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Report No: RDT01-006

SOUNDWALL STANDARDS RESEARCH FOR NEVADA (Part I)

July 2001

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TECHNICAL REPORT DOCUMENTATION PAGE

Report No. RDT 00-006	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle **Soundwall Standards Research for Nevada – Part I**	5. Report Date **July 2001**	
	6. Performing Organization Code	
7. Author(s) **Areg Gharabegian** **Thanh Luc**	8. Performing Organization Report No. **RDT01-006**	
9. Performing Organization Name and Address **Parsons Transportation Group** **840 Grier Drive, Suite 340** **Las Vegas, Nevada 89119**	10. Work Unit No.	
	11. Contract or Grant No. P467-98-011, T.O. 1	
12. Sponsoring Agency Name and Address **Nevada Department of Transportation** **1263 South Stewart** **Carson City, Nevada 89712**	13. Type or Report and Period Covered **June 1999 through September 2000**	
	14. Sponsoring Agency Code	
15. Supplementary Notes		

16. Abstract

The Federal Highway Administration (FHWA) and the Nevada Department of Transportation (NDOT) have established traffic noise guidelines to protect the public on public and private sensitive use lands in close proximity to highways. Along the state highways, soundwalls are constructed where residential or other noise-sensitive properties are adjacent to the highways. Therefore, the primary goal in selecting soundwall materials and designs is to comply with the noise abatement criteria.

The objectives of the Soundwall System Evaluation Study were to establish acceptance criteria for the development of a Qualified Products List (QPL) by NDOT for soundwall systems and products; to develop acceptance criteria and specifications for various soundwall applications; to determine if currently approved and recently submitted soundwall systems meet new standards and specifications; to determine if currently approved and recently submitted soundwall systems meet new standards and specifications; and to define the scope of evaluation for each division within NDOT.

This report focuses primarily on the objectives and approach of the Soundwall System Evaluation Study in developing the soundwall evaluation process, which is necessary for evaluating and qualifying soundwall systems and products to be added to NDOT's QPL. The study researches methods and criteria of soundwall evaluation developed by various state and federal highway agencies.

The means of obtaining information from the various agencies included telephone interviews conducted by Parsons personnel, and a questionnaire that was sent to various state transportation departments via e-mail. Gathered information was compiled in a format that could be evaluated. Using the criteria and other information obtained from various agencies and input from personnel within various divisions of NDOT, customized evaluation factors were established. A set of State of Nevada specific evaluation procedures was also developed for NDOT personnel. As a result of the study, a separate publication, the *Soundwall System Evaluation Manual,* was issued to provide guidelines on the procedures, acceptance criteria, forms and flowcharts necessary to assist NDOT personnel in performing an effective evaluation of soundwall systems.

17. Key Words **soundwall, noise, barrier**		18. Distribution Statement **Unrestricted. This document is available through the National Technical Information Service, Springfield, VA 21161**	
19. Security Classif. (of this report) **Unclassified**	20. Security Classif. (of this page) **Unclassified**	21. No. Of Pages	22. Price

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1. Introduction

The purpose of a state highway soundwall is to provide protection from traffic noise for sensitive land uses on nearby public and private lands. Along the state highways, soundwalls are constructed where residential or other noise-sensitive properties are adjacent to the highways. Therefore, the primary goal when selecting soundwall materials and designs is to comply with the noise abatement criteria. However, there are many other factors, which also must be evaluated.

As technology advances, the number of products being presented to the Nevada Department of Transportation (NDOT) for approval continues to increase. Because there are currently few approved systems and no procedure to evaluate soundwall systems and products, the Soundwall System Evaluation Study was conducted to research methods and criteria of soundwall evaluation developed by various state and federal highway agencies, customize these criteria for the State of Nevada, establish evaluation factors, and develop an evaluation procedure to be used by NDOT personnel. A separate publication, the *Soundwall System Evaluation Manual,* was issued to provide guidelines on the procedures, acceptance criteria, forms and flowcharts necessary to perform an effective evaluation of soundwall systems.

This report focuses primarily on the objectives and approach of the Soundwall System Evaluation Study in developing the soundwall evaluation process, which is necessary for evaluating and qualifying soundwall systems and products to be added to NDOT's Qualified Products List (QPL). Included with this report is Appendix A, the Basics of Noise Attenuation.

2. Study Objectives

This study was conducted to develop guidelines to assist the NDOT in evaluating soundwall systems and products submitted for approval. The following lists the specific objectives and the tasks undertaken for the study:

1. Establish acceptance criteria for the development of a QPL by NDOT for soundwall systems and products.
2. Develop acceptance criteria and specifications for various soundwall applications.
3. Determine if currently approved and recently submitted soundwall systems meet new standards and specifications.
4. Define the scope of evaluation for each division within NDOT.

Project Tasks included:

- Survey, by telephone and e-mail, various state and federal agencies for existing soundwall evaluation criteria, standards, and specifications.
- Conduct interviews with the various NDOT divisions to determine possible evaluation criteria, specifications, standards, application types, and evaluation procedures.
- Compile data and sort by evaluation factors, procedures, and products.
- Develop evaluation factors for NDOT specific criteria.
- Develop the soundwall evaluation process.
- Evaluate currently approved and submitted for approval soundwall systems with the new procedures.
- Develop the soundwall system evaluation manual.

3. Evaluation Methods

The research approach encompassed surveys of existing information, compilation of this data, the development of evaluation factors, an evaluation process, and the evaluation of currently approved and proposed systems with the newly developed procedures.

3.1. Surveys

Various agencies were contacted for soundwall design/construction standards, evaluation criteria, procedures and administration, and recently constructed soundwall types. Through telephone and e-mail contacts, and review of Internet web sites, the following agencies and organizations were contacted:

Federal Agencies

Volpe Center of U.S. Department of Transportation (USDOT)
Federal Highway Administration (FHWA)
Ministry of Transportation of Canada

State Departments of Transportation

Arizona	California	Colorado	Florida
Illinois	Maryland	Massachusetts	Michigan
Minnesota	New Jersey	New York	Oregon
Pennsylvania	Texas	Utah	Virginia
Wisconsin			

Technical Organization

American Association of State Highway and Transportation Officials (AASHTO)

In addition, NDOT sent out a questionnaire to all state DOTs using e-mail. A copy of NDOT questionnaire is included in Appendix B. Listed below are the states that have responded to the NDOT e-mail questionnaire.

California	Delaware	Florida	Georgia	Idaho
Indiana	Kansas	Louisiana	Maine	Maryland
Michigan	Minnesota	Mississippi	Missouri	Montana
Nebraska	Nevada	New Hampshire	New Jersey	New York
Ohio	Oklahoma	Oregon	South Carolina	Tennessee
Texas	Utah	Vermont	Virginia	Wisconsin

Interviews were conducted with NDOT division personnel to determine past experience and preferences with various aspects of the soundwalls. Divisions within NDOT interviewed included Research, Structural Design, Roadway Design, Safety (District 1 & 2), Construction, Environmental, Materials, Maintenance, Landscape, Operations, and Public Relations. Through the meetings, the preferred evaluation criteria and the best/preferred workflow of the soundwall evaluation process were established, as presented in the *Soundwall System Evaluation Manual.* Meeting notes resulting from NDOT division personnel interviews are included in Appendix C.

3.2. Compilation

Some agencies have established procedures to evaluate new products for soundwalls. These procedures were reviewed and pertinent parts of these procedures were used in developing the *Soundwall System Evaluation Manual* for NDOT. In addition to reviewing new product evaluation plans of different states, other documents were also studied. Highway Innovative Technology Evaluation Center (HITEC) and Ontario Ministry of Transportation of Canada have produced documents that contain useful materials for developing evaluation procedures for NDOT.

Following are descriptions of materials from several state DOTs and other organizations that were used:

Arizona

The Arizona Department of Transportation (ADOT) has an established product evaluation policy called PRIDE. This program reviews and evaluates products for ADOT to generate the Approved Product List (APL). The details of this program are included in ADOT's web site.

The Arizona Transportation Research Center of ADOT is responsible for reviewing and evaluating vendor submittals. Each vendor is required to submit a complete formal proposal following guidelines provided in the PRIDE program. Vendors can submit the proposal for products that are acceptable based on current ADOT specifications or products, which have no applicable ADOT specifications. A similar approach was adopted for the NDOT procedure. Some of the requirements of the PRIDE program were also used for the NDOT procedure.

A template for the vendor cover letter and application form for the products that meet ADOT specifications are included in the ADOT web site. The vendor must complete this form on line and then mail a printed copy, with its application to ADOT. ADOT also uses a flow chart, which shows the new product evaluation procedure. Certain concepts of this flow chart were used to develop similar flow charts for NDOT.

California

The California Department of Transportation (Caltrans) has a formal noise barrier product evaluation procedure. The evaluation of new products is coordinated by the Engineering Service Center (Translab) of Caltrans. The vendor is required to submit a completed application form with other backup materials, such as material specifications, photographs, calculations, and drawings.

Caltrans may request that the vendor construct a test section in order to determine the construction and noise attenuation qualities of the proposed material. Once a barrier is approved, it will be placed on the Caltrans list of approved noise barrier designs. Caltrans has a set of standard drawings for each type of approved noise barrier. Soundwall design criteria are included in the *Caltrans Design Manual*. These criteria provide the detailed requirements, such as loads and foundations. Caltrans has a committee for review and approval of new products. This committee consists of representatives from different sections of Caltrans.

Some of the requirements included in the Caltrans procedures were used for developing soundwall evaluation procedures for NDOT.

Colorado

The Colorado Department of Transportation does not have a formal procedure for evaluating new materials for soundwalls. However, all soundwalls must be in accordance with the soundwall design and construction standards. The resident engineer for each project is responsible for checking soundwall design calculations.

Florida

The Florida Department of Transportation (FDOT) uses a product evaluation procedure to evaluate new products or new systems for soundwalls. Evaluation procedures and applications are posted on FDOT's web site. The Product Evaluation Section is responsible for reviewing new products. They normally send the vendor application to different sections within FDOT for review and comments. Each section has its own checklist for evaluating new products. Vendors are required to attach the actual test data for their products in accordance with the applicable standards. The State Specifications Office of FDOT has noise barrier wall specifications. These specifications provide requirements for material and installation of noise barrier. Once a product is approved it will be included in the QPL. Standard drawings for all approved soundwall systems are posted on FDOT's web site. The QPL and drawings of the approved soundwall systems are also posted on FDOT's web site. Parts of the FDOT product evaluation criteria and questions from the application were used when developing NDOT procedures.

Illinois

The Illinois Department of Transportation does not have a formal procedure to evaluate the new soundwall material. However, they ask the vendors for engineering data and some test results. One of their main concerns is the wind load requirement. They also require the vendor to conduct a freeze-thaw cycling test and salt scaling test.

Maryland

The Maryland Department of Transportation has a new product committee which reviews the new materials. However, they have not reviewed or approved any special material for the soundwalls. They almost exclusively use concrete for the soundwalls. The office of Bridge Design reviews the structural integrity of soundwalls.

Michigan

The Michigan Department of Transportation has a qualification procedure for new materials or products. This procedure outlines the procedure to be followed by suppliers in order to have new materials or products considered by the New Materials Committee. There is a one page product evaluation form that must be completed by the vendor and submitted along with the product data sheets, the manufacturer's safety data sheets, test reports, supporting evaluation, and a sample of the material. The vendor must also describe the significant advantages of its system.

Minnesota

The Minnesota Department of Transportation has guidelines for evaluating noise barrier designs. There are no specific applications or forms that potential vendors have to complete. There is a list of several items, such as drawings, calculations, acoustical information, cost, etc. that must be part of the vendor submittal. Also, there are some soundwall minimum structural design criteria, based on AASHTO specifications. Concrete posts with wood panels seem to be the widest use materials for the soundwalls in Minnesota. The Minnesota Department of Transportation has standard drawings for several different types of soundwalls.

New Jersey

The New Jersey Department of Transportation does not have formal procedures to evaluate new materials or systems for the soundwalls.

New York

The New York Department of Transportation has specifications for noise barriers but no formal procedures to evaluate new materials. Most soundwalls in New York are made of concrete.

Oregon

The Oregon Department of Transportation does not have procedures to evaluate new products for the soundwalls. Vendors are normally asked to provide specifications and drawings for review and approval. The majority of soundwalls in Oregon are made of concrete.

Pennsylvania

The Pennsylvania Department of Transportation has the specifications for different types of soundwalls but no procedures to evaluate new materials or systems.

Texas

The Texas Department of Transportation is in the process of preparing a report on noise study and soundwall standards.

Utah

The Utah Department of Transportation's New Product Evaluation Panel provides advice on the value of new products that are offered for use to the Department. This panel is represented by engineers within key divisional units and geographic districts. The Research Division is responsible for updating the QPL.

Virginia

The Virginia Department of Transportation's Sound Barrier Review Committee standardizes and expedites the review of sound barrier designs and materials. The chairman of the committee is from the Environmental Division. No new barrier proposal will be implemented in a construction project unless it has been reviewed and adopted by the committee. There is no application form, but vendor submittal must contain several specific items, such as sample drawings, description of material, aesthetic factors, cost, and acoustical information.

Wisconsin

The Wisconsin Department of Transportation (WisDOT) has developed a method for prequalifying concrete, softwood, and metal noise barriers. The vendor must complete a new product/method preliminary information sheet and submit a proposal according to the established guidelines. In addition, the vendor must design a sample soundwall for a freeway employing the product that is submitted for prequalification. The design must also show the methods of attaching the barrier to the existing bridge. Some parts of WisDOT procedures were used when establishing the evaluation procedures for NDOT.

Highway Innovative Technology Evaluation Center (HITEC)

A report entitled "Guidelines for Evaluating the Performance of Highway Sound Barriers" evaluates the Sight and Sound Screen by USG Corporation. The Sight and Sound Screen is a post-and-panel wall system designed to act as a sight and noise barrier for highways and other properties. Some of the evaluation procedures and standards used in this document were adopted for the *Soundwall System Evaluation Manual* for NDOT.

Ontario Ministry of Transportation

The standard for noise barriers and roadways specifies procedures to certify products as suitable for installation as roadway noise barriers and also provides for certification of the installation of individual barrier sites. It is the intent of this standard to promote standardization of the noise barrier industry across the country (and perhaps North America). This standard was developed to assist: the product manufacturer in developing a safe, durable and effective product; the designer in understanding the complexity and limitations of noise barrier installations; the specifiers in standardizing the preparation of material and construction standards; and the installer in understanding the installation requirements. In order for a noise barrier system or material to be considered for certification, the manufactures must provide specific information that is listed in the standard. However, there is no application form to be completed.

Information obtained from the surveys was compiled and sorted by several categories: 1) administration of soundwall systems and products evaluation, 2) evaluation criteria, 3) evaluation procedures, 4) qualified products, and 5) recent soundwall types. A matrix format was used where possible and included logic statements for each factor, and any other items relevant to the development of the process. Tables 3.2-1 through Table 3.2-5 present the summary and results of the telephone interviews. Table 3.2-6 presents the summary of responses to the NDOT questionnaire e-mailed to various state transportation agencies. The information contained herein was used in the development of the product evaluation form, the vendor application, and the evaluation criteria and procedure included in the *Soundwall System Evaluation Manual.* Appendix E provides a list of documents that were reviewed in detail for this study.

Table 3.2-1 Administration of Soundwall Systems and Products Evaluation

		AZ	CA	CO	FL	IL	MD	MI	MN	NV	NJ	NY	OR	PA	TX	UT	VA	WI	CANADA
1	No specific soundwall material evaluation program					X					X		X		X				
2	Soundwall materials evaluation procedure	X	X		X											X	X	X	X
3	Soundwall system evaluation procedure	X	X		X		X	X									X	X	X
4	Standardized product evaluation policy	X	X		X	X	X	X		X	X					X		X	X
5	Standardized soundwall material evaluation		X																X
6	Soundwall design/construction standards		X	X[1]		X			X	X		X						X	
7	Certain soundwall materials can be prequalified									X				X				X[2]	X
8	Submittal of formal proposal required	X	X						X								X		
9	Flow chart for product submittal process	X																	
10	Flow chart for product evaluation process		X							X									
11	On-line access to standards & procedures				X														
12	On-line access to submittal requirements	X			X														
13	On-line access to submittal forms	X																	
14	E-mail box for vendor comments/questions	X																	

Notes
1 - Resident engineer performs design or checks consultant's design.
2 - Concrete, softwoods and metals. Hardwoods are not permitted. Other materials must be evaluated in a customized review process.

