabilities Act*, it is reported that 15,000 new sidewalk curb ramp installations are needed within the state right of way alone. The estimated cost of these ramps is $7.3 million.[9]

METHODOLOGY

The following tasks were conducted:

1. A literature review was conducted to identify potential test surfaces and successful testing methods.

2. Profiles of the visually and mobility impaired populations in Virginia were developed to guide sample selection and provide information about the primary users of curb ramps.

3. Field tests were conducted to evaluate the detectability of the seven surfaces by the visually impaired. Field testing also included an evaluation of the impact of the surfaces on people with mobility impairments (e.g., users of wheelchairs, walkers, crutches, and canes).

4. Maintenance and installation properties of various ramp surfaces were evaluated by means of a telephone survey of state and local transportation officials; the survey also included questions about public reactions to curb ramp surfaces.

Literature Review

Research on detectable warning surfaces published from 1980 to the present was reviewed, including several studies done outside the United States. Many of the studies focused on the use of detectable warning surfaces on transit platform edges. Though a valuable source of information about the sheer detectability of surfaces, the findings and recommendations of transit-related studies may not be directly applicable to curb ramps for a number of reasons. First, most transit stations are enclosed or at least under shelter. Sidewalks, on the other hand, are continually exposed to weather that can cause surface deterioration and fading of any color pigments used to enhance detectability. Second, routine sidewalk maintenance, such as cleaning, salting, or snow clearing, can cause further deterioration or damage to some warning surfaces. Third, the cues that the visually impaired rely upon in the two environments also differ. For many visually impaired people, the slope of curb ramps can make ramps easier to detect than flat platform edges. In urban areas, continual traffic sounds may also provide cues about the proximity of the street. Noise is often intermittent in transit stations, however, so it may not provide a reliable cue about the proximity of the tracks.

Development of a Profile of Visually and Mobility Impaired Virginians

Several Virginia state agencies, including the Virginia Department for the Visually Handicapped (VDVH) and the Department of Rehabilitative Services (DRS), were contacted to obtain statistics on disabled Virginians. Several national advocacy organizations for the visually impaired (e.g., American Foundation for the Blind, National Society to Prevent Blindness) were also contacted for statistical information. VDVH provided the following types of statistics for the state's visually impaired population:

- degree of vision (i.e., totally blind, light perception, or partial vision)
- ability to detect color or contrast
- current age
- age at onset of disability
- travel or mobility aids used (e.g., cane, guide dog)
- manner in which detection aids are used and the environments in which specific aids are used.

DRS provided a range of statistics on mobility impaired Virginians. This information was used to develop a test sample representing the various users of curb ramps (i.e., those with visual impairments and those with mobility impairments). A summary of this information is presented in Table 2 in the Results section of this report.

Field Testing

The authors developed a method for testing the detectability and navigability of various warning surfaces, based on both the literature and the potential test sites at the Virginia Rehabilitation Center for the Blind (VRCB), a residential training facility in Richmond. A test site was built by installing seven 1.22 by 2.44 m (4 by 8 ft) sections of detectable warning materials in an existing straight sidewalk (Figure 1). DVH mobility trainers told the authors that 1.22-m lengths of the warning surfaces should be adequate for testing people with a variety of stride lengths. The warning surfaces were installed at varying distances from each other to minimize expectancy effects on the test results. Flat sections of warning materials were used rather than ramps to facilitate a more accurate assessment of the surfaces' detectability. DVH trainers emphasized to the authors that most of their visually impaired clients without other disabilities detect curb ramps primarily by their slope (this was later confirmed by the test subjects). By eliminating slope as a cue, the detectability of the surface alone could be better

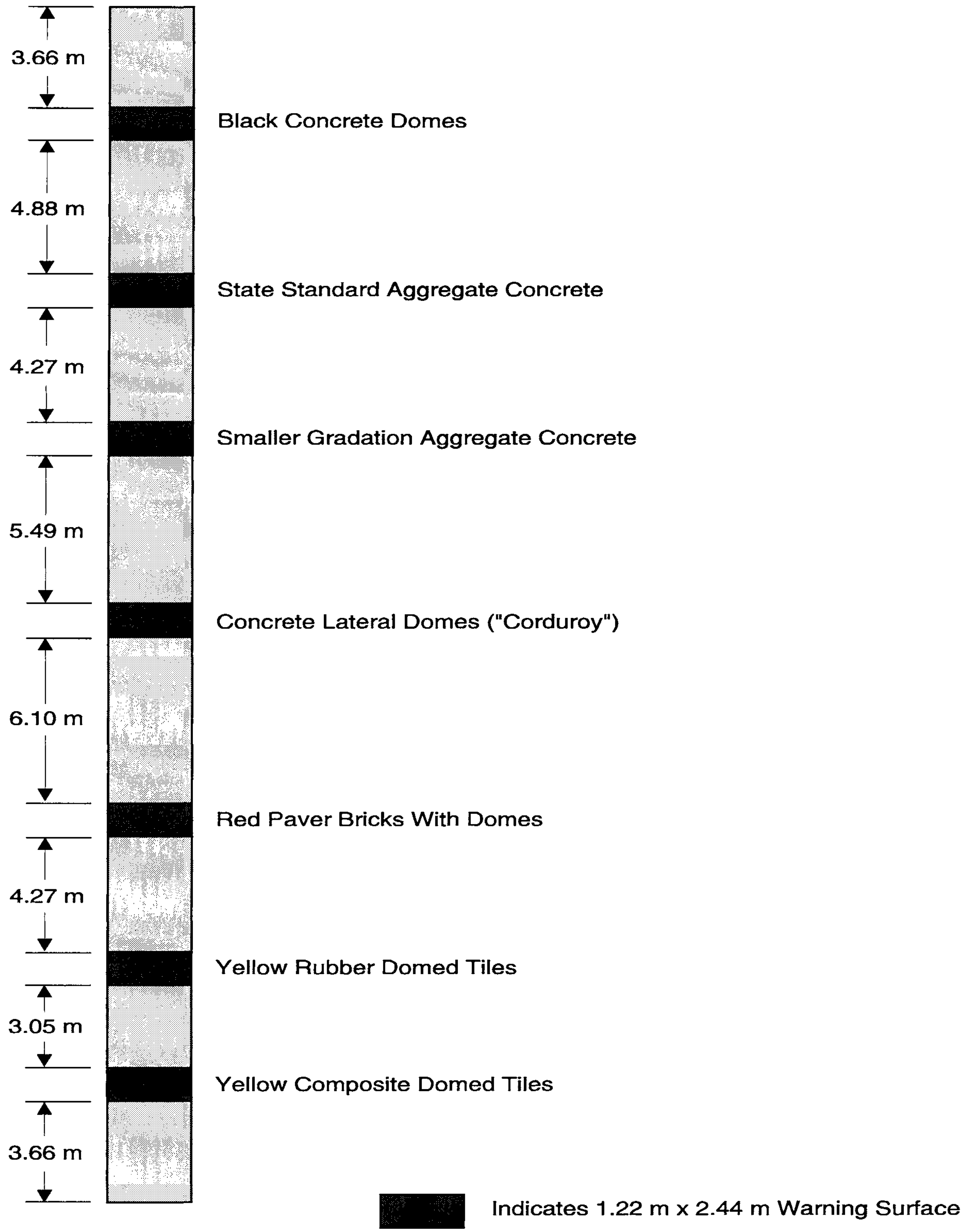

Figure 1. Test Site

evaluated. Other auditory and sensory cues in the testing environment were held constant as much as possible. No testing was done in wet, icy, or very cold weather, nor at dawn or dusk.

The following list of test surfaces was developed based on the literature review and suggestions of project advisors in VDOT's Location & Design Division:

1. precast exposed aggregate constructed according to current state standards (No. 57 river gravel and natural sand) (Figure 2)

2. precast exposed aggregate constructed using a smaller gradation of gravel than required by state standards (No. 7 river gravel and manufactured sand) (Figure 3)

3. precast black concrete raised truncated domes (Figure 4)

4. yellow rubber Pathfinder™ tiles with raised truncated domes (Figure 5)

5. yellow composite Pathfinder™ tiles (Figure 6)

6. precast concrete lateral domes ("corduroy") (Figure 7)

7. red paver bricks with domes (Figure 8).

The red paver bricks were supplied by Old Virginia Brick. The two types of yellow Pathfinder™ tile samples and adhesives for their installation were supplied by Carsonite International. The manufacturer informed the authors that the yellow rubber tiles are susceptible to maintenance problems when used on outdoor slopes, due to thermal expansion and movement of the adhesive. The other (recommended) Pathfinder™ tile is manufactured from a fiber-reinforced bonded ceramic composite. (*Note:* A variety of companies are manufacturing detectable warning tiles conforming to the ADAAG guidelines.) The four remaining precast concrete surfaces were provided by Salem Concrete Products. Precast rather than cast-in-place surfaces were used because the precast samples were donated for the research. All of the surfaces with raised truncated domes conformed to the specifications set forth in the ADAAG.

Testing focused on evaluating the detectability of the surfaces by the visually impaired and their impact on the mobility of other disabled users. Visually impaired participants were asked to walk along the sidewalk using their customary travel aids and to stop as soon as they detected a change in surface. (Appendix A is a sample test data form.) The authors recorded the distance at which participants detected a change in surface and the number of steps taken onto a surface as objective measures of detectability. (*Note:* Many of those with partial vision detected the surfaces before stepping onto them; the individual's distance from the edge of the test surface was recorded in those cases.) When the test participants detected a surface change, the authors asked them several more qualitative questions, including (1) how they detected the change in

