Guidelines for Selection and Approval of Noise Barrier Products

Final Report

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Abstract

State departments of transportation (DOTs) have identified a need for guidance on noise barrier materials products. This study identified and reviewed literature relevant to noise barrier materials and products with respect to characteristics, testing, selection, and approval. A database of manufacturers and vendors of noise barriers and materials, and a sample of product unit costs, was compiled. State DOTs' current requirements were compiled. State DOTs were surveyed regarding their experiences with various noise barrier materials, their priorities and concerns about these materials, and their current practices for evaluation and selection. The study provides recommendations for evaluation and selection procedures of noise barrier materials and products, including applicable standards and specifications. The information from the literature search and the survey was included in a separate resource document in electronic spreadsheet format as a companion to the report. Both documents were developed with the expectation that their main audience would be State DOT staff.

Executive Summary

As highway capacity is increasing through new highway construction and improvements to existing highways, as the extent of our residential communities and other noise-sensitive development continues to increase, and as traffic on the highways continues to grow, the need and desire for noise abatement also increases. The only feasible measure to reduce highway noise in most cases is construction of a noise barrier. The cost of noise barriers has been increasing significantly in recent years. Most state departments of transportation (DOTs) have cost ceilings for providing noise abatement in conjunction highway projects. When these ceilings are expected to be exceeded, noise barriers are considered not to be cost-effective, and in most cases, are not constructed. While barrier costs have been increasing, the DOTs' cost ceilings in many cases have not.

The Federal Highway Administration's (FHWA's) 1995 *Highway Traffic Noise Analysis and Abatement Policy and Guidance* allows the state DOTs flexibility in creating State Noise Abatement Policies, and this flexibility has carried over into noise barrier design. Most state DOTs that have been building barriers have their own specific requirements for barrier construction, and these affect the costs and materials, durability, ability to satisfy aesthetic desires of the public including the nearby residents and localities, and other environmental considerations. In many cases, these specific requirements are the result of trial and error processes used by individual state DOTs, and the results have not always been shared with other DOTs.

State departments of transportation (DOTs) have identified a need for guidance on noise barrier materials products. This study identified and reviewed literature relevant to noise barrier materials and products with respect to characteristics, testing, selection, and approval. We developed an inventory of commercially available noise barrier materials and sound absorbing products that can be used on barriers. The inventory included the information necessary to evaluate the materials/products – properties, constructability, performance in use, test results and certifications, and unit price ranges. In all, the inventory identified more than 240 individual documents and sources that could be of potential use in developing guidance or in providing relevant information to DOT users.

We conducted a survey of state DOTs in order to gain insight into their materials evaluation process and in-use experience with noise barrier materials and products. The survey gathered information about barrier materials currently in use, materials currently approved or banned, priorities in evaluating materials, experiences with specific materials, needs for guidance and information, and current testing requirements.

We organized the information developed in the Task 1 inventory and the Task 2 survey into a database. The database is organized by project component (topic) and was designed to be easily searchable. Documents obtained from the literature search and inventory were reviewed and evaluated for potential usefulness in several topic areas, using a rating scale of High/Likely, Medium/Possible, and Low/Unlikely. DOT staff who are searching the inventory can use these ratings as a general guide in selecting sources to access the full text.

We developed recommendations in the following areas:

- Best Practices and Recommendations for New Noise Barrier Product Evaluation and Approval, such as formation of a noise barrier approval committee, attendance by a DOT representative at barrier material tests, additional approval requirements, and sharing of test results among DOTs through a website.

- Alternative Crash Testing Procedures to Reduce Costs Associated with the Selection and Approval Process. Currently, crash-testing of barriers (including guard rails and jersey barriers used to protect noise barriers from vehicle contact) must be performed in accordance with NCHRP Report 350. However, it is costly to conduct full-scale crash tests. A current NCHRP-funded research project is developing guidelines for verification and validation of detailed finite element analysis for crash simulations of roadside safety features. Computer simulation of barrier crashes appears to have great potential to reduce costs by reducing the need for full-scale physical testing. However, it appears that computer simulation methods are not yet sufficiently mature or standardized to recommend their routine use for barrier manufacturers and State DOTs.

- Specifications Required for Noise Barrier Materials. This study identified specifications that should be required for noise barrier materials, and relevant published standards, by type of performance characteristic and material.

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1. Background

As highway capacity is increasing through new highway construction and improvements to existing highways, as the extent of our residential communities and other noise-sensitive development continues to increase, and as traffic on the highways continues to grow, the need and desire for noise abatement also increases. The only feasible measure to reduce highway noise in most cases is construction of a noise barrier. In most states, barriers are built in conjunction with a Type I highway project (construction of a highway in a new location or the physical alteration of an existing highway which significantly changes the horizontal or vertical alignment or increases the number of through traffic lanes) and are paid for with federal and state funds (and occasionally local funds). Some barriers are built as Type II (retrofit) project for noise abatement on an existing highway. Barriers are also built by developers as part of new residential communities.

The cost of noise barriers has been increasing significantly in recent years (materials, delivery, and installation are the main culprits). Most state departments of transportation (DOTs) have cost ceilings for providing noise abatement in conjunction with Types I and II projects. When these ceilings are expected to be exceeded, noise barriers are considered not to be cost-effective, and in most cases, are not constructed. While barrier costs have been increasing, the DOTs' cost ceilings in many cases have not.

The Federal Highway Administration's (FHWA's) 1995 *Highway Traffic Noise Analysis and Abatement Policy and Guidance* allows the state DOTs flexibility in creating State Noise Abatement Policies, and this flexibility has carried over into noise barrier design. Table 1 indicates the diversity of materials and products available for use in noise barriers. Some states have been building noise barriers since the 1970s, while others are just getting started and have not built any noise barriers to date. Most state DOTs that have been building barriers have their own specific requirements for barrier construction, and these affect the costs and materials, durability, ability to satisfy aesthetic desires of the public including the nearby residents and localities, and other environmental considerations. In many cases, these specific requirements are the result of trial and error processes used by individual state DOTs, and the results have not always been shared with other DOTs.

Although the Federal-State partnership and its flexibility have many proven benefits in allowing DOTs to make investment decisions that balance the needs and priorities of their citizens, there is a need for greater information-sharing. As with some other programs in which individual states are responsible for implementation, most states have similar needs but, the fragmented information available on noise barrier materials has created the potential for inefficiencies. With only limited resources to learn from other state DOTs' experience, each DOT risks duplication of effort. To the extent that material specifications are not consistent across states, barrier material manufacturers may need to produce multiple small batches to meet unique DOT requirements and cannot take advantage of economies of scale that might reduce prices with higher volume production. Manufacturers and DOT testing facilities must conduct greater numbers of tests to evaluate materials where there is no unified specification.

Table 1: State DOTs Have Used a Variety of Materials for Noise Barriers

Barrier Materials	Square Feet Constructed (×1000)
Single Material	
Concrete/Precast	67,926
Block	33,993
Concrete/Unspecified	13,715
Wood/Post & Plank	5,912
Metal/Unspecified	4,279
Berm/Wood/Concrete	348
Berm Only	4,281
Wood/Glue Laminated	3,701
Absorptive (all types)	3,629
Wood/Unspecified	3,055
Other	1,812
Brick	1,152
Combination	
Wood/Concrete	4,281
Berm/Wood	2,990
Concrete/Block	2,154
Other Combination	1,930

Barrier Materials	Square Feet Constructed (×1000)
Combination (Continued)	
Berm/Concrete	1,863
Metal/Concrete	1,786
Berm/Metal	1,439
Berm/Block	795
Concrete/Brick	586
Wood/Metal	464
Wood/Block	283
Berm/Wood/Metal	171
Block/Brick	8
Other Materials	
Glass Block	N.A.*
Glass Fiber Products	N.A.
Glass/Plastic Laminates	N.A.
Plastics	N.A.
Recycled Plastics	N.A.
Stone/Gabions	N.A.