Table 3.2-2 Evaluation Criteria

		AZ	CA	CO	FL	IL	MD	MI	MN	NV	NJ	NY	OR	PA	TX	UT	VA	WI	CANADA
1	ACOUSTICAL PERFORMANCE CRITERIA				X		X	X		X				X			X	X	
	Inserion Loss (IL)				X[1]														
	Transmission Loss (TL or STC)				X		X	X	X	X							X	X	X
	Sound Absorption Coefficients (NRC)				X		X			X	X						X	X	X
	Site-Specific Conditions																		
	Vibration Self-Noise																		
	Other Acoustic Factors																		
2	STRUCTURAL DESIGN CRITERIA	X	X[2]	X	X[2]	X		X[2]	X[2]	X[2]	X[2]			X[2]	X[2]	X	X[2]	X[2]	X
	Wind Loading		X		X	X			X	X	X			X	X		X	X	
	Seismic Loading		X							X	X								
	Geotechnical				X				X										
	Vehicle Impacts		X											X	X				
	Ice and Snow Loading													X					
3	CONSTRUCTIBILITY CRITERIA		X		X		X												
4	MAINTENANCE AND DURABILITY CRITERIA		X		X	X				X							X	X	X
	Maintainability		X		X														
	Outdoor Durability		X		X					X									
	Corrosion Resistance					X												X	X
	UV Exposure									X									
	Accelerated weathering																	X	X
	Freeze-thaw test requirements					X				X							X	X	X
5	COST COMPETITIVENESS CRITERIA		X		X												X	X	
	Initial Cost		X		X												X	X	
	Life Cycle Cost		X																
6	AESTHETICS CRITERIA		X		X		X				X						X	X	
	Viewshed (avoid blocking a view)				X														
	Viewscape (apperarance of wall)				X													X	
	Graffiti Resistance											X		X					
	Landscaping		X		X														
7	OTHER CRITERIA																		
	Sight distance on curves and ramps																		
	Recycled Materials									X									
	Flame resistance									X									

Notes
1 - Minimum IL of 5 dB. Goal is 10 dB or more
2 - Shall comply with most recent AASHTO sound barrier design specifications.

Table 3.2-3 Evaluation Procedures

		AZ	CA	CO	FL	IL	MD	MI	MN	NV	NJ	NY	OR	PA	TX	UT	VA	WI	CANADA
1	Product approval requirements exist	X	X		X	X	X	X	X	X	X	X	X	X		X	X	X	X
2	Standardized product submittal forms used	X	X		X			X										X	
3	Soundwall design/construction standards	X	X	X	X	X		X	X	X	X	X		X	X[1]	X		X	
4	Preliminary material information required	X	X					X		X			X					X	X
5	Vendor certification of prequalified materials																	X	X
6	Intial concept assessment		X					X	X										
7	Submit typical soundwall design and plans		X					X		X			X	X			X	X	X
8	Small sample of wall panel required																X	X	
9	Vendor constructs or provides test wall		X[2]									X							
10	Experimental wall for construction experience		X[3]				X												
11	Field installation of wall for aesthetic review						X											X	
12	Acoustical tests or lab test results required		X				X		X[4]	X								X	X
13	Other tests required					X[5]				X								X[6]	X
14	State inspection of manufacturing process																	X	

Notes:
1 - No state-wide standards. Standards vary district by district.
2 - Provide plans and specs signed by a CA registered Civil Engineer; conduct test wall at own expense per Caltrans requirements; Schedule work so Caltrans rep. can be present during construction and testing; conduct any tests deemed necessary by Caltrans during its initial evaluation.
3 - If Caltrans deems it necessary to construct an experimental sound wall, vendor shall:
(a) Provide design calculations, plans, specs. and details needed to construct in all condition per Caltrans standards. CA registered CE shall sign all documents;
(b) Provide price of noise barrier in writing.
4 - Laboratory TL test required only if not using preapproved standard plans or materials.
5 - Freeze-thaw salt scaling
6 - Accelerated weathering; corrosion resistance; salt scaling resistance for 50 freeze-thaw cycles.

Table 3.2-4 Qualified Products

		AZ	CA	CO	FL	IL	MD	MI	MN	NV	NJ	NY	OR	PA	TX	UT	VA	WI	CANADA
1	Approved product list available	X	X		X	X			X		X					X		X	
2	Approved product list available on-line	X			X											X			

Table 3.2-5 Recent Soundwall Types

		AZ	CA	CO	FL	IL	MD	MI	MN	NV	NJ	NY	OR	PA	TX	UT	VA	WI	CANADA
1	Concrete or masonry block	X	X					X	X	X			X	X					
2	Cast in place concrete									X			X						
3	Tilt-up concrete panels		X																
4	Concrete panels & reinforced masonry posts						X	X		X		X		X	X	X		X	
5	Concrete panel and H-beam posts				X	X	X	X	X		X	X	X		X	X			
6	Fan-Wall system (stability without posts)														X				
7	Horizontal wood planks			X	X				X					X				X[1]	
8	Metal panels		X		X									X				X	
9	2-sided absorptive panels																		
10	1-sided absorptive panels																X		
11	Earthen berm		X												X				
12	Berm topped by soundwall		X		X														
13	Vehicular impact reistant (on safety barrier)		X												X				
14	Other								X	X[2]									

Notes:
1 - Softwoods only: Douglas Fir-Larch, Southern Pine, Hem-Fir; Glue laminated timber: Southern Pine
2 - Composites -- Carsonite

Table 3.2-6 Summary of Responses to NDOT Questionnaire

	CA	DE	FL	GA	ID	IN	KS	LA	ME	MD	MI	MN	MS	MO	MT	NE	NV	NH	NJ	NY	OH	OK	OR	SC	TN	TX	UT	VT	VA	WI
New soundwall type evaluation criteria and standards	Y	N	Y	Y	N[2]	N[2]	Y	Y	N[2]	Y	N	Y	N[2]	N	N[2]	N	Y	N	N[1]	Y	Y	Y	Y	N	N	N[1]	Y	N[2]	Y	Y
Standard plans	X		X	X						X	X	X				X				X	X		X						X
Standard specifications	X		X	X						X	X	X					X			X	X	X	X	(3)				X	X
Design procedures	X		X	X						X	X						X			X			X		X			X	X
Testing procedures	X		X					X		X		X									X				X			X	X
Vendor application procedures	X		X	X						X	X	X		X							X							X	X
Evaluation criteria	X		X				X	X		X				X						X		X	X					X	X
Noise wall policy						X			X								X										X		
New soundwall type evaluation responsibility																														
Several divisions				X							X			X							X			X	X				
One division			X				X	X		X										X		X	X						
Specialized person/division(s)												X				X							X					X	
New products committee				X																				X					
Interdisciplinary committee	X										X																	X	X
Outside consultant															X														
Most effective evaluation procedures																														
Multi-step process	X																				X								
Initial review	X		X																										
Committee review/approval	X			X							X																	X	X
Vendor submittal	X		X					X			X	X								X									X
Construction of test wall	X																												
Testing of test wall	X							X	X																				
Final review	X																												
Recommendation to design chairman	X			X																								X	X
FHWA evaluation guidelines & criteria																				X								X	
ASTM testing procedures												X									X								
AASHTO design guide																					X				X				
HITEC evaluation procedures			X																										
Other testing requirements																					X								
Other established criteria								X													X								
Approved products list								X																					
Use of one basic wall type																X													
Drawbacks or negative comments																														
Time consuming or extensive delays with current process	X			X																									
Many wall types and proprietary designs make evaluation procedures difficult to implement																								X					

(1) Specialized design guide in process yet to be finalized.

(2) Noise barriers unwanted, not needed, or rarely implemented in this state at this time.

(3) Undergoing revision.

3.3. Development of Evaluation Factors and the Evaluation Process

The existing product evaluation application of NDOT was used as the basis for developing the application for the Soundwall System Evaluation Application. The existing application was modified using information gathered from other organizations. The other parts of the manual were prepared by using ideas from similar manual and tailoring them to meet specific needs of NDOT.

Materials that are used for constructing soundwalls should provide adequate transmission loss. Typically, for soundwall noise reduction calculations, it is assumed that the amount of the sound that goes through the soundwall is negligible comparing to the sound that goes over the soundwall. This means that the sound that goes through the soundwall has to be at least 10 dB lower than the sound that goes over the soundwall. Most of the soundwalls along the freeway provide noise reductions between 5 to 13 dB. Under certain circumstances, a noise reduction of up to 18 dB may be achieved.

A soundwall that provides sound transmission of at least 23 dBA would be adequate for the majority of soundwalls. The Sound Transmission Class (STC) is a single number that is used to evaluate sound transmission of different materials. The STC is a rating to compare different materials and it does not necessarily represent the exact sound transmission of a material. Therefore, to achieve a sound transmission of 23 dB for the traffic noise, it is advisable to have a product with an STC of at least 25 dB. It is recommended to approve only products for soundwalls in Nevada that have an STC rating of at least 25 dB. If a soundwall would provide total noise reduction of more than 13 dB then the STC value of the material for that specific soundwall should be at least 12 dBA higher than the anticipated total noise reduction provided by the soundwall. Appendix A provides more description about barrier noise reduction and STC values.

A systematic approach allowed input from all stakeholders at various stages of developing and finalizing the evaluation process. A draft of the evaluation factors and flowcharts of the evaluation process was developed and circulated to the various NDOT divisions for review and comment. After a short review period, an evaluation process development meeting was conducted with various divisions' representatives to refine each evaluation factor and begin to define process steps. The objectives of this meeting were:

- To provide a forum in which all divisions can address their requirements/preferences.
- To ensure that the evaluation factors and process include each division's needs.
- To determine the scope of work for each division in the soundwall evaluation process.
- To determine which existing evaluation methods can be utilized and if new methods need to be developed.
- To determine minimum standards and test methods for each evaluation factor.
- To develop evaluation factors for each critical aspect of soundwalls including, but not limited to, acoustical properties, material properties, constructibility and construction standards, design requirements, life span, environmental compatibility, maintenance requirements, vandal resistance and aesthetics.

Through the inputs of various divisions, the first, second, and final drafts of the procedural document, the *Soundwall System Evaluation Manual,* were created and circulated to all divisions for further review and comment. Subsequently, the final document was produced to address the needs of NDOT.

3.4. Evaluation of Currently Approved Soundwall Systems with the New Procedures

Upon approval of the final draft of the procedural manual, the soundwall evaluation process was used to evaluate the currently approved and proposed soundwall systems. Included in Appendix D is a short description of each system that was evaluated. Where necessary, suggestions were provided to bring the various submitted systems into compliance with the newly established standards.

4. Executive Summary

The FHWA and the NDOT have established traffic noise guidelines to protect the public on public and private sensitive use lands in close proximity to highways. Along the state highways, soundwalls are constructed where residential or other noise-sensitive properties are adjacent to the highways. Therefore, the primary goal in selecting soundwall materials and designs is to comply with the noise abatement criteria.

The ultimate objectives of the Soundwall System Evaluation Study were to establish acceptance criteria for the development of a QPL by NDOT for soundwall systems and products; to develop acceptance criteria and specifications for various soundwall applications; to determine if currently approved and recently submitted soundwall systems meet new standards and specifications; to determine if currently approved and recently submitted soundwall systems meet new standards and specifications; and to define the scope of evaluation for each division within NDOT.

This report focuses primarily on the objectives and approach of the soundwall system evaluation study in developing the soundwall evaluation process, which is necessary for evaluating and qualifying soundwall systems and products to be added to NDOT's QPL. The study researches methods and criteria of soundwall evaluation developed by various state and federal highway agencies.

The means of obtaining information from the various agencies included telephone interviews conducted by Parsons personnel and a questionnaire that was sent to various state transportation departments via e-mail. Gathered information was compiled in a format that could be evaluated. Using the criteria and other information obtained from various agencies and input from personnel within various divisions of NDOT, customized evaluation factors were established. A set of State of Nevada specific evaluation procedures was also developed for NDOT personnel. As a result of the study, a separate publication, the *Soundwall System Evaluation Manual,* was issued to provide guidelines on the procedures, acceptance criteria, forms and flowcharts necessary to assist NDOT personnel in performing an effective evaluation of soundwall systems.

Utilizing the procedures outlined in the *Soundwall System Evaluation Manual,* fifteen soundwall systems that are on file with NDOT were evaluated and a summary matrix of the required items for each vendor was developed and included in Appendix D of this document.

5. Recommendations

To assist NDOT in evaluating the soundwall systems and products submitted by vendors to the department for approval, this Soundwall System Evaluation Study was conducted to establish an appropriate evaluation process. The procedure and criteria for the evaluation of soundwall systems are published and recommended in the *Soundwall System Evaluation Manual.* Basically, two evaluation options are provided in the manual. The two options are:

A. Acceptance based on current NDOT specifications and standards, or
B. Request for specification revisions.

The detailed evaluation process, which includes guidelines on the procedures, acceptance criteria, review forms, and flowcharts, is provided in the *Soundwall System Evaluation Manual.*

6. Implementation Plan

Implementation of the soundwall systems evaluation procedure is explained in the *Soundwall System Evaluation Manual*, which is Part II of this study.

The process begins with the referral of all contacts by vendors regarding new soundwall systems to the Research Division of the Nevada Department of Transportation. Upon being contacted by a vendor, the Research Division will provide the vendor with a Soundwall Systems Application Package, which is included in the *Soundwall System Evaluation Manual*. The vendor must complete and return the Soundwall Systems Application Package along with a formal proposal to the Research Division. Two flowcharts of the evaluation process are contained in the manual to provide guidance in the review process.

Appendix A

Basics of Noise Attenuation

1. Basics of Highway Noise

Noise is often defined as unwanted sound; it is perceived subjectively by each individual. Acceptance of a certain type of noise or noise level varies among neighborhoods, individuals, and time of day. Physically, sound pressure magnitude is measured and quantified in terms of a logarithmic scale in units of decibels, abbreviated dB. The sound pressure level is based on the logarithm of the ratio of a sound pressure over a reference pressure and is expressed in decibels. Research on human sensitivity to noise has shown that a 3 dB increase in the sound level is barely noticeable while a 10 dB increase would be perceived as twice as loud.

Sounds heard in the everyday environment usually consist of a range of frequencies or pitches at different levels. Human hearing is not equally sensitive to sound in all frequencies. A frequency-dependent adjustment called A-weighting has been devised so that sound may be measured in a manner similar to the way the human hearing system responds. An A-weighting network can be selected during noise measurements and the resulting A-weighted sound level provides a generally accepted descriptor for traffic noise. The A-weighted sound level decibel is often abbreviated "dBA."

The A-weighted sound level is adequate for describing the noise at a particular location and instant in time. However, the average level of environmental noise fluctuates with time so that the A-weighted level of background noise changes with the cycle of human activities. The sound level descriptor used in this report is the hourly energy equivalent sound level (Leq). Leq is defined as the continuous A-weighted sound level that, in a specified period of time, contains the same sound energy as the actual time-varying sound during that period. It is a particularly stable and predictable unit for the description of traffic noise and, at the same time, is well correlated to people's reaction to noise.

2. Criteria for Determining Noise Impacts

The Federal Highway Administration (FHWA) has established the Noise Abatement Criteria as outlined in the Procedures for Abatement of Highway Traffic Noise and Construction Noise (23 CFR Part 772). The Nevada Department of Transportation (NDOT) also has noise abatement criteria similar to the FHWA criteria. They are identified in the NDOT Traffic and Construction Noise Abatement policy.

Under FHWA regulations, noise abatement measures must be considered when the predicted traffic noise levels "approach or exceed" the Noise Abatement Criteria or when the predicted noise levels substantially exceed existing noise levels and it is reasonable and feasible to abate. NDOT defines the term "approach" for the purposes of noise analysis on new highway construction or reconstruction projects, as 1 dBA less than the Noise Abatement Criteria. Noise abatement is considered when predicted future traffic noise levels from the proposed project at residential land use, parks, schools, and hospitals are 66 dBA or higher. In many cases, the achievement of lower noise levels would result in even greater benefits to the community and should be considered.

Both the NDOT and Federal standards have abatement requirements when the future noise levels will substantially increase the existing ambient noise levels of adjacent areas. NDOT has defined the term "substantially exceed" as 15 dBA.

The design of noise abatement measures normally is provided for the first row of houses usually adjacent to the right-of-way. The traffic noise impacts could extend to the next tier of structures, but the noise abatement measures designed for the first row of houses will usually reduce the noise impacts at housing further away.