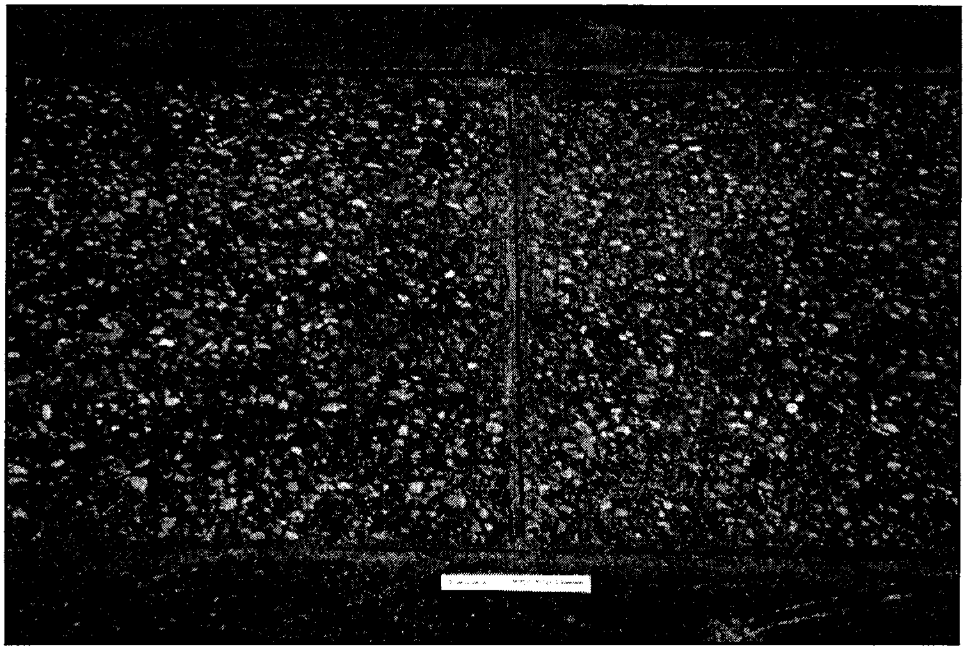

Figure 2. Precast Exposed Aggregate Constructed According to State Standards

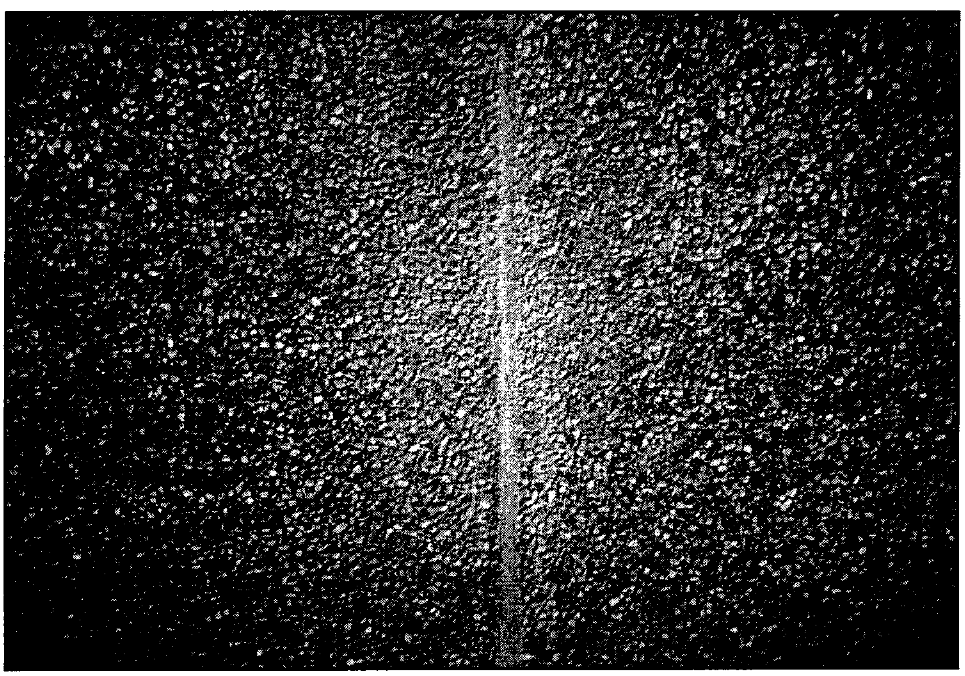

Figure 3. Precast Exposed Aggregate Constructed Using a Smaller Gradation of Gravel Than Required by State Standards

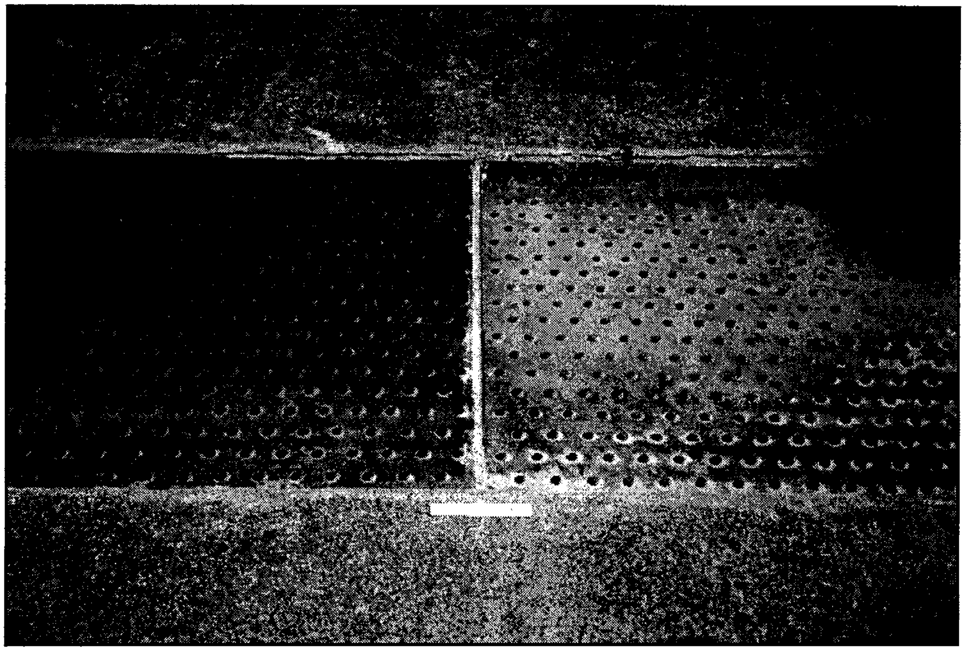

Figure 4. Precast Back Concrete Raised Truncated Domes

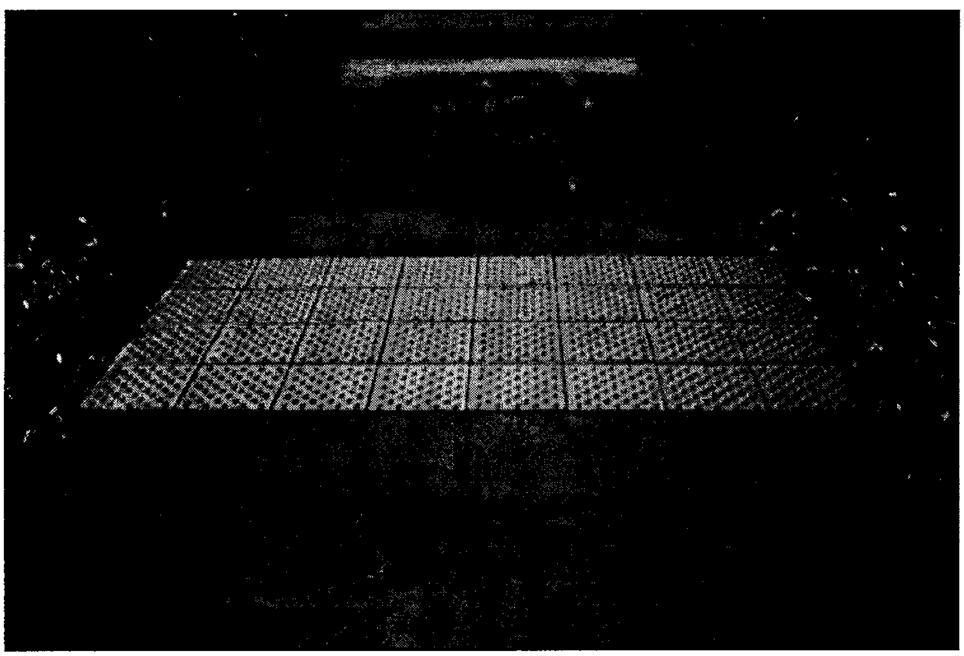

Figure 5. Yellow Rubber Pathfinder Tiles With Raised Truncated Domes

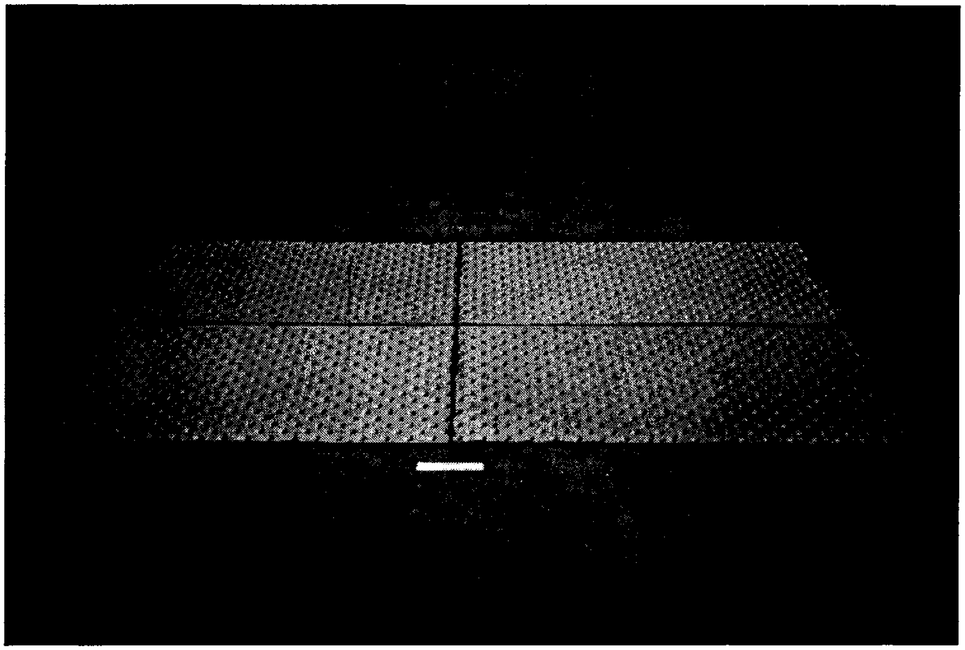

Figure 6. Yellow Composite Pathfinder Tiles

Figure 7. Precast Concrete Lateral Domes (Corduroy)

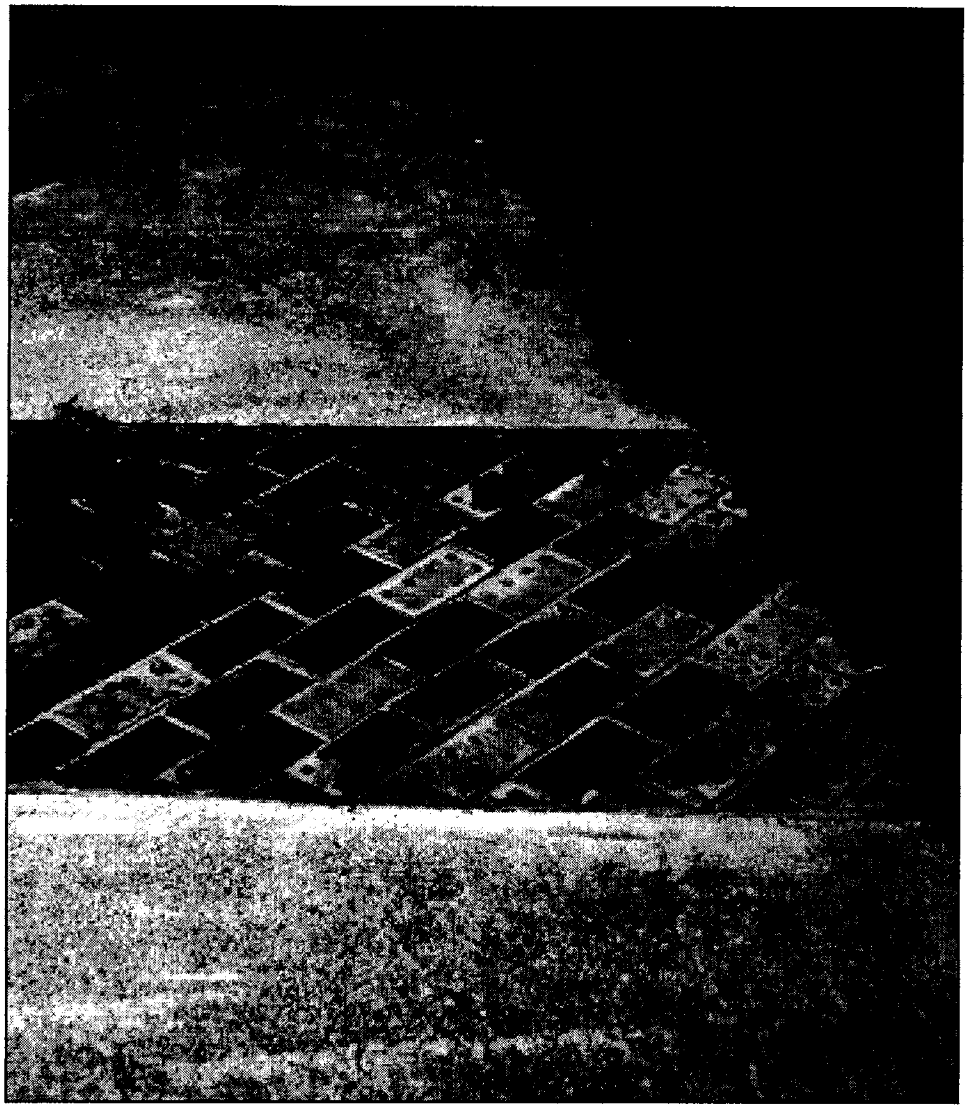

Figure 8. Red Paver Bricks With Domes

surface, (2) how difficult the surface was to detect, and (3) how helpful they thought the surface would be in warning them of a street crossing.