* N.A. = Not available.

Source: Adapted from FHWA 2006, Table 2.

As noted in the Task 40 Problem Statement, noise barrier manufacturers and several states without noise barriers have identified a need for guidance that would provide several elements:

- Review and compilation of DOTs' current requirements for testing, selection, and approval.
- Identification of test procedures appropriate to noise barrier service (as opposed to building material applications).
- Cost data sufficient to evaluate the cost effectiveness of various options for materials and design in a given project application.
- A database of manufacturers and vendors of noise barriers and materials.
- Guidance on selecting materials and barrier products for various in-use scenarios. Criteria for developing scenarios would be defined largely by the DOTs and could include, for example,

durability, cost vs. noise reduction effectiveness, visual acceptability to community members, graffiti resistance, foundation/constructability issues, and climate-related requirements.

This report addresses these needed guidance elements. A separate resource document (the inventory/database) in electronic spreadsheet format was developed as described below. The resource document is a companion to this report. Both documents were developed with the expectation that their main audience would be State DOT staff.

2. Research Approach

Task 1 – Develop Inventory

We developed an inventory of commercially available noise barrier materials and sound absorbing products that can be used on barriers. The inventory included the information necessary to evaluate the materials/products – properties, constructability, performance in use, test results and certifications, and unit price ranges. Previous FHWA studies such as *Summary of Noise Barriers Constructed by December 31, 2004* (released by memo May 25, 2006) provided a starting point. Although the FHWA *Summary* contains much information that remains relevant, it does not include data for California, which has constructed roughly one-fifth of all highway barriers to date. (FHWA intends to prepare the 2007 update of the *Summary* but no new data were available as of May 2008.) Initially we developed a standardized template/checklist to assure that the desired information on each material/product had been sought and obtained. We conducted the inventory using these main approaches:

- First, through a Web search we gathered previously documented information from FHWA, state DOTs, the Transportation Research Board (TRB), and other organizations.
- We conducted a literature review that included a computerized database search of the open peer-reviewed literature, conference proceedings of the TRB, and papers presented at industry noise conferences. This search also included the trade press so that press releases, product reviews, and similar up-to-date industry sources were covered. This search located many documents that have not been posted to the Internet.
- We contacted barrier product manufacturers and barrier suppliers or distributors. These contacts included those with whom the Principal Investigator has worked in the past.
- We searched the Internet using Google for additional products and materials, as well as manufacturers' websites. The Internet search was also used in identifying international product applications.

In all, the inventory identified more than 240 individual documents and sources that could be of potential use in developing guidance or in providing relevant information to DOT users. The inventory was produced as a section of an electronic document which is included in this report by reference as Appendix A.

Task 2 – Conduct Survey

We conducted a survey of state DOTs in order to gain insight into their materials evaluation process and in-use experience with noise barrier materials and products. Using lists published by

FHWA and TRB, we initially identified appropriate contact persons to survey at all 50 state DOTs, as well as at counterpart agencies in the District of Columbia, Puerto Rico, and the Canadian provinces of Ontario and Québec. FHWA staff and NCHRP panel members helped update our list and assure that we identified the current and most appropriate noise contacts, often noise mitigation managers. For many states an initial phone contact nevertheless was required to identify the current contact person. Although this meant extra effort, the initial call also provided an opportunity to introduce the DOT participants to the project and let them know that a survey would follow, and therefore, may have increased the survey response rate. The final survey population consisted of 50 jurisdictions: 45 U.S. state DOTs, the District of Columbia, Puerto Rico, Ontario, Québec, and one intrastate authority. The final survey was not sent to states with no or very few noise barriers, as determined by data supplied by those states or by the Principal Investigator. The states determined to have no or very few noise barriers are Arkansas, Delaware, Mississippi, Montana, and South Dakota. In Massachusetts there are two agencies that are involved in noise barrier construction. In addition to the Massachusetts Highway Department, the Massachusetts Turnpike Authority, an independent agency that builds noise barriers for its roadways, was solicited at the suggestion of the Massachusetts Highway Department and agreed to participate in the survey.

We used an e-mail survey with follow-up telephone calls to selected states. Because it was also important to provide an opportunity to fully explore the DOTs' experiences with materials and products of interest, the questionnaire included open-ended questions in addition to multiple choice or table fill-in questions. Previous related studies that employed surveys, such as *Highway Noise Barriers: 1994 Survey of Practice* (Texas DOT, published as Transportation Research Record 1523, TRB 2004), provided guidance on what kinds of survey questions have proven most useful, and we built upon that guidance. The e-mail survey was constructed to be short and easy to complete, minimizing the time commitment required by participants. We submitted the draft questionnaire to NCHRP for comment before conducting the survey and addressed the panel's comments in the final survey. The survey was sent to all 50 jurisdictions. Participants received an introductory e-mail message with the survey attached as an Excel file. Respondents had only to open the attached file, fill in responses with the aid of drop-down menus, and e-mail the survey back. The survey questionnaire is attached as the Appendix.

The surveys were e-mailed on October 29, 2007. The initial responses were few. To achieve a higher survey response rate, a second e-mail was sent to non-responsive state DOT contacts two weeks after the initial administration of the e-mail survey. In order to get good coverage of the states, including the ones most active in noise barrier construction, we had to follow up with the DOTs individually and extend the 2-week deadline we originally had requested. Some states reported difficulty in responding due to staffing cuts, staff workload commitments, or because individual staff who had critical knowledge had retired.

Several of the first surveys returned contained some consistently anomalous responses to two questions. We detected a pattern in the anomalous responses and traced them to an error within the menu logic in the survey. The error changed the responses to an earlier question if answers were entered to a later question. We examined all the responses to these questions to determine the likelihood that each survey had been affected by the error. To correct the data, we sent out an e-mail query to the affected respondents and updated the analysis with their new responses.

The final number of responses was 37, or 74% of the 50 jurisdictions surveyed, as shown in Table 2.

Table 2: List of Agencies Surveyed

Agencies* to Which Surveys Were Sent				
Survey Completed			**No Survey Completed**	
AK	MA	OH	AL	UT
AZ	MA Turnpike	OK	DC	WY
CA	Authority	Ontario	GA	
CO	MI	PA	HI	
CT	MN	SC	IN	
FL	NE	TN	KS	
ID	NV	TX	MO	
IL	NH	VT	OR	
IA	NJ	VA	PR	
KY	NM	WA	Quebec	
LA	NY	WV	RI	
ME	NC	WI		
MD	ND			
Surveys Completed: 37 (74%)			No Survey Completed: 13 (26%)	
Total Jurisdictions Surveyed: 50 (100%)				
Jurisdictions Not Surveyed: 5 (AR, DE, MS, MT, SD)**				
Total Jurisdictions Contacted: 55				

* State DOTs or equivalent except for Massachusetts Turnpike Authority.

** DOT staff stated in initial contacts that they would have no relevant survey responses because the DOT has built no noise barriers or too few barriers to yield meaningful results.

