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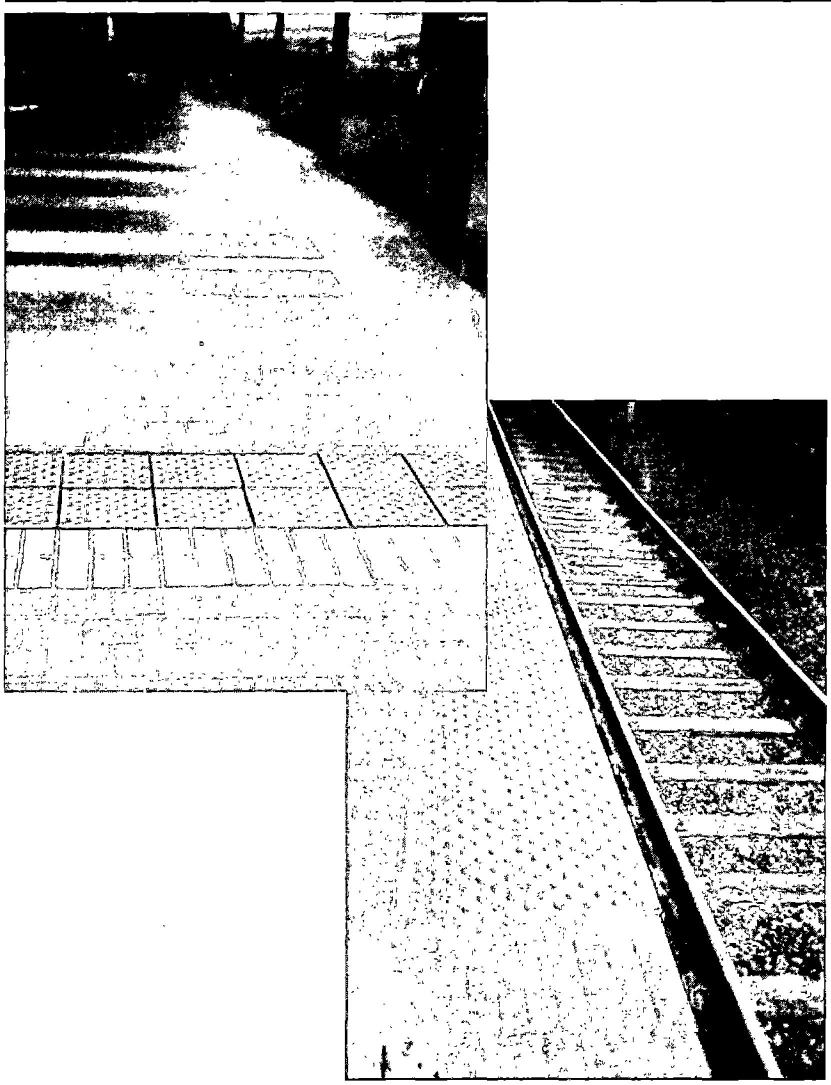
U.S. Department of Transportation
Federal Transit Administration

Detectable Warnings: Testing and Performance Evaluation at Transit Systems



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13. ABSTRACT (Maximum 200 words)

A detectable warning is a standardized surface feature, comprised of closely spaced surface projections (truncated domes), built in or applied to walking surfaces to warn visually impaired individuals of hazards. U.S. DOT regulations, under the Americans With Disabilities Act (ADA), require that transit systems place detectable warnings at key transit stations.

This report presents the results of a comprehensive testing and performance evaluation program for detectable warning materials placed along the edges of a transit station platform. The report is intended to provide information and guidance to rail transit systems to assist them in the selection and installation of detectable warning systems.

The scope of the test and evaluation program included the laboratory testing of 18 detectable warning materials and the subsequent installation of 8 of those materials at indoor and outdoor transit stations in Boston, Cleveland, and Philadelphia. The program evaluated--after 7 months of exposure to weather and passenger traffic--the engineering performance characteristics of the materials with regard to wear, durability, adhesion/bonding to the platform surface, and appearance. A performance assessment of all 8 detectable warning materials and their installation is provided.

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PREFACE

Rail transit systems are required under ADA to place detectable warnings along the edges of transit station platforms as a means of alerting individuals who are blind or who have limited vision of the drop-off hazard. The application of detectable warning materials to existing transit station platform surfaces is a matter of substantial concern to transit system personnel responsible for selection and installation of such materials. This report, one of a series on detectable warnings, sponsored by the Federal Transit Administration, provides engineering information and guidance to rail transit systems and other interested parties on the performance of eight different materials that have been field tested at three transit systems.

This report was prepared by Technology & Management Systems, Inc., of Burlington, Massachusetts. The authors, H. Norman Ketola and David Chia, want to acknowledge the contributions that made this report possible. The FTA's Office of Technical Assistance and Safety sponsored the detectable warnings research with Lawrence L. Schulman, Associate Administrator for Technical Assistance and Safety; Vincent R. DeMarco, Director of the Office of Engineering Evaluations; Ronald D. Kangas, Director, Rail Division; and Irving Chambers, Project Manager, who provided direction and guidance. The project was conducted under a task order contract with the Safety and Security Systems Division of the Volpe National Transportation Systems Center. The authors wish to acknowledge the extensive efforts and contributions of the following individuals at the Volpe Center: William T. Hathaway, Project Supervisor; Patricia H. Ryan, Project Manager/Contract Monitor; and Robert A. Rudich, Senior Engineer.

The project would not have been possible without the full cooperation of the eighteen detectable warning material manufacturers who provided sample materials for laboratory testing and the eight manufacturers who installed their materials for field testing. These manufacturers are identified by name and contact person within the body of the report. The authors also gratefully acknowledge the full cooperation of the Massachusetts Bay Transportation Authority (MBTA), the Greater Cleveland Regional Transit Authority (GCRTA), and the Southeastern Pennsylvania Transportation Authority (SEPTA) in providing test sites and support services for the field testing of detectable warning materials. In particular, we would like to acknowledge the following individuals from the transit systems who provided leadership on the field test activities and who also participated in the meetings of the National Implementation Panel on Detectable Warnings: William H. Bregoli, Chief Engineer, MBTA; John P. Goodworth, Director of Passenger Facilities Programs, GCRTA; and Carol H. Lavoritano, Assistant General Manager, Program Analysis, SEPTA.

Robert W. Stout, Director, Office of Regional Operations and Ramon H. Lopez, Senior Engineer, Office of Grants Management, both of the FTA, also contributed their expertise to the National Implementation Panel.

Finally, the authors would like to thank Tamara L. DeGray for her contributions and effort in the preparation of this report.

METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in) = 2.5 centimeters (cm)
1 foot (ft) = 30 centimeters (cm)
1 yard (yd) = 0.9 meter (m)
1 mile (mi) = 1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2 = 6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2 = 0.09 square meter (m$_2$)
1 square yard (sq yd, yd^2) = 0.8 square meter (m^2)
1 square mile (sq mi, mi^2) = 2.6 square kilometers (km^2)
1 acre = 0.4 hectares (he) = 4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz) = 28 grams (gr)
1 pound (lb) = .45 kilogram (kg)
1 short ton = 2,000 pounds (lb) = 0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp) = 5 milliliters (ml)
1 tablespoon (tbsp) = 15 milliliters (ml)
1 fluid ounce (fl oz) = 30 milliliters (ml)
1 cup (c) = 0.24 liter (l)
1 pint (pt) = 0.47 liter (l)
1 quart (qt) = 0.96 liter (l)
1 gallon (gal) = 3.8 liters (l)
1 cubic foot (cu ft, ft^3) = 0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3) = 0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x-32)(5/9)] °F = y °C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm) = 0.04 inch (in)
1 centimeter (cm) = 0.4 inch (in)
1 meter (m) = 3.3 feet (ft)
1 meter (m) = 1.1 yards (yd)
1 kilometer (km) = 0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2) = 0.16 square inch (sq in, in^2)
1 square meter (m^2) = 1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2) = 0.4 square mile (sq mi, mi^2)
1 hectare (he) = 10,000 square meters (m^2) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gr) = 0.036 ounce (oz)
1 kilogram (kg) = 2.2 pounds (lb)
1 tonne (t) = 1,000 kilograms (kg) = 1.1 short tons

VOLUME (APPROXIMATE)

1 milliliters (ml) = 0.03 fluid ounce (fl oz)
1 liter (l) = 2.1 pints (pt)
1 liter (l) = 1.06 quarts (qt)
1 liter (l) = 0.26 gallon (gal)
1 cubic meter (m^3) = 36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3) = 1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

[(9/5) y + 32] °C = x °F

QUICK INCH-CENTIMETER LENGTH CONVERSION

INCHES	0		1			2			3		4			5		6			7			8		9		10
CENTIMETERS	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25 25.40

QUICK FAHRENHEIT-CELSIUS TEMPERATURE CONVERSION

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and or other conversion factors, see NBS Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50. SD Catalog No. C13 10286.

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1. INTRODUCTION

The Americans with Disabilities Act (ADA) of 1990 requires that all transportation facilities and vehicles be accessible to persons with disabilities. The U.S. Department of Transportation (U.S. DOT) has issued regulations covering transportation facility accessibility, which include a requirement that detectable warnings must be installed along the edges of transit station platforms to alert individuals who are blind or who have limited vision of the drop-off hazard. This requirement is applicable to all new transit stations and to certain existing stations that have been designated as "key stations."

A detectable warning is defined as a standardized surface feature built in or applied to walking surfaces or other elements to warn individuals with visual impairments of hazards along their path of travel. Persons with little or no usable vision rely on tactile, sound, and resilience contrasts to detect hazards. Persons with some vision rely on visual contrasts to detect hazards. For the transit station application, the detectable warning is a 24-inch wide strip running the full length of each platform edge. The standardized surface incorporates closely-spaced small projections or bumps, known as truncated domes.

1.1 PURPOSE AND SCOPE

The transit industry has expressed its concerns to U.S. DOT regarding potential problems with detectable warning materials, particularly, when they are applied to existing transit platform surfaces. These concerns include the potential loss of adhesion between the material and the platform surface, the basic durability and wear characteristics of the materials, and the maintainability (i.e., cleaning and snow and ice removal) of the installation.

This report is intended to provide information and guidance to rail transit systems based upon the results of a comprehensive performance test and evaluation of detectable warning materials. The scope of the testing and evaluation program included:

- Laboratory testing of eighteen detectable warning materials.

- In-service performance evaluation of eight detectable warning material installations at six transit stations located at three transit systems (MBTA in Boston, GCRTA in Cleveland, and SEPTA in Philadelphia).

The focus of the testing and evaluation program was on engineering performance characteristics of the materials and the durability of the field installations on transit station platforms.

The data and results from both the laboratory tests and approximately seven months of weather exposure and foot traffic are presented in this report, including material performance in:

- Adhesion/bonding to platform surface.
- Chipping or cracking.
- Changes in appearance (color).
- Slip resistance.
- Wear resistance.

The report also includes a summary of the findings of a National Implementation Panel for Detectable Warnings. The Panel was formed to provide guidance on the engineering testing and evaluation efforts and to provide a means of gathering and disseminating information about the process of selecting, installing, and maintaining detectable warning materials. Panel members were drawn from rail transit systems, individuals with disabilities who use rail transit, and disability advocates.

The FTA has also sponsored a number of human factors research projects conducted by Boston College related to detectable warnings. The results of these projects, which are presented in References 1 and 2, include:

- Under-foot detectability of thirteen different warning surfaces in a simulated transit platform setting.
- Negotiability (ease/difficulty of maneuvering) on nine different detectable warning surfaces placed on a ramp with a slope of 1:12.
- Detection of visual contrast by persons having very low vision.

1.2 ADA REGULATORY REQUIREMENTS

This subsection is intended to provide some background information on the evaluation of the regulatory requirements for detectable warnings in transit systems. There have been a number of changes in the regulatory requirements for detectable warnings since the Americans with Disabilities Act (ADA) was signed into law on July 26, 1990.

The ADA requires that the Architectural and Transportation Barriers Compliance Board (Access Board) issue guidelines to ensure that buildings, facilities, and vehicles covered by the law are accessible to individuals with disabilities, in terms of architecture and design, transportation, and communication. Regulations issued by the U.S. Department of Transportation (U.S. DOT) must be consistent with the Access Board's guidelines. The Access Board issued the Americans with Disabilities Act Accessibility Guidelines (ADAAG) for buildings and facilities on July 26, 1991; and amended it on September 6, 1991, to include additional requirements for transportation facilities. U.S. DOT has adopted ADAAG as the accessibility standard for new construction and alteration of transportation facilities by public entities covered by Title II of the ADA and for transportation vehicles covered by Titles II and III.

On November 17, 1992, the U.S. DOT published a Notice of Proposed Rulemaking (NPRM) in the *Federal Register* to amend its rules, implementing the ADA. The NPRM stressed U.S. DOT's concerns about how best to retrofit existing station platforms with detectable warning materials. One modification proposed extending the compliance date by eighteen months (from July 26, 1993 to January 26, 1995) for the requirement to install detectable warnings in existing key stations. DOT reasoned, in the NPRM, that rail operators may need additional time to resolve issues of adhesion, durability, and maintainability of detectable warning materials in the context of key station modifications. The NPRM also noted that the Federal Transit Administration (FTA) would pursue additional research and evaluation concerning the durability and detectability of tactile warnings during the extension period that may help rail operators in their efforts to solve the retrofit application problem. This report represents one element of the FTA's efforts to provide additional information.

On November 30, 1993, U.S. DOT issued a Final Rule, amending the completion date for the installation of detectable warnings in key stations to July 26, 1994. The U.S. DOT response in the rule stated that the twelve-month extension, compared to the eighteen-month extension proposed in the NPRM, would give transit properties sufficient time to work out installation and related problems without unduly delaying the addition of this important safety feature.

In addition to the FTA research efforts, the Access Board is conducting a research project on the need for and effectiveness of detectable warnings on curb ramps and on walkways that adjoin a vehicle area where there are no curbs. The research project includes post-construction evaluations at thirty sites involving curb ramps and hazardous vehicle areas which have detectable warnings as required by ADAAG, and at thirty other sites that were constructed without detectable warnings.

The Access Board's detectable warning research project also contains an optional Phase II which includes testing the usability, detectability, and wearability of detectable warnings in the curb ramp application; developing draft recommendations for technical and scoping changes for detectable warnings in the ADAAG; and developing a composite technical report and technical article.

On April 12, 1994, the Access Board published a joint final rule with the Department of Justice and U.S. DOT to suspend temporarily — until July 26, 1996 — requirements for detectable warnings at curb ramps, hazardous vehicular areas, and reflecting pools. This action does not affect the ADAAG requirement for detectable warnings at transit platforms, which remains in effect.

The dimensions of the standardized detectable warning surface have been specified by the Access Board in the ADAAG (at 4.29.2). These consist of a standardized surface that incorporates small truncated domes at closely spaced intervals (see Figure 1-1). The requirements for detectable warnings in transportation facilities were published in Section 10 of the ADAAG. The Access Board required platform edges bordering a drop-off and not protected by platform screens or guard rails to have a detectable warning 24-inches wide running the full length of the platform drop-off in new construction, "key stations" (i.e., existing facilities meeting U.S. DOT criteria), and intercity rail stations.

The Access Board issued "Bulletin #1: Detectable Warnings" in May, 1992, to provide technical guidance to manufacturers and purchasers of detectable warning materials. A revised version of Bulletin #1 was issued in April, 1994 *(Reference 3)*. The dimensions shown in Figure 1-1 are based on diagrams presented in Bulletin #1.