The second part of the field tests involved assessing the effects of the surfaces on wheelchair users and those with other mobility impairments. These participants were asked to maneuver on the test sections and answer a series of questions about their ease or difficulty of movement on the seven surfaces. (See testing form in Appendix B.) These tests were videotaped to allow the authors to make further evaluations and share their findings with the Access Board or other interested parties.

The field testing was conducted from November 1993 through June 1994 at VRCB. VRCB serves a diverse sample of visually impaired clients who vary in age, level of visual impairment, and mobility skills. Administrators from VRCB agreed to allow construction of the test site on their grounds and provided a number of participants for the testing.

Telephone Survey on Surface Installation and Maintenance Characteristics

A telephone survey was conducted to gather information on the field performance of several surfaces that are currently in use, including exposed aggregate and raised truncated domes. A survey instrument (see Appendix C) was developed that included questions on construction, maintenance, and durability of detectable surfaces and public feedback on warning surfaces. Officials in Virginia, 21 other states, and a number of municipalities who are responsible for the installation and maintenance of these surfaces were contacted.

Data Analysis

The considerations or issues that guided the analysis of the field test data were as follows:

1. *Detectability of various surfaces by the visually impaired.* Analysis focused on the percentage of test participants who detected and failed to detect each surface, the number of meters individuals walked before detecting each surface, and participants' responses to questions about how hard it was to detect each surface and how useful the surface would be for warning them of a street crossing.

2. *Effects of surfaces on participants with mobility impairments.* This was evaluated based on verbal responses to questions about the difficulty of maneuvering on the test surfaces and comparisons of videotaped testing sessions.

3. *Ease of construction and maintenance requirements of surfaces.* These were evaluated based on the results of the telephone survey and experience with construction of the test site at VRCB.

RESULTS AND DISCUSSION

Review of Research on Detectable Warning Surfaces

The results of the literature review guided the design of the methodology for the field tests. A number of the surfaces chosen for testing were selected from those shown to be most detectable by visually impaired people in previous studies.

Studies of the detectability of various warning surfaces by the visually impaired date back to 1980. These early studies included the following (with recommendations):

- *Aiello and Steinfeld (1980).* Ribbed rubber matting covering a large area was the preferred surface.[10]

- *Templer and Wineman (1980).* A resilient surface, such as a tennis court surface material or strips of thermoplastic 150 mm (6 in) wide, was recommended for consideration for detectable walkway surfaces.[11]

These early studies reported that the visually impaired could detect and distinguish among different surfaces and that they preferred warning surfaces that differed in texture, resiliency, and sound from the walkway.[8] Further study was recommended to determine standard specifications and explore the range and types of materials suitable for use in outdoor construction.[11]

More recent reports focused on detectable warning surfaces in transit stations. As noted earlier, there are some important differences between transit platforms and curb ramps. The studies of transit environments included the following (with recommendations):

- *Peck and Bentzen (1987).* Rubber tiles with raised truncated domes and "corduroy" were demonstrated to be highly detectable underfoot and with the use of long canes.[12]

- *Metro-Dade Transit Agency (1988).* Raised truncated domes (rubber) were more detectable than standard granite platform edges.[13]

The studies of transit environments identified two particular surfaces—concrete corduroy and rubber raised truncated domes—as the most detectable for the visually impaired and most navigable for the mobility impaired. *Corduroy* is concrete with raised lateral domes that create a ribbed pattern (see Figure 7). Other surfaces tested in the study by Peck and Bentzen included rubber matting, rough steel, and tennis court surfaces.[12]

The Access Board is currently sponsoring a curb ramp study that is being conducted by a team of investigators from Virginia Polytechnic Institute and State University (VPI&SU). The ongoing study, which is being conducted in Roanoke, Virginia, is focused on the effects of curb ramps of different configurations on the ability of visually impaired people to detect intersections. The results from this study and others will help the Access Board in its future ADAAG rulemaking. The authors had several lengthy discussions with the investigators at VPI&SU, who see this study as a complement to their project.

Conflicting opinions about whether detectable warning surfaces are necessary are reflected in the literature. Even within the visually impaired community, there is no consensus about whether warning surfaces are needed and, if they are, which surface is best. The National Federation for the Blind (NFB) opposes the requirement for detectable warning surfaces on sidewalk curb ramps (and along the edges of reflecting pools, etc.) and was instrumental in ANSI's decision to delete references to warning surfaces from its standards for intersections and transit platform edges. NFB argued that "the studies which claim to show the necessity and value of domes or tiles are methodologically flawed and are all based on the assumption that tiles or domes are necessary, the exact point that is not yet proven."[6] In contrast, the American Council of the Blind and the American Foundation for the Blind both favor the detectable warning surfaces, thereby pitting major advocacy groups for the visually impaired against each other on this issue.

Advocacy organizations for the mobility impaired (i.e., Eastern Paralyzed Veterans' Association, Paralyzed Veterans of American, and two state level organizations) have communicated concerns to the Access Board that detectable warnings could adversely affect people who use wheelchairs and other mobility aids. Research results summarized in the *Federal Register* indicate that people using manual wheelchairs may have to exert additional effort to go up ramps with domed surfaces and the front wheels of the chairs may get caught in the grooves between the domes. Similarly, small-tipped canes or walkers may get caught between grooves, and the angle of contact between the small tip of the aid and the domes makes some mobility impaired people feel less stable.[8]

Profile of Visually and Mobility Impaired Virginians

The authors compiled statistics on the numbers of visually and mobility impaired people in Virginia and the history of their impairments, when possible, by contacting national and state agencies. Other data, including information on mobility aids, were also collected. These statistics were used to help formulate the methodology and sampling strategy for the field testing.

Visually Impaired Virginians

VDVH estimates that there are **14,143 legally blind people** in Virginia. A legally blind person has a visual acuity of 20/200 or less in the better eye or a field of vision limited to 20 degrees or less. A person with partial vision has a visual acuity between 20/70 and 20/200 in the better eye (with correction). VDVH estimates that there are **35,075 persons with severe visual impairment** (defined as 20/70 corrected vision or worse) in Virginia. The projected age distribution of legally blind persons in Virginia is shown in Table 1.

Table 1. Age Distribution of Legally Blind Virginians

Age	% of Total[a] (n = 14,143)
Under 5	1.3
5 - 19	7.0
20 - 44	16.6
45 - 64	21.7
65 - 74	19.1
75 - 84	21.0
85 and over	13.3

[a]From *The Virginia Register*, compiled by the Virginia Department for the Visually Handicapped.

The American Foundation for the Blind estimated that the legally blind population can be categorized as follows: 11 percent are totally blind, 11 percent have light perception, and 78 percent have usable vision.[14] Therefore, among the estimated 14,143 legally blind people in Virginia, the authors estimated that 1,556 are totally blind, 1,556 have light perception, and 11,032 have some usable vision.

Regarding mobility aids used by the visually impaired, the American Foundation for the Blind estimated that the ratio of cane users to guide dog users is approximately 11 to 1, based on the results of two national studies.

Mobility Impaired Virginians

Data on the number of mobility impaired persons in Virginia were obtained with the assistance of DRS. DRS provided information from its report *The Virginia Disability Survey: Preliminary Findings* dated March 12, 1991. The overall survey was a "statewide population telephone survey of randomly selected households. The survey was designed to collect information about working age Virginians (aged 16 to 64) who have a health condition that limits their ability to function independently at home or on a job."[15] One limitation of these data was that they included only those individuals who live in private households. Since individuals who live in institutions were not represented in this survey, the DRS survey likely underestimated the true number of disabled Virginians.

DRS estimated that between 288,295 and 322,789 Virginians of working age have work- or housework-limiting health conditions. In their survey, 46 percent of the disabled respondents listed an orthopedic condition as their primary disabling condition. (The "orthopedic conditions" category likely includes impairments that do not affect a person's ability to walk, such as carpal tunnel syndrome of the wrist.) In comparison, 4 percent of those surveyed listed a visual impairment as their primary disabling condition. Among their respondents, 23 percent were limited in their general mobility (yielding an estimate of between 66,308 and 74,241 people).

The onset of the work-limiting conditions occurred at the following times in the lives of those surveyed:

- 7% at birth
- 16% before age 21
- 13% between the ages of 22 and 29
- 39% between the ages of 30 and 49
- 15% after age 50
- 11% uncertain of age.

Aids Used by Mobility Impaired Virginians

Using DRS data and a methodology developed by the National Center for Health Statistics, the types of aids used by mobility impaired Virginians were estimated and are shown in Table 2. Individuals may use more than one type of aid.

Table 2. Estimated Numbers of Virginians Using Various Mobility Aids

Mobility Aid	Estimated Number of Virginia Users	% of Mobility Impaired Users
Cane or walking stick	40,629	68.7
Walker	15,578	26.4
Wheelchair	13,031	22.0
Crutches	6,196	10.5
Scooter	59	1.0
Other mobility aid	2,347	4.0

Field Test Results for the Visually Impaired

A total of 52 visually impaired people (27 men and 25 women) participated in the testing that occurred between December 1993 and June 1994. A breakdown of the sample by age and level of visual impairment is shown in Table 3.

Table 3. Level of Vision and Age Group of Test Participants (%) (N = 52)

Age Group	Partial Vision	Light Perception	Totally Blind	Total
Under 30	23.1	3.8	11.5	38.5
30-39	9.6	1.9	11.5	23.1
40-49	9.6	1.9	9.6	21.2
50-59	7.7	1.9	3.8	13.5
60+	1.9	0.0	1.9	3.8
Total	51.9	9.6	38.5	100.0

Thus, 52 percent of our test participants had partial vision, 10 percent had light perception, and 38 percent were totally blind. Thus, when compared with the estimates of The American Foundation for the Blind, our sample included a disproportionately large number of totally blind people, reflecting, in part, the clientele at VRCB. This sample bias is useful in one respect: in developing its warning surface standard, VDOT needs to be most concerned about those who possess the least vision, the totally blind.

As Table 3 shows, the participants in our testing were a relatively young group; only 17 percent were age 50 or older, and nearly 40 percent were under age 30. To some extent, this also probably reflects the clientele of VRCB.

Table 4 summarizes information about the mobility aids customarily used by the participants in our testing: canes, guide dogs, or sighted human guides. Some study participants used multiple aids (e.g., guide dog and cane). Some individuals with partial vision reported that they used no aids whatsoever to travel outside their homes. Overall, two thirds of the total sample used canes.

Virtually all of the test participants had completed some formal mobility training. The median number of months of mobility training was 2, although one fourth of the study participants had completed 6 or more months of training.

Table 4. Participants' Use of Mobility Aids by Level of Visual Impairment (%) (N = 52)

Type of Aid Used	Partial Vision	Light Perception	Totally Blind
Cane	48.1	60.0	90.0
Guide dog	3.7	20.0	25.0
Sighted guide	18.5	20.0	15.0
Uses no aids	37.0	0.0	0.0
Number of cases	(27)	(5)	(20)

Overall Results of the Detectability Testing

As described in the Methodology section, the detectability tests required participants to walk the entire length of the test sidewalk twice. Tables 5 and 6 show the results of both test trials for all participants. Although the instructions to participants emphasized that they were to stop as soon as they detected a change in the sidewalk's surface, the participants' generally improved performance on the second trial suggests that some subjects may not have initially understood what they were supposed to do. For this reason, subsequent discussions of the testing results focus largely on Trial 2. For some subjects, of course, Trial 2 results may have been better simply as a consequence of practice on the task. For this particular study, however, the potential effects of practice are less problematic than the potential effects of not comprehending

Table 5. Trial 1 Surface Detectability Test Results for Visually Impaired (N = 52)

Surface	% Detecting Surface	% Not Detecting Surface
Black concrete domes	84.6	15.4
State standard aggregate	46.2	53.8
Small gradation aggregate	46.2	53.8
Lateral concrete domes	86.5	13.5
Red paver bricks	90.4	9.6
Yellow rubber domes	92.3	7.7
Yellow composite domes	92.3	7.7

Table 6. Trial 2 Surface Detectability Test Results for Visually Impaired (N = 52)

Surface	% Detecting Surface	% Not Detecting Surface
Black concrete domes	90.4	9.6
State standard aggregate	53.8	46.2
Small gradation aggregate	63.5	36.5
Lateral concrete domes	94.2	5.8
Red paver bricks	98.0	2.0
Yellow rubber domes	96.2	3.8
Yellow composite domes	98.0	2.0

the experimental task. Further, VDOT's goal is for the visually impaired to be very familiar with a widely used warning surface.