3. Noise Reduction of Concrete and Asphalt

Studies have indicated that newly laid open graded asphalt would probably reduce noise levels by 2 to 3 dBA. However, there is great controversy about the longevity of the acoustic benefits of open graded asphalt. Most data suggest degradation within a few years. Differences between open graded asphalt and concrete or regular asphalt would probably be noticed at first, but it is questionable whether this would be true after some years.

The noise reduction effect of the open graded asphalt would become less pronounced as the percentage of heavy truck increases. This is due to the wider variety of noise sources in trucks. Automobiles traveling at highway speeds emit mostly tire noise and comparatively little engine or drive train noise. Heavy truck noise is dominated by three distinct sources: tires, engine, and exhaust stack. Reducing tire noise by itself does not significantly affect the total noise from heavy trucks.

4. Reflective Noise

On the issue of reflective noise, both FHWA and Caltrans have done several detailed studies. These studies dealt with the acoustical performances of parallel noise barriers and the possibility of noise reflection problems.

The following points summarize the finding of these studies:

- Installation of acoustic material reduced the noise by an average of 2 dBA, well below the generally recognized 3-dBA human perception threshold of changes in noise level.
- The soundwall did not appear to significantly (in the sense of human perceptibility) change the noise levels either up or down at the distant receivers behind the barrier.
- The presence of the single reflecting soundwall did appear to result in a small but measurable noise level increase at receptors located at the opposite side of the soundwall. There was a consistent noise level increase, regardless of meteorological class, that ranged from 0.5 to 2.5 dBA and an average increase of 1.5 dBA. This increase is consistent with sound reflection theory that predicts an increase of 0 to 3 dBA.
- The studies did demonstrate the profound effect of meteorological conditions on traffic noise level. Wind was the single most important factor in changing noise levels at distances beyond 61 meters from the barrier, even greater than differences in traffic volumes. For example, fluctuations in noise levels at 0.32 kilometers and greater were as high as 8 dBA

with relatively minor changes in wind speed and direction. Even at 61 meters behind the barrier, minor wind shifts were responsible for noise fluctuations of about 4 dBA.

Multiple reflections between reflective parallel noise barriers (noise barriers on each side of the highway) can potentially reduce the acoustical performance (insertion loss) of each individual barrier. There is an important relationship between the ratio of separation-distance between parallel barrier (W) and their average barrier-height (H), and the amount of insertion loss degradation. This ratio appears to be the best available method of characterizing barrier insertion loss degradation. As a rule of thumb, if the W/H ratio is 10:1 or greater, the insertion loss degradation is less than 3 dBA, and not noticeable to the human ear.

5. Noise Reduction Coefficient

Sound absorption has been promoted as a solution for noise reflection where actual problems have been identified. The amount of noise absorption of the materials is rated by a noise absorption coefficient α. It is a measure of the sound-absorptive property of the material. This coefficient is defined as the ratio of the acoustical energy absorbed by the material to the total energy incident upon that material. For any particular material, α is frequency-dependent, and its value for each specific frequency ranges from 0 (perfect reflector) to 1 (perfect absorber). For example, a sound absorption coefficient of 0.65 indicates that 65 percent of the incident acoustical energy that strikes the material is absorbed. At a given frequency, the absorption coefficient of any material varies with the angle of incidence of the sound waves. For this reason, published values of absorption coefficients of materials represent the coefficients averaged over all angles of incidence. To rate the overall absorptive characteristics of a material, a measure of the average α over the frequency range of interest is often used. Considering the typical frequency range associated with traffic noise, an appropriate measure is the Noise Reduction Coefficient (NRC), which is the arithmetic average of α in four octave bands with center frequencies of 250, 500, 1000, and 2000 Hz. NRC is calculated as follow:

$$NRC = (\alpha_{250} + \alpha_{500} + \alpha_{1000} + \alpha_{2000})/4$$

When noise reflection is not an issue, the NRC of the soundwall is not important. Typically, noise reflection would not be an issue for the State of Nevada soundwalls because the W/H ratio of soundwalls is generally greater than 10. However, when an absorptive noise barrier is planned, the NRC should be 0.80 or greater to minimize any adverse effect of the reflective noise. Materials with NRC of at least 0.80 would absorb 80 percent of incident acoustical energy of sound waves.

Table A-1 presents a summary of NRC evaluation criteria from different agencies. As shown in Table A-1, the required NRCs for all the agencies surveyed are 0.80 or very close to it.

6. Noise Behind a Barrier

The sound waves created by a vehicle moving along a highway will radiate outward in all directions. If there is no soundwall to protect a receiver, one of these directions will be along a straight line between the vehicle and the receiver. This noise is called direct noise, and the path

along which it travels is the direct path. If a noise barrier is constructed between the vehicle and the receiver, the direct path will be obstructed. Instead, another noise path defined by a straight line from the vehicle to the top of the barrier, and originally destined to continue along an upward sloping straight line away from the vehicle, will now be "bent downward" (diffracted) by the top of the barrier to the receiver. Sound waves following the diffracted path will have less acoustical energy than those that followed the before-barrier direct path because the diffracted path is longer than the direct path. The difference between the direct noise (before barrier) and the diffracted noise (after barrier) is called "barrier attenuation." Within a certain range, the greater the angle of diffraction, the more attenuation can be expected. Explanations of perceived increases in noise at a particular distance due to noise barriers have sometimes centered on noise waves "going over the wall and coming back to the ground." This process is called "diffraction." Virtually all accepted noise barrier theories include the process of diffraction to predict barrier attenuation (noise reduction due to a noise barrier).

In general, the higher the barrier is, the more the noise will be attenuated. The process; however, has diminishing returns, so that eventually when a barrier reaches a certain height, no significant additional noise reduction will be experienced by making the barrier higher.

Noise barriers are generally effective in the vicinity of highways; however, noise levels often approach ambient levels (the noise levels associated with normal day-to-day activities in the community) further away from the highway. For obvious reasons, a soundwall cannot attenuate noise below these levels.

7. Sound Transmission Class (STC)

The Sound Transmission Class (STC) is a single number acoustical rating scheme introduced to facilitate comparison of sound transmission properties of different materials. This number is determined by specific laboratory testing as outlined in the ASTM Standard E90 and calculation procedures provided in ASTM Standard E 413. The STC rating correlates in a general way with the subjective impression of sound transmission for speech, radio, television, and similar sources of noise in offices and buildings. This classification is not appropriate to determine the traffic noise reduction or attenuation by a soundwall. The STC rating should only be used to compare the potential sound transmission loss properties of different materials. The exact traffic noise reduction or attenuation provided by a given soundwall would depend on the location, shape, and dimensions of the barrier besides the material, and it should be determined by calculations or testing in the field.

Generally, the transmission loss of a material heavily depends on the material properties, particularly the mass or weight and density of the material. Note that the same weight can be attained by lighter and thicker, or heavier and thinner materials. The greater the density of the material, the thinner the material may be. Heavier materials normally yield higher sound transmission loss. Transmission loss also depends on the stiffness of the material.

Noise levels are combined logarithmically; therefore, when adding two noise sources that differ by at least 10 dB, the contribution of the lower noise level would be negligible in calculating the overall noise level. Since the FHWA noise prediction model operates under the assumption that

the noise transmitted through the barrier will not contribute to the diffracted noise over the top of the barrier, and for the transmitted noise to become negligible, the transmitted noise should be at least 10 dB less than the diffracted noise. For this to be correct, the transmission loss of the barrier must be at least 10 dB greater than the barrier noise attenuation due to diffraction. For example, if the desired barrier attenuation is 10 dB, the transmission loss of the barrier material must be at least 20 dB. Figure B-1 shows the effects of insufficient transmission loss.

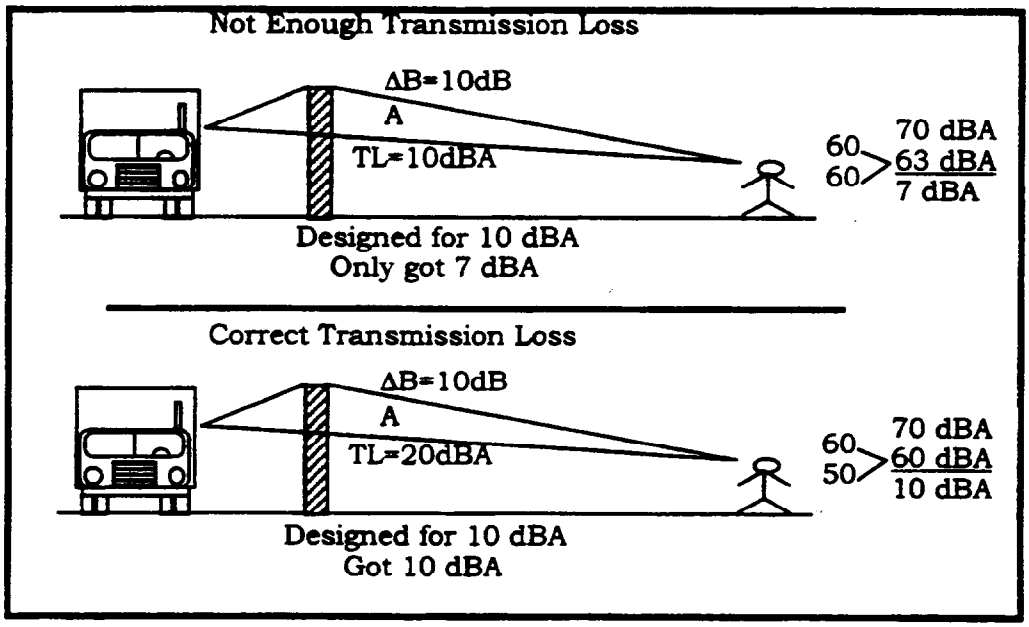

Figure B-1. Barrier Transmission Loss

Table A-1 presents a summary of STC evaluation criteria from different agencies. The required STC ratings for the surveyed agencies varied between 20 and 25 dBA. The basis for establishing the STC criteria is the diffracted noise attenuation of the soundwalls. The variation in values is due to the different criteria used, e.g., conceived achievable maximum noise reduction, average noise reduction for barriers in state, and expected noise reduction for soundwall systems. Most states noted that a 10-dB factor was added to the average noise reduction for barriers in the state or the desired barrier noise reduction to determine the required minimum STC rating for soundwalls.

The majority of soundwalls along highways provide a noise reduction between 5 to 13 dB. Occasionally, some soundwalls may provide noise reduction of up to 18 dB, depending on site-specific terrain condition, among other factors. In theory, soundwall materials with a transmission loss of 23 dB would lower the sound that would be transmitted through a majority of soundwalls to 10 dB below the noise that would be diffracted over the top of soundwalls with a maximum of a 13-dB achievable noise reduction. However, because an STC of 23 dB does not necessarily provide a transmission loss of 23 dB for traffic noise, an additional 2-dB factor of safety is recommended to ensure that the desired 13-dB reduction would be achievable.

Therefore, materials with an STC of at least 25 dB would provide the necessary transmission loss to ensure that receptors behind the soundwall would only be exposed to the diffracted noise over the top of the barrier, and the desired reduction is achieved. Soundwall materials with an STC rating of at least 25 dBA should be acceptable for the State of Nevada.

Results of calculations for some projects may indicate that a noise reduction of more than 13 dBA can be achieved. Only materials that have an STC rating of 12 dB more than the achievable noise reduction will be included in that project's QPL. This approach will ensure that the noise transmitted through the soundwall will not jeopardize the overall noise reduction effects of the soundwalls.

Table A-1. STC and NRC Evaluation Criteria

Agency	Transmission Loss (TL or STC)	Noise Reduction Coefficients for Absorptive Material (NRC)
Caltrans	Expected Soundwall Reduction + 10 dB	Min. 0.85
Canada	Min. 20 dB	Min. 0.70
Civil Eng. Research Foundation	Min. 23 dB	Min. 0.80
Florida	Min. 20 dB @ 500 Hz	Min. 0.79
Maryland	Min. 20-25 dB	Min. 0.80
Michigan	Min. 25 dB	-
Minnesota	Min. 25 dB	-
New Jersey	-	Min. 0.85
Virginia	Min. 23 dB	Min. 0.80
Wisconsin	Min. 20 dB	Min. 0.80
Nevada (Existing)	Min. 35 dB	Min. 0.15
Recommended STC	**Min. 25 dB (for general QPL)** **Noise reduction + 12 dB (for project QPL when more than 13 dB noise reduction is expected)**	**Min. 0.80**

Appendix B

NDOT e-mail Questionnaire

Questionnaire

The Nevada Department of Transportation is currently conducting research on soundwall (noise barrier) systems. The goal of this research is to develop procedures and criteria for the evaluation of Soundwall Systems, establish standard plans and specifications for the various types of soundwalls and create a Qualified Products List. We would appreciate your time in answering this brief questionnaire.

Does your agency have standards and established criteria for evaluation of soundwall systems?

( ) Yes
( ) No

What type of standards does your state have? Please check all that apply.

( ) Standard plans
( ) Standard specifications
( ) Design procedures
( ) Testing procedures
( ) Vendor application procedures
( ) Evaluation Criteria
Other _____
_____

Who is responsible to evaluate new soundwall systems proposed by vendors?

( ) Each division reviews a vendor's application.
( ) One division is in charge of reviewing vendor applications.
( ) We have a department or specialist devoted to soundwalls only.
Other _____
_____

Do you have any advice on which methods/procedures are most effective to evaluate vendor proposed systems?

_____
_____
_____
_____
_____
_____
_____

Your response can be returned via e-mail, fax or mail to:
Ahilton@dot.state.nv.us fax (775) 888- 7230; phone (775) 888-7803

Appendix C

NDOT Division Personnel Interview/ Meeting Notes

MEETING RECORD

Meeting Date: September 16 & 17, 1999 **Project Name:** Soundwall Standards Study

Meeting Location: NDOT HQ, Carson City **Project No.:** NDOT Agreement P467-98-011, T.O. 1 PTG - 642710

Attendees: As noted

The following Meeting Record is a brief synopsis of informal interviews conducted with a representative from each NDOT Division. The purpose of the interviews was to obtain input from each Division on the creation of the Soundwall System Evaluation Standards.

Environmental – Mike Painter x7685

- It is acceptable if the Research Division performs the initial review of a Vendor's application. The major concerns are the STC and NRC rating.
- Partial mitigation is not desired. Use full mitigation for new and retrofit projects. It is better to have a rigid specification and QPL that the Vendor's must follow.
- The state policy for behind-wall noise reduction is 5 dB.
- Cost/Benefit Analysis – The default average value of soundwalls is currently $15/sf.
- Cost shall not be an element for evaluating the product. If product is qualified technical, then market economics will decide about to use the material or not. If the material cost is high, no one will use them.
- Request vendor to provide a complete system not just a component. *(Vendor info, application, NDOT review)*
- Vendor shall provide options for mounting walls on a bridge. It is in the vendor's interest to provide as a complete package as possible; with all options applicable. *(application, NDOT review)*
- Check to see what STC and NRC rating are used by other states. (Parsons ES)
- Wall aesthetics are important but it should not be one of evaluation criteria.
- They do not want a committee for product evaluation. Research Dept. will be the focal point. They want a committee for each project to review the proposed soundwalls for the project. Representatives from the following departments shall be in this committee:
  - Director's office
  - Environmental
  - District Maintenance Engineer
  - Bridge Division
  - Design Division
  - Materials Division (may be)
- They prefer not to have a product scoring system.

Director's Office - Dennis Baughman – x 7440

- The Director is very interested in the cost of soundwalls, especially for retrofit projects.
- Prefer the develop Standards for retrofit & new construction.
- The 3' barrier extensions work when road elevated above houses
- The QuiLite System has conditional approval but it has an STC < 36. This product allows light through.
- Developed Standards will have to be explained to Director
- Aesthetics – The I-15/Cheyenne soundwalls do not look very good from the freeway side..
- There is an assemblyman in Las Vegas who wants to have uniform walls throughout the State. However, DOT doe not think this is a good approach. They want to be open for new and cheaper products. They want the most mileage for the money.
- Retrofits – State trying for matching funds.

Gary Anderson – Specifications x 7586

- If material is on the Qualified Product List (QPL) then there may be no need for specifications for each project. He prefers to have specifications for the soundwall to be included in the contract.
- For other materials, if a vendor's product is on the QPL then another vendor's product, which has similar specifications, can be used. In cases like this Specifications Department reviews the specs and recommends to the Research Department that the new vendor's product to be put in to the QPL.