1.3 TECHNICAL APPROACH

The comments submitted by the industry in response to the rulemaking process indicated that operators of rail transit systems were seeking technical information to answer the following questions:

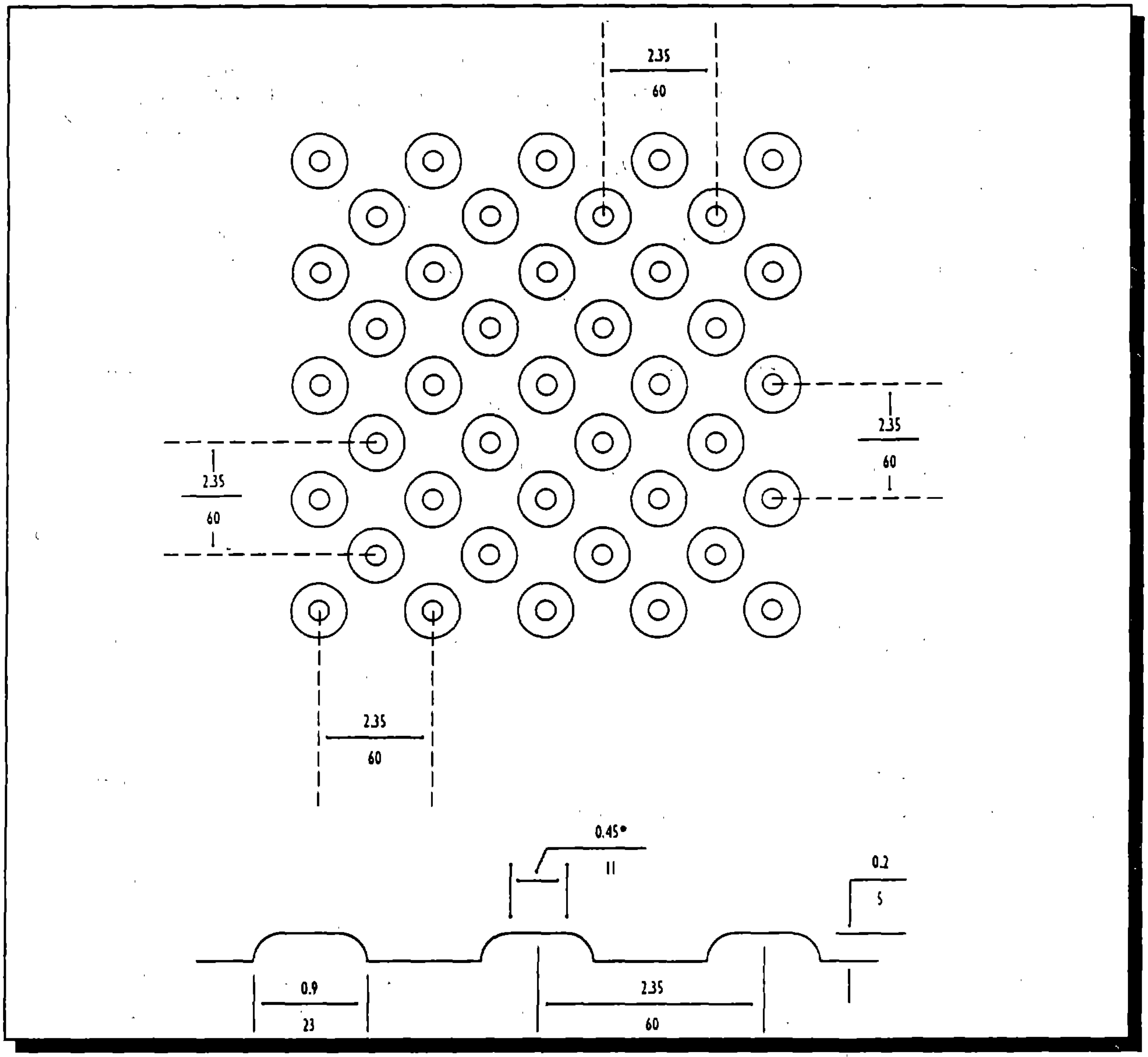
- What problems can be expected if a detectable warning material is installed on top of platforms made of concrete, asphalt, or wood?

- Which materials are most slip-resistant under all potential weather and wetness conditions?

- Which material installations are the most durable in terms of retaining their original characteristics and physical configuration (particularly no lift-off or separation of edges) after extensive use and weather exposure?

- Which materials can be mechanically fastened to provide additional protection against lift-off or separation?

- Which materials are most resistant to the effects of cleaning and maintenance, particularly, snow removal?



* This dimension is shown as "varies per manufacturer" in Access Board Bulletin #1: Detectable Warnings.

Figure 1-1
Detectable Warning Dimensions
(dimensions shown: inches/millimeters)

It was anticipated that the answers to these general technical questions would assist transit systems in selecting materials which best fit their system needs. Furthermore, it was expected that no single material/method of installation would prove to be superior in all respects for all situations. For this reason, it was decided that engineering and field test results would be presented in the form of a comparative evaluation of the performance of all detectable warning materials that were selected for testing and evaluation. Individual transit systems could then use the information from the program, along with their own test results on detectable warning materials, to decide the most suitable for their needs.

There were a number of issues and considerations that had to be factored into the technical approach for the testing and evaluation program. These issues and considerations included: the wide variety of products, indoor and outdoor station requirements, and retrofitting platforms.

Number of Manufacturers, Product Options, and Updates. There are a large number of detectable warning manufacturers, with some offering two different types of materials such as coated metal and polymer composites. In addition, many manufacturers follow a product improvement cycle in which they are regularly making changes in the chemical formulation of the base products, or in the coatings, adhesives, or the mechanical design of the product.

Indoor vs. Outdoor Stations. The requirements for detectable warning material installation at an indoor station are considerably different than those of an outdoor station. For example, the ADAAG requires that interior applications provide a contrast in resilience or in sound when sensed by a cane compared to the adjoining walking surface. With interior stations there are also more concerns with regard to fire resistance of the material and the presence of any volatile organic compounds (VOCs) during the installation process. Outdoor installations have to be more resistant to weather exposure (snow, ice, and sun) and the effects of maintenance (snowplowing and deicing chemicals).

Transit Station Platform Construction. The retrofit of detectable warning materials onto existing platforms is affected by the underlying material surface. Many transit systems have a variety of station construction designs, where the detectable warning material must be placed onto a base surface such as concrete, asphalt, ceramic tile, or wood.

The effect of the factors noted above required that the test program be structured in a manner that narrowed the number of combinations of materials/installations/stations to be field tested in an operating transit environment. To ensure that outcome, the following approach was used.

- Each manufacturer participating in the demonstration program was allowed to submit one material for testing: the one it believed to be best for the outdoor application. An outdoor installation provides a more rigorous environment to test the performance of the materials with regard to adhesion, durability, and wear.

- The detectable warning materials submitted by participating manufacturers were first subjected to laboratory testing by an independent laboratory. The laboratory tests were used to measure mechanical properties and durability characteristics using standardized (American Society for Testing and Materials - ASTM) test protocols.

- The materials that exhibited better performance in the laboratory tests were selected as candidates for installation at transit stations for the field test portion of the demonstration program. No changes in the type or composition/installation characteristics by the manufacturers were allowed between the laboratory tests and the field test.

- Field tests were conducted at both indoor stations and outdoor stations to demonstrate a full range of environmental and passenger use impact on the selected materials. All installations were made on existing concrete platforms or passageways, with the exception of one interior installation on an existing paver tile surface.

The technical approach to data collection during the installation and field testing was designed to provide information on of the following issues and performance characteristics:

- **Retrofit installation.** Requirements of time, level of effort, special tools/equipment, and assessment of skills to install detectable warning materials at an existing transit platform edge.

- **Installation integrity over time.** An evaluation of any lift-off or separation of the materials from the substrate, fractured or chipped domes, cracked or broken tiles, loosened or missing mechanical fasteners, buckling or rolling of surface, or evidence or water penetration under the surface.

- **Durability.** Wear measurements determined by the change in average dome height after a uniform time period and changes in the appearance (color) of the surface after exposure.

- **Weather-related performance.** Changes in the material or installation attributable to weather conditions such as freeze-thaw, exposure to sun, or use of salt or other deicing agents.

- **Maintenance-related performance.** Effect of cleaning agents/techniques on surface color or staining, evidence of gum remnants or cigarette burns, and effect of snow and ice removal.

2. LABORATORY TESTING OF DETECTABLE WARNING MATERIALS

This section provides a description of the process used to identify detectable warning manufacturers, the laboratory testing that was conducted on sample materials submitted by participating manufacturers, an examination of test results, and the selection of materials for field test installation at transit station platforms.

2.1 DETECTABLE WARNING MANUFACTURER PARTICIPATION

The following procedure was used to identify detectable warning manufacturers and solicit their participation in the program.

- Letters were sent to twenty detectable warning manufacturers identified by the Access Board in Bulletin #1 *(Reference 3)* and those additional manufacturers that responded to a notice placed in the *Commerce Business Daily* (April 5, 1993) by the Volpe Center. Out of the twenty manufacturers, one did not respond, and another responded but declined to participate.

- Manufacturers that responded to the initial letter were requested to send twenty sample pieces of their product to an independent laboratory for testing. Eight of the sample pieces were to be bonded to a concrete substrate.

- A total of fourteen manufacturers responded to the request and submitted samples. The manufacturers are identified in Table 2-1. In addition, Table 2-1 contains the names of an additional four manufacturers that had indicated an interest in participating in the FTA program, but whose materials were already being tested by the same independent laboratory under a program sponsored by the New York MTA's Metro-North Commuter Railroad (MNCR). Since the same tests were being conducted, the test results for these four additional materials were also considered (under a cooperative agreement with the MNCR) as potential candidates for the FTA field test program.

Appendix A provides detailed information on each of the eighteen detectable warning materials identified in Table 2-1 including the name and telephone number of the manufacturer, the type of material and dimensions, and typical fastening methods.

Table 2-1

Manufacturers Participating in Laboratory Testing Program

MANUFACTURER	TRADE NAME	MATERIAL DESCRIPTION
A. Materials Tested Under FTA Program		
ADA Consultants	*Alert Mat*	Blended rubber compounds
Advantage Metal Systems	*Detectable Warning Systems*	Polymer coated steel or aluminum
Bridgco	*ADA Path*	Polymer concrete
COTE-L Enterprises	*Safti-Trax*	Polyurethane domes with "Durabak" polyurethane coating
Crossville Ceramics	*Tac-tile*	Unglazed ceramic tile
Dal-Tile Corp.	*Detectable Warning Tile*	Unglazed porcelain tile
Hastings Pavement Co.	*ADA Pavers*	Pre-cast clay or shale bricks
Inco Chemical Supply Co.	*Tactile Warning System*	Polymer concrete
NBS/Aware & Concerned Services	*Detectable Warning Mat*	Rubber mat
Rehau, Inc.	*Access Tactile Tile*	Thermoplastic polyurethane
Steps Plus, Inc.	*Detectable Warning Units*	Pre-cast concrete
Summitville Tile	*Tactile-Tread*	Glazed porcelain tile
Transpo Industries	*Step-Safe*	Polymer concrete
Whitacre-Greer	*Paver*	Slate bricks
B. Materials Tested Under the MNCR Program		
Carsonite International	*Pathfinder*	Fiber reinforced polymer composite
Engineered Plastics	*Armor-Tile*	Vitrified polymer composite
High Quality Tactile Systems	*Tac Strip*	Polymer composite
Strongwall Systems	*Strongwarn*	Two-component polymer concrete

2.2 LABORATORY TESTING PROTOCOL AND RESULTS

A brief summary of the laboratory testing program procedures and results are presented here. (For the complete description see *Reference 4*.) The following laboratory test protocol was adapted based on consultation with the testing laboratory. Whenever possible, the laboratory test procedure was selected from the applicable American Society for Testing and Materials (ASTM) standard test methods.

	LABORATORY TEST PROTOCOL FOR DETECTABLE WARNING MATERIALS
1.	Water Soaking Screening (Non-ASTM) *(initial soaking of samples in a water bath for 55 hours)*
2.	Adhesion/Bond Strength - ASTM C 482 (Dry and Wet) *(applicable to bonded material samples)*
3.	High Pressure Hot Water Resistance (Non-ASTM) *(representative of heavy duty surface cleaning procedure)*
4.	Wear Resistance - ASTM D 658 (Sandblasting)
5.	Slip Resistance - ASTM C 1028 (Dry and Wet) *(to include recessed areas between truncated domes when applicable)*
6.	Impact Resistance - ASTM D 3029 (Cold and Hot)

The general procedure was to conduct each test on all of the materials following the protocol shown above. If a material or bonded sample performed very poorly in the water soaking screening or adhesion/bond strength tests, it was excluded from the balance of the test protocol. The results of the laboratory testing are summarized below.

- The **water soaking screening tests** (non-ASTM) were performed on all materials submitted. After soaking in water for fifty-five hours, materials that were bonded to a substrate were put through the wet strength portion of the **adhesion/bond strength tests** (ASTM). The bond strength test is a wedge test whereby a wedge or "knife edge" is forced in between the material and the substrate and a measurement is made of the force required to cause a failure in the bond. Four of the fourteen materials tested under the FTA program (and one under the MNCR Program) completely failed the wet adhesion/bond strength test; i.e., the detectable warning material separated from the substrate with zero force applied (peeled off easily by hand). These four materials were screened out from further testing. Three additional materials were found to have poor adhesion/bond strength; however, other laboratory tests were conducted to confirm the testing laboratory's assessment of material quality.

Four materials that were bonded by adhesive to a substrate provided good test results with wet adhesion/bond strength ranging from 200 to 1,250 pounds of force. An adhesion/bond strength test was not conducted on four other materials which were mechanically bonded and on two others submitted as unbonded samples.

- The **high pressure hot water tests** demonstrated very little variation in product performance for the materials tested. These tests essentially confirmed the earlier results that were found in the water soaking screening and adhesion/bond resistance tests.

- The **wear resistance tests** showed a wide variety in performance of the various detectable warning materials. The wear created by the sandblast (as measured by the depth of the hole created) ranged from zero to nearly one inch after thirty seconds of blasting. Most materials were in the 0.1 inch to 0.2 inch depth range after thirty seconds.

- The **slip resistance tests** showed that all of the materials were slip resistant and none of them had a coefficient of friction (COF) less than 0.6. This is the minimum value recommended by the Access Board. The range of COF values in dry conditions ranged from a low of 0.81 to a high of 1.14. In wet conditions, the range was 0.66 to 1.03.

- The **impact resistance tests** were conducted under room temperature, hot, and cold conditions. These tests also demonstrated a wide range of material performance. In general, rubber-based and polymer composite materials performed quite well, and the more rigid products (cementitious and ceramic tile), as one might expect, performed poorly. Eight of the products tested were found to be reasonably impact-resistant under all temperature conditions.

It should be noted that the materials tested under the MNCR Program were subjected to a more extensive set of laboratory tests. These additional tests included the Flame Spread Index Test (ASTM E 84), which measures flammability and smoke emission parameters. All of the polymer composite materials tested under the MNCR Program (Carsonite International's Pathfinder, Engineered Plastic's Armor-Tile, and High Quality Tactile Systems' Tac Strip) were subjected to this test. The detailed results from these fire tests, and all other tests conducted, are presented in *Reference 5*. With regard to the ASTM E 84 test, all of the materials tested exhibited fire resistance characteristics which were quite favorable.

2.3 SELECTION OF MATERIALS FOR FIELD TESTING

A total of ten detectable warning material products were selected for field testing, as shown in Table 2-2. These ten materials were selected on the basis of their relative performance in each of the laboratory tests. All materials that were tested in the slip resistance and high pressure hot water tests effectively passed each test, i.e., the COF was above the minimum value and the materials were not affected by the water. Therefore, the materials selection was based on the results from the water soaking screening, adhesion/bond strength, wear resistance, and impact resistance.

The ten selected manufacturers were invited to participate in the field testing program. The invitation included a request that the materials be installed at each of the three transit systems (Boston, Cleveland, and Philadelphia) that had been selected as demonstration test sites. Two of the ten manufacturers, as indicated in Table 2-2, declined the request for field testing of their products.

Table 2-2

Detectable Warning Materials Selected for Field Test

MANUFACTURER	TRADE NAME
ADA Consultants	Alert Mat
Bridgco*	ADA Path
Carsonite International	Pathfinder
Crossville Ceramics	Tac-Tile
Engineered Plastics	Armor-Tile
Hastings Pavement	ADA Pavers
High Quality Tactile Systems*	Tac Strip
Rehau	Access Tactile Tile
Summitville Tile	Tactile-Tread
Transpo Industries	Step-Safe

* These two manufacturers declined the invitation to participate in the field test portion of the program.

3. FIELD TEST INSTALLATIONS AND PERFORMANCE RESULTS

This section of the report describes the field test portion of the program including: a discussion of the purpose of the field testing and the types of information that were collected; the selection of the test sites; the activities conducted to coordinate and oversee the installation of the detectable warning material at the test sites; and performance results from the test installations, presented for each test site and for each installed material.

3.1 FIELD TEST INSTALLATIONS

The primary goal of the field testing was to document the performance of the selected detectable warning materials when subjected to the rigors of revenue transit service. A secondary goal of the field testing was to observe and document the installation procedures of these materials in a retrofit application.

The initial activities of the field testing involved the installation of the detectable warning materials at the transit system test sites. At each system there was an indoor site and an outdoor site. Each installation was monitored and information recorded through written notes, photographs, and videotapes. Data was collected on many subjects: the skill, effort, and tools required for installation; the versatility of the materials under various conditions; and the appropriateness of the materials for retrofit.

The three indoor installation sites were not located along transit platform edges; rather, the sites were located within their respective stations in corridors that had high pedestrian traffic. The intent of these placements was to expose the materials installed indoors to "accelerated" wear in comparison to the wear that they would undergo if installed along a platform edge. This helped to compensate for the compressed time frame of the field testing.