Overall, the domed surfaces were far more detectable than the two aggregate surfaces. Differences in the detectability of the various domed surfaces were small, and no more than 15 percent of the participants failed to detect any of the domed surfaces on either trial. In contrast, on Trial 1, slight majorities of the participants failed to detect the two aggregate surfaces. Although detection improved on Trial 2, 46 percent of all participants still failed to detect the state standard aggregate.

On both trials, if participants detected a change in surface and stopped, they were asked how easy or difficult it was for them to detect a particular surface. The first time they detected a particular surface (whether on Trial 1 or Trial 2) they were also asked, "If this were on a ramp, how helpful would it be in warning you of a street crossing?" The overall results for these two questions are summarized in Tables 7 and 8. If an individual failed to detect a particular surface on either trial, he or she could not validly rate either the ease of detection or the helpfulness of that surface and the data are missing for that case. Consequently, only 50 to 63 percent of the study participants rated the ease of detection and helpfulness of the two aggregate surfaces: the remainder of the participants never detected them. Tables 7 and 8 (and other tables for those questions) include only valid responses from test subjects who detected the surfaces since detection/nondetection rates are reported in separate tables.

The two surfaces most often identified as "very easy" or "easy" to detect were the black concrete domes and the yellow composite domes (Table 7). All of the other domed surfaces,

Table 7. Overall Sample Responses to the Question "How Difficult Was the Surface to Detect?" (%)[a]

Surface	Very Easy	Easy	Neither Hard nor Easy	Hard	Very Hard	Total [b]
Black concrete domes	32.7	63.3	4.1	0.0	0.0	100.0 (49)
State standard aggregate	29.6	25.9	3.7	37.0	3.7	100.0 (27)
Small gradation aggregate	27.3	21.2	12.1	36.1	3.0	100.0 (33)
Lateral concrete domes	24.0	62.0	8.0	2.0	0.0	100.0 (50)
Red paver bricks	30.0	60.0	8.0	2.0	0.0	100.0 (50)
Yellow rubber domes	34.7	53.1	8.2	4.1	0.0	100.0 (49)
Yellow composite domes	34.0	62.0	2.0	2.0	0.0	100.0 (50)

[a]Trial 2 responses are shown. Table percentages include only valid responses from individuals who detected a surface on Trial 2.
[b]Numbers in parentheses are the number of valid responses.

however, were rated as "very easy" or "easy" to detect by at least 85 percent of those detecting them. Fifty-five percent of those who detected the state standard aggregate rated it as "very easy" or "easy" to detect, and 48 percent of those who detected the smaller gradation aggregate rated it similarly. Approximately 40 percent of those who detected the aggregate surfaces said they were "hard" or "very hard" to detect.

Between 60 and 70 percent of those who detected each domed surface reported that the surfaces would be "helpful" or "very helpful" in warning them of a street crossing. Among those who detected the state standard aggregate, 21 percent said it would be helpful or very helpful, but only 4 percent rated the smaller gradation aggregate in that way. The missing data problems for the aggregates should be kept in mind, however (i.e., the ratings for the smaller gradation aggregate are based on 26 individuals who detected the surface from a total sample of 52).

Even though the domed surfaces tended to be rated as "easy" or "very easy" to detect, between 30 and 40 percent of the study participants said either that the surfaces needed revision or that they would not be helpful in detecting a street crossing (Table 8). Between 80 and 95 percent of those who detected the state standard and the smaller gradation aggregate,

Table 8. Overall Sample Responses to the Question "How Helpful Would the Surface Be in Warning You of a Street Crossing?" (%)[a]

Surface	Not Helpful	Needs Revision	Helpful	Very Helpful	Total[b]
Black concrete domes	13.0	21.7	45.7	19.6	100.0 (46)
State standard aggregate	60.7	17.9	21.4	0.0	100.0 (28)
Small gradation aggregate	57.7	38.5	3.8	0.0	100.0 (26)
Lateral concrete domes	22.2	15.6	46.7	15.6	100.0 (45)
Red paver bricks	13.3	24.4	48.9	13.3	100.0 (45)
Yellow rubber domes	15.9	13.6	56.8	13.6	100.0 (44)
Yellow composite domes	25.0	13.6	45.5	15.9	100.0 (44)

[a]Table percentages include only valid responses from individuals who detected a surface on Trial 1 or Trial 2.
[b]Numbers in parentheses are the number of valid responses.

respectively, judged the surfaces to be not helpful in detecting a street crossing or in need of revision. Of course, many visually impaired persons detect street crossings using multiple cues (slope, traffic sounds, etc.), not solely the curb ramp texture.

Visually impaired participants were not specifically asked about what kinds of revisions they thought the surfaces needed. A number of them, however, made negative comments about the domed surfaces being uncomfortable to walk on. The feel of the domed surfaces was likened to "a torn-up street" by one test subject and "a drain cover" by another. Others commented that their feet "caught" on the domes or that the domes needed to be lower. Although these kinds of criticisms of domed surfaces have been expressed before by mobility impaired ramp users and nondisabled pedestrians, it was somewhat surprising to hear these comments from the visually impaired. There were fewer criticisms about the way the aggregates felt underfoot compared to the domes, but there were considerably more criticisms about the lack of tactile and visual (color) contrast between the aggregates and the sidewalk.

Many of the visually impaired test participants had little or no previous experience with domed surfaces. The authors do not know whether visually impaired people who have more experience with domed surfaces object as much to the feel of the surfaces underfoot or whether this is something to which they become accustomed. There is likely to be a tradeoff between the walking comfort and degree of warning provided by surfaces. That is, if a surface does not "catch" a visually impaired person's feet to some extent, does it afford any protection from vehicular or other hazards?

Results for Those with Different Levels of Visual Impairment

The results of the testing differed greatly for those with partial vision and those with total blindness. A majority of those with partial vision, for example, could detect the surfaces without stepping onto them (often from a substantial distance). In contrast, in all but a few instances, totally blind participants had to step onto any warning surface before they knew it was there. The five individuals who had light perception always needed to step onto the warning surfaces in order to detect them as well.

The surface nondetection rates shown in Tables 5 and 6 were clearly related to level of vision. Eighty-five percent of those with partial vision detected at least six of the seven surfaces on Trial 2. In comparison, only 35 percent of the totally blind participants detected six or seven surfaces. The five individuals with light perception detected more surfaces than the totally blind individuals but fewer surfaces than the partially sighted individuals.

Participants with Partial Vision

On Trial 2, all of the warning surfaces were detected by at least 26 of the 27 partially sighted participants **except** the two aggregate surfaces. Thirty percent did not detect the state standard aggregate on Trial 2, and 19 percent did not detect the smaller gradation aggregate (Table 9). Among the partially sighted participants:

- 63 percent detected the yellow composite domes and the black concrete domes from more than 3.05 m (10 ft) away
- 45 to 50 percent detected the other domed surfaces from more than 3.05 m (10 ft) away
- 33 percent detected the aggregate surfaces from more than 3.05 m (10 ft) away.

Thus, the surfaces that provided more color contrast (i.e., all domed surfaces except the lateral concrete domes) were detectable from further away than the aggregates, which provided less color contrast. Although the concrete lateral domes did not afford much color contrast with the surrounding sidewalk, participants readily saw the distinctive ribbed pattern (74 percent said they detected the lateral domes by sight). The difficulty they had in detecting the aggregates may have been due to the fact that the aggregates had both less visual contrast and less tactile contrast with the sidewalk than the domed surfaces.

Eighty-five percent or more rated the five domed surfaces as "easy" or "very easy" to detect (Table 10). Among those who detected the aggregates, approximately 60 percent rated them as "easy" or "very easy" to detect. The two aggregate surfaces were the only surfaces rated as "hard" or "very hard" to detect by an appreciable number of participants. Forty-two percent rated the state standard aggregate as "hard" or "very hard" to detect; 32 percent rated the smaller gradation aggregate similarly.

As was true for the overall sample, the evaluations of partially sighted participants of the helpfulness of the surfaces in detecting a street crossing were not as positive as their ratings of the ease of detecting the surfaces (Table 11). For example, although the concrete lateral domes and the black concrete domes were readily detectable to them, 30 and 39 percent of the partially sighted participants, respectively, felt either that the surfaces needed revision or that they would not be helpful in detecting a street crossing. For the aggregates, approximately 90 percent of the partially sighted participants judged the surfaces not helpful or in need of revision.

The less positive evaluations of the helpfulness of surfaces may partly reflect the reliance of partially sighted participants on other kinds of cues to detect street crossings (e.g., visual cues). Also, exceedingly few (if any) of the test participants had consistently encountered any warning surface indicating the presence of a curb ramp. In the future, if test participants have consistently encountered a detectable surface on curb ramps, it is possible that their assessments of the **actual** helpfulness (versus the hypothetical helpfulness) of surfaces could be different.

Table 9. Surface Detection for Participants with Partial Vision (%) (N = 27)[a]

Distance to Detect Surface	Black Concrete Domes	State Standard Aggregate	Small Gradation Aggregate	Concrete Lateral Domes	Red Paver Bricks	Yellow Rubber Domes	Yellow Composite Domes
More than 6.10 m away from surface	44.4	22.2	25.9	33.3	29.6	40.7	0
3.06 - 6.10 m away	18.5	11.1	7.4	18.5	14.8	11.1	63.0
0.34 - 3.05 m away	3.7	11.1	25.9	14.8	22.2	18.5	14.8
0.00 - 0.33 m away	3.7	7.4	0	3.7	7.4	0	7.4
0.01 - 0.33 m onto surface	14.8	3.7	3.7	11.1	0	11.1	3.7
0.34 - 0.61 m onto surface	7.4	7.4	3.7	3.7	18.5	7.4	3.7
0.62 - 0.91 m onto surface	3.7	3.7	3.7	11.1	7.4	3.7	3.7
0.92 - 1.22 m onto surface	0	3.7	11.1	0	0	0	3.7
More than 1.22 m onto surface	0	0	0	0	0	7.4	0
Did not detect surface	3.7	29.6	18.5	3.7	0	0	0
Total	100	100	100	100	100	100	100

[a]Data are from Trial 2.

Table 10. Partially Sighted Participants' Responses to the Question "How Difficult Was the Surface to Detect?" (%)[a]

Surface	Very Easy	Easy	Neither Hard nor Easy	Hard	Very Hard	Total %[b]
Black concrete domes	40.7	51.9	7.4	0.0	0.0	100.0 (27)
State standard aggregate	42.1	15.8	0.0	36.8	5.3	100.0 (19)
Small gradation aggregate	40.9	18.2	9.1	27.3	4.5	100.0 (22)
Lateral concrete domes	33.3	55.6	7.4	3.7	0.0	100.0 (27)
Red paver bricks	48.1	40.7	11.1	0.0	0.0	100.0 (27)
Yellow rubber domes	57.7	38.5	3.8	0.0	0.0	100.0 (26)
Yellow composite domes	48.1	48.1	3.7	0.0	0.0	100.0 (27)

[a]Trial 2 responses are shown. Table percentages include only valid responses from individuals who detected a surface on Trial 2.
[b]Numbers in parentheses are the number of valid responses.