Tom Adams – Reno Maintenance

- Graffiti – It is easier to remove graffiti from smooth surfaces. Vandals will place graffiti on any type of surface such as split face block. The normal method is to paint over it, using rollers, and the smooth surface makes this easy to complete.
- Accessibility to both sides is okay for maintenance but it also provides access to vandals.
- Weather conditions for the state should be considered in the evaluation guidelines. There could be a material that is not suitable to be used on the north because of snow and salt. But the same material may be used in the southern part of the state. There is some impact of snow against walls @ 35 mph, so this may need to be included in the criteria.
- It is desirable that the soundwall has substantial impact resistance to avoid maintenance problems.
- Access doors – These are desirable on new systems for both maintenance and emergency access.

Materials – Darren Tedford x7520

- Mostly use ASTM & AASHTO material specifications. A complete list of the specifications should be included in the application. Each vendor can include the specifications that apply to his product.

- There has not been much testing of wall materials. The vendor should give a warranty on all materials.
- NDOT has modified some ASTM standards for Nevada, but none will apply to soundwalls.
- They do not have any reservation against any material as long as it passes the established standards of NDOT.
- Vendor should provide some references for past usage in other states. *(application, NDOT review)*
- If the internal review check list has the required limits for different tests, then Research Department can review material testing and Materials Dept. does not need to see it. *(NDOT review)*
- NDOT will provide a statement that vendor has to sign which will guarantee the results of all tests and claims. *(application)* NDOT to provide wording.
- Prepare an attachment similar to but shorter than Chapter 2 of the HITEC document as an attachment (if possible).

Bridge – Todd Stefonowicz, x7550

- Designs should confirm to AASHTO.
- Use 80 mph wind – possibly 90 mph in special areas.
- Wind Pressure should follow: basic = 0-25, int = 25-35, high = 35+.
- Seismic Loading– 0.15g in Las Vegas; 0.4g in Reno. Check NDOT's policy on this.
- Soundwalls should be designed for the AASHTO 10K impact load.
- Include Snow Loads on the walls for both impacts while plowing and as a lateral load when the snow has been plowed and is piled up against the soundwall.
- Stability calculations should be provided with the same Factors of Safety that apply to retaining walls. This includes Overturning, Sliding and Bearing on soil.
- The application should state if the soundwall is suitable for mounting on a bridge rail.
- Calculations should have a Nevada registered PE stamp.
- Fatigue – Check AASHTO's Guide for the Structural Support of Luminaires etc.

Research – Alan Hilton x7803, Tie He x7220

- E-mail Questionnaire - Request a copy of standards/policies. It is preferred to receive less process, more standards.
- Include the NDOT cover letter for new product applications.
- Product evaluation committee should not need to be involved since soundwalls will have criteria and specifications that must be followed.
- Specification revisions will need to be reviewed by the PEC.
- Internet/email – In the future all policies and application materials will be on NDOT's web site.

Operations – Russ Law x7192

- Russ is involved in the state economics and long range financial planning. Soundwall costs are a concern considering the growth in Las Vegas and the potential for a large volume of soundwall installations.
- Current masonry costs are approximately $17-22/sf. This as much as 120' of concrete pavement. Need cost effective ways of mitigating noise.
- Criteria – Would like to see statements of the principles of each criterion in the manual.
- He wants a short write-up about basics of highway noise and use of soundwalls. It is not clear where such a write-up will be used.
- Add a note about concrete or asphalt and which one is better for the noise. Again it is not clear where such a statement shall be used.
- Snow areas – Address durability, sand blasting and salt corrosion.

Mark Elicegui – Construction x7460

- Suggest the use of Standard Plans for Masonry and Precast concrete.
- Check projects #2853 & 2989 in Henderson.
- Vendor should be notified that NDOT requires a full system and not a component. *(Vendor info, application, NDOT review)*
- Vendor should also provide a short description of their installation procedures, equipment, and production rate. The concern is how many lanes shall be closed and for how long. Use of a certain wall may not be practical for some projects due to the traffic control requirements. Other issue will be if a system may use a pile driver and only time construction can be done is during night then that system may not be practical. Pile driving can cause noise impacts. *(Vendor info, application, NDOT review)*
- Vendor should provide a comment about how graffiti can be removed from the wall. *(application)*
- Construction does not see any need to review vendor applications, unless there is a specific need.

Design – Rand Pollard x7590, Dennis Coyle x7591

- Avoid intro of new products during construction
- Involved early in NEPA process
- Aesthetics – accommodate public info process
- Method of payment, cost/unit
- Conformance/adaptability to existing standards
- Design manual – Should contain soundwall issues checklist.
- The Design Division wants to review applications.
- The soundwalls should accept signage and lighting.
- Components such as base/posts could be designed to accommodate drainage/utilities etc.
- Standard plans/specs aid in cost estimating.

- Having standard drawings will reduce DOT staff time.
- They would like to make an NDOT policy to use only material that are on the approved product list.
- Area that is required for the construction.
- Information about foundation is required to evaluate effect in utilities, drainage, etc.
- Construction time and traffic control requirements should be identified.
- Weight of wall could make a difference.
- It will be good to know if a vendor has a product or procedure, which will be more suitable for retrofit cases. This can be bolting a wall on an existing rail without major construction efforts. *(application)*
- Equipment and materials that are needed to maintain the system. *(application)*
- Frequency of maintenance. *(application)*
- Areas that are needed for maintenance. *(application)*
- Availability of parts. Should DOT stockpile some parts? *(application)*
- Estimated life cycle cost. *(application)*
- Will safety performance of the safely shape barriers would be effected by this wall? *(application)*
- Can a sign or light be mounted on the wall? *(application, NDOT review)*
- Can vine grow on the wall? *(application)*
- Can trash be accumulated in voids or openings. *(application)*
- Design Dept. wants to review the vendor application. *(NDOT review)*
- Design Dept. does not mind approval of components only, but they prefer a full system.
- If there are only few types of walls, then it may be good to have standards. If there are too many types of soundwalls, then standards do not make sense.

Appendix D

Evaluation of Previously Submitted Soundwall Systems

Evaluation of Previously Submitted Soundwall Systems

NDOT currently has fifteen soundwall systems on file. All fifteen soundwall systems were evaluated according to the procedures outlined in the *Soundwall Systems Evaluation Manual.* A brief synopsis of the results of the initial evaluation is included in this appendix of the study. Contained herein is a brief description of each of the fifteen systems, and a summary matrix of the required items for each vendor.

None of the fifteen submittals was complete according to the evaluation criteria listed in the *Soundwall Systems Evaluation Manual.* At this point, NDOT is reviewing submittals that, on average, are 40% complete. As evidenced by the amount of correspondence, NDOT personnel have spent excessive time researching each system. The average amount of time to review one soundwall system package was two hours. It is expected that the new application procedures and evaluation process will significantly decrease the review time.

The summary matrix of the required items for each vendor is presented in Table D-1.

Below are brief summaries of the soundwalls submitted to NDOT by various vendors:

1. BASALITE
BASALITE's system is a post-tensioned, non-load bearing, concrete masonry system. This soundwall can reach heights up to 14 feet and has a unique footing system.

2. CYRO
Cyro's system is a transparent acrylic panel installed with an I-beam support system. This acrylic panel is anchored on a four-foot split-face masonry block wall. There are steel rods placed from the footing up through the cells in the blocks of the wall and are post-tensioned after the wall is erect. This transparent wall allows for clear viewing on either side of the wall and extinguishes the feeling of "tunnel vision" along highways.

3. DURISOL
Durisol uses their own precast concrete posts with a panel sliding in between. This product is composed of natural raw materials-specially graded wood shavings that are neutralized and mineralized before being bonded together with cement.

4. EMPIRE (ABSORPTIVE)
The Empire absorptive soundwall is a post and panel system. The panels can be mounted horizontally on top of one another, or vertically side by side. Each section consists of a tray that is filled with six-pound density mineral wool, covered with a perforated 24-gauge face panel.

5. EMPIRE (REFLECTIVE)
The Empire reflective soundwall is an interlocking post and panel system. The panels are fabricated from galvanized steel.

6. EVERGREEN
Evergreen's system uses precast concrete for their wall units. The wall units are filled with soil, allowing vegetation to prosper throughout the wall.

7. HAY BALES
This system uses concrete footings with steel and anchor bolts. The straw bales are tied at the center of each bale and then there is 2 inches of shotcrete applied to the outside. The top of the wall has a layer of Xypex or Thorough seal for water protection.

8. IAC
The Industrial Acoustics Company's wall is a post and panel design. It consists of a hollowcore slab made from precast, prestressed concrete stacked panels. The "H" columns can be fabricated of concrete or steel, depending on the need. All columns have concrete foundations.

9. INSTEEL
The Insteel system has four components in their 3-D system. The 3-D system starts with a core of modified expanded polystyrene that is flanked by 2-in. x 2-in. welded wire mesh. It is then connected with galvanized truss wires and field coated with concrete.

10. INSULOCK
This system is a tongue and groove design. Once Insulock blocks are dry stacked, reinforcing steel is placed in selected cores which are then filled with concrete. The blocks are made of polyurethane foam resin.

11. MBI
The Multi-bloc product is a "lego"-style interconnecting block for use as erosion control and bank stabilization. The blocks are made from recycled tires.

12. PRESTO
The PRESTO system is a reinforced earth berm. PRESTO uses a geotextile framework and structurally stable sand, soil or rock. The lightweight GEOWEB layers are stacked and filled with site available soil or special order fill. GEOWEB strips are made out of polyethylene and have equal distribution of carbon black throughout the material for ultraviolet protection.

13. QUILITE
Quilite's soundwall is a modern post and panel system. The panels are factory-assembled polycarbonate mounted on a steel frame.

14. SUPERIOR
Superior Concrete is a post and panel system. The posts are anchored in concrete footings and the panels are interlocked together in one-foot sections. The panels are made from a precast concrete mold.

15. USG

The US Gypsum design is a post and panel system. The panel consists of a rigid foam core and a thin layer of DUROCK cement with an acrylic finish. These DUROCK sections are slid in the steel column framework. The DUROCK panel is an aggregated portland cement board reinforced with a polymer coated, glass fiber mesh.

Table E-1. Phase IV Evaluation of Previously Submitted Soundwall Systems

ITEMS NEEDED FOR 100% PACKAGE COMPLETION	SOUNDWALL SYSTEMS, VENDOR NAME						
	BASALITE	CYRO	DURISOL	EMPIRE (ABSORPTIVE)	EMPIRE (REFLECTIVE)	EVERGREEN	HAY BALES
ENVIRONMENTAL DIVISION							
SOUND TRANSMISSION CLASS	P	P	-	P	F	-	-
NOISE REDUCTION COEFFICIENTS	-	-	P	P	F	-	-
VIEWSHED IMPACTS	+	+	+	+	+	+	-
VIEWSCAPE	+	+	+	+	+	-	-
GRAFFITI RESISTANT	-	+	-	-	+	+	-
LANDSCAPE COMPATIBLE	+	+	+	-	+	+	-
RETROFIT IN THE FUTURE	+	-	-	-	-	-	-
STRUCTURAL DESIGN DIVISION							
CALCULATIONS/STAMPED BY NV PE	F	-	-	-	-	F	-
1989 AASHTO SPECIFICATIONS	P	-	P	-	-	F	-
WIND LOAD	F	-	-	-	-	-	-
SEISMIC LOAD	F	-	-	-	-	-	-
SNOW LOAD	-	-	-	-	-	-	-
OVERTURNING (FOS)	F	-	-	-	-	-	-
SLIDING (FOS)	P	-	-	-	-	-	-
BEARING (FOS)	-	-	-	-	-	-	-
FATIGUE CALCULATIONS	-	-	-	-	-	-	-
10 kip IMPACT LOAD	-	-	-	-	-	-	-
MOUNT ON BRIDGE RAIL	-	+	-	-	-	-	-
ROADWAY DESIGN DIVISION							
ACCOMMODATE UTILITIES	+	-	-	-	-	-	-
CONSTRUCTION METHOD	+	+	-	-	-	-	-
RELIABLE PERFORMANCE RECORD	+	+	+	+	+	-	-
REQUIRED FOOTPRINT AREA	-	-	-	-	-	-	-
EASEMENT NECESSARY	-	-	-	-	-	-	-
PARTS AVAILABILITY	+	+	+	-	-	-	-
COST OF SYSTEM PER SQUARE FOOT	-	$30	$11-$16	$14	$12	-	-
LIFE CYCLE COST	-	-	-	-	-	-	-
SIGNS AND LUMINAIRES	-	-	-	-	-	-	-
DRAINAGE	-	-	-	-	-	-	-
MATERIALS DIVISION							
WARRANTY	-	+	-	-	-	-	-
ASTM/AASHTO SPECIFICATIONS	-	-	-	-	-	F	-
SAFETY DIVISION							
VEHICLE IMPACT DATA	-	P	-	-	-	-	-

F INDICATES DATA WAS SUPPLIED BUT DID NOT MEET THE CRITERIA

P INDICATES DATA WAS SUPPLIED AND MET THE CRITERIA

* INDICATES LIFE CYCLE COST DOES NOT MATCH CRITERIA

ITALICS INDICATE QPL FACTORS

- INDICATES INSUFFICIENT DATA

+ INDICATES VENDOR SUPPLIED DATA

++ INDICATES VENDOR SUPPLIED PICTURES. NO DATA

Table E-1. Phase IV Evaluation of Previously Submitted Soundwall Systems (Continued)

ITEMS NEEDED FOR 100% PACKAGE COMPLETION	SOUNDWALL SYSTEMS, VENDOR NAME							
	IAC	INSTEEL	INSULOCK	MBI	PRESTO	QUILITE	SUPERIOR	USG
ENVIRONMENTAL DIVISION								
SOUND TRANSMISSION CLASS	P	-	P	-	-	F	P	P
NOISE REDUCTION COEFFICIENTS	P	-	-	-	-	F	-	F
VIEWSHED IMPACTS	+	+	+	-	+	+	+	+
VIEWSCAPE	+	+	+	-	+	+	+	+
GRAFFITI RESISTANT	+	-	-	-	+	+	-	+
LANDSCAPE COMPATIBLE	+	-	-	-	+	-	+	+
RETROFIT IN THE FUTURE	+	-	-	-	+	-	+	+
STRUCTURAL DESIGN DIVISION								
CALCULATIONS/STAMPED BY NV PE	-	-	-	-	-	F	F	F
1989 AASHTO SPECIFICATIONS	P	-	-	-	P	F	-	P
WIND LOAD	-	P	-	-	-	P	P	P
SEISMIC LOAD	-	-	-	-	-	-	F	-
SNOW LOAD	-	-	-	-	-	-	-	-
OVERTURNING (FOS)	-	-	-	-	-	-	-	-
SLIDING (FOS)	-	-	-	-	-	-	-	-
BEARING (FOS)	-	-	-	-	-	-	-	-
FATIGUE CALCULATIONS	-	-	-	-	-	-	-	-
10 kip IMPACT LOAD	-	-	-	-	-	-	-	-
MOUNT ON BRIDGE RAIL	-	-	-	-	-	-	-	++
ROADWAY DESIGN DIVISION								
ACCOMMODATE UTILITIES	-	+	-	-	+	-	+	-
CONSTRUCTION METHOD	+	+	+	-	+	+	+	+
RELIABLE PERFORMANCE RECORD	+	+	+	-	+	-	+	+
REQUIRED FOOTPRINT AREA	-	-	-	-	+	-	-	-
EASEMENT NECESSARY	-	-	-	-	+	-	+	-
PARTS AVAILABILITY	-	+	-	-	+	-	+	+
COST OF SYSTEM PER SQUARE FOOT	-	$35	-	-	$15-$25	$25-$33	$12-$18	$12.76
LIFE CYCLE COST	-	-	-	-	*	-	*	*
SIGNS AND LUMINAIRES	-	-	-	-	-	-	-	-
DRAINAGE	-	-	-	-	+	-	++	+
MATERIALS DIVISION								
WARRANTY	-	-	-	-	+	F	+	+
ASTM/AASHTO SPECIFICATIONS	-	-	-	-	-	-	-	P
SAFETY DIVISION								
VEHICLE IMPACT DATA	-	-	-	-	-	+	-	-

F INDICATES DATA WAS SUPPLIED BUT DID NOT MEET THE CRITERIA

P INDICATES DATA WAS SUPPLIED AND MET THE CRITERIA

* INDICATES LIFE CYCLE COST DOES NOT MATCH CRITERIA

ITALICS INDICATE QPL FACTORS

- INDICATES INSUFFICIENT DATA

+ INDICATES VENDOR SUPPLIED DATA

++ INDICATES VENDOR SUPPLIED PICTURES, NO DATA

Appendix E

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NDOT Research Report

Report No: RDT01-006

SOUNDWALL STANDARDS
RESEARCH FOR NEVADA
Soundwall System Evaluation Manual (Part II)

July 2001

Prepared by Research Division
Nevada Department of Transportation
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NEVADA DOT

Executive Summary

The soundwall standards study was undertaken to establish the criteria and methods by which soundwall systems will be evaluated by the Department. As part of this study, the *Soundwall System Evaluation Manual* was developed to document the criteria and procedures that the Department will use to evaluate soundwall systems. Systems that meet the established criteria will be placed on the Qualified Products List (QPL) for soundwall systems and may be considered for use on construction projects. A soundwall system is defined as a group of components, such as framing, panels and foundations, which is supplied by one vendor to be installed on a roadway project. Individual soundwall components will not be evaluated for the QPL or on a project-specific basis.