Of the three outdoor installation sites, two were along rapid rail platform edges and one was adjacent to a commuter rail platform edge. The materials installed at these sites were also exposed to pedestrian traffic. The primary purpose for the outdoor installations, however, was to expose the materials to the effects of weather (particularly winter conditions) and the winter maintenance practices of the transit systems, e.g., snow and ice removal.

3.1.1 <u>Selection of Installation Sites</u>

Selection of the transit systems was based on the following criteria:

- Rail stations, both indoor and outdoor, where test materials could be installed, were available to the transit systems.

- The availability of the rail stations fit within the time frame of the project.
- The transit system was located in an area with snowy and icy winters.
- The transit system was able to provide some technical and administrative support in arranging and monitoring the installations.
- The transit system allowed cutting and removal of concrete substrate from platform edges and interior corridors to accommodate the placement of detectable warning materials.

After reviewing the criteria with several transit systems, the MBTA (Boston), GCRTA (Cleveland), and SEPTA (Philadelphia) were selected. These transit systems met the criteria and also expressed their interest in acting as hosts for the field tests and in using the findings of the demonstration and evaluation program to help them choose detectable warning materials for their rail stations.

3.1.2 Preparation for Installation Activities

Once the MBTA, GCRTA, and SEPTA agreed to host the field tests, it was necessary to work closely with staff from each of the systems to select the stations where the installations would take place and to set up procedures for scheduling individual installations.

The installation sites at the indoor stations had to meet these criteria:

- High pedestrian traffic.
- Surface that could be cut to a depth of, at least, three inches.[1]
- Once installed, the materials would not disrupt passenger flow or confuse individuals with vision impairments.

The three outdoor installation sites had to meet these criteria:

- Direct exposure to precipitation.
- Surface that could be cut to a depth of, at least, two inches.[2]
- Once installed, the materials would not pose a safety hazard to passengers or confuse individuals with vision impairments.

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(1) The depth of surface cut at the indoor locations was based on the need to accommodate a thick material (approximately 2 inches).

(2) The depth of cut at the outdoor locations was based on the need to avoid cutting of platform edge structural reinforcements.

In addition, the host transit systems had their own considerations in the selection of the installation sites. For example, all three systems chose outdoor sites at stations that were scheduled to have major renovations within the next few years. Table 3-1 lists the six installation sites for the field tests.

Table 3-2 provides information about each station's passenger traffic, exposure to the environment, and transit system maintenance.

The operations, facilities, and engineering divisions of the host systems were involved to make sure that electric power and water needed by the installers would be available at the installation sites. It was also necessary to determine the times and days when installation could take place and provide any special arrangements that were necessary for an installation (e.g., flaggers for work along a track). Table 3-3 lists installation size, the times and days available for installation, and special conditions for installation of the detectable warning materials.

Coordination of the test installations with the manufacturers began immediately after their products were selected for the field tests. The dates for each installation were arranged to meet the schedules of both the manufacturer and the transit system. In addition, some of the installations involved a fourth party: manufacturers that did not have in-house staff to install their material had to hire a local contractor to perform the work.

In advance of the installations, manufacturers were provided information, including a station specification page, on each of the installation sites. Figure 3-1 presents a sample specification page. Each manufacturer that installed its material at the MBTA's Orient Heights station received this specification page.

3.1.3 Installation

Each test installation of the manufacturers' detectable warning materials was monitored by the project staff. Monitoring responsibilities included the recording of information and observations about the installation on a data collection form. The information collected included:

- Weather conditions (for outside installation).
- Installation size and location.
- Installation crew size and tools used.
- Installation steps.

Appendix B presents the data collection form used at installations. In addition, photographs and videos were taken of each installation.

Table 3-1

Field Test Installation Sites

SYSTEM	STATION (LINE)	LOCATION WITHIN STATION
Outdoor		
MBTA	Orient Heights *(Rapid Transit - Blue Line)*	Outbound Platform Edge
GCRTA	Triskett Street *(Rapid Transit - Red Line)*	Outbound and Inbound Platform Edges
SEPTA	Bethayres *(R3 Commuter Rail)*	At Top of Steps Between Platforms and Station
Indoor		
MBTA	South Station *(Rapid Transit - Red Line)*	Pedestrian Corridor on Mezzanine Level
GCRTA	Brookpark *(Rapid Transit - Red Line)*	Pedestrian Corridor Leading to Platforms
SEPTA	8th Street *(Rapid Transit - Blue Line)*	Pedestrian Overpass Connecting Eastbound and Westbound Platforms

Table 3-2

Station Environment

STATION *(SYSTEM)*	AVG. WEEKDAY RIDERSHIP	PLATFORM MAINTENANCE PRACTICES	WEATHER CONDITIONS	OTHER NOTES
Outdoor				
Orient Heights *(MBTA)*	4,177	♦ Wet mopped 2 to 3 times each week ♦ Scraped monthly (to remove gum, etc.) ♦ Annual power washing	♦ Platforms are partially covered ♦ Snow, rain, ice, salt water spray ♦ Snow and ice removal by shovels and chippers; sand applied ♦ Temperature range of 0° to 105°F	Station scheduled for major renovation in Fall 1995 — including new platforms
Triskett Street *(GCRTA)*	600	♦ Broomed and hosed once per week	♦ Platforms are partially covered (test area is completely exposed) ♦ Snow, rain, ice ♦ Snow and ice removal by shovel Salt applied ♦ Temperature range of -20° to 100°F	Station scheduled for major renovation in 1996
Bethayres *(SEPTA)*	290	♦ Swept 3 times each week	♦ Platform and test area are totally exposed ♦ Snow, rain, ice ♦ Snow and ice removal by shovels and snow blowers; calcium chloride is applied to assist in melting ♦ Temperature range of 15° to 100°F	

Source: Individual Transit Systems

Table 3-2

Station Environment (Continued)

STATION *(SYSTEM)*	AVG. WEEKDAY RIDERSHIP	PLATFORM MAINTENANCE PRACTICES	WEATHER CONDITIONS	OTHER NOTES
Indoor				
South Station *(MBTA)*	16,275	◆ Wet-mopped 3 to 4 times each week, more often in winter ◆ Power cleaned with detergent spray annually	◆ Water carried in by foot traffic	Third busiest station in MBTA system Terminal for Commuter Rail and Amtrak
Brookpark *(GCRTA)*	650	◆ Mopped and cleaned with mild soap every day; hosed down	◆ Water, snow, sand carried in by foot traffic	
8th Street *(SEPTA)*	11,500	◆ Mopped twice weekly or more if needed	◆ Pedestrian entrance exposes installation area to outside temperatures	Transfer station for PATCO rail service

Source: ***Individual Transit Systems***

Table 3-3

Installation Site Issues

SYSTEM (STATION)	NO. OF INSTALLATIONS	SIZE OF INDIVIDUAL INSTALLATION	INSTALLATION TIMES	OTHER CONDITIONS
Outdoor				
MBTA *(Orient Heights)*	4 1 1	30' x 2' 31' x 2' 20' x 2'	1:00 am to 5:00 am (no revenue service)	MBTA flagger needed
GCRTA *(Triskett Street)*	1 1 2	20' x 2' 24' x 2' 12' x 2'	All times	Must hire certified flagger Contractor must provide lighting for evening work
SEPTA *(Bethayres)*	1	9'5" x 2'	Weekdays only: 9:00 am to 3:30 pm; 8:00 pm to midnight	Contractor must provide lighting for evening work
Indoor				
MBTA *(South Station)*	7	8' x 2'	Midnight to 5:00 am	—
GCRTA *(Brookpark)*	4	8' x 2'	10:00 pm to 4:30 AM (no revenue service)	Daytime installation OK if no cutting of surface
SEPTA *(8th Street)*	3	7' x 2'	Weekdays: 9:30 am to 3:00 pm; 8:00 pm to 4:30 am Weekend: all times	No more than two installers at one time

Installation Conditions—Boston
Detectable Warning Materials

Outdoor—MBTA Blue Line, Orient Heights Station, Outbound Platform
Indoor—MBTA Red Line, South Station, Mezzanine Level Walkway

Pre-Installation

- Fill out MBTA *Permit to Visit* and *General Release*
- Attend safety orientation — rapid transit

Installation at Orient Heights

- Work hours
  - 1:00 am to 5:00 am weekdays and Saturday
  - 1:00 am to 6:00 am Sunday
  - Materials and equipment can be moved onto platform starting at 12:00 midnight
  - All materials and equipment to be removed and area to be broom clean at end of work hours
- Station access for equipment
  - Station is at grade level, entry through 4-foot wide gate
- Utilities available
  - Electric power—120 volt, 15 amp power; contractor to provide extension cords
  - Water—available from a washroom; contractor to supply hose or bucket
  - Restrictions on use of gasoline-powered equipment: none
- Platform description
  - Platform depth: 7 inches
  - Rebar depth is greater than 2 inches
  - No metal edge or bumper at platform edge
  - Platform condition: Good—minimal spalling or cracking

Figure 3-1
Specification Sheet for Orient Heights Station

The installations extended over a much longer period than originally planned. This was due to a combination of several factors. First, the selection of installation dates was delayed for certain manufacturers whose in-house installers were occupied by other projects, or who needed extra time to hire a local contractor. The delays led to the postponing of installations from the fall of 1993 to the winter of 1993-1994. During the winter the abundance of snow, rain, and extreme cold caused further delays.

The staggered installation dates meant that various materials had different exposure periods to passenger traffic and weather, for example, the exposure period for materials installed in December was longer than the exposure period for materials installed in the following February. The evaluation process accounts for the time exposure variable, and the presentation of performance results for each material always includes the number of exposure days.

Six of the participating manufacturers were able to install their products at two transit systems, while the other two were able to install only at one system. Most manufacturers were unwilling to install at all three transit systems due to the cost. In addition, because of the weather delays, certain manufacturers that had planned to install at all three transit systems were not able to schedule the full set of installations. Table 3-4 lists the completed test installations, at both the indoor and outdoor test sites at each system.

In addition to observation and data collection, the on-site project staff monitor at each installation acted as a facilitator, working with transit system staff to resolve any unexpected problems. These included: changes in installation time windows, obtaining extra time for the setting of adhesives used in the bonding of materials to the station surface, obtaining flagger services, and ensuring access to utilities.

3.2 FIELD TEST RESULTS

The results of the field tests of the detectable warning materials are presented in two parts:

- Qualitative information and photographs illustrating the condition of the material and the installation after a specified number of days of exposure.

- Quantitative data on the wear resistance of the materials based on the measurement of dome heights at the indoor "accelerated wear" test section.

Table 3-4

Completed Test Installations

MANUFACTURER *PRODUCT NAME*	INDOOR			OUTDOOR		
	MBTA	GCRTA	SEPTA	MBTA	GCRTA	SEPTA
ADA Consultants *Alert Mat*		✓			✓	
Carsonite International *Pathfinder*	✓	✓		✓	✓	
Crossville Ceramics *Tac-Tile*	✓		✓	✓		
Engineered Plastics *Armor-Tile*	✓		✓	✓		✓
Hastings Pavement *ADA Paver*	✓	✓				
Rehau *Access Tactile Tile*	✓		✓	✓		
Summitville Tile *Tactile Tread*	✓			✓		
Transpo Industries *Step-Safe*	✓	✓		✓	✓	

3.2.1 Field Test Results — Condition of the Material and Installation After Exposure

At each field test site there were at least two sets of observations and photographs recorded in order to determine changes in the condition and performance of each material. The first set of observations and photographs were taken immediately after the installation was complete. These measurements served as the baseline for the initial material/installation condition and visual appearance. The last set of observations was made at the latest possible date allowed by the evaluation time schedule (May/June 1994) in order to allow the maximum exposure time for all installations. The specific dates for each test installation measurement and the number of exposure days for each material is cited as part of the results. Appendix C displays the form used to collect data during the observation visits to each test site.

The specific observations and photographs recorded include the following condition and performance factors:

- Cracking and chipping of the material.
- Lifting edges or bubbles under the material.
- Problems with mechanical fasteners.
- Discoloration of the surface.
- Integrity of the installation.

The field test results on material and installation condition are presented for each transit system. The results for each transit system include the number of exposure days for each material and a brief description of some typical problems encountered. Photographs are used to illustrate specific problems of material conditions.

A summary section presenting a comprehensive overview of the condition of each material and installation follows the transit system descriptions and photographs.

3.2.1.1 MBTA — Table 3-5 lists the test installations at the Orient Heights station (outdoor) and at South Station (indoor), along with the number of days of exposure for each material, as of June 1, 1994. The two Boston sites had the greatest number of installations, with seven materials at South Station and six materials at Orient Heights.

In terms of ridership, South Station was the most heavily used indoor station in the test program. The materials installed at South Station were subject to the most foot traffic.

The Orient Heights station was the busiest of the test program's outdoor sites. In addition, four of the six materials were in place during a particularly cold and snowy winter. This provided a good initial test for their performance in an outdoor setting.

Some typical results of exposure are shown in Figure 3-2, which presents a photograph of the installation of Rehau's Access Tactile Tile at South Station. One of the tiles has completely lifted off the surface. Complete results for this material and all other materials are presented in the field test summary section.

Figure 3-3 shows a portion of the installation of Transpo's Step-Safe at Orient Heights. One tile has cracked and is no longer bonded to the platform.

Table 3-5

MBTA Test Installations

MANUFACTURER *PRODUCT NAME*	EXPOSURE DAYS (AS OF JUNE 1, 1994)	
	ORIENT HEIGHTS (OUTDOOR)	SOUTH STATION (INDOOR)
Carsonite International *Pathfinder*	177	179
Crossville Ceramics *Tac-Tile*	14	121
Engineered Plastics *Armor-Tile*	165	164
Hastings Pavement *ADA Paver*	Not Installed*	141
Rehau *Access Tactile Tile*	36	78
Summitville Tile *Tactile Tread*	161	167
Transpo Industries *Step-Safe*	168	167

*Material too thick for installation on platform.

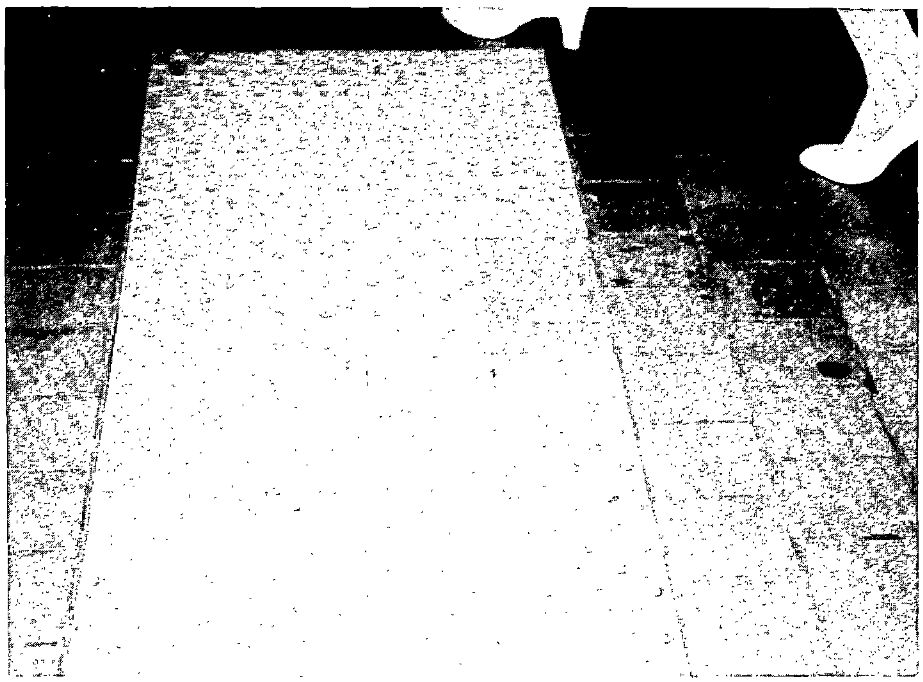

Figure 3-2
Rehau: Access Tactile Tile
Installation at MBTA South Station Illustrating Missing Tile
(Photo Taken after 78 Exposure Days)