Task 3 – Provide Database

We organized the information developed in the Task 1 inventory and the Task 2 survey into a database. The database is organized by project component (topic) and was designed to be easily searchable. Documents obtained from the literature search and inventory were reviewed and evaluated for potential usefulness in several topic areas, using a rating scale of High/Likely, Medium/Possible, and Low/Unlikely. DOT staff who are searching the inventory can use these ratings as a general guide in selecting sources to access the full text. The following topic areas were evaluated for each document:

- Material Properties
- Barrier Constructability
- Performance in Use

- Test Results and Certifications
- Unit Price Ranges
- Specifications
- Testing Procedures
- Manufacturer Information
- Copyright Status

The complete inventory and evaluation data are contained in the "Literature" tab of the database. Internet references were assigned hyperlinks to allow easy access to the source materials. References, product data, manufacturer data, and survey results were categorized in separate tabs reflecting our assessment of user needs to access the different types of information.

We selected a flat-file database (spreadsheet) format with multiple tabs (worksheets) based on the characteristics of the inventory and survey data. An important consideration in the selection of the spreadsheet format was the needs of likely users. The final product of this research will be a tool that can be used easily by state DOT staff. Most DOT staff can be expected to have at least a basic level of expertise with Microsoft Excel or similar spreadsheet software. Far fewer are likely to have experience with more specialized database software, even those database applications that provide a convenient user interface. The spreadsheet-format Task 3 database requires only that the user be familiar with navigating an Excel file and using hyperlinks to access the documents cited. The database is an electronic document included in this report by reference as Appendix A.

3. Findings and Applications

Relevant Information in Literature

The inventory identified more than 240 individual documents and sources that could be of potential usefulness in developing guidance or in providing relevant information to DOT users. Many of the documents and sources contain specialized information that would be of value mostly to researchers or to DOT staff with a specific material or question in mind. For the user who is looking for general information or an introduction to noise barriers, existing FHWA guidance documents remain the best set of resources for U.S. practice. The following FHWA documents are especially useful for information on noise regulation and noise barriers:

- *Highway Traffic Noise Analysis and Abatement Policy and Guidance* (FHWA, 1995),
- *Highway Traffic Noise Regulations and Guidance* (FHWA, 2007), and
- *Noise Barrier Design Handbook* (FHWA, 2000).

Current DOT Priorities for Evaluating Barriers

The survey results show that when the respondents evaluate barriers and materials, the most important criteria are, in order of importance:

1. Durability
2. Acoustical properties
3. Materials and Installation Cost
4. Maintenance Issues
5. Aesthetics
6. Public Opinion
7. Other Material Properties
8. Graffiti Resistance

This indication of DOT priorities is familiar given the results of previous surveys. The responses within each of the top four areas, Durability, Acoustical Properties, Installation Cost, and Maintenance Issues were quite clustered, with at least 77% of DOTs (at least 18 of the 23 responses to this question) giving the area the highest rating of "essential", or the second-highest, "very important". Responses for the other areas showed greater diversity ranging down to the lowest rating, "not at all important".

The criteria ratings by the states with the most noise barrier experience are somewhat different from the ratings of the respondents as a whole. We defined the states with the most noise barrier experience as the top 11 states with the most noise barrier construction by area or length (FHWA, 2004). From the 2004 FHWA report we identified the top 10 states with the most barrier construction by area and the top 10 by length. These 2 lists had 9 states in common. The 2 states that were not in common were added to this "most experienced" list, for a total of 11 states. The 11 states in order of number or length of barriers constructed are CA, VA, AZ, NJ, OH, MD, MN, NY, FL, PA, and CO. All exceptionally experienced states responded to the relevant questions. Responses from these ten states indicate nearly universally that durability and acoustical properties are "essential" criteria. Aesthetics also ranked very highly among this group of states, with less variability than in the responses of all states for aesthetics. On average, the states with exceptional experience rated installation cost and maintenance issues as less essential than other states did. Although the survey responses did not indicate an explanation for this pattern, it is possible that states with the most barrier experience are more likely than others to have instituted effective procedures to ensure durability and that such procedures also may lead to fewer problems with installation cost and maintenance.

General Experience with Barrier Materials

Key survey findings on DOTs' general experience with noise barrier materials include:

- The three most commonly approved and/or used materials are, in order, precast concrete, earthen berm, and masonry block.
- Timber (wood products) is the fourth most commonly approved or used material. However, timber also was the material for which maintenance issues were reported most frequently, followed by precast concrete and proprietary materials.

- Most states have banned at least one material or product for use in noise barrier projects. The materials most frequently banned are vegetation, shotcrete/gunite on chain link fence, and timber.
- The materials with which states most frequently reported problems were timber (wood products), precast concrete, and proprietary materials. For timber products, the most frequently cited problems were warping, rotting, weathering, and ultraviolet (UV) degradation. At least one wooden barrier in Virginia has had to be fully replaced twice since it was constructed in the 1980s. Concrete was reported to have a range of problems which were different for each state, but included UV degradation, cracking, and spalling. The frequency of these materials being associated with barrier problems is not necessarily an indictment of those products. Rather, the frequency of problems reported for those materials is most probably related to the frequency of use of the materials.
- Problems reported for proprietary materials were: lack of material replacement parts, weathering, rusting, warping, and spalling. When absorptive concrete was first used in Virginia, the absorptive material began breaking off the barrier shortly after construction. The problem in that case was the method used to manufacture the panels. Adequate testing and evaluation, and sharing of test information among DOTs, can minimize these problems.
- Most states, not surprisingly, have experienced problems with graffiti and with collision damage to noise barriers.
- Asked how they evaluate or test new materials/products, the plurality of states (13 of 31 responses) indicated that they do not have formal testing programs or requirements. Of those DOTs that have requirements, the most frequent practice (12 states) is to accept results of tests by the manufacturer or an independent organization contracted by the manufacturer. Six DOTs use state testing facilities and 6 use state-contracted facilities. The individual responses sum to greater than the total of 31 because some DOTs accept multiple test venues. Also, some of the DOTs that do not have formal testing or evaluation requirements noted that they occasionally develop test methods or conduct small-scale tests on an as-needed basis.

Barrier Surface Textures and Treatments

Key survey findings on state DOTs' use of barrier surface textures and treatments include:

- All DOTs reported using surface textures of some kind. Most states use form liners and many also report using fractured fin, smooth, and exposed aggregate surfaces.
- Twenty state DOTs reported using some kind of absorptive treatment on noise barriers while 12 DOTs reported using no absorptive treatments. Many states that reported no use of absorptive treatments cited cost as the primary reason. Some states reported that noise reflection was not a problem or that other design elements sufficiently controlled noise.

Environmental Conditions Considered

Key survey findings on state DOTs' consideration of environmental conditions include:

- Vulnerability to high winds was almost universally considered to be an important factor for the selection of barrier materials.
- Most states consider the effects of freezing and thawing when choosing barrier materials. However, northern states were more likely to consider freezing and thawing than those in the southern portions of the country.
- Only a few respondents reported that other environmental conditions were important, and some of these conditions reflected regionally specific factors. The most commonly mentioned factor (cited by 3 states) was snow removal, including debris from snow plowing and salt spray.

Barrier Design and Approval Process

Key survey findings on DOTs' barrier design and approval process include the following.