In accordance with FHWA noise guidelines, NDOT's Traffic and Construction Noise Abatement Policy and as a result of the study presented herein, the acceptance criteria for noise attenuation are established at a minimum Sound Transmission Classification (STC) rating of 25 dB and a minimum Noise Reduction Coefficient (NRC) rating of 0.80 for absorptive materials. The established criteria for structural design are based on the current version of the applicable AASHTO design specifications. The components of the soundwall systems will be evaluated on their ability to meet the applicable ASTM standards listed in the manual.

Due to the subjective nature of many of the evaluation criteria, it was necessary to group the acceptance criteria into two different categories. Objective criteria, including noise attenuation, structural integrity and materials durability, are grouped together and classified as primary evaluation factors. Subjective evaluation criteria such as aesthetics, adaptability to signage or lighting, and constructability are grouped together and classified as secondary evaluation factors.

Application for soundwall system approval will be made through the Research Division, which will distribute as necessary for divisional review. The systems will initially be evaluated based on the complete criteria including both primary and secondary evaluation factors. All soundwall systems are required to meet the primary evaluation factors to be approved for placement on the general QPL. The secondary evaluation factors will be further considered on a project-specific basis by a project soundwall team composed of representatives from several divisions to identify those systems listed in the general QPL that meet project-specific criteria. It is proposed that this evaluation be performed at the 60% project-development level. As indicated herein, the project soundwall team will develop a recommendation of suitable systems for a specific project for final approval by the director's office. Systems meeting these criteria will be placed on the project specific QPL within the Special Provisions and will be permitted to bid on the project.

It is expected that the procedures and acceptance criteria presented herein will be subject to revision as the evaluation procedures are implemented. Revisions to acceptance criteria may also be necessary as design codes and Department policies are updated and new materials are incorporated into soundwall systems or other material tests are identified and/or developed. Manual updates will be developed and distributed as necessary to incorporate these revisions. Soundwall systems approved under earlier versions of this manual may be subject to re-evaluation as revisions are developed.

Table of Contents

1. Introduction

1.0 Background

The purpose of a state highway soundwall is to provide protection from traffic noise for sensitive land uses on nearby public and private lands. Soundwalls are constructed where residential or other noise-sensitive properties are adjacent to state highways. Therefore, the primary goal in selecting soundwall materials and designs is compliance with the noise abatement criteria. However, there are many other factors which also must be evaluated.

As technology advances, the number of products being presented to NDOT for approval continues to increase. Some of these new products may perform poorly or could quickly become technologically obsolete, so a soundwall system evaluation program was established. The Soundwall Standards Committee included representatives from several NDOT divisions who provided technical review and oversight for the development of this manual.

A separate research publication, *Soundwall Standard Research for Nevada, Part I,* formed the basis for the evaluation and factors included in this manual.

1.1 Manual Contents

This manual contains procedures, forms and criteria that are to be utilized during the evaluation of submitted soundwall systems. The manual is separated into two primary topics: Evaluation Procedures and Evaluation Factors. Procedures for the evaluation of soundwall systems for use by NDOT personnel are in Section 2. Evaluation factors that are to be used when reviewing a vendor's submittal are listed in Section 3.

Appendix A contains the Soundwall System Application Package, which is to be used by vendors when applying for an evaluation of their soundwall system. Appendix B contains a brief treatise on noise attenuation and is included in this manual to give the reviewers an overall perspective on the objectives of soundwall installations.

1.2 Objectives

The objective of this manual and the soundwall evaluation process is to develop a Qualified Products List (QPL) of soundwall systems that will be accepted for use on Department projects. To be added to the QPL, systems must satisfy the primary evaluation factors of Section 3.1 of this manual. In addition, included in Section 3.2 are numerous, more subjective secondary evaluation factors that will be considered. These factors are used on a project specific basis to suit special requirements, such as aesthetics and landscaping. All noise barriers that are used for a project must satisfy NDOT's Noise Abatement Policy. NDOT only considers barriers that provide noise reduction of at least 5 dBA for the first row of impacted residents.

2. Procedure for the Evaluation of Soundwall Systems

2.0 Introduction

Contacts by vendors regarding new soundwall systems will be referred to the Research Division. The Research Division will provide the vendor with a Soundwall System Application Package (this package is included in Appendix A). The vendor must complete and return the Soundwall System Application Package along with a formal proposal to the Research Division. A flowchart of the evaluation process is contained at the end of this section.

2.1 Evaluation

NDOT provides two evaluation options:
A. Acceptance based on current NDOT specifications and standards, or
B. Acceptance based on request for specification revision.

2.1.1 Acceptance Based on Current NDOT Specifications

Vendors whose soundwall system meets or exceeds the current NDOT specifications would request this option. The vendor must submit two copies of a request for product acceptance to initiate such an evaluation. The required contents of the request are listed in Section 2.2.

Laboratory tests must be provided and certified as true and complete by the vendor. The required test standards are listed in Section 3.1.3. Any submittal that does not meet these criteria will be rejected. The vendor must correct any deficiencies before resubmitting the system for evaluation.

2.1.2 Request for Specification Revision

Vendors, whose system meets specifications or criteria that are different than the current NDOT specifications, would be permitted to request product approval through this option. To be approved, the proposed system must meet, and should improve upon, the minimum criteria defined herein. As an example, a soundwall system may meet a newer specification or test developed by the FHWA or the Highway Innovative Technology Evaluation Center (HITEC), which is an improvement upon the currently accepted NDOT specifications or tests.

The protocol for this option is as follows:

1. NDOT Divisions review the submittal. Recommendations are forwarded to the Product Evaluation Committee (PEC).
2. The PEC reviews the submittal and recommends acceptance or rejection.

3. If accepted, the system will be added to the QPL. The evaluation manual will then be revised according to the new specification. Currently approved systems that do not meet the revised specification must submit additional information within 60 days, which shows that they meet the new specification.

2.2 Formal Proposal

Vendors must prepare a separate proposal for each system. Each proposal shall contain, as a minimum, the following:

1. The "Cover Letter" and "Application" signed by the vendor's authorized agent.
2. A full description of the soundwall system. The vendor must identify any inherent system limitations for use under conditions occurring along Nevada highways. System samples, photos, or other visual aids that enhance NDOT evaluation are requested.

   System specimens should be no greater than approximately 305 mm (12 in) x 305 mm (12 in) x 305 mm (12 in) and weigh no more than 12 kg (25 lb). If a reasonable specimen of the system exceeds these parameters, please contact the Research Division so other arrangements can be made to view the proposed soundwall system.

   Photographs should include clear overall views and close-up views from 1 to 1.5 m (3 to 5 ft), which show aesthetic qualities, such as texture and color. One copy of videotape is optional.

3. Description of construction method and requirements, including necessary equipment, staging area size, need for lane closures, and other information pertinent to construction cost estimation.

4. The estimated 20-year lifecycle costs for a 3.66 m (12 ft) high by 1,000 m (3,300 ft) long possible installation on flat terrain, with up to 130 km/h (80 mph) winds and temperature range from -12° C to 49° C (10° F to 120° F).

5. Design plans, drawings, and detail sheets, including specifications for the materials, components and/or system. Design calculations and drawings must be signed by a civil engineer registered in Nevada.

6. History of past use. Identify any location(s) where the product has been installed and all prior evaluation results available, including names and phone numbers of contacts, and whether or not the prior evaluations support the claimed advantages. If possible, enclose a list of other state DOTs or agencies that have approved the soundwall system for use, including the name and telephone number of the contact person. Note, if the product has not been used elsewhere.

7. Verification of system design and materials. Include laboratory reports, data, calculations, etc. Soundwall system tests shall be conducted by an independent testing laboratory to determine whether the soundwall materials, components or system meet all applicable national standards or specifications, such as ASTM or AASHTO. *Product literature is not sufficient; copies of actual independent laboratory test reports are required to be submitted.*

8. Availability of product; i.e., commercial production status, including in-stock quantities, or schedule of availability.

9. Safety and environmental precautions. Provide material and product specifications for important components of the soundwall system. Include a completed copy of the OSHA Materials Safety Data Sheet (MSDS), if applicable. List all precautions in handling and hazards to health. If the product is considered a hazardous material, the manufacturer and/or vendor must accept the unused portion of the sample and the expense involved in the return of the material.

10. Description of maintenance and repair methods and requirements, including availability of components, needed equipment, graffiti removal method(s), and other information pertinent to maintenance and repair cost estimation.

11. Permission for NDOT to reproduce in full or in part any information supplied by the vendor, unless specifically stated otherwise. This includes any material with copyrights held by the vendor.

12. Technical data must be provided in metric units with corresponding English units in parentheses.

13. Specific claimed advantages over existing systems or construction methods. Descriptions of other beneficial, outstanding or special features, and any other favorable information not requested elsewhere.

14. Estimate of the cost of the wall system. Include cost per square foot for previous installations.

2.3 Submittals

The Research Division of NDOT will be the focal point of the soundwall system evaluation effort. There are specific evaluation criteria that concern different NDOT divisions. Each division will examine whether the new soundwall system meets those criteria. After evaluation, each division will complete the evaluation form for its particular discipline, note the approval and any reasoning behind the choice.

The Research Division will perform the initial completeness review of the submitted proposal. The Proposal Package Checklist is in Section 3.3.

If the submittal is complete, the Research Division will circulate the proposal to the following divisions for their review: Structural Design, Roadway Design, Materials, Safety, District 1, District 2, and Construction. The Research Division will perform the initial review for the Environmental and Maintenance division. If it is determined that the proposal is questionable, the Research Division will forward the proposal for their review as well.

2.4 Evaluation Forms

Forms to assist each division's evaluator are provided in Section 3.3.

2.5 Approvals

Upon review of the Soundwall System Submittal Package and after evaluation by the appropriate divisions, NDOT will recommend one of the following:

A. Approval of the proposal;
B. Rejection of the proposal.

NDOT will provide specific reasons for any soundwall system that is rejected. The applicant will be responsible for seeking formal approval from NDOT for any revisions to a previously approved soundwall system.

2.5.1 General Qualified Product List

The Soundwall System Evaluation Process for the general QPL is based on primary evaluation factors. Figure 2-1 shows the procedure that is used for including a product in the general QPL.

2.5.2 Project-Specific Qualified Product List

The Soundwall System Evaluation Process for the Project-Specific QPL is based on secondary evaluation factors. Figure 2-2 shows the procedure that is used for including a product in the project-specific QPL. A product cannot be on the Project-Specific QPL unless it is on the general QPL.

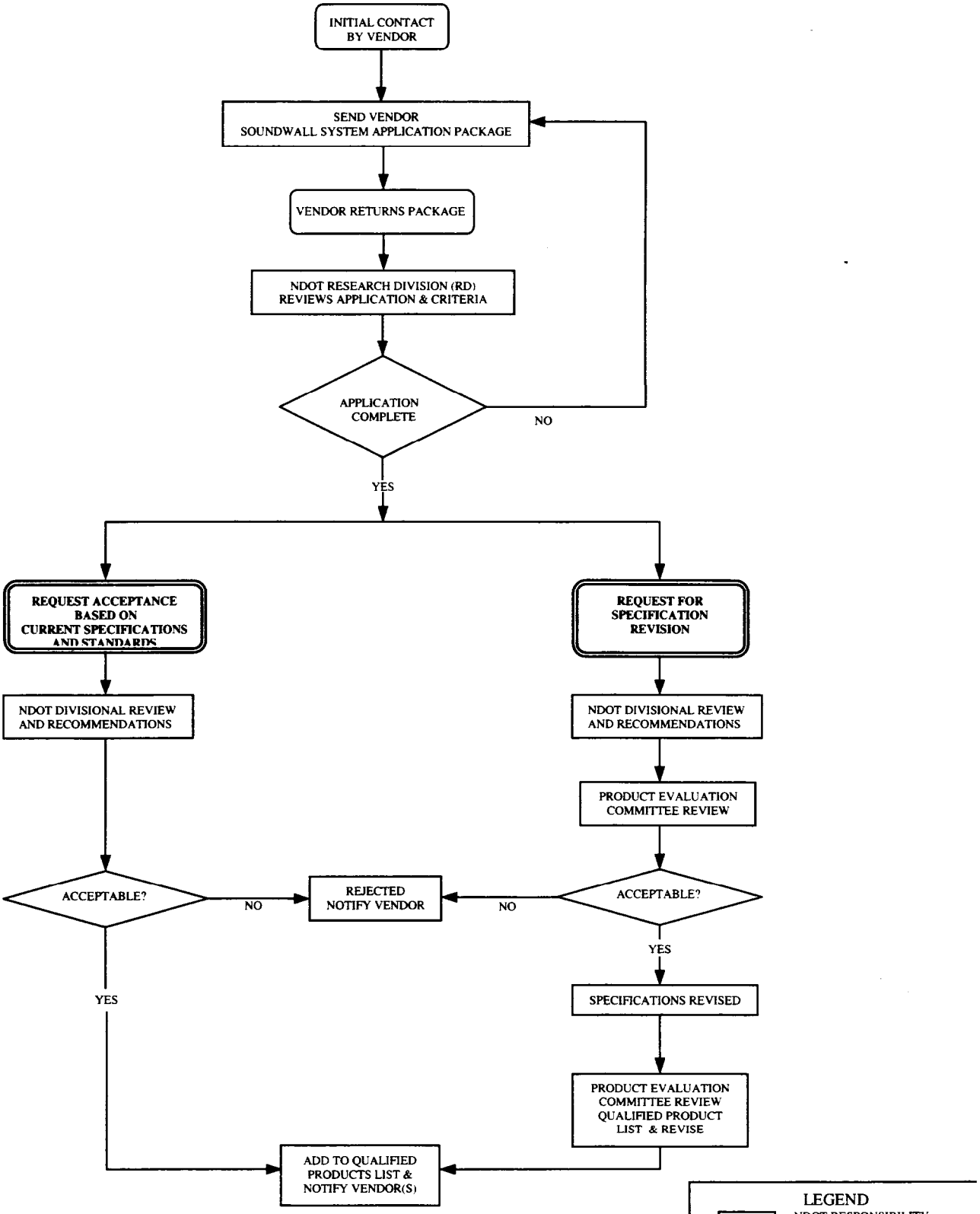

FIGURE 2-1
Soundwall System Evaluation Process for
General Qualified Product List Development