Table 11. Partially Sighted Participants' Responses to the Question "How Helpful Would This Surface Be in Warning You of a Street Crossing?" (%)[a]

Surface	Not Helpful	Needs Revision	Helpful	Very Helpful	Total[b]
Black concrete domes	8.7	30.4	43.5	17.4	100.0 (23)
State standard aggregate	70.6	17.6	11.8	0.0	100.0 (17)
Small gradation aggregate	53.3	40.0	6.7	21.7	100.0 (15)
Lateral concrete domes	21.7	8.7	47.8	21.7	100.0 (23)
Red paver bricks	9.1	18.1	59.1	13.6	100.0 (22)
Yellow rubber domes	4.8	9.5	66.7	19.0	100.0 (21)
Yellow composite domes	9.1	13.6	54.5	22.7	100.0 (22)

[a]Table percentages include only valid responses from individuals who detected a surface on Trial 1 or Trial 2.
[b]Numbers in parentheses are the number of valid responses.

Participants with Light Perception

Since there were only five test participants with light perception, only the surface detection test results are reported for them. Needless to say, results for a group of five individuals are suggestive at best. Nonetheless, the pattern of results in Table 12 is consistent with the patterns observed earlier: the aggregates were definitely less detectable than the domed surfaces by participants with light perception.

Participants detected surfaces only after stepping onto them (as did totally blind participants). The surfaces with the highest detection rates at distances of 0.61 m (2 ft) or less onto the surface were the black concrete domes and the yellow composite domes (four of five individuals detected them at that distance). With the exception of one person, those who detected either aggregate had to be more than 0.91 m (3 ft) onto the surface before they detected it. This was almost never the case with any domed surface (the only exception was one person who did not detect the lateral domes until he was more than 0.91 m onto the surface).

Totally Blind Participants

As noted earlier, problems with detecting aggregate surfaces were most pronounced among the totally blind participants. The differences in detection rates for the aggregate surfaces versus the domed surfaces were striking for this group. As Table 13 shows, only 30 percent of these participants detected the state standard aggregate on Trial 2, and 35 percent detected the smaller gradation aggregate. By comparison, all of the domed surfaces except the black concrete domes were detected by 90 to 95 percent on Trial 2 (the black concrete domes were detected by 80 percent).

This group of test participants nearly always stepped onto the warning surfaces before detecting them, but in a few instances, participants detected surfaces in advance with their cane or their guide dog stopped. As Table 13 shows, differences in the detectability of the various domed surfaces were small. The results showed that the totally blind participants needed to travel further on the black concrete domed surface to detect it (compared to the other domed surfaces), but eventually, 100 percent detected it. Table 13 also shows that they tended to travel a shorter distance before detecting the yellow rubber domed surface. It should be noted that the guide dogs used by 5 of the 20 totally blind participants were not trained to stop at the sight of a change in surface on a flat sidewalk, although some of the dogs did so for some of the surfaces.

Table 14 shows the responses of the totally blind participants to questions about the ease or difficulty of detecting the various surfaces. Only 5 of the 20 detected (and rated) the state standard aggregate. Among them, 4 said it was easy to detect and 1 said it was hard to detect. Similarly, only 7 detected and rated the smaller gradation aggregate; 3 said it was hard to detect, 2 were neutral, and 2 judged it easy to detect. Clearly, since 65 to 75 percent of the totally blind participants could not detect the aggregates on the second trial, these ratings cannot be assumed to be representative for these participants. Possibly, the ratings for the aggregate are

Table 12. Surface Detection Test Results for Participants with Light Perception (%) (N = 5)[a]

Distance to Detect Surface	Black Concrete Domes	State Standard Aggregate	Small Gradation Aggregate	Concrete Lateral Domes	Red Paver Bricks	Yellow Rubber Domes	Yellow Composite Domes
0.03 - 0.30 m onto surface	0	0	20.0	0	0	40.0	20.0
0.31 - 0.61 m onto surface	80.0	0	0	40.0	60.0	0	60.0
0.62 - 0.91 m onto surface	20.0	0	0	40.0	40.0	60.0	20.0
0.92 - 1.22 m onto surface	0	60.0	40.0	20.0	0	0	0
More than 1.22 m onto surface	0	0	20.0	0	0	0	0
Did not detect surface	0	40.0	20.0	0	0	0	0
Total	100	100	100	100	100	100	100

[a]Data are from Trial 2.

Table 13. Surface Detection Test Results for Totally Blind Participants (%) (N = 20)[a]

Distance to Detect Surface	Black Concrete Domes	State Standard Aggregate	Small Gradation Aggregate	Concrete Lateral Domes	Red Paver Bricks	Yellow Rubber Domes	Yellow Composite Domes
More than 0.30 m away	0.0	0	0	0	5.0	5.0	0.0
0.00 - 0.30 m away	0.0	5.0	0	0	5.0	10.0	5.0
0.01 - 0.30 m onto surface	25.0	0.0	10.0	35.0	20.0	20.0	35.0
0.31 - 0.61 m onto surface	15.0	10.0	10.0	20.0	25.0	25.0	5.0
0.62 - 0.91 m onto surface	25.0	10.0	15.0	10.0	20.0	25.0	30.0
0.92 - 1.22 m onto surface	15.0	0.0	0	25.0	20.0	5.0	20.0
More than 1.22 m onto surface	0.0	5.0	0	0	0	0	0
Did not detect surface	20.0	70.0	65.0	10.0	5.0	10.0	5.0
Total	100	100	100	100	100	100	100

[a]Data are from Trial 2.

Table 14. Responses of Totally Blind Participants to the Question "How Difficult Was the Surface to Detect?" (%)[a]

Surface	Very Easy	Easy	Neither Hard nor Easy	Hard	Very Hard	Total[b]
Black concrete domes	29.4	70.6	0.0	0.0	0.0	100.0 (16)
State standard aggregate	0.0	80.0	0.0	20.0	0.0	100.0 (5)
Small gradation aggregate	0.0	28.6	28.6	42.9	0.0	100.0 (7)
Lateral concrete domes	16.7	61.1	11.1	11.1	0.0	100.0 (18)
Red paver bricks	11.1	77.8	5.6	5.6	0.0	100.0 (18)
Yellow rubber domes	11.1	66.7	11.1	11.1	0.0	100.0 (18)
Yellow composite domes	16.7	77.8	0.0	5.6	0.0	100.0 (18)

[a]Trial 2 responses are shown. Table percentages include only valid responses from individuals who detected a surface.
[b]Numbers in parentheses are the number of valid responses.

representative of the most capable travelers among the totally blind test participants, but that cannot be said unequivocally. Among the domed surfaces, the black concrete domes, the yellow composite domes, and the red paver bricks were rated “easy” or “very easy” to detect by approximately 90 percent or more of the totally bind participants who answered. Ratings for both the concrete lateral domes and the yellow rubber domes included 78 percent “easy” or “very easy,” 11 percent neutral, and 11 percent “hard to detect” responses.

Table 15 shows the responses to the question about how helpful the surfaces would be in warning participants of a street crossing. The two domed surfaces receiving the most positive ratings were the black concrete domes and the yellow rubber domes, each of which was rated "helpful" or "very helpful" by approximately 60 percent of those responding. Ratings for the red paver bricks, lateral concrete domes, and yellow composite domes were nearly evenly split between negative ratings ("not helpful" or "needs revision") and positive ratings ("helpful" or "very helpful"). The responses of the 8 totally blind individuals who rated the state standard aggregate were also evenly split between positive and negative ratings. All 7 who detected and rated the smaller gradation aggregate said it was either "not helpful" or "needs revision." Again, the fact that fewer than half of the totally blind participants rated the aggregate surfaces must be kept in mind.

It may be difficult for totally blind respondents to answer hypothetical questions about warning surfaces on ramps helping them detect street crossings if (1) they have seldom encountered warning surfaces on ramps and/or (2) they rely on other kinds of cues to determine where street crossings are. It would seem, though, that none of these warning surfaces was judged to be ideal by all of the visually impaired people who participated in the testing. This reflects the differences of opinion that have been expressed on the national scene. The raised domes that were clearly more detectable than the aggregates in our testing have been enthusiastically endorsed by some national advocacy groups for the blind (American Council of the Blind, American Foundation for the Blind) and criticized by others (NFB).

Mobility Impaired Participants

Despite extensive recruitment efforts by the authors, the test sample of mobility impaired pedestrians consisted of only six individuals. Given the small number of cases, no statistical analyses were performed. Their comments about the various surfaces warrant mention, however.

The travel aids used by these participants included wheelchairs, crutches, canes, and human assistants. The participants were asked specifically about how their mobility was affected by each of the seven surfaces and what modifications they would suggest. Not surprisingly, they preferred smoother surfaces, such as the aggregates, to the domed surfaces.

The domed surfaces elicited a number of comments. Two individuals said they would avoid travel over any domed surface, and two others said they would specifically avoid the

Table 15. Responses of Totally Blind Participants' to the Question "How Helpful Would This Surface Be in Warning You of a Street Crossing?" (%)[a]

Surface	Not Helpful	Needs Revision	Helpful	Very Helpful	Total[b]
Black concrete domes	16.7	16.7	38.9	27.8	100.0 (18)
State standard aggregate	25.0	25.0	50.0	0.0	100.0 (8)
Small gradation aggregate	42.9	57.1	0.0	0.0	100.0 (7)
Lateral concrete domes	23.5	29.4	35.3	11.8	100.0 (17)
Red paver bricks	22.2	27.8	33.3	16.7	100.0 (18)
Yellow rubber domes	33.3	5.6	50.0	11.1	100.0 (18)
Yellow composite domes	35.3	17.6	35.3	11.8	100.0 (17)

[a]Table percentages include only valid responses from individuals who detected a surface on Trial 1 or Trial 2.
[b]Numbers in parentheses are the number of valid responses.

lateral domes (the corduroy surface). All six made negative comments about the lateral domes, which they said made their movement unstable or hazardous. Those who used wheelchairs complained about the wheels becoming stuck in the grooves of the lateral domed surface. The truncated domes also elicited negative comments: the domes were too high and too difficult to maneuver over. As one of those who used a wheelchair commented about the yellow composite domes, "they prevent you from going in the direction you want." These negative comments are consistent with research results and comments cited in the *Federal Register*.[8] One participant said she would avoid any textured surface, as she preferred the curb ramps without them.

Two participants found that the concrete lateral domes, red paver bricks, and yellow composite raised truncated domes made their movement unstable. The mobility impaired participants judged the two aggregate surfaces to be the easiest on which to maneuver and the most conducive to stability (on the flat test site).

Although based on a very small sample, these comments and the videotapes of the maneuvers of mobility impaired participants on the surfaces provided valuable information about the effects of the various surfaces on their travel. Clearly, the domed surfaces, particularly the lateral domes, made travel more difficult. These findings confirm those found in public commentary on the domes in the *Federal Register*[7,8] and other sources: **there is a definite tradeoff between high detectability for the visually impaired and ease of movement for the mobility impaired.** The two aggregate surfaces, both of which went undetected by high percentages of the totally blind test participants, were favored by the mobility impaired participants.

Assessment of the Maintenance and Performance of Surfaces: Survey Results

Respondents to the telephone survey on the performance characteristics of warning surfaces were from Virginia and 21 other states. Those interviewed were responsible for construction and/or maintenance of curb ramps in their state or locality (job titles varied). Virginia respondents were asked specifically about their experience with exposed aggregate, since it has been the VDOT standard since 1992. The 21 other states were chosen for their similarity to Virginia with regard to climate, previous innovation in transportation, and/or their participation in a 1992 survey related to this research. Officials in other states were asked about their state's use (if any) of detectable warning surfaces, current state standards, maintenance history of surfaces, and public comments received.

Curb Ramp Surface Standards

Multiple delays of the ADAAG rulemaking on ramp surface requirements caused a number of states to delay changing their standards, in some cases on the advice of their state's attorney general. A number of the states are using various concrete finishes, not all of which can be considered detectable warning surfaces (e.g., broom finish concrete is not). Some of the surfaces used included:

- *Brush or broom finish concrete:* Massachusetts, Delaware, Tennessee, Ohio, Texas, and Michigan

- *Grooved concrete:* Georgia, Kentucky, and Colorado

- *Metal-stamped gridded concrete:* Florida.

Additionally, South Carolina is researching color standards for pigments to be mixed in concrete ramps. They reported that, so far, brick red provides the best contrast. (*Note*: A number of studies included in the literature review identified bright yellow as the most detectable color for those who have some usable vision. This was confirmed by DVH mobility trainers.)