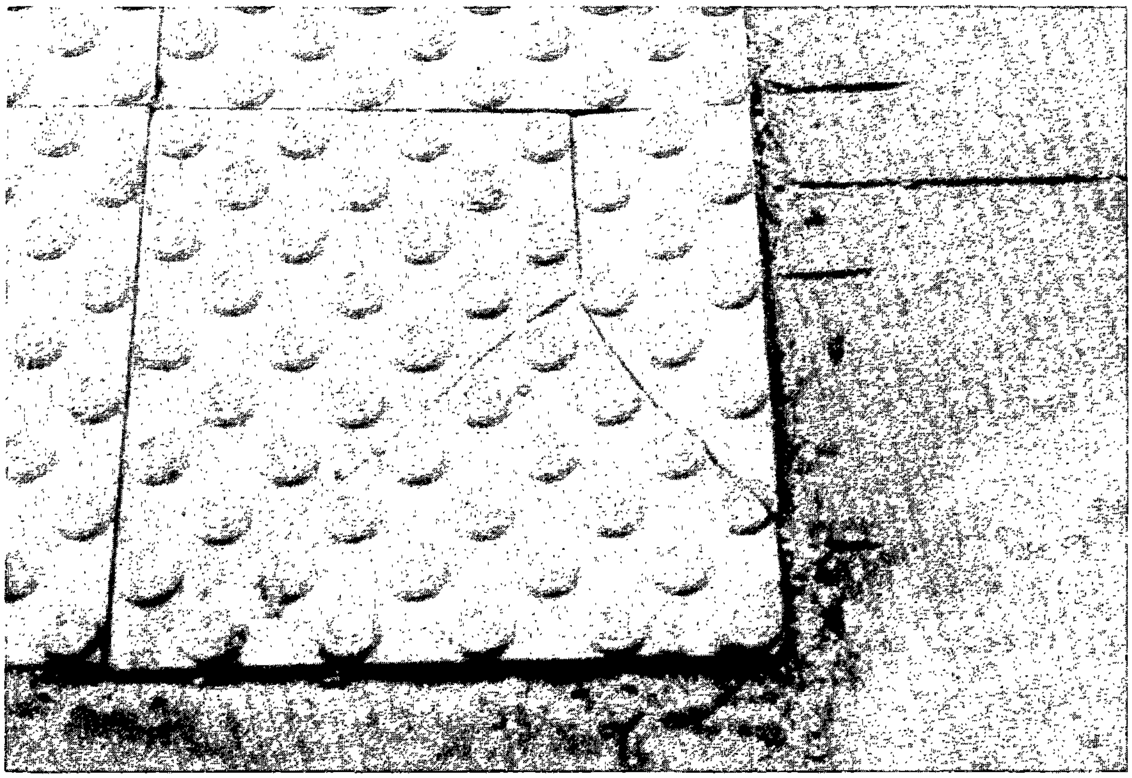

Figure 3-3
Transpo Industries: Step-Safe
Installation at MBTA Orient Heights Station Illustrating Cracked Tile
(Photo Taken after 167 Exposure Days)

3.2.1.2 GCRTA — Table 3-6 lists the test installations at the Triskett Street station (outdoor) and at the Brookpark station (indoor), along with the number of days of exposure for each material, as of May 23, 1994. Of the six test sites, these two sites had the longest exposure to passenger traffic, maintenance and cleaning, and weather. The final set of measurements and observations at the Cleveland stations took place nearly seven months after completion of the installation of the materials.

The ridership at the two stations was much lower than the ridership at the MBTA stations or at SEPTA's 8th Street station. The resulting wear that took place at Triskett and Brookpark may be typical of the wear that takes place at stations of small- and medium-size rail systems, or low-use stations of larger rail systems.

Selected results demonstrate a change in the color of ADA Consultant's Alert Mat installation at Brookpark after 200 days of exposure as shown (see Figure 3-4). The sample piece in the center is a portion of the material that was not installed.

Figure 3-5 displays a portion of the Transpo Industries' Step-Safe installation at Triskett Street. Notice the three chipped domes along the bottom row.

Table 3-6

GCRTA Test Installations

MANUFACTURER *PRODUCT NAME*	**EXPOSURE DAYS (AS OF MAY 23, 1994)**	
	TRISKETT STREET (OUTDOOR)	**BROOKPARK (INDOOR)**
ADA Consultants *Alert Mat*	200	201
Carsonite International *Pathfinder*	201	202
Hastings Pavement *ADA Paver*	Not Installed*	200
Transpo Industries *Step-Safe*	200	201

*Material too thick for installation on platform

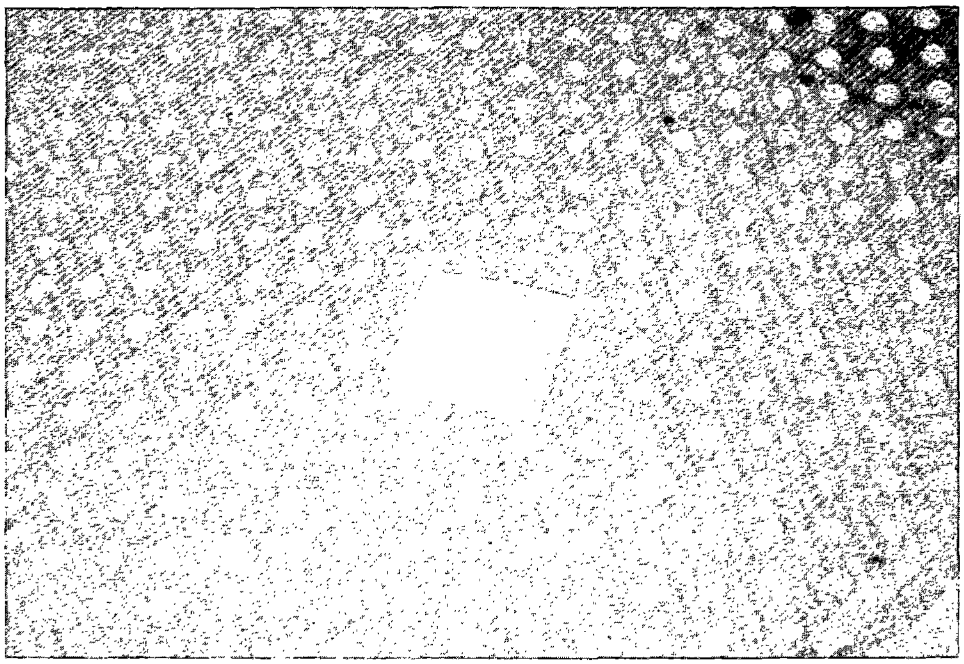

Figure 3-4
ADA Consultants: Alert Mat
Installation at GCRTA Brookpark Station Illustrating Change From Original Color
(Sample Piece in Center of Photo)
(Photo Taken After 201 Exposure Days)

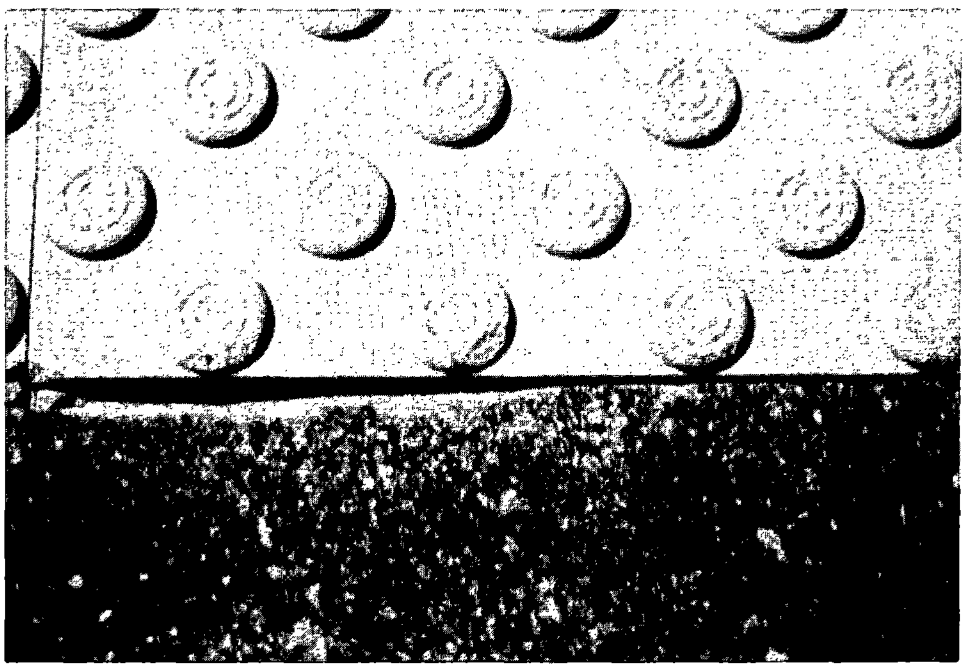

Figure 3-5
Transpo Industries: Step-Safe
Installation at GCRTA Triskett Street Station Illustrating Chipped Domes
(Photo Taken After 200 Exposure Days)

3.2.1.3 SEPTA — Table 3-7 lists the test installations at Bethayres station (outdoor) and at the 8th Street station, along with the number of days of exposure for each material, as of May 20, 1994.

Many of the manufacturers who had already installed their products for evaluation at MBTA and GCRTA did not carry out installations at the last site. For this reason, as shown in Table 3-7, there were only three materials tested at 8th Street and one material at Bethayres.

Selected results include the display of a portion of Rehau's Access Tactile Tile installation at 8th Street (see Figure 3-6). The caulking at the bottom edge has begun to loosen from both the tile and the platform surface.

Figure 3-7 displays a portion of Engineered Plastics' Armor Tile installation at Bethayres. There is some accumulated dirt and sand but no visible chipping or adhesion problems.

Table 3-7

SEPTA Test Installations

MANUFACTURER *PRODUCT NAME*	EXPOSURE DAYS (AS OF MAY 20, 1994)	
	BETHAYRES (OUTDOOR)	8TH STREET (INDOOR)
Crossville Ceramics *Tac-Tile*	Not Installed*	40
Engineered Plastics *Armor-Tile*	87	86
Rehau *Access Tactile Tile*	Not Installed*	113

*Due to cold temperature conditions

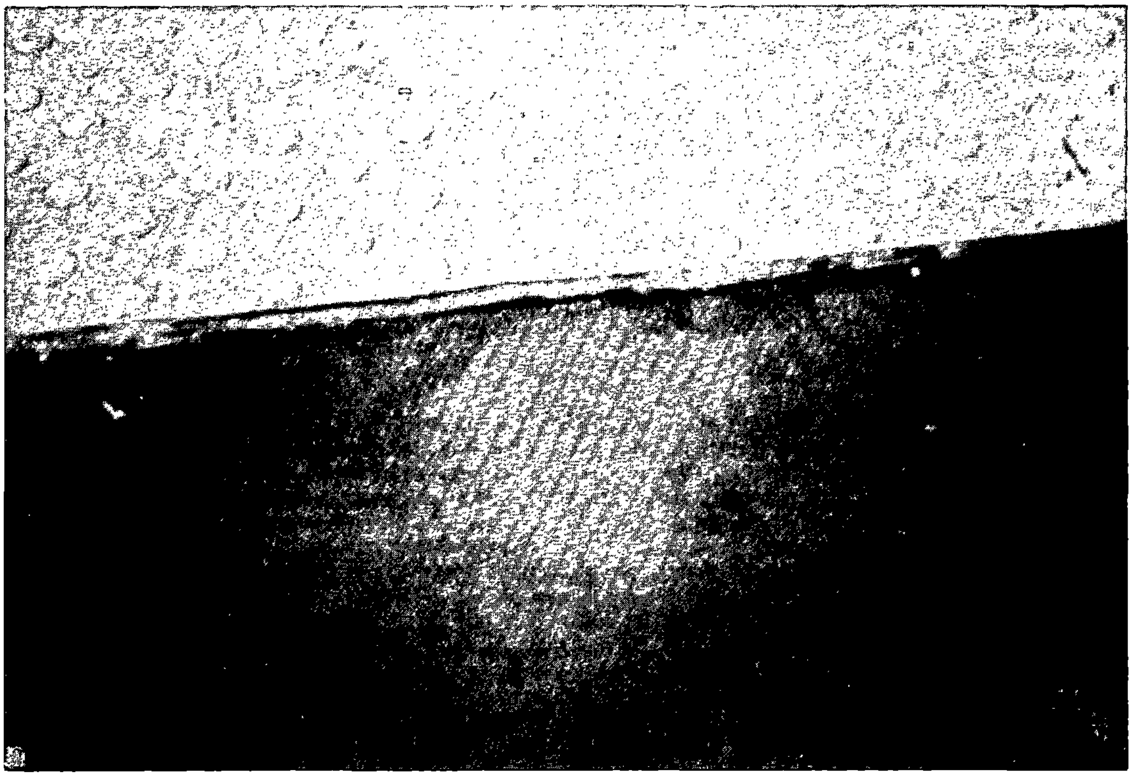

Figure 3-6
Rehau: Access Tactile Tile
Installation at SEPTA 8th Street Station Illustrating
Lifting Tiles and Loose Caulking
(Photo Taken After 113 Exposure Days)

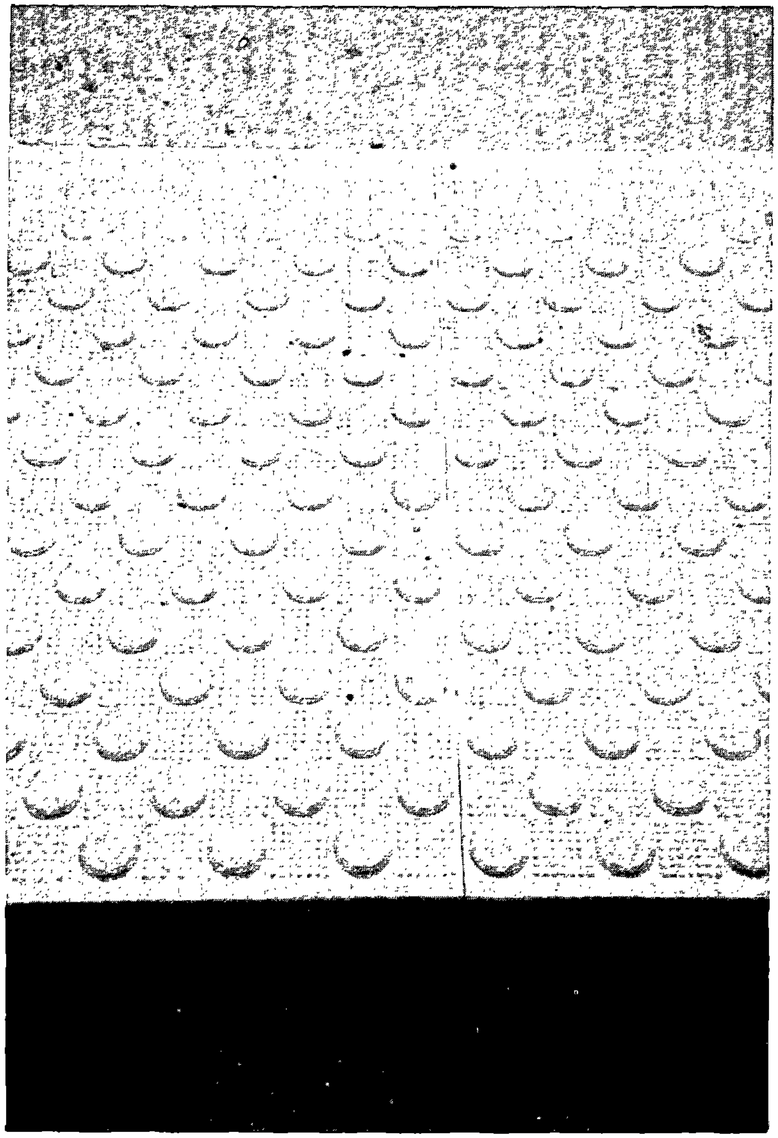

Figure 3-7
Engineered Plastics: Armor-Tile
Installation at SEPTA Bethayres Station Illustrating
Small Accumulation of Dirt and Sand
(Photo Taken After 87 Exposure Days)

3.2.2 Summary of Field Test Results — Condition of Materials and Installation

Tables 3-8 through 3-15 provide a summary of the field test results for each material based on a compilation of the observations made during site visits. The summary for each product includes the following information:

- Station(s).
- Installation size(s).
- Days of exposure.
- Observations.

The observations for each material are grouped by either outdoor or indoor installation. The observations note conditions such as:

- Visible wearing of the domes or base.
- Cracks and chips in the material.
- Changes in color.
- Accumulation of dirt.
- Loosening of tiles or fasteners.
- Loss of adhesives.

These observations, along with the analysis of the dome wear at the indoor installations, form the basis for the performance assessment of the materials presented in Section 4.

Table 3-8

Performance of Installed Materials

ADA Consultants
"Alert Mat"

OUTDOOR INSTALLATION(S):

Station:	GCRTA Triskett
Size:	24' x 2' (yellow); 12' x 2' (black)
Exposure Days (as of May 23):	200

Observations:

1. Base surface has many cracks along inside edge of installation.
2. Yellow mats have faded considerably.
3. Nearly all fasteners are rusted.
4. Large air bubbles under 2 (of 4) yellow mats.
5. Yellow mats can be easily pried off platform using fingers.