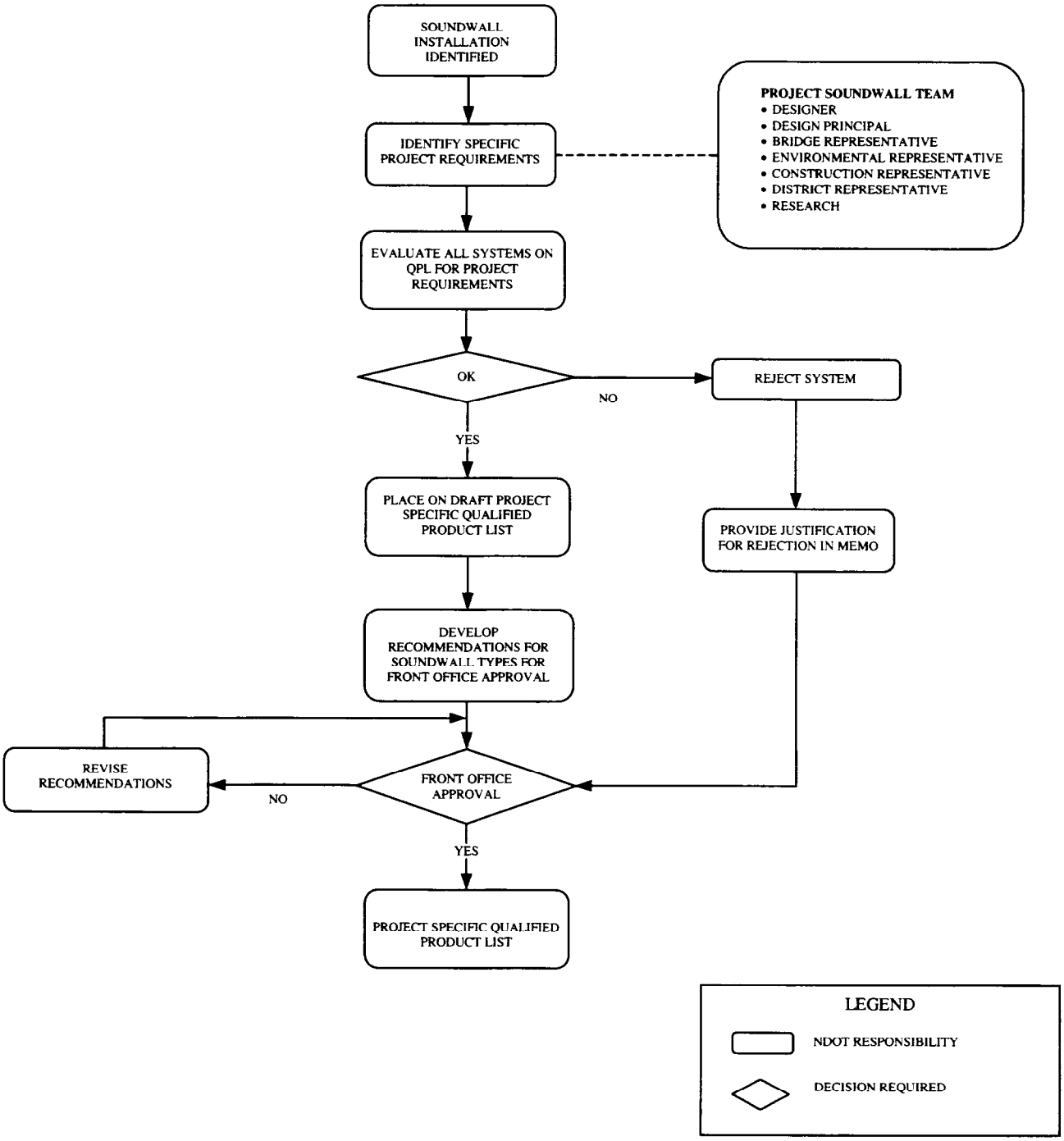

FIGURE 2-2
Soundwall System Evaluation Process for Project-Specific Qualified Product List Development

3. Evaluation Criteria

3.0 Introduction

When evaluating soundwall systems, numerous factors and criteria will be used. Some of these factors are objective while many more are subjective. NDOT has two lists of criteria: primary evaluation factors and secondary evaluation factors.

Primary evaluation factors are to be used when a vendor submits a soundwall system for inclusion on the general QPL. These are the most basic criteria: noise attenuation, structural integrity, materials durability, and safety. All soundwall systems must meet the factors listed in this section. These criteria are applicable to all soundwall installations on interstate, freeway and highway facilities throughout the state and must not be compromised in any way.

Secondary evaluation factors will be applied to the specific conditions of each project to satisfy local issues such as aesthetics, viewshed impacts, material availability, or signing and lighting considerations. These factors are applied at the discretion of the project soundwall team.

3.1 Primary Evaluation Factors

3.1.1 Environmental

Adequate acoustical performance is the primary objective of a soundwall system. Proposed soundwall systems must have a Sound Transmission Class (STC) value of 25 dBA or greater. They must also have a Noise Reduction Coefficient (NRC) greater than or equal to 0.8 if the wall is to be used as an absorptive wall. A more detailed explanation of acoustical performance is included in Appendix B.

3.1.2 Structural

All soundwalls are required to be designed according to the current version of AASHTO Guide Specifications for Structural Design of Sound Barriers and the Standard Specifications for Highway Bridges, including both of the interims and the following modifications:

1. Wind pressure
   Minimum value of 958 Pa (20 psf)

2. Seismic loads
   Minimum acceleration coefficient (A) of 0.15
   Minimum deadload coefficient (f) of 0.75

Calculations must be provided by the vendor and be stamped by a professional civil engineer who is registered in the State of Nevada. It should be obvious in the

calculations that the soundwall has been designed for AASHTO criteria concerning external stability, including the following:

Overturning: 2.0 Factor of Safety
Sliding: 1.5 Factor of Safety
Bearing: 1.5 Factor of Safety

Each project will have its own design requirements, however, the criteria noted above is the minimum for all projects.

3.1.3 Materials

The objective of the materials evaluation is to ensure that the soundwall materials are durable, maintainable, structurally sound, and do not adversely affect the surrounding environment.

Materials used in soundwall systems, as a minimum, must conform to the current NDOT *Standard Specifications for Road and Bridge Construction.* In order to conform to the standard specifications, the vendor is required to have the soundwall materials tested according to numerous ASTM and AASHTO standard tests. Each vendor is required to submit certified laboratory tests with their application. Omission of certified laboratory tests is cause for rejection.

It is anticipated that soundwall systems composed of materials not covered by this evaluation manual may be proposed for use, necessitating the inclusion of new material specifications. It is also anticipated that new or more appropriate material specifications will be developed or identified for materials currently covered herein. In either case, this evaluation manual will be modified to include the new or alternate specifications. All soundwall systems included on the general QPL at the time of the evaluation manual update will be subject to re-evaluation under the revised specifications.

Newly developed materials or materials not covered in the specification must be certified and laboratory tested. All the tests shall be in accordance with the appropriate ASTM, AASHTO, or other reputable standards. Results of these test data must be submitted to NDOT. Following is a list of material standards to be used in the evaluation:

All Materials

All soundwall system materials must conform to the following requirements.

Effect	ASTM Test	Required Value
Flame spread	E84	140 maximum
Smoke development	E84	180 maximum
Fungus resistance	G21	0

Coating Durability

All coating materials must meet the following test requirements. Testing for weathering effects should occur for up to 2,400 hours of exposure with recommended evaluations at every 800-hour interval.

Effect	ASTM Test	Required Value
Checking	D660	No checking
Cracking	D661	No cracking
Blistering	D714	No blistering
Color change	D2244	5 NBS maximum
Adhesion	D3359	No loss of adhesion
Chalking	D4214	7 minimum
Abrasion	D968	Minimum deterioration
Corrosion	B117	No corrosion

Concrete and Portland Cement Based Materials

Soundwall system materials within this category must conform to the following sections of the standard specifications:

701 Portland Cement
702 Concrete Curing Materials and Admixtures
713 Reinforcement

Precast concrete panels should also meet the requirements of the following tests.

Effect	ASTM Test	Required Value
Freeze-Thaw	Modified C666	No cracking, spalling or aggregate disintegration
Salt scaling	Modified C672	Loss of mass < 0.2 lbs/S.F. after 50 cycles

Steel and Metal

Steel and metal components must conform to the following sections of the standard specifications:

710 Structural Steel
712 Miscellaneous Metal

The following list of material standards can be used for soundwall components:

Description	ASTM Specification	Use
Standard steel	A36	Structural steel components
High-strength bolts	A325	High-strength connections
Anchor bolts	A307	Anchoring structures to foundations
Steel pipe	A53, Type S, Grade B	Posts and foundations
H-piles	A36	Posts and foundations
Pile shells	A252, Grade 2	Foundations

Masonry

Masonry materials must conform to sections 640.02.02 and 640.03.01 of the NDOT standard specifications.

Timber

Timber materials must conform to sections 615, Preservative Treatments for Timber, and 718, Timber Materials, of the standard specifications. Timber components must be resistant to decay for 20 years.

Glazing Material

All glazing material must conform to ANSI standard Z26.1 for flat safety glazing plastics and laminated glass.

Composites, Synthetics, Plastics and Fiberglass

Materials in this category must be tested for exposure to ultraviolet light according to ASTM G53. Exposure time must not be less than 1,500 hours and no delamination, chalking, fading or embrittlement may occur.

These materials must also be tested according to the modified ASTM C666, Freeze-Thaw and C672, Salt Scaling.

3.2 Secondary Evaluation Factors

3.2.1 Environmental Factors

While a soundwall has been deemed acceptable under the acoustical criteria listed in Section 3.1.1 for the general QPL, there may be other factors that will determine if a soundwall system is suitable for a project QPL. A higher STC rating may be required for some projects. Aesthetics is an important factor in many highway projects and, since soundwalls are a prominent element in the public's view, the viewshed and viewscape impacts must be considered as well as graffiti and landscaping.

Project-Specific STC - Most of the soundwalls along a freeway provide noise reductions between 5 to 13 dB. The recommended STC of 25 dBA would be adequate for soundwall installations that are estimated to provide noise reduction of up to 13 dB. Under certain circumstances, a noise reduction of up to 18 dB may be achieved. If it is expected that a soundwall installation will provide total noise reduction of more than 13 dB, then the STC value of a soundwall should be at least 12 dB higher than the anticipated noise reduction in order to be included in the project QPL.

Viewshed - The viewshed is the area beyond the soundwall outside of the highway right-of-way. The project soundwall team must consider several issues when selecting soundwall types to be included in the project specifications. How will the soundwall affect the adjacent properties? Will the view be partially or fully eliminated? Does the

material reflect light excessively? With these questions in mind, the Soundwall System Evaluation Form includes items for light transmission, reflectivity and appearance.

Viewscape - The viewscape is the way the soundwall and immediate surroundings look to the adjacent property owner and the motorist. Aesthetic treatment tends to increase the cost of the soundwall - a critical consideration on every project. Larger projects may be more suitable for special aesthetic treatments as economies of scale can reduce the overall cost of the soundwalls. Currently, the most cost-effective aesthetic treatments are form-lined faces on precast or cast-in-place concrete.

Graffiti - Graffiti is another issue that must be considered. Recently, product manufacturers have claimed to have developed graffiti-resistant paints and other materials. Some of these materials may be included in soundwall systems and could be appropriate for areas of high population density where graffiti is a problem. NDOT will normally paint over graffiti on concrete or masonry walls. Smooth walls are easier to repaint than textured walls but normally are less aesthetically pleasing.

Landscaping - Landscaping around soundwalls is an excellent method of improving wall aesthetics. In addition, some soundwall manufacturers have developed walls that will allow landscaping to be placed on or within the soundwall itself. Issues to consider are irrigation requirements, maintenance costs and time, and effects of irrigation on the wall, roadway, or adjacent properties.

Existing Structures - All soundwalls should match or be similar to the aesthetics of the surrounding area. This measure is to ensure a uniform look, matching the soundwalls with existing aesthetics and with structures such as bridges, walls, and buildings.

3.2.2 Structural Factors

There are several structural aspects to consider on a project-specific basis. Can the soundwall system be easily mounted to a bridge? Can it be retrofitted in the future? Is the soundwall capable of supporting signs or lighting? Does the soundwall accommodate through-the-wall access doors?

There will be many situations within urban areas that will require a soundwall to be mounted on a bridge. Even though this factor is not a must for the soundwall system to be included on the general QPL, it will be considered for projects where bridge mounting is required. Soundwalls mounted on bridges will experience the highest wind and seismic loads. Therefore, it is important for the design engineer to carefully review the vendor's submitted calculations to ensure that the soundwall meets the project-specific level of wind and seismic loading.

It is NDOT's policy not to allow large signs or lights to be mounted on soundwalls. Small signs such as speed limit signs have been successfully mounted to a soundwall, but the design engineer must ensure that the structural integrity of the wall is maintained. In

any case, Structural Design Division approval must be secured before any signs are attached to a soundwall.

All soundwalls must be designed according to the current version of AASHTO Guide Specifications for Structural Design of Sound Barriers, and the standard specifications for highway bridges including both of the interims and the following modifications:

1. Wind Pressure up to a maximum of 2,155 Pa (> 45 psf) depending on project location and type of installation.
2. Seismic Loads –
   Up to the following maximums:
   Acceleration coefficient (A) = 0.40
   Deadload Coefficient (f) = 2.50
   Deadload Coefficient (f) = 8.0 for connection of prefabricated walls to a bridge.
3. Vehicle Impact –
   It should be obvious in the calculations if the soundwall has been designed for the AASHTO 45 kN (10 kip) impact load. Location of the soundwall will dictate if the vehicle impact is a necessary factor.

3.2.3 Other Factors

The project soundwall team must consider a myriad of factors, such as constructability, economics, maintenance, and safety in determining the project QPL. Not all soundwall systems on the general QPL are suitable for each project.

Constructability - Constructability is a critical factor in evaluating the system's impact on the schedule, particularly if time to construct is a part of the project schedule's critical path. Factors to consider in this category include complexity of construction, the required area necessary for foundations or equipment, and compatibility with utilities and drainage. Complex construction techniques require more time to install, more cost in labor and equipment, and may cost more to maintain. The importance of constructability increases with the number of soundwalls. The number of soundwalls is likely to increase in urban environments. The project-soundwall team must consider this impact to the project.

Maintenance - Reliable performance during the life of the facility is essential to the selection of soundwall systems. New materials may meet all the criteria for the QPL, but if excessive maintenance time, labor and parts are required, then they may not be economically justified in the selection process. In addition, the means of maintaining the soundwall, once constructed, should be given primary consideration. What is the required footprint area for maintenance? Is access required from both sides? Will an easement be necessary to gain access to the wall?

A final consideration is repair of the soundwall system after vehicle impact or other means of destruction. Are proprietary spare parts needed and are they readily available?

Or, can generic parts be used? High-maintenance walls are not desirable and should not be selected.

Economics - Economic factors to consider include initial construction cost, life-cycle costs, maintenance and repair costs, and design costs. Also, aesthetics and other enhancements add cost both initially and during the life of the soundwall. Ideally, the soundwall should have a life-cycle similar to that of the remainder of the roadway facility.

Integration with other project elements - The project-soundwall team must consider the integration of multiple elements within each project. Soundwalls are another potential impact to other facilities such as drainage, utilities, signing and lighting. It is not desirable to mount anything to a soundwall. Therefore, signs and lighting will need their own foundations and the soundwall should not interfere with the position of the poles. In fact, the soundwall system should accommodate sign and light poles in some manner, especially when there is limited space adjacent to the roadway.

There are several questions that need to be considered during design. How will the soundwall's foundations impact underground facilities? How will the soundwall impact overhead facilities? Does the soundwall enhance or hamper drainage of the roadway system; (i.e., is it a barrier or does it convey excessive drainage?). Does the system have an integral drainage system that could be beneficial? Can drainage or utilities easily pass through the soundwall if necessary? Will local drainage corrode the soundwall system and shorten its life?

Safety – Soundwalls are normally placed near the area of noise generation, the highway, or at the area of desired noise protection, residential or other noise-sensitive properties. Since, a large majority of soundwalls will be constructed at or near the roadside, they can become a hazard to motorists if not properly designed or protected.

Soundwalls located at the edge of a shoulder should be mounted on or behind an acceptable barrier, but should also meet minimum impact requirements to prevent shattering of the material. Light reflected to motorists must be minimized.

3.3 Evaluation Forms

The evaluation form is separated into primary evaluation factors and secondary evaluation factors for each division. The checklist denotes what required or optional materials were submitted.

Soundwall Systems Evaluation Form

Vendor: _____ Product: _____

Date of Review: _____ Reviewer: _____

Research Division

Required Materials:

- ☐ Cover Letter
- ☐ Soundwall System Evaluation Application
- ☐ Full description of the Soundwall System
- ☐ Construction Method
- ☐ Life-Cycle Costs
- ☐ Design Plans and Calculations with Nevada PE stamp
- ☐ System Advantages
- ☐ Independent Laboratory Test Reports
- ☐ History of Past Use
- ☐ Product Availability Information
- ☐ Material Safety Data Sheets
- ☐ Maintenance/Repair Methods
- ☐ Literature Reproduction Agreement
- ☐ Technical Data in Required Unit Format

Optional Materials:

- ☐ Samples
- ☐ Photographs/Video
- ☐ Other: _____

Conclusions:

- ☐ Package Complete, for distribution.
- ☐ Package Incomplete.