Although raised truncated domes have been tested in a number of the states and municipalities included in the survey, only North Carolina and Washington have ever required domes. Austin, Texas, also currently requires domes. In North Carolina, Greensboro and Charlotte required domes before the state standard required them. In North Carolina, domes must provide a 70 percent color contrast with the sidewalk. New York has experimented with raised truncated domes (i.e., Pathfinder™ tiles) but has not changed its standard to require them. In an earlier phase of this research, the authors learned that Japan has used raised truncated domes for more than 10 years, but Japanese officials had not responded to the Access Board's request for information.

Virginia was the only state in the survey that uses exposed aggregate (in the 1992 survey, however, the city of Baltimore, Maryland, was using aggregate). States and cities that do not currently require any detectable warning surfaces include California, Connecticut, Washington, D.C., Georgia, New York, Ohio, Pennsylvania, South Carolina, and West Virginia.

Surface Maintenance Characteristics

States using the brushed concrete or grooved finishes reported that the surfaces require no special maintenance (ice accumulation in the grooves, however, was reported as a problem in the 1992 survey). A Massachusetts respondent also reported that frost caused settlement cracks on the surface of their broom finish concrete ramps.

The survey results indicated that truncated domes generally require more maintenance than the various other kinds of ramp surfaces, and domes create some maintenance problems. In North Carolina, domes have broken off the surface, sometimes necessitating replacement of ramp sections. Texas has had similar experiences. Austin requires that the domes be stamped onto the surface with an optional yellow pigment mixed into the concrete; they have had problems, however, with dome breakage due to improper mixing of the pigment. Kentucky also reported problems with the yellow ceramic domed tiles tested at some of its rest areas. The ceramic tiles were installed in parking lots, where vehicles traveling across the surface cracked and cut up the tiles. New York reported maintenance problems with the rubber Pathfinder™ tiles. In their samples, the top of the ramp surface expanded and contracted at different rates, causing the tiles to loosen and come off. (This problem with rubber tiles was confirmed for the authors by the manufacturer, who no longer recommends them for outdoor use.)

New Jersey has also had experience in maintaining truncated dome surfaces. Although the state does not use them on curb ramps, their use on rail platforms provides some information on surface durability. Stampcrete™ (stamped concrete domes) has been tested extensively there. New Jersey officials reported that although the surface is generally receiving positive reviews, maintaining the domes is difficult: snow plows broke off 50 percent of the domes in the course of one winter.

Few survey respondents had any comments about the maintenance of exposed aggregate, except to say that it is too new to require any repairs. In many areas of Virginia, fewer than 5 percent of existing ramps have the aggregate surface. The only maintenance reported to date on aggregate surfaces was due to improper construction. Manassas reported problems with loose gravel in the surface. Norfolk and Portsmouth reported that portions of the aggregate had peeled off some ramps. Virginia respondents also expressed concerns that the aggregate could loosen as the cement washes out over time. As water fills the surface, respondents said, the aggregate could loosen, requiring replacement. Applying a sealant could prevent the loosening, but doing so would increase the slipperiness of the surface, which is already reported to be a problem in wet weather.

Local Virginia officials expressed a number of concerns about the cost and difficulty of installing aggregate. Staunton reported that it cost $1,000 per intersection to retrofit four concrete ramps with an exposed aggregate surface. Finally, problems have arisen in some rural areas where it is difficult to locate suppliers of the materials needed to mix aggregate conforming to the state standard.

Public Reaction to Detectable Warning Surfaces

The public has voiced a variety of concerns about the warning surfaces currently in use. Massachusetts and Colorado were the only states participating in the survey that have received any feedback about the textured concrete finishes. Colorado received comments that the grooved finish works well because it is easily detected by a cane. In Massachusetts, Boston officials commented that the disabled community is generally not well served in the state and that their current standard (brush finish concrete) does not provide enough warning for the visually impaired. Some suggested that an audible traffic signal would provide a better warning of street crossings, but engineers objected to this alternative because of the loudness of the signal.

Public opinion has been divided on the domed surfaces. Officials in New Jersey think that the domes have definitely helped blind people detect rail platform edges, and the state continues to experiment with domes for this purpose. Visually impaired citizens in Austin, Texas, reported no problems except that they would like the domes to be more pronounced. The latter finding is interesting in light of the complaints the authors heard from visually impaired test participants about domes being too high.

Reactions to the domes have been more negative in a number of other areas. In the words of one North Carolina official, there are perceptions that the domes are "more of a hazard than a benefit." Wheelchair users in New Jersey and North Carolina have complained about the difficulty of maneuvering over the domes, and women wearing high heels have responded similarly in North Carolina and Florida. Florida reported one incident in which a woman tripped on a concrete truncated dome surface and sprained her ankle. Florida is no longer installing the domes; instead, it is using metal stamped gridded concrete. North Carolina also plans to discontinue installing domes in future construction projects. Officials in Colorado suspect that the domes represent a tripping hazard and, for that reason, they continue to use the grooved concrete finish.

Virginia survey respondents reported that they had heard criticisms of exposed aggregate from VDOT field personnel, local officials, and some pedestrians. Public reaction to the aggregate has been mixed. Although some localities are receiving requests to install warning surfaces, many disabled users do not know why the aggregate has been installed or what it signifies. In a number of areas (e.g., Fredericksburg and Salem), many sidewalks are composed entirely of exposed aggregate, providing no tactile contrast with the curb ramps. In Charlottesville and Northern Virginia, citizens have complained about slipping on aggregate in rain and snow. Although some citizens like the aesthetic appearance of aggregate, others do not, particularly in historic areas. Some members of the public have expressed views that warning surfaces in general are a waste of money. Of course, there have been similar reactions to other requirements under the ADA.

Durability of Warning Surfaces at the Test Site

The test surfaces installed in November 1993 at VRCB in Richmond have provided some information on installation difficulties and surface durability. A number of the seven surfaces, particularly the precast concrete sections, have settled, forming cracks in a number of joints (joints between the slabs and the existing sidewalk and some center joints within the precast sections). Since the test site is an existing sidewalk retrofitted with detectable warning sections, the cracks could be due to deficient installation, a material problem, or both.

In addition, the yellow rubber domed tiles faded quite visibly between November and May. This was not unexpected, however, since the manufacturer no longer recommends the rubber tiles for outdoor use. The yellow composite domed tiles are showing some small faded spots but otherwise are still bright yellow.

A number of the raised truncated domes on the black concrete and red brick surfaces also were damaged. The exact cause of this damage is unknown. According to Don Callahan, maintenance supervisor at VRCB, the only winter maintenance performed on the test sidewalk was snow blowing no more than 4 times during the (relatively harsh) winter. The snow blower was raised so that it would not touch the domes when used. It seems unlikely that routine use of the sidewalk accounts for the damage (apart from the testing, in fact, the sidewalk is infrequently used by VRCB residents). The surfaces could have been run over by skateboards or bicycles on weekends or evenings, but there is no proof of this.

The authors consulted Dr. Celik Ozyildirim of VTRC, who is a concrete expert, about the possible causes of the cracking and the broken off domes. In his judgment, the cracks are likely due to deficient installation, specifically, insufficient preparation of the base under the precast slabs. If the domes were not broken off by some kind of physical damage, he said, they may have broken off as a consequence of freeze-thaw cycles. That is, the particular concrete mixture used for the test slabs may not have completely withstood the expansion and contraction caused by water.

CONCLUSIONS

None of the seven surfaces tested emerged as ideal for **all** curb ramp users. A number of tradeoffs became apparent in the course of this research.

On the question of detectability to the visually impaired, our results were unequivocal: **raised truncated domes are far more detectable than exposed aggregate.** In our testing, 70 percent of the totally blind participants failed to detect the state standard aggregate, even after completing one trip down the test sidewalk; the highest nondetection rate for any domed surface tested was 20 percent. Partially sighted test participants favored bright yellow surfaces and red surfaces, to a lesser extent; they were critical of the aggregates' relative lack of color contrast with the sidewalk. Although both DVH mobility trainers and visually impaired test participants identified slope or gradient as the primary cue used to detect curb ramps, the national debate about detectable warning surfaces suggests that slope is not a failsafe cue for all visually impaired people. The poor detectability of exposed aggregate is therefore a cause for concern.

Our findings were also unequivocal on the question of ease of maneuverability for mobility impaired people. **The domed surfaces were difficult to maneuver upon,** confirming comments published in the *Federal Register.*[8] The aggregate surfaces were clearly preferred. Some visually impaired participants rated aggregate preferable to the domed surfaces for walking comfort. The most fundamental tradeoff involved in the choice of a curb ramp surface is this:

the more detectable a surface, the greater the extent to which it "catches" feet, wheels, cane tips, etc.

On the questions of ease of installation, maintenance requirements, and durability, both aggregate and domed surfaces have liabilities, although those for aggregate appear to be less serious based on the limited evidence available. States using domed surfaces reported high rates of winter maintenance damage; aggregate appears to be much less susceptible to this. Installation of domed tiles and bricks is definitely time-consuming, but Virginia respondents to our survey said that constructing aggregate ramps to meet the state standard can also be time-consuming. When precast concrete surfaces are used, as they were for some sections of the test site, installation times for aggregate and raised truncated domes should be similar. Some states participating in our survey also reported problems with dyes and pigments used to make concrete ramp surfaces more detectable by the partially sighted.

Other issues and considerations also become apparent in the course of this study. Some advocacy groups for the visually impaired object to all detectable warning surfaces on the grounds that (1) such surfaces are unnecessary, (2) some visually impaired people will not persevere in learning mobility skills if warning surfaces are widely installed, and/or (3) such surfaces will perpetuate societal misconceptions about the visually impaired. In the authors' view, however, the potential liability of state and local governments necessitates consideration of the less capable travelers among the visually impaired who may need a warning surface to avoid injury.

There are an estimated 3,000 people in Virginia who are either totally blind or have only light perception. In our testing, these were the groups who frequently could not detect aggregate. An additional 11,000 Virginians have partial vision. There are many more (approximately 28,000) mobility impaired Virginians using wheelchairs or walkers. These are the groups most likely to have difficulty maneuvering on domed surfaces. Needless to say, however, there is much variation in the travel skills of visually and mobility impaired individuals. Lest the relative numbers be given too much weight in policy decisions, it should be borne in mind that failure to detect a curb ramp can result in serious injury or loss of life for the visually impaired. Properly constructed curb ramps do not generally pose that kind of risk for the mobility impaired.

Finally, there are numerous policy, administrative, and legal issues involved in the selection of a curb ramp surface standard. The federal government will not issue guidelines until 1996 at the earliest; for that reason, a number of states have been advised not to change their current standards. For VDOT, and other state DOTs, every change in the standard entails costs and a "learning curve" on the part of those who install the surfaces, those who inspect the surfaces, etc. Given the thousands of ramp locations throughout the state, changes in the standard must be carefully considered. Frequent changes in the standard are likely to create problems for VDOT, contractors, and localities.

RECOMMENDATIONS

1. VDOT should retain its current exposed aggregate standard for curb ramp surfaces, at least until the federal government issues guidelines in 1996.

2. VDOT should consider permitting selected localities that request an exception from the exposed aggregate standard (for aesthetic or other reasons) to install domed curb ramp surfaces conforming to the ADAAG guidelines, on a case-by-case basis. Their maintenance experiences with the alternative surfaces should be monitored by VDOT's Location & Design Division.

3. The Location & Design Division should continue to follow public commentary on detectable warning surfaces by mobility impaired people in the *Federal Register* and other sources until the Access Board makes its decision.