- In designing and constructing noise barriers most states rely on AASHTO protocols and guidelines. The most often cited documents were, in order:
    1. AASHTO *Guide Specifications for the Structural Design of Sound Barriers* (AASHTO, 2002a) (cited by 23 of the 31 DOTs responding)
    2. State DOT specifications, guidelines, or policies (20 DOTs)
    3. AASHTO *Standard Specifications for Highway Bridges* (AASHTO, 2002b) (14 DOTs)
    4. Other AASHTO Specifications (12 DOTs)
    5. AASHTO *Roadside Design Guide* (AASHTO, 2006) (10 DOTs)
    6. Other protocols and guidelines (15 DOTs)

  The individual responses sum to greater than the total of 31 because many DOTs use or accept multiple guidelines.
- No regional trends were identified regarding DOTs' use or sharing of guidelines and specifications for barrier construction.
- Three-fourths of the DOTs (24 of 32) use outside consultants to design the acoustical aspects of barriers. Many DOTs (19) use in-house staff at the state headquarters for designing the acoustical aspects. Fewer DOTs (8) rely on in-house staff at a district level. The individual responses sum to greater than the total of 32 because some DOTs use more than one source for acoustical designs.
- Barrier materials/products are most often approved by DOT staff at state headquarters (two-thirds of survey respondents), although about a quarter of the respondents instead approve projects at the district level. A few DOTs approve barrier materials through other means, such as a research and materials person, construction manager or engineer, or a pre-approval from the DOT headquarters such that the construction contractor may

select a barrier from a pre-approved list. The person or office that has approval authority for the barrier material/product is not necessarily the same one that approves the noise barrier project as a whole.

- Information needs to support decisions related to barriers: DOTs were asked what information from the following list would best assist them when choosing a noise barrier material. All of these items were generally rated very important:
  - Barrier material durability issues and information.
  - Material specification failure information.
  - Information on material or construction cost overruns.
  - Issues or information with construction specifications not being achieved.
  - Information or issues with specific manufacturers.
- In some states, communications with the noise representative suggested that information on the DOT's noise barrier experience may not be compiled in reports or guidance materials, or filed in any one place. Those agencies' ability to evaluate materials and products may depend on the experience of individual employees who have critical knowledge (or "institutional memory"), and the necessary knowledge may be lost when those employees retire.

4. Conclusions and Recommendations

Guidelines and criteria for the evaluation and approval of new noise barrier types and materials were developed based on the data and findings developed in this study.

Currently Available Noise Barrier Materials and Unit Costs

The 2006 FHWA report, *Summary of Noise Barriers Constructed by December 31, 2004*, shows that in terms of square feet constructed, use of concrete noise barriers far exceeds that of any other material (see Table 1). Concrete barriers are built primarily of precast concrete, although concrete block has also been used. Between these two types, 100 million square feet of noise barrier had been constructed in the United States as of the end of 2004. Another 14 million square feet of unspecified concrete barrier has also been constructed.

The area of wood barriers built by 2004 is a distant second to concrete with only 13 million square feet, while unspecified metal barrier square footage was third with only 4 million. It is likely that some of the area of absorptive material used is of metal. Berm-only barriers also accounted for 4 million square feet. 18.7 million square feet of combination barriers had been constructed.

The survey conducted as part of this study shows that currently a number of barrier materials are being used by state DOTs in addition to concrete. These include metal (primarily steel and aluminum), wood, brick, glass, plastic, and earthen berms. Currently, concrete and metal barriers are available as both absorptive and reflective. Although used primarily in single material barriers, many of these materials can be used in combination, such as wood and concrete, metal and concrete, brick and concrete, metal and wood, and earthen berms with concrete, wood, or metal.

An important factor used by State DOTs to determine which barrier product to select is the cost. The four basic cost items are the materials, the manufacturing process, the transport of the product from the plant to the jobsite, and the installation of the barrier. All but the barrier installation are normally the responsibility of the manufacturer. The cost of materials can fluctuate significantly, and the manufacturing cost for some products is affected by quantity produced. The cost of transporting the product to the jobsite depends on the distance, fuel prices, and any barrier damage occurring while in transport. This variability in cost for the same product can make a difference in a state's decision regarding barrier type. For example, a DOT with a steel barrier manufacturer located near the project site and a concrete barrier manufacturer located much farther away might select the steel barrier on the basis of lower total cost when transportation is included, even if the DOT favored concrete for its performance characteristics.

The type of material used can also be affected by current demand for a given product. The worldwide demand for steel and the resulting shortage in the United States over the last 15 years has led to the development of other barrier materials. Also, the increased usage of barriers with absorptive finishes, which initially favored concrete barrier manufacturers, has led to the development of other absorptive products.

Site-specific concerns may limit the range of applicable materials. When barriers are to be located on a bridge, materials with weight lighter than concrete are usually desired to minimize the dead load on the bridge. If a barrier is to be transparent, the choice is limited to certain plastic and glass products.

Brick has been used for barriers in some locations, primarily for its aesthetic value. However, the cost of these barriers, not so much for the material, but rather for installation, has limited its use. One state had a brick barrier practically given to it a number of years ago. It was so well liked by the community and the roadway users passing it, that the state acceded to requests to use brick for other barriers in the area, and this time for its real cost.

In order to define unit costs, quotations were obtained from barrier manufacturing companies. Table 3 presents the responses. The results shown in Table 3 should be interpreted with caution because many manufacturers and distributors were reluctant to divulge detailed information, and provided costs only on condition that that the firm not be named. The basis for the per-square foot costs was not consistent among the companies. Transportation costs were included with some estimates but not with others. Also, some firms reported a cost range for an assumed range of quantities, while others provided only one figure. For a specific noise barrier project the actual cost to the state will be the installed cost of the barrier (post, panel and foundation) at the unit cost applicable to the actual quantity installed.

Table 3: Vendor Information on Unit Costs for Barrier Materials

Product I.D.	Quoted Cost per sq ft*	Transportation Cost to Job Site	Material Type – Vendor's Description	Reflective/ Absorptive

Product I.D.	Quoted Cost per sq ft*	Transportation Cost to Job Site	Material Type – Vendor's Description	Reflective/ Absorptive
A	$9.50**	Included	Polymer composite – boards, glass-reinforced, unfilled	Reflective
B	$10	Included	Concrete – precast	Absorptive
C	$10-$20	Included	Steel – panel	Reflective
D	$10-$20	Included	Steel – tray, filled with mineral wool and covered by perforated metal	Absorptive
E	$10-$40	Range reflects quantity pricing and varying transportation costs	Steel – perforated	Absorptive
F	$10.80**	Included	Polymer composite – boards, glass-reinforced, filled with pulverized tire scrap	Reflective
G	$12	Included	Concrete – machine made	Reflective
H	$13-$15	Included	Concrete – precast	Absorptive
I	$15	Additional	Concrete – precast	Reflective
J	$15	Additional	Concrete – precast, glass fiber and steel reinforced	Reflective
K	$16	Included	Concrete – precast, shallow foundation	Reflective
L	$16	Included	Concrete – precast	Reflective
M	$16-$17	Included	Concrete – precast	Absorptive
N	$17-$25	Included	Unspecified – synthetic shell, UV and color stabilized	Absorptive
O	$17-$25	Included	Unspecified – premium acoustic absorptive media inserted	Absorptive
P	$17-$25	Included	Unspecified – panel, contains acoustic sound board	Absorptive
Q	$17.50	Included	Polymer composite – boards, glass-reinforced, unfilled	Reflective
R	$18	Additional	Aluminum	Reflective
S	$18	Additional	Aluminum – perforated, with fiberglass fill	Absorptive
T	$18	Additional	Steel	Reflective
U	$18	Additional	Steel – perforated, with fiberglass fill	Absorptive
V	$19	Included	Concrete – precast	Reflective
W	$19	Included	Concrete – precast	Absorptive
X	$19.50	Included	Polymer composite – boards, glass-reinforced, filled with pulverized tire scrap	Reflective
Y	$22.50	Included	Aluminum – panel	Reflective
Z	$22.50	Included	Aluminum – panel, perforated	Absorptive

Product I.D.	Quoted Cost per sq ft*	Transportation Cost to Job Site	Material Type – Vendor's Description	Reflective/ Absorptive
AA	$22.50	Included	Steel – panel	Reflective
BB	$22.50	Included	Steel – panel, perforated	Absorptive
CC	$23	Included	Concrete – precast	Absorptive
DD	$40	Included	Aluminum – panel, perforated	Reflective

* Unit costs generally are affected by quantity and transportation distance.