Items Requested	Date
_____	_____
_____	_____
_____	_____

Soundwall Systems Evaluation Form

Vendor: _____ Product: _____

Date of Review: _____ Reviewer: _____

Environmental Division

1. Primary Evaluation Factors

☐ Sound Transmission Class (STC) ≥ 25 dB (ASTM E413)

Actual test result: _____

☐ E90 – Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions

☐ N/S ____ TL at 125 Hz ____ TL at 250 Hz

For classification as an absorptive soundwall system:

☐ Noise Reduction Coefficients (NRC) ≥ 0.8 (ASTM C423)

Actual test result: _____

☐ C423 – Sound Absorption and Sound Absorption Coefficients by the Reverberation Method

☐ N/S _____ NRC Rating ☐ Meets Requirement (0.80)

Recommendation

☐ Accept

☐ Reject - Comment: _____

2. Secondary Evaluation Factors

Viewshed impacts – is the soundwall

☐ Opaque?

☐ Translucent?

☐ Transparent?

☐ Reflective?

☐ Data provided? _____

☐ Viewscape

Comment: _____

_____

Graffiti resistance

Comment: _____

Soundwall Systems Evaluation Form

Vendor: _____ Product: _____

Date of Review: _____ Reviewer: _____

Structural Design Division

1. Primary Evaluation Factors

- ☐ Calculations submitted and stamped by a Nevada PE?
- ☐ Conforms to the current version of AASHTO *Guide Specifications for Structural Design of Sound Barriers*, the *Standard Specifications for the Design of Highway Bridges* and interims.
- ☐ Wind load/wind pressure used: _____

  Highest wind load/wind pressure resisted: _____
- ☐ Seismic loads used: _____

  Highest seismic load resisted: _____

External stability calculations included for:

- ☐ Overturning: 2.0 Acceptable Factor of Safety _____
- ☐ Sliding: 1.5 Acceptable Factor of Safety _____
- ☐ Bearing: 1.5 Acceptable Factor of Safety _____

Recommendation

- ☐ Accept
- ☐ Reject

  Comment: _____

  _____

2. Secondary Evaluation Factors

- ☐ Fatigue calculations included _____
- ☐ Foundation accommodates utilities.

  Comment: _____

  _____
- ☐ Suitable for mounting on bridge rail.

  Comment: _____

  _____

Soundwall Systems Evaluation Form

Vendor: _____ Product: _____

Date of Review: _____ Reviewer: _____

Structural Design Division (continued)

☐ Capable of supporting signs or lighting.

Comment: _____

_____

☐ Access doors.

Comment: _____

_____

☐ Soundwall meets AASHTO 45kN (10 kip) impact load requirements.

Comment: _____

_____

Will this system result in extensive review of submittals, i.e. shop drawings?

☐ Yes

☐ No

Comment: _____

_____

Soundwall Systems Evaluation Form

Vendor: _____ Product: _____

Date of Review: _____ Reviewer: _____

Materials Division

1. Primary Evaluation Factors

☐ This soundwall system has material warranties. (List warranties and any comments)

_____

_____

_____

Material standards (check the standards that should apply to this submittal and indicate the results as noted, indicate if Not Submitted - N/S and/or Not Applicable - N/A.)

All Materials

All soundwall system materials must conform to the following requirements:

Effect	ASTM Test	Required Value	Test Results	Pass	Fail
Flame spread	E84	140 maximum			
Smoke development	E84	180 maximum			
Fungus resistance	G21	0			

Comments:

_____

_____

_____

Soundwall Systems Evaluation Form

Vendor: _____ Product: _____

Date of Review: _____ Reviewer: _____

Materials Division (continued)

Coating Durability

All coating materials must meet the following test requirements. Testing for weathering effects should occur for up to 2,400 hours of exposure with recommended evaluation at every 800-hour interval. Actual exposure time: _____ Actual evaluation interval time: _____

Effect	ASTM Test	Required Value	Test Results	Pass	Fail
Checking	D660	No checking			
Cracking	D661	No cracking			
Blistering	D714	No blistering			
Color change	D2244	5 NBS maximum			
Adhesion	D3359	No loss of adhesion			
Chalking	D4214	7 minimum			
Abrasion	D968	Minimum deterioration			
Corrosion	B117	No corrosion			

Comments:

_____

_____

_____

Concrete and Portland Cement Based Materials

Does this system contain precast concrete elements? ☐ Yes ☐ No

Does this system have other types of concrete elements? ☐ Yes ☐ No

Certified mix design submitted? ☐ Yes ☐ No

Other information provided (describe)

_____

_____

_____

Soundwall Systems Evaluation Form

Vendor: _____ Product: _____

Date of Review: _____ Reviewer: _____

Materials Division (continued)

Precast concrete elements should also meet the requirements of the following tests:

Effect	ASTM Test	Required Value	Test Results	Pass	Fail
Freeze-Thaw	Modified C666	No cracking, spalling or aggregate disintegration			
Salt scaling	Modified C672	Loss of mass < 0.2 lbs./S.F. after 50 cycles			

Comments:

_____

_____

_____

Glazing Materials

All glazing material should conform to ANSI standard Z26.1 for flat safety glazing plastics and laminated glass.

☐ Complies ☐ Does not comply.

Comments:

_____

_____

_____

Masonry

☐ C90 – Load-Bearing Concrete Masonry Units

☐ N/S ☐ Complies with specification

Comments:

_____

_____

_____

Soundwall Systems Evaluation Form

Vendor: _____ Product: _____

Date of Review: _____ Reviewer: _____

Materials Division (continued)

Steel and Metal

Description	ASTM Specification	Component	Utilized in this Soundwall System?
Standard steel	A36	Structural steel components	
High-strength bolts	A325	High-strength connections	
Anchor bolts	A307	Anchoring structures to foundations	
Steel pipe	A53, Type S, Grade B	Posts and foundations	
H-piles	A36	Posts and foundations	
Pile shells	A252, Grade 2	Foundations	

Indicate other types and grades of submitted materials:

_____

_____

_____

Comments:

_____

_____

_____

Timber

Indicate proposed timber grades and types:

_____

_____

_____

Comments:

_____

_____

_____

Soundwall Systems Evaluation Form

Vendor: _____ Product: _____

Date of Review: _____ Reviewer: _____

Materials Division (continued)

Composites, Synthetics, Plastics, and Fiberglass

Materials in this category must be tested for exposure to ultraviolet light according to ASTM G53. Exposure time must not be less than 1500 hours and no delamination, chalking, fading or embrittlement may occur.

☐ N/S ☐ Complies with specification

These materials must also be tested according to the modified ASTM C666, Freeze-Thaw and C672, Salt scaling.

Effect	ASTM Test	Required Value	Test Results	Pass	Fail
Freeze-Thaw	Modified C666	No cracking, spalling or aggregate disintegration			
Salt scaling	Modified C672	Loss of mass < 0.2 lbs./S.F. after 50 cycles			

Comments:

_____

_____

_____

Are there any concerns about corrosion?

☐ Yes

☐ No

Comment: _____

2. Recommendation

☐ Accept

☐ Reject

Comments:

_____

_____

Soundwall Systems Evaluation Form

Vendor: _____ Product: _____

Date of Review: _____ Reviewer: _____

Roadway Design Division

1. Secondary Evaluation Factors

Drainage

Does this soundwall system enhance or hamper drainage? _____

_____

☐ Conventional drainage systems can be used adjacent to this soundwall.

☐ Drainage features are integrated.

Utilities

Can this soundwall system be integrated into existing overhead and underground utilities? _____

Maintenance or construction zone

What is the required footprint area for maintenance? _____

Will an easement or other right-of-way (fee title) be necessary? _____

_____

Signing and Lighting (Input required from Chief Traffic Engineer)

☐ Signs and luminaires can be mounted to this system.

☐ Mounting requires special details and foundations.

☐ Details may result in traffic interference or view obstruction.

Comment: _____

_____

Cost

Initial cost of soundwall system: _____

Other factors that will increase the initial installation cost: _____

_____

Supply an estimate of the unit cost of wall: _____

_____

Soundwall Systems Evaluation Form

Vendor: _____ Product: _____

Date of Review: _____ Reviewer: _____

Roadway Design Division (continued)

☐ Life-cycle cost data provided.

Concurrence/Comments: _____

Miscellaneous

How does this soundwall system prevent criminal activity.

☐ It is not easily scalable.

☐ It is graffiti-resistant.

☐ Appropriate vehicle impact data have been provided.

☐ Soundwall meets minimum impact requirements.

How does it appear that this soundwall system will react to a vehicle impact?

_____

☐ Other _____

☐ Reflection is minimized.

How can this soundwall enhance sight distance? _____

Landscaping

☐ Plants grow on this soundwall.

Comment: _____

2. Recommendation

☐ Accept

☐ Reject

Comment: _____

_____

Soundwall Systems Evaluation Form

Vendor: _____ Product: _____

Date of Review: _____ Reviewer: _____

Construction Division

1. Secondary Evaluation Factors

Maintainability

☐ Reliable performance record

Number of past installations _____

Number of years in service _____

Required maintenance equipment, labor, materials and frequency (check one and provide reasons).

☐ Excessive _____

☐ Intermediate _____

☐ Low _____

Are parts readily available? Stockpiling necessary? _____

_____

Constructablility

☐ Complex construction

Comment: _____

_____

☐ Vendor oversight required

Comment: _____

_____

☐ Required Construction Area of concern?

Comment: _____

_____

2. Recommendation

☐ Accept

☐ Reject

Comment: _____

_____

A. Introduction

This Soundwall System Application Package contains the requirements and the procedures to be followed by vendors to have soundwall systems considered by the Nevada Department of Transportation (NDOT). A new soundwall system cannot be used in the State of Nevada for NDOT projects if it is not on the current NDOT soundwall Qualified Product List (QPL).

Product evaluations may be requested by vendors as a means of demonstrating that the soundwall system meets NDOT's standards. The evaluation process requires NDOT to commit an extensive amount of personnel time and resources. Therefore, it is the vendor's responsibility to comply with the policies stated herein so that NDOT product evaluations are uniform and impartial. Deviations from these policies may cause delay or rejection of the evaluation request.

The vendor is solely responsible for the formal proposal required with a request for evaluation of any soundwall system not on the current NDOT QPL. NDOT will only accept complete soundwall systems for evaluation. Soundwall materials or products will not be evaluated unless they are part of a complete soundwall system.

The format of the submittal is presented in this package. A separate proposal must be submitted for each system. Furthermore, a system with more than one potential application for NDOT shall be submitted with a separate proposal for each application. All proposals must be submitted to the Research Division of NDOT with the appropriate forms and other required information.

The Soundwall System Application Package provides sufficient information to allow NDOT to evaluate soundwall systems. The applicant is responsible for seeking formal approval from NDOT for any revisions to a previously approved soundwall material or system.

B. Evaluation Options

Please request only <u>one</u> of the following evaluation options:

1) Acceptance based on current NDOT specifications and standards, or

2) Request for a specification revision.

Acceptance Based on Current NDOT Specifications

Vendors whose soundwall systems meet or exceed the current NDOT specifications should request this option. To initiate this type of an evaluation, the vendor must submit two copies of its proposal to NDOT. Each copy of the proposal must contain the items listed under "Soundwall Proposal." Any submittal that does not meet the current NDOT specifications will be rejected. The vendor would then need to correct any deficiencies if it wishes to resubmit its system.

Request for Specification Revision

Upon request, NDOT evaluates a new soundwall system or construction method that is currently not approved for use, including substantial variations or modifications to a previously approved soundwall system. This option should be chosen by vendors whose system meets specifications or criteria which are different than the current NDOT specifications. However, the submitted system must meet the minimum criteria defined in the NDOT specification and should improve upon the NDOT specification. As an example, a soundwall system may meet a newer specification or test identified by the FHWA or HITEC that is an improvement upon the currently accepted NDOT specifications or tests.

C. Soundwall Proposals

Each proposal must contain, as a minimum, the following:

1. The "Cover Letter" and "Application" signed by the vendor's authorized agent.
2. A full description of the soundwall system. The vendor must identify any inherent system limitations for use under conditions occurring along Nevada highways. System samples, photos, or other visual aids that enhance NDOT evaluation are requested.

   System specimens should be no greater than approximately 305 mm (12 in.) x 305 mm (12 in.) x 305 mm (12 in.) and weigh no more than 12 kg (25 lb). If a reasonable specimen of the system exceeds these parameters, please contact the Research Division, so other arrangements can be made to view the proposed soundwall system.

   Photographs should include clear overall views and close-up views 1 to 1.5 m(3 to 5 ft), which show aesthetic qualities, such as texture and color. One copy of videotape is optional.

3. Description of construction method and requirements, including necessary equipment, staging area size, need for lane closures, and other information pertinent to construction cost estimation.

4. The estimated 20-year lifecycle costs for a 3.66 m (12 ft), 1,000 m (3,300 ft) long possible installation on flat terrain, with up to 130 km/h (80 mph) winds and temperature range from -12° C to 49° C (10° F to 120° F).

5. Design plans, drawings and detail sheets, including specifications for the materials, components and/or system. Design calculations and drawings must be signed by a civil engineer registered in Nevada.

6. History of past use. Identify any location(s) where the product has been installed and all prior evaluation results available, including names and phone numbers of contacts, and whether or not the prior evaluations support the claimed advantages. If possible, enclose a list of other state DOTs or agencies that have approved the soundwall system for use,

including the name and telephone number of the contact person. Please indicate, if the product has not been used elsewhere.

7. Availability of product; i.e., commercial production status, including in-stock quantities, or schedule of availability.

8. Safety and environmental precautions. Provide material and product specifications for important components of the soundwall system. Include a completed copy of the OSHA Materials Safety Data Sheet (MSDS), if applicable. List all precautions in handling and hazards to health. If the product is considered a hazardous material, the manufacturer and/or vendor must accept the unused portion of the sample and the expense involved in the return of the material.

9. Description of maintenance and repair methods and requirements, including availability of components, needed equipment, graffiti removal method(s), and other information pertinent to maintenance and repair cost estimation.

10. Permission for NDOT to reproduce in full or in part any information supplied by the vendor, unless specifically stated otherwise. This includes any material with copyrights held by the vendor.

11. Technical data must be provided in metric units with corresponding English units in parenthesis.

12. Specific claimed advantages over existing systems or construction methods. Verification of claimed advantages, include laboratory reports, data, calculations, etc. Soundwall system tests shall be conducted by an independent testing laboratory to determine whether the soundwall materials, components or system meet all applicable national standards and specifications, such as ASTM and AASHTO. *Product literature is not sufficient; copies of actual independent laboratory test reports are required to be submitted.* Description of other beneficial, outstanding or special features, and any other favorable information not requested elsewhere.

13. Estimate of the cost of the wall system. Include cost per square foot for previous installations.

D. Exceptions

The requested evaluation program will not preclude NDOT from performing, on its own initiative, evaluations or field tests of any soundwall material, product or system, which it may deem beneficial. This includes products or procedures originating from sources other than the vendor, as well as any vendor proposal which includes exceptions to requirements set forth in this policy.

E. Product Approval or Denial

If a soundwall system is approved at any step in this process, it will be placed on the NDOT QPL. The soundwall system may then be competitively bid as an approved alternative in future construction contracts. Placement on the approved QPL does not guarantee that the soundwall system will be included as an alternative on any individual project. The selection of soundwall systems for a specific project is determined by NDOT through the project development process, which includes public input.

If NDOT modifies its design standards for soundwall materials or systems, the vendor is responsible for modifying its design to comply with the new standards. If the vendor changes details or specifications, then NDOT must review those changes.

F. Product Endorsement

The evaluation and/or use of a product does not constitute an endorsement by NDOT nor does it imply a commitment to purchase, recommend, or specify the product in the future. **Implementation of all or a portion of the Department's guidelines for soundwall evaluations and selection for each proposed soundwall installation shall be at the sole discretion of the NDOT Director.**

G. Timing

Requests for acceptance based on current specifications and requests for new soundwall system evaluations may be received by NDOT at any time. The submitted information, including the test data, will be reviewed for conformance to NDOT requirements by various divisions. The turn-around time on a new soundwall system approval request is variable and depends upon the type of product, the degree of evaluation deemed necessary, and the priority of other projects assigned for evaluation. The vendor will be notified in writing of the result of the evaluation. NDOT reserves the right to verify submitted test results or re-evaluate a product at any time by conducting its own laboratory or field tests.

COVER LETTER

Instructions: Please fill out the appropriate sections of this letter. When finished, sign and date the bottom of the form. Mail all forms and information to the address below.

I, _____ (*Your Name*) being an authorized agent of _____ (*Company*) request that the Nevada Department of Transportation performs a product evaluation of _____ _____. (*Name of the Product*)

I have read and understand the Soundwall System Application Package that was transmitted to me along with this form. I am:

☐ Submitting the product for acceptance based on current specifications and standards.

☐ Requesting a specification revision.