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APPENDIX A: TESTING FORM FOR VISUALLY IMPAIRED PEOPLE

DETECTABILITY OF TEST SURFACES TO THE VISUALLY IMPAIRED

Date:_______________ Subject #________________

Examiner's Name(s):____

OPENING COMMENTS: WE ARE WORKING ON A STUDY TO HELP THE STATE OF VIRGINIA CHOOSE THE MOST SUITABLE WARNING SURFACE TO BE PLACED ON CURB RAMPS. THE EXPERIMENT THAT WE'RE CONDUCTING TODAY IS TO SEE HOW DETECTABLE SEVERAL DIFFERENT SURFACES ARE TO VISUALLY IMPAIRED PEOPLE. WE HAVE IDENTIFIED SURFACES THAT HAVE BEEN EFFECTIVE IN PREVIOUS STUDIES, AND WE'D LIKE YOUR HELP IN EVALUATING THESE SURFACES SOME MORE.

WE'LL BE ASKING A NUMBER OF PEOPLE FROM THE CENTER TO JUDGE THESE SURFACES, AND TODAY, WE'D LIKE TO GET YOUR OPINION. OUR PURPOSE IS TO FIND OUT HOW DETECTABLE DIFFERENT SURFACES ARE TO A GROUP OF PEOPLE. WE'RE NOT CONCERNED WITH ANY ONE PERSON'S ABILITY TO DETECT CHANGES IN SURFACES.

WE HAVE INSTALLED SEVERAL DIFFERENT SURFACES IN THIS EXISTING SIDEWALK THAT RUNS FROM THIS PARKING LOT TO AZALEA AVENUE. WHEN WE BEGIN, I AM GOING TO ASK YOU TO WALK DOWN THE SIDEWALK AT YOUR NORMAL PACE, USING THE MOBILITY METHOD THAT YOU WOULD NORMALLY USE FOR A SIDEWALK. I'LL BE WALKING NEXT TO YOU IN THE GRASS. I'D LIKE YOU TO STOP AS SOON AS YOU DETECT A CHANGE IN THE SIDEWALK SURFACE. IT DOESN'T MATTER HOW YOU DETECT IT, WHETHER IT'S BY CANE, FOOT OR BY VISUAL CONTRAST. YOU MAY EVEN DETECT IT BEFORE YOU STEP ONTO IT.

WHEN YOU STOP, THAT WILL LET ME KNOW THAT YOU HAVE DETECTED A NEW SURFACE. I WILL MEASURE THE DISTANCE FROM THE EDGE OF THE SURFACE TO YOUR FOOT OR TO THE TIP OF YOUR CANE, DEPENDING ON HOW YOU DETECTED THE SURFACE. AFTER I GET MY MEASUREMENT, I'M GOING TO ASK YOU A FEW QUESTIONS CONCERNING HOW YOU DETECTED THE SURFACE AND WHETHER IT WAS EASY OR DIFFICULT FOR YOU. AFTER WE FINISH WITH ONE SURFACE, I'LL ASK YOU TO CONTINUE WALKING UNTIL YOU DETECT ANOTHER CHANGE IN THE SURFACE.

IN ORDER TO MAKE THE RESULTS OF THE EXPERIMENT MORE RELIABLE, WE'D LIKE FOR YOU TO WALK THE ROUTE TWICE. DO YOU HAVE ANY QUESTIONS?

BEFORE WE BEGIN, I HAVE A FEW GENERAL QUESTIONS:

1) AGE:__________ 2) M OR F 3) TYPE OF SHOES

____

4) WHAT IS THE DEGREE OF YOUR VISUAL IMPAIRMENT?

TOTALLY BLIND _____
LIGHT PERCEPTION _____
LOW PARTIAL VISION _____
HIGH PARTIAL VISION _____

COMMENTS:____
____

5) HOW LONG HAVE YOU HAD THIS DEGREE OF VISUAL IMPAIRMENT ?
____________ YEARS

COMMENTS:____
____

6) WHAT TYPES OF TRAVEL AIDS DO YOU NORMALLY USE?
____
____
____
____
____

7) HAVE YOU RECEIVED FORMAL ORIENTATION AND MOBILITY TRAINING?
___ YES ____NO
WHERE AND FOR HOW LONG?
____
____
____
____
____

OKAY, LET'S BEGIN THE EXPERIMENT AND REMEMBER TO STOP AS SOON AS YOU DETECT A CHANGE IN THE SIDEWALK SURFACE.

SURFACE	DETECT	METHOD	DISTANCE	STEPS	DIFFICULTY *	QUESTIONS 2-4
1. Black Concrete Raised Truncated Domes	1=Yes 2=No	1=Sight 2=Dog 3=Foot 4=Cane			5=VERY HARD 4= HARD 3= NEITHER HARD NOR EASY 2= EASY 1= VERY EASY	How did you know that this surface was different?__________ What difference can you see between this surface and the sidewalk?__________
	1=Yes 2=No	1 2 3 4			5 4 3 2 1	If this were on a ramp, how helpful would be in warning you of a street crossing?__________
2. Exposed Aggregate (State Standard)	1=Yes 2=No	1=Sight 2=Dog 3=Foot 4=Cane			5=VERY HARD 4=HARD 3=NEITHER HARD NOR EASY 2=EASY 1=VERY EASY	How did you know that this surface was different?__________ What difference can you see between this surface and the sidewalk?__________
	1=Yes 2=No	1 2 3 4			5 4 3 2 1	If this were on a ramp, how helpful would be in warning you of a street crossing?__________
3. Exposed Aggregate (Smaller Gradation)	1=Yes 2=No	1=Sight 2=Dog 3=Foot 4=Cane			5=VERY HARD 4=HARD 3=NEITHER HARD NOR EASY 2=EASY 1=VERY EASY	How did you know that this surface was different?__________ What difference can you see between this surface and the sidewalk?__________
	1=Yes 2=No	1 2 3 4			5 4 3 2 1	If this were on a ramp, how helpful would be in warning you of a street crossing?__________

* PLEASE TELL US HOW EASY OR DIFFICULT IT WAS TO DETECT THIS SURFACE:

SURFACE	DETECT	METHOD	DISTANCE	STEPS	DIFFICULTY *	QUESTIONS 2-4
4. Concrete Lateral Domes	1=Yes 2=No	1=Sight 2=Dog 3=Foot 4=Cane			5=VERY HARD 4= HARD 3= NEITHER HARD NOR EASY 2= EASY 1= VERY EASY	How did you know that this surface was different?______ What difference can you see between this surface and the sidewalk?______
	1=Yes 2=No	1 2 3 4			5 4 3 2 1	If this were on a ramp, how helpful would be in warning you of a street crossing?______
5. Red Paver Bricks	1=Yes 2=No	1=Sight 2=Dog 3=Foot 4=Cane			5=VERY HARD 4=HARD 3=NEITHER HARD NOR EASY 2=EASY 1=VERY EASY	How did you know that this surface was different?______ What difference can you see between this surface and the sidewalk?______
	1=Yes 2=No	1 2 3 4			5 4 3 2 1	If this were on a ramp, how helpful would be in warning you of a street crossing?______
6. Yellow Rubber Raised Truncated Domes	1=Yes 2=No	1=Sight 2=Dog 3=Foot 4=Cane			5=VERY HARD 4=HARD 3=NEITHER HARD NOR EASY 2=EASY 1=VERY EASY	How did you know that this surface was different?______ What difference can you see between this surface and the sidewalk?______
	1=Yes 2=No	1 2 3 4			5 4 3 2 1	If this were on a ramp, how helpful would be in warning you of a street crossing?______

* PLEASE TELL US HOW EASY OR DIFFICULT IT WAS TO DETECT THIS SURFACE:

SURFACE	DETECT	METHOD	DISTANCE	STEPS	DIFFICULTY *	QUESTIONS 2-4
7. Yellow Raised Truncated Domes (Composite Tiles)	1=Yes 2=No	1=Sight 2=Dog 3=Foot 4=Cane			5=VERY HARD 4= HARD 3= NEITHER HARD NOR EASY 2= EASY 1= VERY EASY	How did you know that this surface was different?________ What difference can you see between this surface and the sidewalk?________
	1=Yes 2=No	1 2 3 4			5 4 3 2 1	If this were on a ramp, how helpful would it be in warning you of a street crossing?________

* PLEASE TELL US HOW EASY OR DIFFICULT IT WAS TO DETECT THIS SURFACE

(MISCELLANEOUS COMMENTS)

FINAL QUESTIONS AFTER COMPLETING TESTS:

1) OF ALL THE SURFACES THAT YOU DETECTED **(LIST)** IS THERE ONE THAT YOU FOUND MUCH EASIER TO DETECT THAN ALL THE OTHERS?

____

____

2) IS THERE ONE THAT YOU LIKED TO WALK ON MORE THAN THE OTHERS?

____

____

3) SOME CURB RAMP SURFACES ARE ALREADY IN USE IN THE RICHMOND AREA. HAVE YOU ENCOUNTERED A BUMPY SURFACE WITH SMALL RAISED DOMES? ____NO____YES OR A ROUGH STONE SURFACE? ____NO____YES

4) WHICH DO YOU PREFER? AND WHY?

____

____

____

____

____

____

____

5) WHICH CUES ARE MOST IMPORTANT TO YOU IN DETECTING A CURB RAMP?

____

____

____

____

6) HOW USEFUL WOULD DETECTABLE WARNING SURFACES BE TO YOU?

____

____

____

7) CURRENTLY, THE VIRGINIA STATE STANDARD IS THE ROUGH STONE SURFACE, CALLED EXPOSED AGGREGATE. DO YOU HAVE ANY OPINIONS ABOUT THIS SURFACE IN PARTICULAR?

____

____

____

____

____

____

APPENDIX B. TESTING FORM FOR MOBILITY IMPAIRED PEOPLE

Examiner's Name(s):____

Date:__________________ Subject #______________________

Opening Comments: WE'RE WORKING ON A STUDY TO HELP THE STATE OF VIRGINIA CHOOSE THE MOST SUITABLE WARNING SURFACE TO BE PLACED ON CURB RAMPS. WE'RE INTERESTED IN DETERMINING WHICH SURFACES ARE MOST EASILY DETECTED BY THE VISUALLY IMPAIRED, BUT WE WANT TO BE SURE THAT THE RECOMMENDED SURFACE WILL NOT IMPEDE THE MOBILITY OF OTHER USERS. WE'VE IDENTIFIED SEVEN SURFACES THAT HAVE BEEN EFFECTIVE IN PREVIOUS STUDIES, AND WE'D LIKE YOUR HELP IN EVALUATING THESE SURFACES SOME MORE.

THE PURPOSE OF TODAY'S TEST IS TO DETERMINE IF ANY OF THESE SURFACES WOULD IMPAIR YOUR MOBILITY. SEVEN DIFFERENT SURFACES HAVE BEEN INSTALLED IN THIS EXISTING SIDEWALK THAT RUNS FROM THIS PARKING LOT TO AZALEA AVENUE. WHEN WE BEGIN THE TEST, I'M GOING TO ASK YOU TO TRAVEL DOWN THE SIDEWALK IN YOUR NORMAL MANNER. AT EACH NEW SURFACE, I'D LIKE YOU TO STOP AND MAKE A SMALL RIGHT TURN. THIS WILL HELP US SEE IF YOU HAVE ANY DIFFICULTY MANEUVERING. I'M GOING TO THEN ASK YOU A FEW QUESTIONS ABOUT THE EASE OR DIFFICULTY OF MANEUVERING OVER THE SURFACE, AND HOW STABLE YOU FEEL. I'D ALSO LIKE TO KNOW IF THE PRESENCE OF THE SURFACE ON A CURB RAMP WOULD DISCOURAGE YOU FROM USING THAT ROUTE. THEN WE'LL CONTINUE TO THE NEXT SECTION. DO YOU HAVE ANY QUESTIONS? BEFORE WE BEGIN, I HAVE A FEW GENERAL QUESTIONS.

1) AGE:____________________ 2) CIRCLE ONE: M OR F

3) WHAT IS THE NATURE OF YOUR MOBILITY IMPAIRMENT?