** For quantity >16,000 sq ft.

From the data in Table 3, generalized cost ranges for barrier materials may be summarized as shown in Table 4.

Table 4: Summary of Barrier Material Unit Costs

Material Type	Reflective/Absorptive	Generalized Cost range (per sq ft)
Concrete – Precast	Absorptive	$10 - $23
Concrete – Precast	Reflective	$16 - $19
Concrete – Machine made	Reflective	$12
Metal	Absorptive	$10 - $40
Metal	Reflective	$10 - $40
Wood	–	No products reported

Current Practices in Evaluation of Barrier Products

The DOT survey results (see Section 3) indicate that when the respondents evaluate barriers and materials, the most important criteria are, in order of importance:

1. Durability
2. Acoustical properties
3. Materials and installation cost
4. Maintenance issues
5. Aesthetics
6. Public opinion
7. Other material properties
8. Graffiti resistance

Durability and acoustical properties often vary together. In general, durable noise barrier products meet the acoustic requirements because the mass and density necessary to ensure that the material will be durable also provides the necessary resistance to sound transmission. The costs of barriers today are and even twenty years ago were such that noise barriers must last a minimum of twenty years without any significant repairs. Unfortunately, with some new barrier products, especially absorptive concrete, trial and error has been the typical method of testing durability. For example, in some cases the absorptive finish on precast concrete barriers has fallen off and peeled off, both of which can be dangerous as well as very costly. Repairs generally take long periods of time, primarily because the peeling needs to be complete first. In most cases these problems can be solved without replacing the barrier, but completion of repairs will depend on availability of funding.

Wooden barriers, which were used more in the early days of highway noise walls, may have durability problems due to warping, cracking, and other deterioration which can reduce the noise attenuation. Once deterioration sets in, wooden barriers normally need full replacement rather than spot repairs. Some of the other barrier types hold up for an acceptable length of time unless they are damaged by impacts from vehicles.

Acoustical properties of barriers should not be determined through trial and error, but rather need to be known prior to construction. Transmission loss is the acoustical property that is of major importance. Any barrier that is solid, does not have holes or openings, major cracks, etc. and goes all the way to the ground should have satisfactory transmission loss. For most barrier materials currently used by state DOTs, the transmission loss is more than sufficient. In situations calling for absorptive barriers the required absorbability should be specified.

Three other criteria listed in the top eight from the survey are related. Aesthetics, public opinion, and graffiti resistance are all related to the appearance of the barrier and the surroundings. However, for the most part, they are not directly connected with barrier acoustic performance or durability. Aesthetics affects the public's opinion of a barrier, though not necessarily at the extremes of the opinion spectrum: some people may not want a barrier at all regardless of how nice it looks, while others may not care what it looks like as long as they get a noise barrier. Still others may only want it because they perceive a safety benefit from the noise barrier. Aesthetics and public opinion of a proposed barrier material can be evaluated through outreach to the community.

Graffiti resistance generally cannot be easily or immediately tested. While state DOTs normally along with the FHWA finance the barriers, they are not always as concerned about graffiti as are the local communities. Some barrier materials are easy graffiti victims, though some barrier materials can be treated such that readable messages cannot be painted on the surface. The barrier material is not always the problem or solution. The location of the barriers can also play a major role. For example, barriers that are easily accessible on foot, or are located in areas where graffiti artists are unlikely to be deterred by community pressure, may be candidates for graffiti-resistant materials. Graffiti can be viewed as a site-specific maintenance issue in that it extends beyond the materials selection decision and may require continuing management by the DOT or the responsible municipality.

Best Practices and Recommendations for New Noise Barrier Product Evaluation and Approval

The survey responses (see Section 3) indicate that there is no one method used by all states to evaluate existing and new noise barrier products for durability, acoustics, material properties, structural properties, maintenance requirements, maintenance costs, and context-sensitive design characteristics. The literature search and inventory revealed that many states have issued specifications or guidance that relate in some way to product evaluation and approval, but the scope and content varies. A previous compilation of evaluation methods (Waters 2006) cites a number of international standards as well as state DOT practices, and also provides useful summary information.

Some states accept results of tests by the manufacturer or an independent organization contracted by the manufacturer, some use state testing facilities or state-contracted facilities, and some do not have formal testing or evaluation requirements but do occasionally develop test methods or conduct small-scale tests on an as-needed basis. However, based on DOT experiences, a requirement for acceptance of any manufacturer-sponsored test should be that a DOT representative be present at the testing.

One practice that can be very helpful in evaluating new noise barrier products is an in-house committee made up of specialists in several areas that deal with the design and construction of noise barriers. It is recommended that state DOTs have a noise barrier review committee made up of DOT staff with expertise in the following areas: noise, materials, construction, design, aesthetics and structures. An FHWA representative with experience in these areas may also be helpful. The purpose of the committee is to review new barrier material proposals and make recommendations for approval or disapproval of the new barrier material. The committee would be responsible for checking the history of the product and of the manufacturer. If the committee learns that other DOTs have experienced problems with the product and/or the manufacturer, the committee should determine what the problems were and whether product improvements have been made. The DOT should require that products new to the DOT be tested at cost to the manufacturer, with committee members being present both at the manufacturing plant when the product test sample is made, and at the test itself.

Once a new material has been approved by the DOT, any revisions to the product or its production process should require approval from the committee before being used. Due to changing production methodologies and technologies, the noise barrier product approval should have an expiration date. Ten years from the date of initial approval is suggested. A new application should then be required to be submitted for review and approval by the committee.

Test findings should be shared among DOTs through a website. Additional testing might be required by other states, but if earlier test results were satisfactory, they might eliminate the need for additional testing. The results of the survey of the DOTs indicate that very few states share their findings with other states. Sharing data and experiences, especially test results and in-service lives of various barrier products, would help DOTs to purchase barriers that are of high quality, that perform as advertised, are aesthetically pleasing, are durable, and that do not need frequent maintenance.

Alternative Crash Testing Procedures to Reduce Costs Associated with the Selection and Approval Process

While noise barriers can make it more comfortable and enjoyable for nearby residents to use the exterior of their properties, the barriers also may create a hazard at locations where they are constructed within the clear zone of the highway. Crash-testing the noise barriers and placing guard rails or jersey barriers in front of them can help minimize the danger. However, the costs of traditional crash tests can be high.

Crash-testing must be performed in accordance with NCHRP Report 350 (TRB, 1994) in order for the barriers to be used on the National Highway System. NCHRP 350 contains evaluation criteria for longitudinal barrier crash testing. The potential impact conditions on a barrier, in terms of vehicle size, vehicle speed and angle of incidence, are highly variable. NCHRP 350 specifies crash tests with a limited number of combinations of these conditions. It is extremely costly to conduct a large number of full-scale crash tests to cover all the possible combinations and to validate the barrier performance.