INDOOR INSTALLATION(S):

Station:	GCRTA Brookpark
Size:	8' x 3'4"
Exposure Days (as of May 23):	201

Observations:

1. Domes are smoothest of the four materials installed at Brookpark.
2. Mats have accumulated much dirt; original yellow color is hardly visible.
3. About three-fourths of fasteners are rusted.

Table 3-9

Performance of Installed Materials

Carsonite International
"Pathfinder"

OUTDOOR INSTALLATION(S):

Station:	GCRTA Triskett
Size:	12' x 2'
Exposure Days (as of May 23):	201
Station:	MBTA Orient Heights
Size:	30' x 2'
Exposure Days (as of June 1):	177

Observations:

1. (BOTH) Cracks spreading from many fastener domes.
2. (GCRTA) Some chipped domes along inside edge of installation.
3. (BOTH) Dirt has accumulated on fastener caps.
4. (BOTH) Air pocket under several panels.

INDOOR INSTALLATION(S):

Station:	GCRTA Brookpark
Size:	8' x 2'
Exposure Days (as of May 23):	202
Station:	MBTA South Station
Size:	8' x 2'
Exposure Days (as of June 1):	179

Observations:

1. (BOTH) Visible wear on domes: many textured domes are now smooth.
2. (BOTH) Dirt has accumulated on fastener caps.
3. (BOTH) Lip of installations are noticeably higher than adjoining surface.

Table 3-10

Performance of Installed Materials

Crossville Ceramics
"Tac-Tile"

OUTDOOR INSTALLATION(S):

Station:	MBTA Orient Heights
Size:	20' x 2'
Exposure Days (as of June 1):	14

Observations:

1. "A" and "B" tiles not alternating: improper dome spacing.
2. No wear problems to date.

INDOOR INSTALLATION(S):

Station:	MBTA South Station
Size:	8' x 2'
Exposure Days (as of June 1):	121
Station:	SEPTA 8th Street
Size:	7' x 2'
Exposure Days (as of May 20):	41

Observations:

1. (MBTA) "A" and "B" tiles not alternating: improper dome spacing.
2. (BOTH) Dull yellow color.
3. (BOTH) No signs of wearing or chipping.

Table 3-11

Performance of Installed Materials

Engineered Plastics
"Armor-Tile"

OUTDOOR INSTALLATION(S):

Station: MBTA Orient Heights
Size: 30' x 2'
Exposure Days (as of June 1): 165

Station: SEPTA Bethayres
Size: 9'5" x 2'
Exposure Days (as of May 20): 87

Observations:

1. (SEPTA) One chipped dome.
2. (SEPTA) Fastener caps have faded in color.
3. (MBTA) Sand has accumulated among base nubs.
4. (MBTA) "Newest" looking installation at Orient Heights..

INDOOR INSTALLATION(S):

Station: MBTA South Station
Size: 8' x 2'
Exposure Days (as of June 1): 164

Station: SEPTA 8th Street
Size: 7' x 2'
Exposure Days (as of May 20): 86

Observations:

1. (BOTH) Installations have accumulated sand and dirt more than other materials.
2. (BOTH) No signs of chipping or fading.

Table 3-12

Performance of Installed Materials

Hastings Pavement
"ADA Pavers"

OUTDOOR INSTALLATION(S):

Station:	NONE

INDOOR INSTALLATION(S):

Station:	GCRTA Brookpark
Size:	8' x 2'
Exposure Days (as of May 23):	200
Station:	MBTA South Station
Size:	8' x 2'
Exposure Days (as of June 1):	141

Observations:

1. (BOTH) Chips along edges of individual pavers: occurred at installation.
2. (BOTH) Pavers have turned to grayish-brown color.
3. (GCRTA) Pit marks throughout installation, both base and domes.
4. (MBTA) White flecks show on surface that were not apparent at installation.

Table 3-13

Performance of Installed Materials

Rehau
"Access Tactile Tile"

OUTDOOR INSTALLATION(S):

Station:	MBTA Orient Heights
Size:	31' x 2'
Exposure Days (as of June 1):	36

Observations:

1. Several tiles are lifting off platform.
2. Caulking around edge of installation (track side and inside) is coming off in several locations.

INDOOR INSTALLATION(S):

Station:	SEPTA 8th Street
Size:	7' x 2'
Exposure Days (as of May 20):	113
Station:	MBTA South Station
Size:	8' x 2'
Exposure Days (as of June 1):	78

Observations:

1. (MBTA) One tile has come off completely.
2. (MBTA) Most caulk around edges is gone or tearing off.
   (SEPTA) Caulk is beginning to tear off.
3. (SEPTA) Lifting of several tiles.
4. (MBTA) More noticeable accumulation of dirt and grime compared to other installations.

Table 3-14

Performance of Installed Materials

Summitville Tile
"Tactile-Tread"

OUTDOOR INSTALLATION(S):

Station:	MBTA Orient Heights
Size:	30' x 2'
Exposure Days (as of June 1):	161

Observations:

1. Three cracks, perpendicular to track, all aligned with foundation cracks.
2. One crack, perpendicular to track, aligned with expansion joint.
3. One chipped dome.
4. Dirty, but no discoloration.

INDOOR INSTALLATION(S):

Station:	MBTA South Station
Size:	8' x 2'
Exposure Days (as of June 1):	167

Observations:

1. No signs of wearing; no chips.
2. Little accumulation of dirt.

Table 3-15

Performance of Installed Materials

Transpo Industries
"Step-Safe"

OUTDOOR INSTALLATION(S):

Station:	GCRTA Triskett
Size:	20' x 2'
Exposure Days (as of May 20):	200
Station:	MBTA Orient Heights
Size:	30' x 2'
Exposure Days (as of June 1):	168

Observations:

1. (BOTH) Scraped and chipped domes, both along edges of installation and interior domes. These domes reveal specks of brownish/rust color — more so at GCRTA.

2. (MBTA) One tile is completely cracked and can be lifted from platform.

3. (GCRTA) Tiles have faded to several shades of yellow. Several shades of yellow appear on single tiles.

4. (GCRTA) One tile has hollow sound when stepped on, indicating separation from platform.

5. (MBTA) Base and domes are "pitted."

Table 3-15

Performance of Installed Materials

Transpo Industries
"Step-Safe"

(Continued)

INDOOR INSTALLATION(S):

Station:	GCRTA Brookpark
Size:	8' x 2'
Exposure Days (as of May 23):	201
Station:	MBTA South Station
Size:	8' x 2'
Exposure Days (as of June 1):	167

Observations:

1. (MBTA) Visible wear on domes: textured tops often worn smooth.

2. (MBTA) Pit marks, similar to Orient Heights installation.

3. (GCRTA) Epoxy between several sets of tiles is cracking; in two cases, epoxy is falling out.

4. (GCRTA) Epoxy has stuck to tops of about half of tiles. This occurred at installation. There is a greater accumulation of dirt on top and adjacent to this epoxy.

5 (BOTH) Slightly uneven setting of tiles. Not a tripping hazard, but locations for accumulation of dirt.

3.2.3 Field Test Results — Measurement of Wear Resistance

One of the major interests of the transit industry is the wear resistance of the various detectable warning material compositions produced by the manufacturers. The laboratory testing of detectable warning materials, as discussed in Section 2, showed a considerable variation in wear resistance.

The wear resistance of the materials used in the field tests was measured by the change in average dome height. The measurements were taken on materials installed at the indoor test sites because each material was exposed to the same foot traffic and environmental factors (dirt, moisture, salt, and other materials carried in by passenger/employee use). The indoor test sites were selected specifically because they were passageways or walkways where passengers would be restricted to walking on all of the materials.

Figure 3-8 illustrates the arrangement of detectable warning materials at the indoor test site at MBTA South Station. Passengers walk across all of the test samples placed in the walkway as they move into and out of the station. Similar test section arrangements were made for the indoor walkway test sites at GCRTA and SEPTA.

The initial and final measurements of dome height were completed on all of the materials at the same time in order to ensure that all materials were subject to the same number of exposure days over the same time frame. The initial measurements of dome height were made immediately after all of the installations were complete. The final measurements were made at the latest possible date in the evaluation time schedule in order to accumulate the maximum exposure time.

Measurements of wear are reported for the indoor installations at GCRTA and MBTA based on the following number of days of exposure:

- GCRTA - 198 exposure days (6.6 months)
- MBTA - 69 exposure days (2.3 months)

Wear measurements for the SEPTA installation are not reported because the exposure time was too short.

The measurement of wear was based on the change in dome height between the initial and final measurements. In order to obtain a reasonably accurate measurement of the changes in height, 64 domes on each test panel were measured. The initial (nominal) height of each dome is five millimeters, therefore it was necessary to use a micrometer for measuring height to an accuracy of 0.01 millimeters.

Measurement details, including the location of all dome height measurement points, are cited in Appendix D.

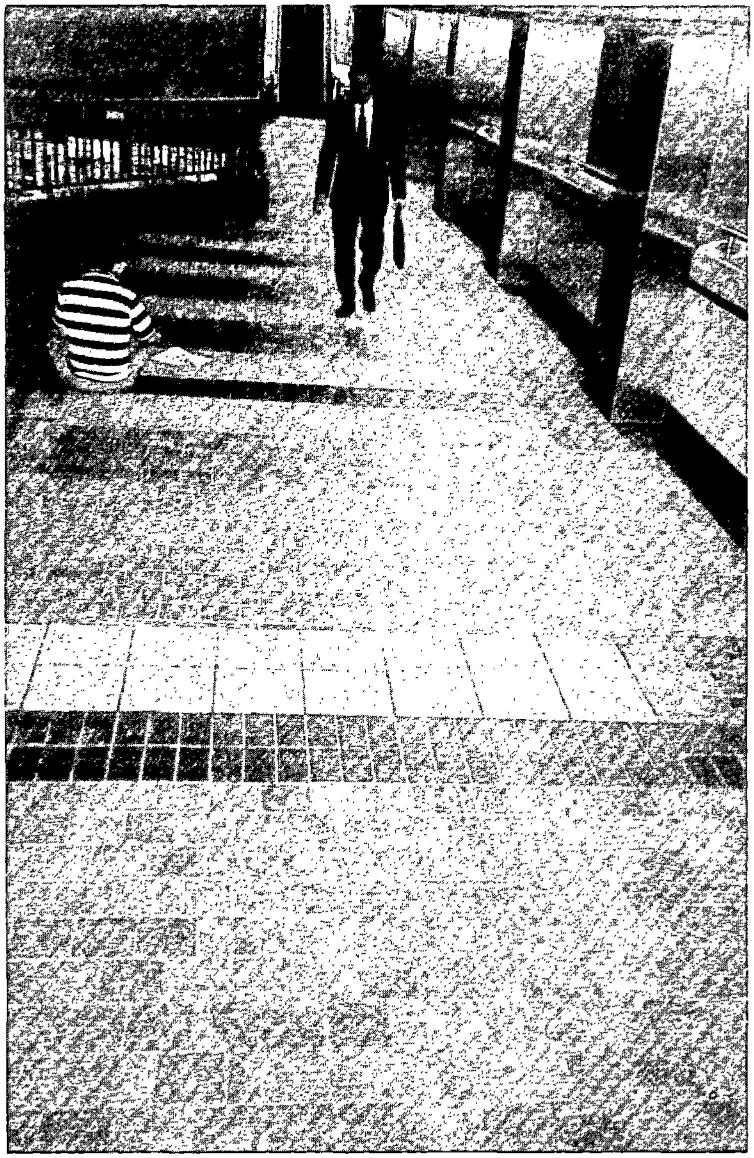

Figure 3-8
Arrangement of Detectable Warning Materials at MBTA South Station Test Site

Transit systems are concerned with the useful life of a detectable warning material installed at the station platform edge and not for an installation in a walkway or passageway. The "accelerated wear" test section approach was selected because it would ensure that all materials were exposed to the same concentrated wear conditions. In order to provide a more useful comparison of the relative wear resistance of each of the materials tested, the wear measurements were converted from the accelerated wear test section numbers to an equivalent value applicable to the platform edge. The computation of this conversion or "acceleration" factor is presented in Appendix D. The acceleration factors, computed using information supplied by the transit systems are:

- GCRTA - 15
- MBTA - 20

For example, an acceleration factor of 15 for GCRTA simply means that each unit length (foot) of test material in the passageway at Brookpark handles 15 times more passenger foot traffic than a unit length (foot) of active platform at that station.

The wear resistance results are presented in terms of the estimated annual average wear, as measured by the average decrease in height and expressed as a percentage of the initial height of the dome. All wear resistance results presented in this section are projections for the platform edge based on one year of use. Therefore, if a material is reported to wear by 5 percent per year on average, the domes at the platform edge could be expected to be one-half or 50 percent of their original height at the end of 10 years, assuming that the measured wear rate remains the same over that time.

Figure 3-9 presents the projected annual wear rate for the materials installed at GCRTA's Brookpark station. This is a relatively low passenger volume station (estimated by GCRTA at 650 riders per day). The annual wear rates range from approximately 0.4 percent to 1.1 percent. This indicates that the wear resistance of all of these materials is satisfactory. If the indicated wear rate is consistent over a long term, such as 10 years, the average dome height would only be reduced by 4 to 11 percent.

Figure 3-10 presents similar information on projected annual wear rates for the seven detectable warning materials installed at the MBTA South Station site. This station is a high passenger volume station with an estimated 16,275 passengers per day, approximately 25 times greater than that of the Brookpark station. In this case, the projected annual percentage wear rate ranges from a low of 0.28 percent to a high of 3.2 percent. The highest wear rate would result in a 32% average reduction in dome height over a period of 10 years, assuming that the rate remained constant over that period..

It is important to point out that many of the dome wear measurements demonstrated a significant variation around the average of mean values cited above; this means that in many instances certain domes showed little or no wear while others were considerably more than the average. The details of these measurement variations are provided in Appendix D. The overall wear resistance performance of all materials tested was quite satisfactory when projected to the platform edge application. There was, however, a considerable variation in the relative wear resistance of each material as illustrated in Figures 3-9 and 3-10.

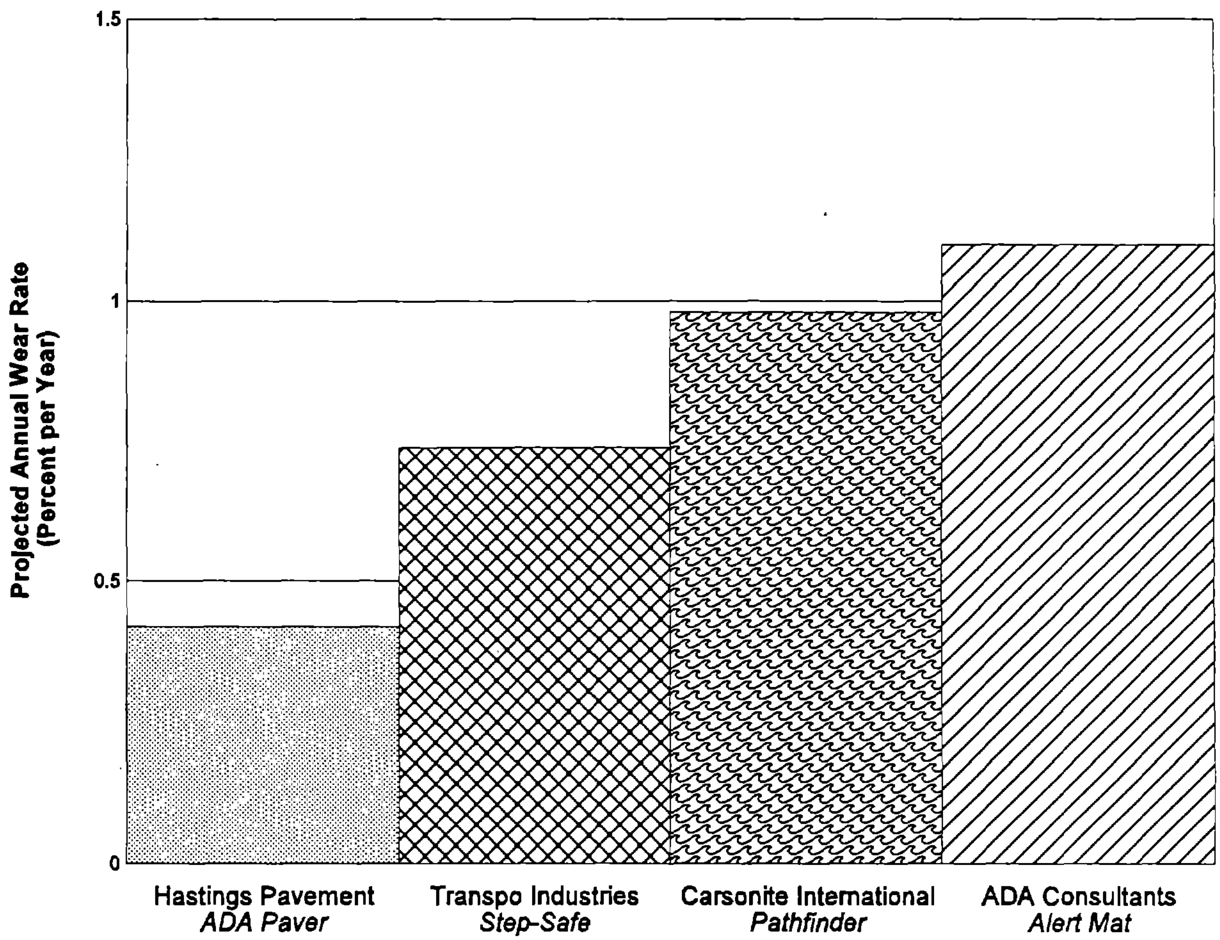

Figure 3-9
Projected Annual Wear Rate of Detectable Warning Materials at Platform Edge for Low Passenger Volume Station at GCRTA (Brookpark)

Source: Measurements of Dome Height Wear for Approximately 7 Months at Interior Test Section at Brookpark Station.