___ Manual Wheelchair (1)
___ Motorized Wheelchair (2)
___ Walker (3)
___ Other (7)
_____ Crutches(4)
_____ Braces (5)
_____ Cane (6)

Comments or Details____

____

4) CAN YOU BRIEFLY DESCRIBE YOUR CURRENT TRAVELING BEHAVIOR? (i.e. travel alone, type of aid, frequency, duration, type of area - urban, suburban, rural, how often, how far)

____

____

____

SURFACE	STABLE[1]	MANEUVER[2]	
1. Black Concrete Raised Truncated Domes	1=Yes 2=No	5=VERY HARD 4=HARD 3=NEITHER HARD NOR EASY 2=EASY 1=VERY EASY	Please explain the nature of any difficulties: __________ Can you suggest any modifications to the surface that would eliminate your difficulties? __________ If this were on a ramp, how would your mobility be affected? __________ Anything else you'd like to say about this surface? __________
2. Exposed Aggregate (State Standard)	1=Yes 2=No	5=VERY HARD 4=HARD 3=NEITHER HARD NOR EASY 2=EASY 1=VERY EASY	Please explain the nature of any difficulties: __________ Can you suggest any modifications to the surface that would eliminate your difficulties? __________ If this were on a ramp, how would your mobility be affected? __________ Anything else to add about this surface? __________

1. DO YOU FEEL STABLE OR UNSTABLE ON THIS SURFACE?
2. PLEASE TELL US HOW EASY OR DIFFICULT IT WAS TO MANEUVER ON THIS SURFACE:

SURFACE	STABLE	MANEUVER	
3. Exposed Aggregate (Smaller gradation)	1=Yes 2=No	5=VERY HARD 4=HARD 3=NEITHER HARD NOR EASY 2=EASY 1=VERY EASY	Please explain the nature of any difficulties: _____ Can you suggest any modifications to the surface that would eliminate your difficulties? _____ If this were on a ramp, how would your mobility be affected? _____ Anything else you'd like to say about this surface? _____
4. Concrete Lateral Domes	1=Yes 2=No	5=VERY HARD 4=HARD 3=NEITHER HARD NOR EASY 2=EASY 1=VERY EASY	Please explain the nature of any difficulties: _____ Can you suggest any modifications to the surface that would eliminate your difficulties? _____ If this were on a ramp, how would your mobility be affected? _____ Anything else to add about this surface? _____

1. DO YOU FEEL STABLE OR UNSTABLE ON THIS SURFACE?
2. PLEASE TELL US HOW EASY OR DIFFICULT IT WAS TO MANEUVER ON THIS SURFACE:

SURFACE	STABLE	MANEUVER	
5. Red Paver Bricks	1=Yes 2=No	5=VERY HARD 4=HARD 3=NEITHER HARD NOR EASY 2=EASY 1=VERY EASY	Please explain the nature of any difficulties: ________ Can you suggest any modifications to the surface that would eliminate your difficulties? ________ If this were on a ramp, how would your mobility be affected? ________ Anything else you'd like to say about this surface? ________
6. Yellow Rubber Raised Truncated Domes	1=Yes 2=No	5=VERY HARD 4=HARD 3=NEITHER HARD NOR EASY 2=EASY 1=VERY EASY	Please explain the nature of any difficulties: ________ Can you suggest any modifications to the surface that would eliminate your difficulties? ________ If this were on a ramp, how would your mobility be affected? ________ Anything else to add about this surface? ________

1. DO YOU FEEL STABLE OR UNSTABLE ON THIS SURFACE
2. PLEASE TELL US HOW EASY OR DIFFICULT IT WAS TO MANEUVER ON THIS SURFACE:

SURFACE	STABLE	MANEUVER	
7.Yellow Composite Raised Truncated Domes	1=Yes 2=No	5=VERY HARD 4=HARD 3=NEITHER HARD NOR EASY 2=EASY 1=VERY EASY	Please explain the nature of any difficulties: Can you suggest any modifications to the surface that would eliminate your difficulties? If this were on a ramp, how would your mobility be affected? Anything else you'd like to say about this surface?

FINAL QUESTIONS:

OF ALL THE SURFACES THAT DID PRESENT SOME DIFFICULTY TO YOUR MOBILITY, ARE THERE ANY THAT YOU WOULD AVOID USING? WHY?

DURING YOUR NORMAL TRAVEL, HAVE YOU ENCOUNTERED ANY OF THE CURB RAMP SURFACES THAT ARE CURRENTLY BEING USED IN VIRGINIA SUCH AS A ROUGH STONE SURFACE CALLED EXPOSED AGGREGATE ____ Yes ____ No
OR A BUMPY SURFACE WITH SMALL DOMES? ____ Yes _____No

DID THESE SURFACES HAVE ANY EFFECT ON YOUR MOBILITY? IF SO, PLEASE DESCRIBE THE NATURE OF THIS EFFECT?

APPENDIX C: A SURVEY ON THE FIELD PERFORMANCE OF DETECTABLE WARNING SURFACES
(Version 1: Other States and Localities Outside Virginia

Hello, my name is ___________. I work at the Virginia Transportation Research Council in Charlottesville. We are conducting a study on the field performance of detectable warning surfaces for sidewalk curb ramps. We are calling a number of state and local governments, public works officials, and businesses regarding this study. Do you have a moment to talk with me about your knowledge of ramp surfaces? YES NO (circle one)

If **NO**, ask if you could call back at a more convenient time or if they know of someone else you could talk to about ramp surfaces and fill out the information below. Thank them.

If **YES**, *the survey, which will take about ten minutes, consists of three sections -- one on the types of surfaces your state is currently using; one section is on the maintenance history of the surfaces; and the final section is on public reaction to the surfaces. Can you help with any or all of these questions?* YES NO (circle one)

If **NO,** *are there others in your department who might be able to answer the other questions?*

Name____
Title____
Phone Number____

Name____
Title____
Phone Number____

If **YES**, continue.

This survey is part of an FHWA-sponsored study on detectable warning surfaces being conducted by the Research Council for the Virginia Department of Transportation (VDOT) in order to determine the most suitable surface to be used on curb ramps in the Commonwealth. Before beginning the questions, I'd like to assure you that the answers you provide will be confidential. The first few questions deal with the types of warning surfaces used on curb ramps in your state.

TURN THE PAGE.

-SURFACE INFORMATION-

1. *What types of detectable warning surfaces, if any, are installed most frequently on curb ramps in your state/city?* (i.e., raised truncated domes or Pathfinder tile, lateral domes, exposed aggregate, etc.)

1a. If a **GOVERNMENT UNIT**, *is this surface required in your state's official standards for curb ramps?* YES NO (circle one)

If **YES**, *how long has it been required?* ____ YEARS/MONTHS (circle one)

2. *What material(s) is the surface(s) made from?* (i.e., concrete, rubber, steel, etc.)

3. *Does the standard require that the surface(s) be colored?* YES NO (circle one)

3a. If **YES**, *what color(s)?*

3b. If **YES**, *is the color mixed into the material or applied to it after installation?*

____mixed in material ____ applied to it.

How?

TURN THE PAGE.

4. *What percentage of the ramps in your state/city have this surface(s)?* ____%

5. *How long has this particular surface(s) been used?*

_____ YEARS/MONTHS (circle one)

-MAINTENANCE OF SURFACE(S)-

This next set of questions has to do with the maintenance of the ramp surface(s).

6. *What kinds of routine maintenance, if any, does the surface(s) require?*

6a. *How often is this maintenance typically performed?*

____ times a year **OR** every ____ years **OR** ____ when necessary

7. *What specific comments have maintenance staff made about the surface(s)?*

8. *Would you say that the maintenance cost of the surface(s) is*

LOW MEDIUM HIGH (circle one)

TURN THE PAGE.

9. *Have there been any material failures that you are aware of?* (i.e., loosening of tiles, breakage, etc.) YES NO (circle one)

9a. If **YES**, *what were they?*

9b. If **YES**, *what was the cause?*

10. *Have there been any injuries or other problems due to the failure(s) that you are aware of?* YES NO (circle one)

If **YES**, *what were they?*

11. *Have ramp users mentioned any problems with the surface(s)?* (i.e., slipping, tripping, discomfort, etc.) YES NO (circle one)

If **YES**, *what were they?*

TURN THE PAGE.

-PUBLIC REACTION-

Thank you. I have just a couple more questions for you about the public reaction to this surface(s).

12. *What comments have you received about this surface(s) from:*

visually impaired people? (i.e., people who are blind or partially sighted)

mobility impaired people? (i.e., people in wheelchairs, cane users, etc.)

other ramp users? (i.e., pedestrians, joggers, people with baby strollers, etc.)

13. *Do you have any other comments or information on the surface(s) that might help us?*

TURN THE PAGE.

Thank you for helping with this survey. Are you interested in receiving a copy of the results of this survey and/or a copy of the report when it is completed?

Survey Results? YES NO (circle one)

Final Report? YES NO (circle one)

If **YES** to either, *we anticipate these reports being completed in early fall* Ask for the following information.

Name____

Title____

Organization____

Address____

—

City__________________________ State_________________ Zip_____________

We'll send you the document(s) you requested when it(they) is(are) completed. Thanks again for your assistance.

A SURVEY ON THE FIELD PERFORMANCE OF DETECTABLE WARNING SURFACES
(Version 2: VDOT Residencies)

Hello, my name is ____________. I work at the Virginia Transportation Research Council in Charlottesville. We are conducting a study on the field performance of detectable warning surfaces for sidewalk curb ramps. We are calling a number of residencies throughout the state regarding this study. Do you have a moment to talk with me about your knowledge of ramp surfaces? YES NO (circle one)

If **NO**, ask if you could call back at a more convenient time or if they know of someone else you could talk to about ramp surfaces and fill out the information below. Thank them.

If **YES**, *the survey, which will take about ten minutes, consists of two sections -- one on the maintenance history of the surface and one on public reaction to the surface. Can you help with any or all of these questions?* YES NO (circle one)

If **NO,** *are there others who might be able to answer the other questions?*

Name____
Title____
Phone Number____

Name____
Title____
Phone Number____

If **YES**, continue.

This survey is part of an FHWA-sponsored study on detectable warning surfaces being conducted by the Research Council for the Virginia Department of Transportation (VDOT) in order to determine the most suitable surface to be used on curb ramps in the Commonwealth. We are interested in your experience with the exposed aggregate surfaces currently mandated by VDOT. The first set of questions has to do with the maintenance of these surfaces.

TURN THE PAGE.

-MAINTENANCE OF SURFACE(S)-

1. *What kinds of routine maintenance, if any, does the surface require?*

1a. *How often is this maintenance typically performed?*

____ times a year **OR** every ____ years **OR** ____ when necessary

2. *What specific comments have maintenance staff made about the surface?*

3. *Would you say that the maintenance cost of the surface is*

LOW MEDIUM HIGH (circle one)

4. *Have there been any material failures that you are aware of?* (i.e., loosening of tiles, breakage, etc.) YES NO (circle one)

4a. If **YES**, *what were they?*

TURN THE PAGE.

4b. If **YES**, *what was the cause?*

5. *Have there been any injuries or other problems due to the failure(s) that you are aware of?* YES NO (circle one)

   If **YES**, *what were they?*

6. *Have ramp users mentioned any problems with the surface?* (i.e., slipping, tripping, discomfort, etc.) YES NO (circle one)

   If **YES**, *what were they?*

TURN THE PAGE.

-PUBLIC REACTION-

The last few questions are about the public reaction to this surface.

7. *What comments have you received about this surface from:*

visually impaired people? (i.e., people who are blind or partially sighted)

mobility impaired people? (i.e., people in wheelchairs, cane users, etc.)

other ramp users? (i.e., pedestrians, joggers, people with baby strollers, etc.)

8. *Do you have any other comments or information on the surface that might help us?*

TURN THE PAGE.

Thank you for helping with this survey. Are you interested in receiving a copy of the results of this survey and/or a copy of the report when it is completed?

Survey Results? YES NO (circle one)

Final Report? YES NO (circle one)

If **YES** to either, *we anticipate these reports being completed in early fall* Ask for the following information.

Name____

Title____

Organization____

Address____

City_____________________ State______________ Zip_________

We'll send you the document(s) you requested when it (they) is (are) completed. Thanks again for your assistance.