Guard rails and jersey barriers are normally sufficient in keeping most vehicles from contacting the noise barriers when inside the clear zone or "zone of influence". However, heavy vehicles such as tractor-trailers can penetrate to the noise barriers, which increases danger and can damage the barriers, especially those made from material other than concrete. The barriers can be designed to increase safety by designing the barrier foundations in accordance with the requirements of the current AASHTO *Standard Specifications for Highway Bridges* (AASHTO, 2002b). Foundation designs may require pilings, caissons, or special design as indicated by subsurface investigations to establish soil capacity.

According to FHWA (Artimovich, 2008), "Noise barriers with safety shapes at the base are currently the norm. However, there is an increased concern with impacts from large trucks that can lean over the barrier. If a noise wall is on top, then that barrier must be designed to withstand the impact. Another option is to place it far enough behind to be outside of the 'zone of influence', typically about 3 to 4 feet."

With recent advances in computer technology, computer simulation of such complicated impact phenomena is becoming possible for simulating different impact scenarios. A current research project by Worcester Polytechnic Institute funded under NCHRP 22-24 (TRB, 2008) is developing guidelines for verification and validation of detailed finite element analysis for crash simulations of roadside safety features:

> The focus of these guidelines will be on establishing accuracy, credibility, and confidence in the results of crash test simulations intended (1) to support policy decisions and (2) to be used for approval of design modifications to roadside safety devices that were originally approved with full-scale crash testing.
>
> Crash simulations using finite element (FE) analysis are being used to design and help evaluate the safety performance of roadside safety hardware and features. Roadside safety crash simulations involve developing FE models of vehicles and roadside appurtenances and using these models to simulate the vehicles impacting

> the appurtenances. Use of simulation has progressed from modeling crash tests, to supporting hardware design decisions, and to providing guidance for roadside hardware placement. Effective use of simulation permits design optimization and minimizes the number of crash tests required to achieve acceptable impact performance, thus reducing both the development cost and installed cost of roadside hardware. Additionally, simulation provides a tool for assessing the performance limits of roadside hardware under conditions that cannot be readily tested with full-scale vehicles, such as sideways vehicle impacts and hardware installed on non-level terrain.
>
> Historically, the safety performance of roadside safety hardware has been evaluated through full-scale vehicular crash testing. The testing process is typically iterative as design weaknesses and flaws are sequentially discovered and corrected. This type of physical experimentation is expensive and time consuming. Additionally, full-scale crash testing is often required to approve modifications to roadside safety devices that have already been fully crash tested. Crash simulation has the potential to be used for approval of design modifications. FHWA is beginning to consider acceptance of simulation in lieu of full-scale crash tests in approving some modifications to roadside safety systems.
>
> However, there are no comprehensive and objective procedures for verification and validation of crash simulations. Verification and validation procedures have been developed for FE models in other disciplines (e.g., weapons systems, space crafts, and nuclear waste packaging). Sandia National Laboratories has developed a Phenomena Identification and Ranking Table. The American Institute of Aeronautics and Astronautics has published a Guide to Verification and Validation of Computational Fluid Dynamics Simulations (G-077-1998). The American Society of Mechanical Engineers has established a committee (PTC 60) on Verification and Validation in Computational Solid Mechanics. Although the verification and validation procedures mentioned above may be applicable to crash testing, there are many modeling issues that are unique to the roadside safety field.
>
> Particularly relevant to this project are the ongoing activities of the recently established Computational Mechanics/Europe (CM/E) group. CM/E, which exists under the auspices of the European Committee for Standardization (CEN), is engaged in defining simulation reporting procedures, defining objective validation procedures, defining requirements for vehicle and barrier models, and defining analyst competency criteria.

Computer simulation of barrier crashes appears to have great potential to reduce costs by reducing the need for full-scale physical testing. However, as the NCHRP 22-24 description suggests, it appears that computer simulation methods are not yet sufficiently mature or standardized to recommend their routine use for barrier manufacturers and State DOTs.

Specifications Required for Noise Barrier Materials

This study has identified specifications that should be required for noise barrier materials. These are discussed below by type of performance characteristic and material. References to specific ASTM and other standards and specifications are bolded.

Durability

Clearly the type of barrier material helps determine durability. For concrete products, the freeze-thaw test can be very useful in states that experience frequent significant temperature changes. The test should be conducted in accordance with **ASTM C666 Method B** (ASTM, 2003a), calling for 300 cycles. The product should experience a maximum weight loss of no more than of 7% and no physical distress (no cracking or breaking).

Structural design loadings for noise barrier walls should be based on a design life of not less than 50 years. They should be designed in accordance with the requirements of the current **AASHTO *Guide Specifications for Structural Design of Sound Barriers*** (AASHTO 2002a). References in the AASHTO noise barrier specification to "an industry recognized specification" shall not apply. All concrete, steel, and aluminum members should be proportioned with reference to the service load design methods (allowable or working stress design) of the current **AASHTO *Standard Specifications for Highway Bridges*** (AASHTO, 2002b). Fatigue and traffic impact shall be considered in the design of these structures. Noise barriers subject to lateral earth pressure should have those portions so loaded, designed in accordance with the aforementioned AASHTO specifications. In all cases, settlement should also be considered.

Wooden barriers tend to crack and warp and need frequent repair if effective noise attenuation is to be maintained. No recommended specifications for wooden barriers were identified.

Acoustic Performance

While barrier durability is important, so is the acoustical performance. To be effective, regardless of the barrier material, noise barriers should provide a transmission loss of at least 23 dB(A) when tested in accordance with the requirements of **ASTM E90-04** (ASTM, 2004a) using the typical truck noise spectrum and should have vibration-free joints and fittings. To aid in preventing the transmission of noise through the barrier, the design should minimize or eliminate gaps or openings.

Absorptive noise barriers must be designed so that the absorptive portion on the highway side has a minimum noise reduction coefficient of 0.70 when measured in accordance with the requirements of **ASTM C423-08** (ASTM, 2008a).

Design Standards: All Materials

The following design standards are recommended.

Panel Weights Structure-mounted noise barrier panels should not weigh more than 7.5 pounds per square foot (psf) and the structure-mounted noise barrier system should not weigh more than

15 psf. Posts for structure-mounted noise barrier wall panels should not be spaced more than 8 feet on center. Posts should be mounted on the outside of parapets only. Posts for ground-mounted noise barrier panels should not be spaced more than 24 feet on center (The 24-foot span maximum applies only to ground-mounted noise barriers and accordingly should be achievable.)

Materials The following material-specific standards are recommended.

Concrete Concrete for reflective noise barrier panels or concrete posts should be class A5. Concrete for footings or leveling pads should be Class A3. All other concrete should be class A5 or A4. Noise absorptive concrete should be considered a coating subject to other provisions in the specifications; the manufacturer's cited standards or proprietary materials. The use of systems employing such sound absorptive concrete materials should require pre-approval of the DOT.

Protective Color Coating Protective Color Coating for concrete panels should be a semi-opaque toner containing methyl methacrylate-ethyl acrylate copolymer resins with toning pigments suspended in solution at all times by a chemical suspension agent and solvent. Color toning pigment should consist of laminar silicates, titanium dioxide and inorganic oxides. There should be no settling or color variation. The use of vegetable or marine oils, paraffin materials, stearates, or organic pigments in the coating formulation should not be permitted.

Sound absorptive materials may require special coatings to avoid clogging the pores in the absorptive material. Color coating material for absorptive noise barriers should be tested before use to ensure that the coating does not reduce the barrier absorptivity.