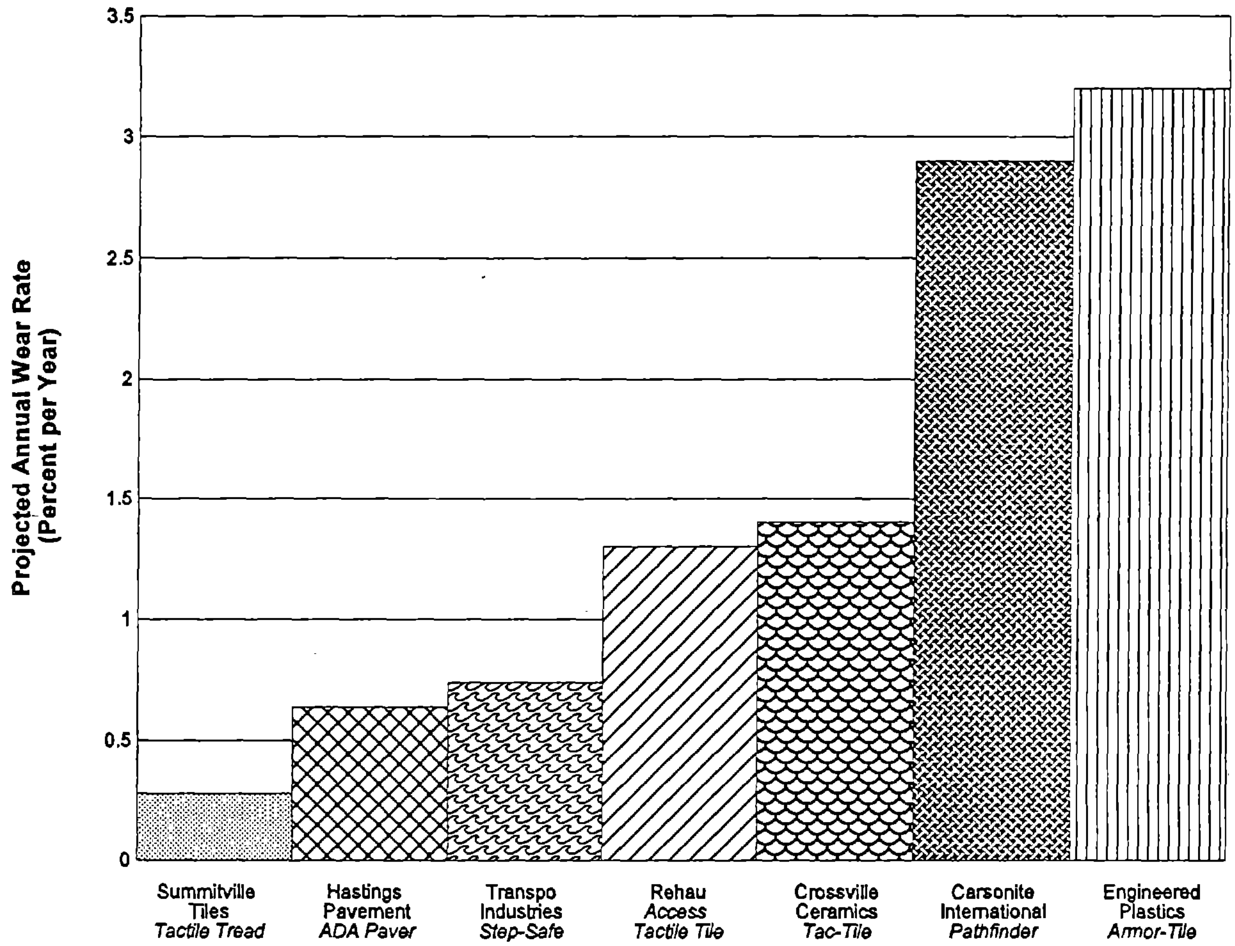

Figure 3-10
Projected Annual Wear Rate of Detectable Warning Materials at Platform Edge for High Passenger Volume Station at MBTA (South Station)

Source: Measurements of Dome Height Wear for Approximately 2.5 Months at Interior Test Section at South Station.

4. COMPARATIVE PERFORMANCE OF DETECTABLE WARNING SYSTEMS

This section of the report presents an overall assessment and comparison of all detectable warning systems that were field tested at the participating transit systems. The term "detectable warning system" is used to emphasize the fact that performance is dependent upon the physical characteristics of each material, the mechanics and quality of the material bond to the platform substrate, the surface preparation of the substrate, and the nature and quality of maintenance efforts to keep the surface clean and free of water, ice, or snow.

The section is divided into two parts. The first part includes observations and some general conclusions regarding the detectable warning installation and maintenance processes. The second part of the section assesses the performance of each detectable warning system by comparing and ranking each field test installation using four performance parameters.

4.1 INSTALLATION AND MAINTENANCE OF DETECTABLE WARNING SYSTEMS

The opportunity to observe approximately two dozen installations and to monitor their physical condition and appearance over a period of approximately seven months provides some insights into the installation and maintenance processes. The observations and general conclusions derived from this experience may provide some useful guidance to rail transit system operators and others who are concerned about the retrofit installation and maintenance of detectable warning materials on an existing transit station platform.

4.1.1 Observations and General Conclusions Regarding Installation

Transit systems will consider several factors when selecting a detectable warning product for their platform edges. In a retrofit situation, ease of installation is one of these factors. Ease of installation includes: the skills required of the installers; the tools required for installation; and the ease of replacing worn or broken portions of the material. An ideal product for retrofit installation is one which combines ease of installation with a long useful life and low maintenance costs.

Proper installation of the detectable warning material is crucial to the performance and durability of the material. This is particularly true for outdoor installations. The four installation factors that affect performance and durability of the detectable warning system are:

- **Ambient conditions** — include an acceptable temperature range, acceptable moisture on the installation surface (usually none), and acceptable precipitation (usually none).

- **Surface preparation** — includes some combination of cleaning (with a brush, water, or solvent); sanding; cutting an outline of the installation area; and removing a sufficient depth of the surface material to allow the installed material to be flush with the surrounding surface.

- **Application of material** — includes creating a setting bed (if needed) for the material; placing the material in the proper position; applying adhesive to the surface or the material; and, for certain materials, using mechanical fasteners to attach the material to the surface.

- **Setting period** — the time required before the installed material can sustain passenger traffic.

Based on experience with two dozen separate installations, there was a substantial variation of skills of the individuals who performed the work for the manufacturers. The installers could be placed into three groups:

- Manufacturers' installers.
- Manufacturers' marketing staff.
- Outside contractors.

Some caution should be used when comparing experience with these test installations to full-scale installations where the installers are expected to be more experienced and skilled. The installation experience is presented here as a means of conveying information about the potential problems that may occur if installers lack the proper experience and skills.

Two of the eight manufacturers had their **own installers** perform the work. Their knowledge of their respective material and installation procedures was apparent in their work. They had the proper tools, and they knew the "tricks" of the work. All of their installations went smoothly.

Three manufacturers had **marketing staff** conduct the field installations. Two of these products required few special skills for installation. Their respective marketing staffs installed the material without difficulty. Marketing staff from the third manufacturer knew how to install their product, but they experienced some difficulties due to problems with the tools they used in the installations.

Three of the manufacturers (all with "tile" products that are typically one foot square sections) employed **outside contractors** to install their material. Two manufacturers had company staff supervising the work. All of the outside contractors had experience in laying tile, and generally they did a good job in the installation. One installation had difficulty due to epoxy adhesive (at one location) that was forced out onto the tile surface, likely due to premature exposure to foot traffic. Another contractor experienced some initial difficulty in cutting and removing the concrete surface, presumably due to lack of experience with this procedure.

A less effective job of installing a detectable warning material may have contributed to a less effective performance of the material in this field evaluation. This emphasizes the importance of correct installation. Where applicable, this is noted in the comparative assessment of materials.

4.1.2 Maintenance of Detectable Warning Systems

All of the field test installations of detectable warning materials were subject to normal maintenance practices of the three participating transit systems. For reference, these standard platform maintenance practices are summarized in Table 3-2, Station Environment.

In general, there were no reports of any maintenance problems with any of the test materials during the evaluation period (November 1993 to June 1994). The field test results cited in Section 3 showed that some materials accumulated more sand and dirt than others. This was not the result of cleaning procedures because all test materials were subject to the same cleaning method and frequency.

A major concern of many transit systems located in the northern parts of the U.S. is the maintenance of detectable warning systems under winter time conditions. The transit systems were selected to ensure that all outdoor installation sites were exposed to sun and precipitation, including accumulations of ice and snow. While each transit system used slightly different procedures, none of them encountered any problems in removing ice or snow from the various detectable warning materials. Each transit system used the same tools and chemicals on its detectable warning materials as on the rest of the platform surfaces.

The following is a list of the tools and chemicals used for snow and ice removal by the three systems:

- GCRTA: Shovels and salt mixture.
- MBTA: Shovels, ice chippers, and sand.
- SEPTA: Shovels, snow blowers, and calcium chloride.

No system reported any difficulties in the removal of ice or snow. There was no report of ice or snow getting stuck between domes of a detectable warning material.

Some materials (including both ceramic and composite-based materials) at the GCRTA and MBTA outdoor installations had chipped domes. The chips were most likely caused by the banging and scraping of shovels and ice chippers during ice and snow removal.

None of the cracks in the detectable warning materials installed at outdoor sites as reported in Section 3 can be directly attributed to ice and snow removal. However, the presence of rain or melted ice or snow can lead to problems. If there are gaps between the tiles of installed material, water can seep in. The water can then re-freeze, causing cracks or separation of the material from the platform.

4.2 PERFORMANCE ASSESSMENT

This part of the report provides a performance assessment of the eight detectable warning systems that have been field tested. The performance assessment is based on the field test results consisting of quantitative data measuring wear resistance (see Section 3) and qualitative information on the condition of the material and the installation after exposure to passenger traffic and weather. Consequently the following four categories have been selected for the assessment of material performance:

- Resistance to wear.
- Maintenance of bond with surface.
- Resistance to cracking and chipping.
- Maintenance of color.

The first category is a quantitative one and the next three are based on qualitative information produced through on-site observations. All four performance categories are important to a transit system when it is selecting a detectable warning material for retrofit on its stations' platform edges.

Each test material has been ranked according to its performance in each performance category. There has been no attempt to determine an overall ranking combining all four performance categories because that would require the assignment of relative weight to each category. It is expected that transit systems will examine the results in each performance category and make their own judgement on overall performance and applicability to their system.

4.2.1 Considerations in Interpreting Rankings

The field tests were designed to gather information on the detectable warning materials that is both relevant to the concerns of transit systems and reliable for developing rankings of the materials on key characteristics. Two features of the field tests helped to provide relevant and reliable information:

- Side-by-side installation of materials at each of the six sites (as many as seven materials at one site).

- Exposure of these materials to daily revenue service, at both indoor and outdoor sites.

It is important to note that the performance rankings presented here are based strictly on the measured and observed data and information from the field test. Issues that a transit system should consider when reviewing the rankings include the following:

- The abbreviated **time frame** of the field test evaluation limits the scope of observations and data collection. Even with several inspections of each installation site, these are only "snapshots" of materials that are exposed to pedestrian traffic, weather, and maintenance on a daily basis. The time frame issue also relates to the difference between the period of exposure for this program (up to seven months) versus the manufacturers' claims of the materials' lifetimes (five to ten years). It is often difficult to project long-term performance using short-term data.

- Because these are **field tests**, it is not possible to subject each material to identical environmental conditions. The materials have been exposed to all conditions that come with rail stations in daily use. For example, a single chipped dome at an outdoor installation of a material may have resulted from an atypically rough attempt by a maintenance worker to remove ice from the surface. The rankings de-emphasize single, small flaws and focus on systematic problems, especially those that occur at more than one installation.

- Three of the rankings rely on **engineering judgment** of qualitative information. The use of standardized forms to record observations helped to achieve a high degree of consistency in these judgments. In order to insure consistency of the data collection process, the number of observers was limited to three persons for the installations, and only one person conducted the subsequent site visits and carried out all dome wear measurements. In the wear test, several of the components that are used to derive the "acceleration factor" are rough estimates based on the judgment of transit system staff. However, the resulting acceleration factors are applied in the same manner to the measured dome height data of all materials; therefore, the relative ranking of the materials is unaffected.

- Finally, the **quality of the installation** of a product has a significant influence on the long term performance of the material. As much as possible, the rankings take into account (based on a review of the available written, photographic, and video documentation) performance weaknesses that can be directly attributable to problems in the initial material installation.

4.2.2 Performance Rankings

The tables presented in this section summarize the comparative performance of the eight detectable warning materials that were field tested. Each table ranks the performance of the materials using four categories: wear resistance, bonding with the surface, resistance to chipping and cracking, and maintenance of color. The performance levels are:

- ○ Best performance, that is, little or no problem
- ⊙ Noticeable but small flaws in performance
- ⊗ Significant performance flaw at one site or consistent minor flaws at several sites
- ● Poor performance that raises concern about the usefulness of the material installed on a transit station platform

Within each performance level, the manufacturers are listed in alphabetical order to indicate that there is little, if any, difference in performance.

The text for each performance category provides a brief description of the data and observations that led to the specific ranking of materials. For more detailed information, see Section 3, particularly, Tables 3-8 to 3-15 and Figures 3-9 and 3-10.

A summary of the rankings for all materials is presented at the end of the section.

4.2.2.1 Wear Resistance - Table 4-1 rates performance of the eight materials installed in the field test sites by the resistance to wear of the materials. No material was judged to have poor performance. As noted earlier in Section 3.2.3, "Field Test Results--Measurement of Wear Resistance," all of the materials were estimated to have a relatively long useful life for the platform edge application. The third ranking was given to the material that showed the highest wear at Brookpark (ADA Consultants' Alert Mat) and to the two materials with the highest wear at South Station (Carsonite's Pathfinder and Engineered Plastics' Armor-Tile).

Table 4-1

Ranking of Materials by Resistance to Wear

○	Hastings Pavement - ADA Paver
○	Summitville Tiles - Tactile Tread
⊙	Crossville Ceramics - Tac-Tile
⊙	Rehau - Access Tactile Tile
⊙	Transpo Industries - Step-Safe
⊗	ADA Consultants - Alert Mat
⊗	Carsonite International - Pathfinder
⊗	Engineered Plastics - Armor-Tile

○	Best performance, little or no problem	⊗	Significant flaw at 1 site or consistent minor flaws at several sites
⊙	Small flaws in performance	●	Poor Performance

4.2.2.2 Maintenance of Bond with Platform Surface - Table 4-2 rates performance of the eight materials installed in the field test sites by the maintenance of bond of the materials to the platform surface. The performance of the materials varied greatly in this category. Four of the eight materials showed no problem with their adhesion to the surface. In two instances Transpo's Step-Safe underwent some loss of bond between individual tiles and the surface. Observation of Carsonite International's Pathfinder at two different sites revealed air pockets under several panels. The two products rated as poor performers exhibited significant problems including complete loss of adhesion and large air bubbles under the mat.

Table 4-2

Ranking of Materials by Maintenance of Bond with Surface

○	Crossville Ceramics - Tac-Tile
○	Engineered Plastics - Armor-Tile
○	Hastings Pavement - ADA Paver
○	Summitville Tiles - Tactile Tread
⊙	Transpo Industries - Step-Safe
⊗	Carsonite International - Pathfinder
●	ADA Consultants - Alert Mat
●	Rehau - Access Tactile Tile

○	Best performance; little or no problem	⊗	Significant flaw at 1 site or consistent minor flaws at several sites
⊙	Small flaws in performance	●	Poor Performance

4.2.2.3 Resistance to Chipping and Cracking - Table 4-3 rates performance of the eight materials installed in the field test sites by the resistance of the materials to chipping and cracking. No material was judged to have poor performance. Two materials (Crossville's Tac-Tile, Rehau's Access Tactile Tile) had no chips or cracks in any of their test installations. The next four materials had a few chips or cracks but no pattern of problem in this performance category. The last two materials had repeated instances of cracked domes (Transpo's Step-Safe at two outdoor locations) and cracks along its base surface (ADA Consultant's Alert Mat at the outdoor installation).