Physical properties of the coating should be as follows:

Weight per gallon	8.3 pounds minimum
Solids by weight	30 percent minimum
Solids by volume	21 percent minimum
Drying time	30 minutes maximum at 70 degrees F and 50% humidity

Coating material should not oxidize and should show no appreciable change in color after 1000 hours when tested in accordance with **ASTM D822** (ASTM, 2006a); should have excellent resistance to acids, alkalis, gasoline and mineral spirits when tested in accordance with **ASTM D543** (ASTM, 2006b): should allow moisture vapor from the concrete interior to pass through when tested in accordance with **ASTM E398-03** (ASTM 2003b) or **ASTM D1653-03** (ASTM, 2008b); and should reduce the absorption rate of exterior moisture into the pores of the concrete surface when tested in accordance with **Federal Specification TT-C-555 B(1)** (GSA, 2001).

Surface preparation, application rate and application procedures should be as specified by the coating manufacturer, using airless spray equipment, having a minimum capacity of 1,000 pounds per square inch (psi) and ½ gallon per minute. Coating should not be applied when the air temperature is below 50 degrees F, to damp surfaces, or when the air is misty or unsatisfactory for this work.

Wood Wood used for noise barriers should be CCA preservative pressure treated with a minimum net retention of 0.60 pcf in accordance with **American Wood Protection Association standards category UC4B** (American Wood Protection Association, 2008). . Panel design should result in a sound transmission class of 38 or better when tested in accordance with the requirements of **ASTM E90-04** (ASTM, 2004a) or **ASTM E413-04** (ASTM, 2004b). The use of wood noise barrier systems should be limited to those applications specifically identified on the project plans or in contract documents.

Plastic Plastic used in noise barrier designs should be of high density, high impact resistant material such as, but not limited to, acrylic, glass fiber, polyethylene, polyvinyl chloride, or polyurethane; with antioxidant additives and UV stabilizers; and should be capable of being produced with integral color pigmentation where such color is identified by the contract documents or plans.

Barrier Mounting Requirements The type of location determines the acceptable materials and the requirements for mounting methods.

Ground-Mounted Barriers Base panels should be a minimum height of 2 feet and should be embedded in the ground a minimum of 6 inches to prevent noise leaks. A nonabsorptive durable finish is required on that portion of the base panels below ground and 6 inches above the ground line. This is to protect the base panel from damage due to grass cutting and weed trimming just in front of the barrier.

Structure-Mounted Barriers All structure-mounted noise barrier panels should be a pre-approved lightweight material. The bottom portion of the panels within 6 inches of the top of the parapet to which the wall is to be mounted should not have an absorptive finish. Panel orientation should be such that panels are free-draining to prevent moisture buildup and possible corrosion. For aesthetic purposes, the panels on structure-mounted noise barriers generally should be oriented either vertically or horizontally to match any adjacent ground mounted noise barrier walls. Structure-mounted noise barriers should aesthetically match any adjacent ground mounted barriers as to color.

The contractor and wall manufacturer should be responsible for the anchorage of the noise barrier wall to the structure, to include the location of anchor rods, pattern or layout of rods, size, length of embedment, base plate for attachments, and posts. Anchor rods for structure-mounted barriers should be integrally cast into parapets. Slip forming of the elements of structures that are designed to receive noise barriers should not be permitted. Connections between the panel and the posts and the panel and the bridge should account for the movement of the bridge as well as the expansion and contraction of the panels.

Drainage Requirements Ground surface drainage should be accommodated in the design. Noise barriers should be designed to deter impoundment and trapping of water. Disturbed areas should be graded in front and behind the noise barrier to control and dispose of roadway and slope drainage using a graded ditch or functional drainage. The ground-mounted noise barrier posts and bottom noise barrier panel should be designed with consideration for additional load created by the ditch slope where it rests against the wall.

Weep holes should be provided in panels, where necessary, to facilitate proper drainage. Drainage design should not create noise leaks.

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Appendix A

Inventory and Survey Results Database

(Electronic Document)

Appendix B

Survey Questionnaire

INTRODUCTION

This survey is being conducted for the **National Cooperative Highway Research Program (NCHRP)** to develop guidelines or criteria for the evaluation and approval of new noise barrier types and materials.

Survey information submitted will be used at an aggregate level and will not identify the name of the individual(s) completing the survey questionnaire. For clarification purposes, we ask that you provide your contact information.

Name:	
Title:	
Telephone:	
State Agency:	
E-mail:	
Fax:	

The survey contains a majority of multiple choice and table fill in questions which can be answered by checking the check boxes provided. Other questions are open ended and require specific data or text to be added in the spaces provided.

Some of the survey questions ask for specific data such as dates. If exact data is unavailable, please estimate.

If your responses do not fit in the spaces provided or if you have additional comments, please use the space provided in the comments section and indicate the question to which the response applies.

If you can only partially complete the survey, please return the partially completed version as any information could be pertinent.

The survey contains three sections:

Section I includes questions related to noise barrier materials.
Section II includes questions related to noise barrier specifications.
Section III includes space provided for additional comments or suggestions.

Please return the completed survey to Melissa Zgola at: MZgola@icfi.com

If you have questions, please contact:

Mr. David A. Ernst
Project Manager
ICF International
33 Hayden Avenue
Lexington, MA 02421
Tel: 781-676-4048
Fax: 781-676-4066
dernst@icfi.com

Thank You For Your Participation

Section I: Noise Barrier Materials (14 Questions)

1. Which materials or products have been approved by your state DOT for either Type I or Type II noise barriers? Check all that apply and the year each was approved if known.

- ☐ Masonry Block
- ☐ Brick
- ☐ Concrete (Cast in place)
- ☐ Concrete (Precast)
- ☐ Earthen Berm
- ☐ Shotcrete or Gunite on Chain Link Fence
- ☐ Vegetation
- ☐ Timber (Wood Products)
- ☐ Plastic ______ Please specify
- ☐ Metal ______ Please specify
- ☐ Recycled ______ Please specify
- ☐ Composites ______ Please specify
- ☐ Transparent ______ Please specify
- ☐ Proprietary ______ Please specify
- ☐ Other ______ Please specify

2. Are any noise barrier materials or products pending approval by your state DOT?

☐ **No** ☐ **es**

If yes, please specify material type?

2a) ______

2b) ______

3. What materials/products have actually been used for noise barriers on Type I or Type II projects in your state? Check all that apply.

- ☐ Masonry Block
- ☐ Brick
- ☐ Concrete (Cast in place) ______ Please specify
- ☐ Concrete (Precast)
- ☐ Earthen Berm
- ☐ Shotcrete or Gunite on Chain Link Fence
- ☐ Vegetation
- ☐ Timber (Wood Products)
- ☐ Plastics ______ Please specify
- ☐ Metal ______ Please specify
- ☐ Recycled ______ Please specify
- ☐ Composites ______ Please specify
- ☐ Transparent ______ Please specify
- ☐ Proprietary ______ Please specify
- ☐ Other ______ Please specify

4. **What material/product will your DOT not use for noise barriers on Type I or Type II projects in your state? Check all that apply.**

- [ ] Masonry Block
- [ ] Brick
- [ ] Concrete (Cast in place)
- [ ] Concrete (Precast)
- [ ] Earthen Berm
- [ ] Shotcrete/Gunite
- [ ] Vegetation
- [ ] Timber (Wood Products)
- [ ] Plastics
- [ ] Metal
- [ ] Recycled
- [ ] Composites
- [ ] Transparent
- [ ] Proprietary
- [ ] Other

Please specify

5. **On a scale of 1 to 10, with 10 being the most important, what criteria are most important when choosing a material for a Type I or Type II noise barrier? Check all that apply.**

- Acoustical Properties
- Installation Cost
- Material Properties
- Maintenance Issues
- Public Opinion
- Graffiti Resistant
- Durability
- Aesthetics (ability to accept graphics/colors/textures)

Additional Comments:

6. **Does your state DOT require or use surface textures for Type I or Type II noise barriers?**

- [ ] **No**
- [ ] **es**

If yes, please select any surface texture used in existing or planned noise barriers.