Table 4-3

Ranking of Materials by Resistance to Chipping and Cracking

○	Crossville Ceramics - Tac-Tile
○	Rehau - Access Tactile Tile
⊙	Carsonite International - Pathfinder
⊙	Engineered Plastics - Armor-Tile
⊙	Hastings Pavement - ADA Paver
⊙	Summitville Tiles - Tactile Tread
⊗	ADA Consultants - Alert Mat
⊗	Transpo Industries - Step-Safe

○	Best performance; little or no problem	⊗	Significant flaw at 1 site or consistent minor flaws at several sites
⊙	Small flaws in performance	●	Poor Performance

4.2.2.4 Maintenance of Color - Table 4-4 rates performance of the eight materials installed in the field test sites by the maintenance of color of the materials. Three materials showed no color changes, either at indoor or outdoor sites. Carsonite International's Pathfinder had some fading around its fastener domes; Rehau's Access Tactile Tile color changes were due to the greatest retention of dirt and grime of any test material at each of its installation sites. Hastings Pavement's ADA Paver and Transpo's Step-Safe both revealed flecks of different colors on their tiles not visible at installation. ADA Consultants' Alert Mat showed major color changes at both its indoor and outdoor installations. At the indoor station the Alert Mat product appeared to absorb dirt and changed from a bright yellow to a grey mottled color, while at the outdoor station the product turned to a grey-green color.

Table 4-4

Ranking of Materials by Maintenance of Color

○	Crossville Ceramics - Tac-Tile
○	Engineered Plastics - Armor-Tile
○	Summitville Tiles - Tactile Tread
⊙	Carsonite International - Pathfinder
⊙	Rehau - Access Tactile Tile
⊗	Hastings Pavement - ADA Paver
⊗	Transpo Industries - Step-Safe
●	ADA Consultants - Alert Mat

○	Best performance; little or no problem	⊗	Significant flaw at 1 site or consistent minor flaws at several sites
⊙	Small flaws in performance	●	Poor Performance

4.2.2.5 Summary of Rankings - Table 4-5 presents a summary of rankings for all performance categories. The eight manufacturers are listed alphabetically. As noted earlier in this section of the report, there is no weighting of the characteristics, nor is there a composite ranking to determine the overall best material.

Table 4-5

Summary of Performance Rankings

	WEAR	BONDING	CHIPPING CRACKING	COLOR
ADA Consultants - Alert Mat	⊗	●	⊗	●
Carsonite International - Pathfinder	⊙	⊗	⊙	⊙
Crossville Ceramics - Tac-Tile	⊙	○	○	○
Engineered Plastics - Armor-Tile	⊗	○	⊙	○
Hastings Pavement - ADA Paver	○	○	⊙	⊗
Rehau - Access Tactile Tile	⊙	●	○	⊙
Summitville Tiles - Tactile Tread	○	○	⊙	○
Transpo Industries - Step-Safe	⊙	⊙	⊗	⊗

○	Best performance; little or no problem	⊗	Significant flaw at 1 site or consistent minor flaws at several sites
⊙	Small flaws in performance	●	Poor Performance

5. SUMMARY OF NATIONAL IMPLEMENTATION PANEL ACTIVITIES

The National Implementation Panel for Detectable Warnings was established as a separate entity under the FTA Detectable Warnings Program for the following purposes:

- Provide input and guidance on the overall FTA-sponsored research and test activities regarding detectable warnings.
- Review the findings of the human factors research and the engineering tests and evaluation.
- Make recommendations and provide information that will assist the transit industry in the selection and installation of detectable warning systems at transit station platform edges.

The activities of the Panel and its achievements are described in *Reference 6*. This section of presents information exchanged through the Panel meetings regarding transit system experience with detectable warning procurement and installation. This information complements the results of the testing and performance assessments reported in the preceding sections of the report.

5.1 PANEL COMPOSITION

The Panel was comprised of individuals who are members of diverse constituencies that have an immediate stake in the implementation of detectable warnings. Panel Members include transit personnel with direct responsibility for detectable warnings installation, persons with disabilities, a representative of a prominent senior citizen's organization, and experts in disability policy and practice. Table 5-1 lists the Panel Members and their organizational affiliations.

The Panel was assisted by a group of Panel Observers, selected for their technical knowledge and experience with detectable warnings. Panel Observers included technical representatives from the Federal Transit Administration (FTA), a representative of the American Public Transit Association (APTA), technical staff from the Volpe Center, and representatives of the three transit systems participating in the field tests of detectable warning systems. Panel Observers also included technical research staff from Technology & Management Systems, Inc. (TMS), and Boston College. Table 5-2 lists the Panel Observers and their organizational affiliations.

Table 5-1

National Implementation Panel for Detectable Warnings Panel Member List

Robert Beck
Long Island Railroad

George Fleisher, M.D.
Department of Rehabilitation Medicine
St. Vincent's Medical Center

Margaret Groce
New York City Public Schools
Travel Training for the Handicapped

Geraldine Kelley
New York City Public Schools
Educational Vision Programs and Services

Gertrude Landau
New York Citizen's Committee on Aging

Karen Luxton-Gourgey, Ph.D.
Computer Center for the Visually Impaired
City University of New York

Harry Nagy
Office of Special Services
New Jersey Transit

Walter Noonan
New York City Transit Authority

Dona Sauerburger
Volunteers for the Visually Handicapped

Marilyn Saviola
New York Center for the
Independence of the Disabled

Nicholas Scarano
Metro North Commuter Railroad

Rolf Skogland
Port Authority of NY and NJ
Journal Square Transportation Center

Ralph Weule
Safety & Investigations
San Francisco Bay Area Rapid Transit District

Table 5-2

National Implementation Panel for Detectable Warnings
Panel Observer List

Billie Louise Bentzen
Accessible Designs for the Blind
Boston College

William H. Bregoli, Jr.
Massachusetts Bay Transportation Authority

David Capozzi (invited)
Architectural and Transportation Barriers Compliance Board

Vincent R. DeMarco
Federal Transit Administration

Deborah L. Dubin
American Public Transit Association

John P. Goodworth
Greater Cleveland Regional Transit Authority

William Hathaway
Volpe National Transportation Systems Center

H. Norman Ketola
Technology & Management Systems, Inc.

Carol H. Lavoritano
Southeastern Pennsylvania Transportation Authority

Ramon A. Lopez
Federal Transit Administration

Patricia Ryan
Volpe National Transportation Systems Center

Robert W. Stout
Federal Transit Administration

The Panel was established in the fall of 1993. Panel activities were organized and facilitated by the American Foundation for the Blind (AFB). AFB also conducted a national review of the experience of transit systems and transit users with detectable warnings. The purpose of this national information collection effort was to obtain the reactions of people in "key stakeholder" groups about issues that had been raised in the rulemaking process on detectable warnings at transit platform edges. A total of fifty-four persons in thirteen states were interviewed by telephone. The results are presented in *Reference 6*.

5.2 PANEL ACTIVITIES

The first Panel meeting took place on December 3, 1993, at AFB's National Headquarters in New York City at which time the Panel reviewed the results of the national information collection effort. The Panel also framed the critical issues it wished to address and heard reports describing detectable warnings performance at the Bay Area Rapid Transit System (BART), human performance testing of detectable warnings, and plans for engineering testing and field evaluations of detectable warnings installations to be carried out during the winter of 1993 - 1994. Panel Members participated in an implementation scenario exercise to prepare for detectable warnings implementation. The first Panel meeting reached the following conclusions:

- The issues related to detectable warnings were a matter of serious concern. Panel Members acknowledged the emotional nature of the topic and expressed mutual respect for each other's concerns.

- The cost of detectable warnings implementation was a serious matter, although the Panel viewed cost as secondary to transit system safety and access, a fundamental responsibility of transit systems. The Panel stressed that all transit infrastructure costs were "big ticket items" and detectable warnings fit into this category.

- There was a critical need to gather and disseminate accurate information about detectable warnings in the transit industry and disability communities.

- Detectable warnings should be viewed as a transit design element that was beneficial to the safety of all passengers.

The second Panel meeting was held on May 11, 1994, at AFB's National Headquarters in New York City. At this meeting the Panel reviewed the findings of the engineering laboratory testing and interim results of the field evaluations of detectable warnings carried out at the three transit properties during the winter of 1993 - 1994. The Panel also heard reports about the experiences of eight transit systems involved in detectable warnings installation and testing and developed the blueprint and content for a detectable warnings implementation document.

5.3 SUMMARY OF TECHNICAL INFORMATION FROM THE PANEL

This section provides a summary of the technical information and guidance provided by the Panel Members and Panel Observers that has a direct bearing on the needs of the transit industry with regard to the selection, procurement, installation, and maintenance of detectable warning systems. The information is organized into two categories as follows:

- Experiences with detectable warning materials procurement and installation.

- Tips for implementing detectable warning requirements.

5.3.1 Experiences with Detectable Warning Procurement and Installation

Panel Members and Observers during the panel meetings presented a series of observations related to their experiences with the procurement and installation of detectable warning systems. These observations are provided here for purposes of information; however, it should be noted that they do not cover all aspects of selection, procurement, and installation.

- A number of systems have conducted laboratory tests or limited field tests of detectable warning materials that provide additional sources of information to the transit industry.

- Most transit systems have to develop their own specifications for detectable warning materials and installations in order to accommodate the wide variety of station platform construction materials and platform physical conditions.

- Transit platform surface conditions and preparation required should be specifically described in the specifications to avoid disputes and additional costs when installation is underway.

- A number of transit systems have chosen to provide detectable warnings procurement and installation as part of a general contractor's task to bring a complete station into ADA compliance. This approach appears to have created problems when the general contractor is able to select one of a number of materials that meet the specification. Disputes and legal action have been initiated by manufacturers whose products meet the specifications but are not selected by the general contractor.

- Transit systems that contracted with a manufacturer for the procurement and installation of a specific detectable warning material in a single integrated contract, generally, reported prompt and satisfactory progress on system installation.

- One transit system expressed a concern about the limited availability of installation contractors which effectively hampered competition and precluded the selection of manufacturers whose products were completely acceptable but who lacked the capacity to carry out effective installations.

- Installation is a challenging task at most transit systems requiring much of the work to be completed during late night and early morning hours. Special track use must be arranged to isolate specific platforms. Work must be performed on separate halves to avoid putting a station out of service due to unanticipated installation problems.

- One transit system placed a patent release clause in its contract to preclude future problems when the time came for product replacement. This clause allows the system to solicit competitive bids for an identical product.

- One transit system decided not to use mechanical fasteners at outside stations because of a concern that a salt mixture used in the winter would penetrate the fastener holes, weaken the concrete platform steel reinforcement bars, and threaten platform structural integrity.

- Other transit systems were concerned about bonding materials completely to the platform that would prevent easy removal and replacement of damaged sections. They opted, instead, for removable mechanical fasteners and edge bonding.

- Most systems noted that preparation of substrate and careful installation is critical in order to avoid future problems with the installation.

- One transit system left a drainage gap of two inches for every ten feet of platform length to avoid accumulation of water under the material.

- One transit system had its station maintenance staff visit other systems to collect detailed information on material cleaning techniques in order to develop their own detectable warning cleaning and maintenance procedures.

- Removal of snow and ice from detectable warnings can be accomplished using routine snow and ice removal procedures (shoveling, plowing, and chemical treatment). Ice that accumulates between the raised domes can be readily treated with calcium chloride (preferable to sodium chloride) as a standard part of routine winter maintenance.

5.3.2 Tips for Implementing Detectable Warning Requirements

In addition to relating the specific experiences of participating transit systems, the Panel also tried to generalize their experiences as a series of recommendations or implementation tips. The following items provide a summary of some of the key tips:

- Transit systems should view a retrofit installation of detectable warnings as the installation of a "system" that includes the detectable warning material itself, the adhesion and/or mechanical fastening materials utilized, and the substrate on which the warnings are applied.

- Transit systems should explore the range of materials and installation options available when planning to install detectable warnings. Costs for procurement, installation, and maintenance should be based on consideration of the "detectable warning system."

- Transit systems should contact other transit systems that have had experience with detectable warnings to learn about the "track record" of their materials and installations.

- Transit systems should plan carefully for the operational impact of the installation process by contacting other systems to learn about their experiences.

- Installing detectable warnings is new for many contractors. Transit systems that have begun the installation process report that installations carried out by inexperienced contractors have taken longer than anticipated.

- Transit systems should create a working document that is a comprehensive internal "game plan" for implementing the detectable warnings requirements, identifying:

  - System's specific objectives and time frames (e.g., "will complete installations at three key stations by July 26, 1994").

  - All aspects of the implementation process including facility design, contract and procurement administration, engineering considerations, maintenance, public education, marketing, or any other areas that are relevant to an individual transit system.

  - Departments and key individuals involved in each phase of implementation process with a time frame for the involvement.

  - Internal constituencies in a transit agency and the external community constituencies for marketing and public education. Organizations of and for persons with disabilities, senior citizens' organizations, and generic transit consumer groups such as a "straphangers" association are valuable resources for identifying and reaching key constituencies.

- Checklists created for materials specifications, contents of a request for proposal and scope of work, installation and maintenance procedures, and public education activities will assist transit systems in managing the process of detectable warnings installation.

- Transit systems should be aware that often it is difficult to distinguish between factual information updates and rumors and that accurate information is not reaching the places where it is needed. Information can be obtained from the Federal Transit Administration and the Volpe National Transportation Systems Center. Transit systems should verify all information they receive regarding detectable warnings, especially information conveyed by telephone, regardless of how plausible new information may appear.

- Flexibility with respect to a transit system's current operating and maintenance procedures is essential when initiating a detectable warnings installation program. This flexibility is important, especially at the time of installation of the material, to assure that the installation is done correctly. A major reason for the failure of a detectable warnings system is poor installation, rather than a problem with the detectable warning material.

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3. *Bulletin #1: Detectable Warnings.* Washington, D.C.: U.S. Architectural and Transportation Barriers and Compliance Board. Advisory Bulletin, April, 1994.

4. Ketola, H.N. and Chia, D. *Results of Laboratory Testing of Detectable Warning Materials.* Burlington, MA: Technology & Management Systems, Inc. Technical Memo No. 65_09-1, November, 1993.

5. Sandor, L.W. *Testing of Tactile Warning Materials.* New York: Weintraub & diDomenico in association with Vollmer Associates. Test Report prepared for the Metro North Commuter Railroad, November, 1993.

6. Joffee, E. *The National Implementation Panel for Detectable Warnings: A Detectable Warnings Implementation Document.* New York: American Foundation for the Blind. Final Report, September, 1994.

APPENDIX A. INFORMATION ON MATERIALS INCLUDED IN LABORATORY TESTS

ADA Consultants
"Alert Mat"

Contact Name and Telephone Number:

Bob Sprouse (919) 872-5330

Material Information:

Type of Material:	Rubber Compound Mat
Mat Size:	6' x 3'4"; 6' x 2'
Mat Thickness:	⅛ inch
Material Color:	Yellow, Black
Adhesive Used?:	Yes
Mechanical Fasteners Used?:	Yes

Special Characteristics (if any):

Base surface of mat is ribbed.

Advantage Metal Systems
"Detectable Warning Systems"

Contact Name and Telephone Number:

Helmut Klohn (508) 580-5177

Material Information:

Type of Material:	Steel or Aluminum Coated with Polymer
Panel Size:	10' x 2'
Panel Thickness:	⅛ inch
Material Color:	Yellow
Adhesive Used?:	No
Mechanical Fasteners Used?:	Yes

Special Characteristics (if any):

Detectable Warnings Evaluation Project

Materials Tested

Bridgco
"ADA Path"

Contact Name and Telephone Number:

Mike Bridgeman (800) 466-4884

Material Information:

Type of Material:	Polymer Concrete, Molded at Point of Installation
Application Size:	3' x 2' (size of one form)
Application Thickness:	⅜ inch
Material Color:	Yellow, Red
Adhesive Used?:	No
Mechanical Fasteners Used?:	No

Special Characteristics (if any):

Carsonite International
"Pathfinder"

Contact Name and Telephone Number:

Peter Mileo (800) 648-7974

Material Information:

Type of Material:	1.	Polymer Composite
	2.	Synthetic Rubber Compound (not tested)
Panel Size:	4' x 2'	
Panel Thickness:	⅛ inch	
Material Color:	Yellow	
Adhesive Used?:	Yes (optional)	
Mechanical Fasteners Used?:	Yes	

Special Characteristics (if any):

Textured pattern on top of domes and tile base.