- [ ] Smooth
- [ ] Exposed Aggregate
- [ ] Form Liners
- [ ] Veneers
- [ ] Stucco
- [ ] Fractured Fin
- [ ] Pressed (Dimpled) Surfaces
- [ ] Other

Please specify

Additional Comments:

7. **What environmental conditions in your region are most important when choosing a noise barrier material?**

- [ ] Freeze-Thaw
- [ ] Wind Speeds
- [ ] UV
- [ ] Humidity
- [ ] Seismic Activity
- [ ] Other

Please specify

Additional Comments:

8. What significant malfunctions or problems has your state DOT experienced with material/product durability and performance?

- ☐ UV Degradation
- ☐ Cracking Concrete
- ☐ Rusting
- ☐ Wind Damage
- ☐ Insect Infestation
- ☐ Graffiti Removal
- ☐ Drainage Issues
- ☐ Lack of Material Replacement Parts
- ☐ Vibrations Loosening Barrier Parts
- ☐ Material not meeting Specifications
- ☐ Fire (toxic fumes)
- ☐ Material Load Stresses (snow, ice)
- ☐ Collision Damage
- ☐ Reflection
- ☐ Vegetation Overgrowth (mowing issues)
- ☐ Vandalism
- ☐ Peeling Paint
- ☐ Gaps or Holes Developing Between Planks
- ☐ Snow Removal
- ☐ Other ______

Additional Comments: ______

9. Can you please describe the noise barrier material type and any relevant durability or performance issues experienced? (e.g., Wood - weathering caused cracking and shrinkage of wood panels)

9a) ______

9b) ______

9c) ______

9d) ______

10. What percentage of the existing noise barriers installed in your state utilize absorptive treatments such as sound absorbent materials?

- ☐ 100% - 90%
- ☐ 90% - 80%
- ☐ 80% - 70%
- ☐ 70% - 60%
- ☐ 60% - 50%
- ☐ 50% - 40%
- ☐ 40% - 30%
- ☐ 30% - 20%
- ☐ 20% - 10%
- ☐ 10% - 0%
- ☐ 0% (see below)

If 0%, can you list the reason or reasons for not utilizing absorptive treatments?

10a) ______

11. Can you list the type of absorptive treatments or absorptive materials your state DOT has had the most success with?

11a) ______

11b) ______

11c) ______

11d) ______

11e) ☐ **Absorptive treatments/materials not utilized**

12. Can you list the type of absorptive treatments or absorptive materials your state DOT has had the most failures or problems with?

12a)

12b)

12c)

12d)

12e) ☐ **Absorptive treatments/materials not utlized**

13. Has your state DOT used any proprietary noise barrier materials for Type I or Type II noise barriers? (e.g., Durisol®, or Soundtrap®)

If yes, can you list any proprietary noise barrier materials used?

13a)

13b)

13c)

13d)

14. What information would best assist your state DOT when choosing a noise barrier material and by what percent of importance?

☐ Barrier material durability issues and/or information

☐ Material specification failure information

☐ Information on material or construction cost overruns

☐ Issues or information with construction specifications not being achieved

☐ Information or issues with specific manufacturers

☐ Other (please specify below)

Additional Information:

End Section I

Section II: Noise Barrier Design Policies and Protocols (12 Questions)

1. What design guidelines or protocols does your DOT follow when designing a noise barrier wall?

- ☐ AASHTO Guide Specifications for the Structural Design of Sound Barriers
- ☐ AASHTO Roadside Design Guide
- ☐ AASHTO Standard Specifications for Highway Bridges
- ☐ AASHTO Structural Design Specifications
- ☐ AISC Design Guides
- ☐ ASCE Design Guidelines
- ☐ ASCE Design Guidelines
- ☐ SpecsIntact (NAVFAC, 1986; USACE, 1988)
- ☐ State DOT Specifications
- ☐ Uniform Building Code
- ☐ Vendor Specification
- ☐ Other (please specify below)

1a)

1b)

1c)

2. Who most often designs the acoustical aspects of a noise barrier wall for your state DOT, either Type I or Type II construction?

- ☐ Outside Consultants
- ☐ In-house DOT staff at district level
- ☐ In-house DOT staff at state headquarters
- ☐ Other (please specify)

3. Has your DOT developed a set of guidelines or protocols for noise barrier materials?

☐ **No** ☐ **es**

If yes, please reference any document(s).

3a)

3b)

4. Has your DOT developed standard specifications for various noise barrier materials?

☐ **No** ☐ **es**

If yes, please reference any document(s).

4a)

4b)

5. Who most often approves a noise barrier material for a Type I or Type II project?

- ☐ In-house DOT staff at district level
- ☐ In-house DOT staff at state headquarters
- ☐ Other (please specify below)

6. **Does your state DOT share in-house noise barrier specifications or resources with other state DOT's?**

☐ **No** ☐ **es** ☐ **vailable on the Internet**

If yes, what state(s) has your state DOT shared in-house noise barrier information with?

7. **Has your state DOT developed any documents on acoustic effectiveness in relation to noise barrier materials?**

☐ **No** ☐ **es**

If yes, please reference any document(s).

4a)

4b)

8. **How does your state DOT evaluate or test new materials/products for noise barriers?**

☐ State testing facility
☐ Contracted Testing Facility
☐ Manufacturer Testing Facility
☐ None

Additional Comments:

9. **Has your state DOT been subject to noise barrier materials not performing to standards after installation?**

☐ **No** ☐ **es**

If yes, which noise barrier material/product type have not met specifications?

☐ Masonry Block
☐ Brick
☐ Concrete (Cast in place)
☐ Concrete (Precast)
☐ Earthen Berm
☐ Proprietary

☐ Plastics
☐ Metal
☐ Recycled
☐ Composites
☐ Transparent
☐ Other Please specify

10. **Can you list specific noise barrier material type and specifications that have not been attained after installation?** (e.g., *Proprietary - Noise abatement criteria not attained*)

10a)

10b)

10c)

10d)

11. **Can you comment on what actions or proceedings your state DOT took after realizing a noise barrier material type had not achieved specifications or project requirements after installation?**

Comment:

11a)	
11b)	
11c)	
11d)	

12. **How have bid costs for Type I or Type II noise barrier installations compared to actual construction costs?**

☐	Comparative	
☐	Lower	By what percent?
☐	Higher	By what percent?

End Section II

Part III: Comments

Please provide any comments or suggestions in the space provided below.

Your help in completing this survey is appreciated.
Thank You

Double click below

Name:	0
Title:	0
Telephone:	0
State Agency:	0
E-mail:	0
Fax:	0

References

1. Storey, Beverly B., Godfrey, Sally H., 1994. *Highway Noise Abatement Measures: 1994 Survey of Practice* . TX-95/1994-4.

2. Kay, D., and S. Morgan, and N. Bodapati, 1997. Highway Noise Barrier Service Life, *Survey of U.S. DOTs for Illinois Transportation Research Center Project IIB-H1 "Evaluation of Service Life of Noise Barrier Walls in Illinois"* .