Detectable Warnings Evaluation Project

Materials Tested

COTE-L Enterprises
"Safti-Trax"

Contact Name and Telephone Number:

Cyrus Fine (201) 836-0733

Material Information:

Type of Material:	Polyurethane Domes with "Durabak" Polyurethane Coating
Application Size:	No Standard Size
Application Thickness:	Applied Directly to Surface
Material Color:	Black, Grey
Adhesive Used?:	No
Mechanical Fasteners Used?:	No

Special Characteristics (if any):

Domes are attached to base coating at point of installation.

Crossville Ceramics
"Tac-Tile"

Contact Name and Telephone Number:

Barrie Decker (312) 975-9872

Material Information:

Type of Material:	Unglazed Ceramic Tile
Tile Size:	1' x 1'
Tile Thickness:	5/16 inch
Material Color:	Yellow
Adhesive Used?:	Setting Bed and Cement
Mechanical Fasteners Used?:	No

Special Characteristics (if any):

"A" and "B" tiles with complementing dome patterns to create proper spacing of domes.

Dal-Tile Corporation
"Detectable Warning Tile"

Contact Name and Telephone Number:

Larry Kelly (214) 309-4535

Material Information:

Type of Material:	Unglazed Porcelain Tile
Tile Size:	2-1/16" x 2-1/16" (available in 23½" x 12¾" sheets)
Tile Thickness:	⅛ inch
Material Color:	"Daffodil", Black, White
Adhesive Used?:	No
Mechanical Fasteners Used?:	No

Special Characteristics (if any):

Engineered Plastics
"Armor-Tile"

Contact Name and Telephone Number:

Ken Szekely (800) 682-2525

Material Information:

Type of Material:	Vitrified Polymer Composite
Panel Size:	1' x 1' or 4 ' x 2'
Panel Thickness:	⅛ inch
Material Color:	Yellow
Adhesive Used?:	Yes (optional)
Mechanical Fasteners Used?:	Yes

Special Characteristics (if any):

- Alignment of domes is parallel and perpendicular to flow of travel (not 45°).
- Dome heights are tapered — shorter domes in rows further from platform edge.
- Domes and surface are nubbed.

Hastings Pavement Co.
"ADA Pavers"

Contact Name and Telephone Number:

Donald Kehoe (800) 874-4717

Material Information:

Type of Material:	Concrete Brick
Paver Size:	1' x 1'
Paver Thickness:	2 inches
Material Color:	Brownish-Yellow
Adhesive Used?:	Setting Bed and Cement
Mechanical Fasteners Used?:	No

Special Characteristics (if any):

Spacing of domes does not conform to regulations.

High Quality Tactile Systems "Tac Strip"

Contact Name and Telephone Number:

Stacey Arbetter (617) 935-8450

Material Information:

Type of Material:	Polymer Composite
Panel Size:	10' x 2'
Panel Thickness:	⅛ inch
Material Color:	Yellow
Adhesive Used?:	No
Mechanical Fasteners Used?:	Yes

Special Characteristics (if any):

Domes and surface are nubbed.

Inco Chemical Supply Co.
"Tactile Warning System"

Contact Name and Telephone Number:

Murray Goldenberg (800) 752-4626

Material Information:

Type of Material:	Polymer Concrete
Application Size:	No Standard Size
Application Thickness:	Applied Directly to Surface
Material Color:	Yellow
Adhesive Used?:	No
Mechanical Fasteners Used?:	No

Special Characteristics (if any):

NBS/Aware & Concerned Services "Detectable Warning Mat"

Contact Name and Telephone Number:

Craig Benett (800) 655-3780

Material Information:

Type of Material:	Rubber Mat
Mat Size:	50" x 25"
Mat Thickness:	Applied Directly to Surface
Material Color:	Yellow
Adhesive Used?:	Yes
Mechanical Fasteners Used?:	No

Special Characteristics (if any):

Rehau, Inc.
"Access Tactile Tile"

Contact Name and Telephone Number:

Eric Mingo (703) 777-5255

Material Information:

Type of Material:	Thermoplastic Polyurethane
Tile Size:	6" x 12"
Tile Thickness:	Applied Directly to Surface (⅛ inch)
Material Color:	Yellow
Adhesive Used?:	Yes
Mechanical Fasteners Used?:	No

Special Characteristics (if any):

Alignment of domes does not conform to regulations.

Steps Plus, Inc.
"Detectable Warning Units"

Contact Name and Telephone Number:

Robert Kopp (315) 446-8050

Material Information:

Type of Material:	Pre-cast Concrete
Tile Size:	1' x 1'
Tile Thickness:	1 inch
Material Color:	Yellow, Blue
Adhesive Used?:	No
Mechanical Fasteners Used?:	No

Special Characteristics (if any):

Generally not appropriate for retrofit installations.

Detectable Warnings Evaluation Project

Materials Tested

Strongwall Systems
"Strongwarn"

Contact Name and Telephone Number:

Bill Kokoletsos (201) 445-4633

Material Information:

Type of Material:	Two-component Polymer Concrete Molded at Point of Installation
Application Size:	No Standard Size Uses of Variety of Sizes (5' x 1' most common)
Application Thickness:	Applied Directly to Surface
Material Color:	Yellow, Blue
Adhesive Used?:	No
Mechanical Fasteners Used?:	No

Special Characteristics (if any):

Summitville Tile
"Tactile-Tread"

Contact Name and Telephone Number:

Peter Johnson (216) 223-1511

Material Information:

Type of Material:	Glazed Porcelain Tile
Tile Size:	1' x 1'
Tile Thickness:	⅜ inch
Material Color:	Yellow, Tops of Domes are Brown
Adhesive Used?:	Yes (2-part epoxy)
Mechanical Fasteners Used?:	No

Special Characteristics (if any):

Spacing of domes does not conform to regulations.

Transpo Industries
"Step-Safe"

Contact Name and Telephone Number:

John Karlson (914) 636-1000

Material Information:

Type of Material:	Polymer Concrete
Tile Size:	1' x 1', 2' x 4' (not tested)
Tile Thickness:	¾ inch
Material Color:	Yellow
Adhesive Used?:	Yes (2-part epoxy)
Mechanical Fasteners Used?:	No

Special Characteristics (if any):

Textured pattern on top of domes.

Whitacre-Greer
"Paver"

Contact Name and Telephone Number:

Richard Dana (216) 823-1610

Material Information:

Type of Material:	Shale Brick
Brick Size:	4" x 8"
Brick Thickness:	1½, 2¼ inches
Material Color:	4 Shades of Red/Brown
Adhesive Used?:	Setting Bed and Cement
Mechanical Fasteners Used?:	No

Special Characteristics (if any):

Spacing and alignment of domes do not conform to regulations.

APPENDIX B. INSTALLATION DATA COLLECTION FORM

Detectable Warnings Evaluation Project
Field Test Installation

Date ______________________ Manufacturer ______________________

Station______________________ Product ______________________

outside/inside

Weather (outside installation):

Installation size: Location:

Crew Size:

Tools:

Steps: Start Time: End Time:

Observations:

APPENDIX C. FIELD TEST DATA AND OBSERVATION FORM

Detectable Warnings Evaluation Project
Field Test: Performance and Durability Data

Date ____________________ Manufacturer ____________________

Station____________________ Product ____________________

outside/inside

(attach photos)

Wear (measured in mm)

- Domes:

- Base:

Change in Slip Resistance:

Chipping, cracking:

Discoloration:

Other observations:

APPENDIX D. DOME HEIGHT MEASUREMENTS AND COMPUTATION OF WEAR

One of the important quantitative performance measures is the relative wear of each detectable warning material surface. In order to determine wear, dome heights were measured for each of the materials installed at the indoor sites. This task involved measuring the height, relative to the material's base, of 64 truncated domes—16 clusters of four domes spread across each eight-foot by two-foot test section—to the precision of 0.01 millimeters using a depth micrometer. The 16 clusters of domes are located at the same relative locations for each installed material. Figure D-1 presents the locations of the measured cluster of domes on the test installations.

Measurements of dome heights were always made at the same time in each test section. Two sets of measurements were made with a time interval of 198 days at GCRTA and 69 days at MBTA. The average absolute decrease and the percent decrease in dome heights relative to the initial measurements were computed using the raw data collected for dome heights. It was also necessary to derive wear results that considered that the indoor test installations were subject to "accelerated" wear because of their placement in passageways with concentrated passenger traffic.

A conversion factor, or *acceleration factor*, was derived by the authors to convert the measured dome height wear at the accelerated wear test section to a projected wear at the platform edge. The following equation was used to derive the acceleration factor:

$$\text{Acceleration Factor} = A * B * C * D * E * F * G / H$$

where,

A = Number of platform edges at the station.

B = Number of cars per train during off peak service.

C = Peak hour car factor: adjustment to account for a greater number of cars per train during the peak periods. On the MBTA Red Line, an off-peak train has four cars; a peak train, six cars. On the GCRTA Red Line, an off-peak train has two cars; a peak train, three cars.

D = Number of doorways per car.

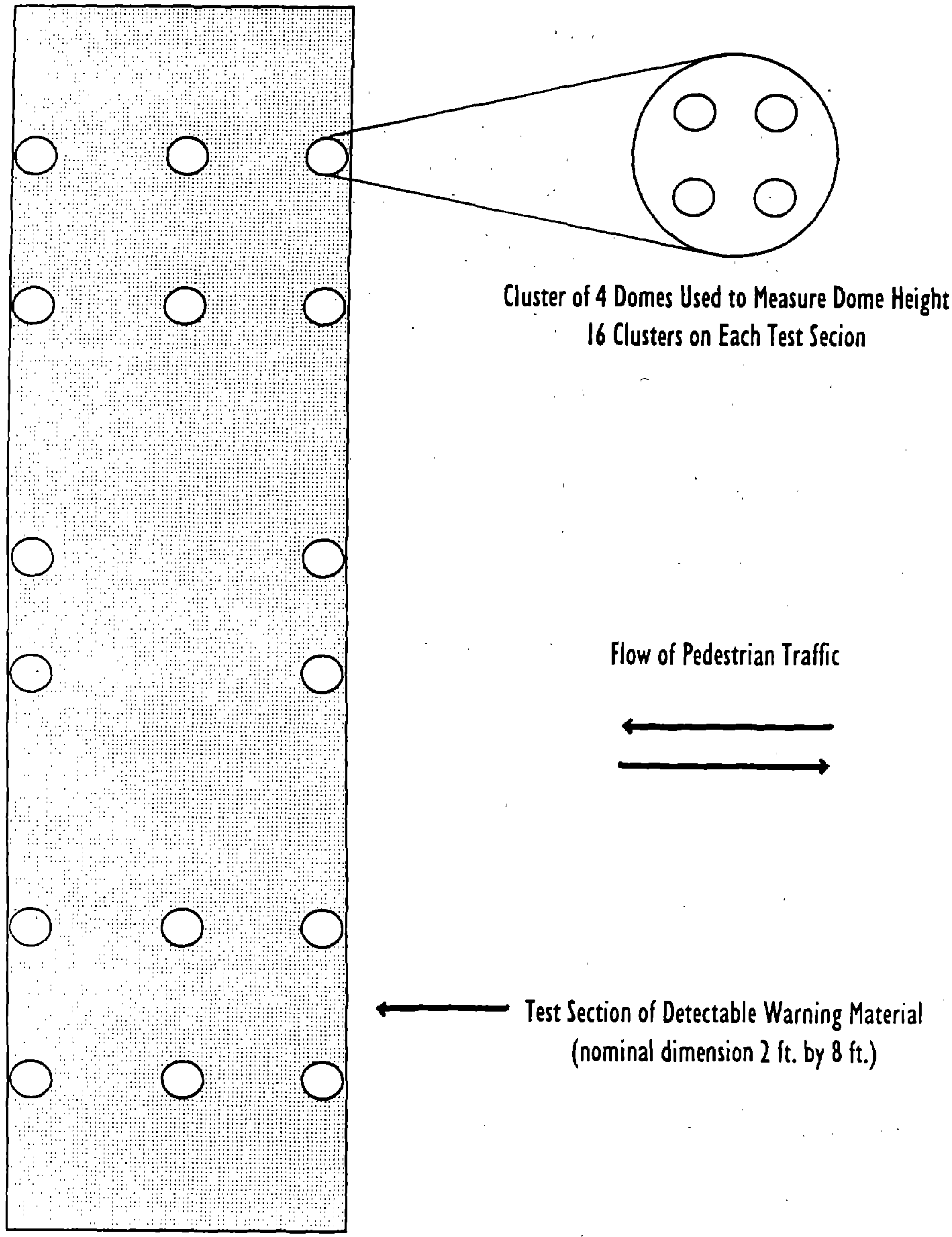

Figure D-1
Location of Measured Dome Clusters on Indoor Installations

E = Width of a doorway (feet).

F = Variability of the stopping location of the doorways along the station platform. Variability = 1 signifies that the doorways always open at the same locations. Variability of "n" signifies that each doorway opens within a section of the platform "n" times the width of the doorway.

G = Proportion of the station's ridership (both boarding and alighting) that cross the test installation. Proportion = 1 signifies that 100% of the passengers travel across the test installation in both directions.

H = Width of the test installation (feet).

These following values were used to calculate the acceleration factors for GCRTA's Brookpark station and the MBTA's South Station:

	Brookpark	South Station
A	2	2
B	2	4
C	1.25	1.15
D	3	3
E	4	4
F	2	5
G	1	⅓
H	8	8
Acceleration Factor	**15**	**23**

The values for F are very rough estimates provided by the transit system staff. The value for G for South Station is also a rough estimate; the proportion of passengers travelling across the test installation may well be less than one-third. **Consequently, the value used for South Station's acceleration factor was rounded to 20.**

Measured wear at the accelerated wear test section is calculated directly from the dome height measurements:

Measured Wear = [[(Initial Dome Height) - (Final Dome Height)] / (Initial Dome Height)] * 100

Measured wear is expressed as a percent of the initial dome height. An average (mean) value of dome wear was computed for each test section based on measurements from the 64 selected domes. These average values are reported in this section.

The projected wear (expressed as a percentage) at the station platform edge was computed as follows:

Projected Wear = (Measured Wear) / (Acceleration Factor)

In order to make the projected wear values more readily understandable, they were converted to annual estimates as follows:

Projected Annual Dome Wear = [(Projected Wear) * 365] / (Exposure Days Between Initial and Final Measurements)

All of the wear rates are expressed as dome height decrease as a percentage of the original dome height.

Tables D-1 and D-2 present the measured and the projected annual dome height wear values (percentage of initial dome height) for the materials installed at Brookpark and South Station, respectively. The tables also provide a range of projected annual wear rates based on the variation in the individual dome height wear measurements. This can be considered as the potential variability of dome height wear.

Table D-1
Measured and Projected Dome Height Wear — Brookpark

A. Exposure Days Between Measurements 198
B. Acceleration Factor 15

MANUFACTURER *PRODUCT NAME*	MEASURED WEAR (PERCENT OVER EXPOSURE PERIOD)	PROJECTED ANNUAL WEAR AT PLATFORM EDGE (PERCENT)	RANGE OF PROJECTED ANNUAL WEAR RATES (BASED ON VARIABILITY OF MEASURED DATA)
ADA Consultants *Alert Mat*	8.9	1.1	0.4 to 2.1
Carsonite International *Pathfinder*	8.0	0.98	0.4 to 1.4
Hastings Pavement *ADA Paver*	3.5	0.42	0.0 to 1.1
Transpo Industries *Step-Safe*	6.0	0.74	0.0 to 1.3

Table D-2
Measured and Projected Dome Height Wear — South Station

A. Exposure Days Between Measurements 69
B. Acceleration Factor 20

MANUFACTURER *PRODUCT NAME*	MEASURED WEAR (PERCENT OVER EXPOSURE PERIOD)	PROJECTED ANNUAL WEAR AT PLATFORM EDGE (PERCENT)	RANGE OF PROJECTED ANNUAL WEAR RATES (BASED ON VARIABILITY OF MEASURED DATA)
Carsonite International *Pathfinder*	11.0	2.9	2.6 to 3.4
Crossville Ceramics *Tac-Tile*	5.4	1.4	0.0 to 1.8
Engineered Plastics *Armor-Tile*	12.0	3.2	0.3 to 5.1
Hastings Pavement *ADA Paver*	2.4	0.64	0.0 to 0.8
Rehau *Access Tactile Tile*	5.1	1.3	0.1 to 2.8
Summitville Tile *Tactile Tread*	1.1	0.28	0.0 to 2.9
Transpo Industries *Step-Safe*	2.8	0.74	0.1 to 1.9

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