I understand that the evaluation and/or use of a product does not constitute an endorsement by NDOT nor does it imply a commitment to purchase, recommend, or specify our product in the future.

_____	_____	_____
Signature	Title	Date

Please send the completed proposal along with all supporting documentation to:

Nevada Department of Transportation
Research Division
1263 South Stewart Street
Carson City, NV 89712

Application

Date:_____

1. **Distributor/Manufacturer:** _____
   A. Contact Person: _____
   B. Phone: _____ Fax: _____
   C. Email: _____
   D. Address: _____

2. **Product Description/Trade Name:** _____

   _____

   A. Primary Use: _____

   _____

   B. Secondary Use:_____

   _____

   C. Which products on the current NDOT Qualified Product List (QPL) are identical or equivalent to this product? (Use additional sheet for all supporting information)_____

   _____

   D. Outstanding Features or Advantages Claimed (Be Specific): _____

   _____

   E. Material Composition: _____

   F. Material Density in kg/m^3 (lb/ft^3): _____

   G. Approved for use by the following agencies (use additional sheet if necessary):
      1. Agency: _____
         Contact Person: _____
         Phone: _____Fax: _____
         Email: _____
      2. Agency: _____
         Contact Person: _____
         Phone: _____Fax: _____
         Email: _____

H. Existing Installation (use additional sheet if necessary):

1. Location: _____

   Contact Person: _____

   Phone: _____ Fax: _____

   Email: _____

   Performance Evaluation: _____

2. Location: _____

   Contact Person: _____

   Phone: _____ Fax: _____

   Email: _____

   Performance Evaluation: _____

I. The estimated 20-year lifecycle costs for a 3.66 m (12 ft), 1,000 m (3,300 ft) long section installed on flat terrain, with up to 130 km/h (80 mph) winds and a temperature range of -12°C (120°F) to 49° (120°F).

_____

J. Product Availability:

1. In commercial production: Yes / No
2. If yes, in what quantities: _____
3. If no, when will it be available and in what quantities: _____
4. Include estimated cost and a description of the basis of the estimate.

K. Provide certified laboratory test reports for the following standardized tests: (Complete all that apply. Use N/S for Not Supplied and N/A for Not Applicable. Use additional sheets if necessary.):

1. ASTM Standard Tests:
   The vendor must provide test results from a certified laboratory approved by NDOT.

All Materials

All soundwall system materials must conform to the following requirements:

Effect	ASTM Test	Required Value	Actual Test Results
Flame spread	E84	140 maximum	
Smoke development	E84	180 maximum	
Fungus resistance	G21	0	

Coating Durability

All coating materials must meet the following test requirements. Testing for weathering effects should occur for up to 2400 hours of exposure with recommended evaluation at every 800-hour interval.

Actual Exposure Time: _____ Hours

Evaluation Interval Time: _____ Hours

Effect	ASTM Test	Required Value	Actual Test Results
Checking	D660	No checking	
Cracking	D661	No cracking	
Blistering	D714	No blistering	
Color change	D2244	5 NBS maximum	
Adhesion	D3359	No loss of adhesion	
Chalking	D4214	7 minimum	
Abrasion	D968	Minimum deterioration	
Corrosion	B117	No corrosion	

Concrete and Portland Cement Based Materials

Will precast concrete elements be used in this system? Yes / No
Description: _____

Will other types of concrete elements be used in this system? Yes / No
Description: _____

Concrete materials must conform to the following sections of the NDOT Standard Specifications for Road and Bridge Construction:

701 Portland Cement (indicate type used and attach certified mix design)

_____

702 Concrete Curing Materials and Admixtures (indicate types used in mix design)

_____

_____

706 Aggregates for Portland Cement Products (attach certified mix design)

713 Reinforcement (indicate types and grades used)

_____

_____

Precast concrete panels must also meet the requirements of the following tests:

Effect	ASTM Test	Required Value	Actual Test Results
Freeze-Thaw	Modified C666	No cracking, spalling or aggregate disintegration	
Salt scaling	Modified C672	Loss of mass < 0.2 lbs./S.F. after 50 cycles	

Glazing Material

All glazing material must conform to ANSI standard Z26.1 for flat safety glazing plastics and laminated glass. (Indicate type and grade of glazing materials used)

_____

_____

Steel and Metal

Steel and metal components must conform to the following sections of the NDOT Standard Specifications for road and bridge construction:

710 Structural Steel
712 Miscellaneous Metal

The following list of material standards can be used for soundwall components:

Description	ASTM Specification	Component	Utilized in this Soundwall System?
Standard Steel	A36	Structural steel components	
High-strength bolts	A325	High-strength connections	
Anchor bolts	A307	Anchoring structures to foundations	
Steel pipe	A53, Type S, Grade B	Posts and foundations	
H-piles	A36	Posts and foundations	
Pile shells	A252, Grade 2	Foundations	

Masonry

Masonry materials must conform to sections 640.02.02 and 640.03.01 of the standard specifications. (Indicate materials and grades used)

_____

_____

_____

Timber

Timber materials must conform to sections 615, Preservative Treatments for Timber, and 718, Timber Materials, of the standard specifications. Timber components must be resistant to decay for 20 years (indicate materials and grades used).

_____

_____

_____

Composites, Synthetics, Plastics, and Fiberglass

Materials in this category must be tested for exposure to ultraviolet light according to ASTM G53. Exposure time must not be less than 1500 hours and no delamination, chalking, fading or embrittlement may occur (indicate test results and attach certified laboratory test results).

_____

_____

_____

These materials should also be tested according to the modified ASTM C666, Freeze-Thaw, and modified C672, Salt scaling.

Effect	ASTM Test	Required Value	Actual Test Results
Freeze-Thaw	Modified C666	No cracking, spalling or aggregate disintegration	
Salt scaling	Modified C672	Loss of mass < 0.2 lbs./S.F. after 50 cycles	

2. Other materials or tests not listed (describe and attach supporting information such as test results etc.):

_____

_____

_____

_____

L. Acoustical test results (include certified test results):

1. STC $\geq$ 25 dB: Yes / No Test result (in dB): _____
2. NRC $\geq$ 0.8: Yes / No Test result: _____

M. Can access doors be installed on this product and how? Yes / No

_____

N. Is this product suitable for a retrofit project and how? Yes / No

_____

O. Can a sign or light be mounted on this product and how? Yes / No

_____

P. Can entrapment and ponding of water, dirt, and debris on or within this product be minimized and how? Yes / No

Q. Can plants grow on this product? Yes / No

R. Is this product graffiti resistant? Yes / No

S. Can the foundation of this product accommodate utilities? Yes / No

T. Is this product suitable for mounting on a bridge rail? Yes / No

U. Does this product have material warranties? Yes / No

V. What is the required footprint area for maintenance?

W. Structural Requirements

All soundwalls are required to be designed in accordance with the current editions of the AASHTO "Guide Specifications for Structural Design of Sound Barriers," and "Standard Specifications for Highway Bridges" including all interim specifications and the requirements noted below. Structural calculations submitted as part of the application must be stamped by a professional civil (or structural) engineer registered in the State of Nevada.

All soundwalls are required to be designed according to AASHTO's "Guide Specifications for Structural Design of Sound Barriers," the "Standard Specifications for Highway Bridges with Interims," and the following modifications (check and complete all that apply).

1. Design Heights
Typical soundwall installations vary in height from 2.44 m (8 ft) to 6.71 m (22ft).
Provide information and calculations in support of the height(s) for which the soundwall system is proposed for use.
Maximum height this soundwall system can be considered for use (as verified by design calculations): _____

2. Wind Pressure
The required minimum value is 958 Pa (20 psf) for initial system approval, a maximum value of up to 2155 Pa (45 psf) may be applicable depending on project location, wall height and type of installation.
Maximum wind load this soundwall system can withstand (as verified by design calculations): _____

3. Seismic Design
In reference to the Seismic Load section of the AASTO guide specification, the required minimum acceleration coefficient (A) is 0.15 for initial system approval, a maximum value of up to 0.40 may be applicable depending on project location.
Maximum acceleration coefficient this soundwall system can withstand (as verified by design calculations): _____

In addition, the applicable dead load coefficient (f) indicated in the AASTO guide specification must be in the design calculations. Those soundwall systems claiming the ability to be mounted to bridge rails must provide calculations using the higher dead load coefficients indicated in the guide specification.

4. Provide loads used and/or maximum values calculated for the following items:

External Stability Calculations for:

- ☐ Overturning (minimum FOS = 2.0)_____
- ☐ Sliding (minimum FOS = 1.5)_____
- ☐ Bearing (minimum FOS = 1.5)_____

☐ Fatigue Calculations_____

☐ AASHTO 10 kip Impact Load _____

Y. Include historical cost information _____

3. Agreement and Permission:

Permission for NDOT to reproduce in full or in part any information supplied by the vendor, unless specifically stated otherwise. This includes any material with copyrights held by the vendor: _____

Yes / No Initial: _____

This application will not be accepted unless signed.

Person furnishing information: _____

Title: _____

Signature: _____ Date:_____

ALL INFORMATION PROVIDED IN THIS APPLICATION AND SUPPORTING DATA IS ACCURATE AND CORRECT AT THIS DATE.

This application is for informational purposes only and in no way obligates the Nevada Department of Transportation in any way regarding your product.

For consideration by the Department of Transportation, please submit the original and two copies of this application and all documentation to:

Nevada Department of Transportation
Research Division
1263 South Stewart Street
Carson City, NV 89712

1. Basics of Highway Noise

Noise is often defined as unwanted sound; it is perceived subjectively by each individual. Acceptance of a certain type of noise or noise level varies among neighborhoods, individuals, and time of day. Physically, sound pressure magnitude is measured and quantified in terms of a logarithmic scale in units of decibels, abbreviated dB. The sound pressure level is based on the logarithm of the ratio of a sound pressure over a reference pressure and is expressed in decibels. Research on human sensitivity to noise has shown that a 3 dB increase in the sound level is barely noticeable while a 10 dB increase would be perceived as twice as loud.

Sounds heard in the everyday environment usually consist of a range of frequencies or pitches at different levels. Human hearing is not equally sensitive to sound in all frequencies. A frequency-dependent adjustment called A-weighting has been devised so that sound may be measured in a manner similar to the way the human hearing system responds. An A-weighting network can be selected during noise measurements and the resulting A-weighted sound level provides a generally accepted descriptor for traffic noise. The A-weighted sound level decibel is often abbreviated "dBA."

The A-weighted sound level is adequate for describing the noise at a particular location and instant in time. However, the average level of environmental noise fluctuates with time so that the A-weighted level of background noise changes with the cycle of human activities. The sound level descriptor used in this report is the hourly energy equivalent sound level (L_{eq}). L_{eq} is defined as the continuous A-weighted sound level that, in a specified period of time, contains the same sound energy as the actual time-varying sound during that period. It is a particularly stable and predictable unit for the description of traffic noise and, at the same time, is well correlated to people's reaction to noise.

2. Criteria for Determining Noise Impacts

The Federal Highway Administration (FHWA) has established the Noise Abatement Criteria (NAC) as outlined in the Procedures for Abatement of Highway Traffic Noise and Construction Noise (23 CFR Part 772). The Nevada Department of Transportation (NDOT) also has noise abatement criteria similar to the FHWA criteria. They are identified in the NDOT Traffic and Construction Noise Abatement policy.

Under FHWA regulations, noise abatement measures must be considered when the predicted traffic noise levels "approach or exceed" the noise abatement criteria or when the predicted noise levels substantially exceed existing noise levels and it is reasonable and feasible to abate. NDOT defines the term "approach" for the purposes of noise analysis on new highway construction or reconstruction projects, as 1 dBA less than the noise abatement criteria. Noise abatement is considered when predicted future traffic noise levels from the proposed project at residential land use, parks, schools, and hospitals are 66 dBA or higher. In many cases, the achievement of lower noise levels would result in even greater benefits to the community and should be considered.

Both the NDOT and Federal standards have abatement requirements when the future noise levels will substantially increase the existing ambient noise levels of adjacent areas. NDOT has defined the term "substantially exceed" as 15 dBA.

The design of noise abatement measures normally is provided for the first row of houses usually adjacent to the right-of-way. The traffic noise impacts could extend to the next tier of structures, but the noise abatement measures designed for the first row of houses will usually reduce the noise impacts at housing farther away.

3. Noise Reduction of Concrete and Asphalt

Studies have indicated that newly laid open graded asphalt would probably reduce noise levels by 2 to 3 dBA. However, there is great controversy about the longevity of the acoustic benefits of open-graded asphalt. Most data suggest degradation within a few years. Differences between open-graded asphalt and concrete or regular asphalt would probably be noticed at first, but it is questionable whether this would be true after some years.

The noise reduction effect of the open-graded asphalt would become less pronounced as the percentage of heavy truck increases. This is due to the wider variety of noise sources in trucks. Automobiles traveling at highway speeds emit mostly tire noise and comparatively little engine or drive-train noise. Heavy-truck noise is dominated by three distinct sources: tires, engine, and exhaust stack. Reducing tire noise by itself does not significantly affect the total noise from heavy trucks.

4. Reflective Noise

On the issue of reflective noise, both FHWA and Caltrans have done several detailed studies. These studies dealt with the acoustical performances of parallel noise barriers and the possibility of noise reflection problems.

The following points summarize the finding of these studies:

- Installation of acoustic material reduced the noise by an average of 2 dBA, well below the generally recognized 3-dBA human perception threshold of changes in noise level.
- The soundwall did not appear to significantly (in the sense of human perceptibility) change the noise levels either up or down at the distant receivers behind the barrier.
- The presence of the single-reflecting soundwall did appear to result in a small but measurable noise level increase at receptors located at the opposite side of the soundwall. There was a consistent noise level increase, regardless of meteorological class, that ranged from 0.5 to 2.5 dBA and an average increase of 1.5 dBA. This increase is consistent with sound reflection theory that predicts an increase of 0 to 3 dBA.
- The studies did demonstrate the profound effect of meteorological conditions on traffic noise level. Wind was the single most important factor in changing noise

levels at distances beyond 61 meters from the barrier, even greater than differences in traffic volumes. For example, fluctuations in noise levels at 0.32 kilometers and greater were as high as 8 dBA with relatively minor changes in wind speed and direction. Even at 61 meters behind the barrier, minor wind shifts were responsible for noise fluctuations of about 4 dBA.

Multiple reflections between reflective parallel noise barriers (noise barriers on each side of the highway) can potentially reduce the acoustical performance (insertion loss) of each individual barrier. There is an important relationship between the ratio of separation-distance between parallel barrier (W) and their average barrier-height (H), and the amount of insertion-loss degradation. This ratio appears to be the best available method of characterizing barrier insertion-loss degradation. As a rule of thumb, if the W/H ratio is 10:1 or greater, the insertion-loss degradation is less than 3 dBA, and not noticeable to the human ear.

5. Noise Reduction Coefficient

Sound absorption has been promoted as a solution for noise reflection where actual problems have been identified. The amount of noise absorption of the materials is rated by a noise absorption coefficient α. It is a measure of the sound-absorptive property of the material. This coefficient is defined as the ratio of the acoustical energy absorbed by the material to the total energy incident upon that material. For any particular material, α is frequency-dependent, and its value for each specific frequency ranges from 0 (perfect reflector) to 1 (perfect absorber). For example, a sound absorption coefficient of 0.65 indicates that 65 percent of the incident acoustical energy that strikes the material is absorbed. At a given frequency, the absorption coefficient of any material varies with the angle of incidence of the sound waves. For this reason, published values of absorption coefficients of materials represent the coefficients averaged over all angles of incidence. To rate the overall absorptive characteristics of a material, a measure of the average α over the frequency range of interest is often used. Considering the typical frequency range associated with traffic noise, an appropriate measure is the Noise Reduction Coefficient (NRC), which is the arithmetic average of α in four octave bands with center frequencies of 250, 500, 1000, and 2000 Hz. NRC is calculated as follows:

$$NRC = (\alpha_{250} + \alpha_{500} + \alpha_{1000} + \alpha_{2000})/4$$

When noise reflection is not an issue, the NRC of the soundwall is not important. Typically, noise reflection would not be an issue for the State of Nevada soundwalls because the W/H ratio of soundwalls is generally greater than 10. However, when an absorptive noise barrier is planned, the NRC should be 0.80 or greater to minimize any adverse effect of the reflective noise. Materials with NRC of at least 0.80 would absorb 80 percent of incident acoustical energy of sound waves.

Table A-1 presents a summary of NRC evaluation criteria from different agencies. As shown in Table A-1, the required NRCs for all the agencies surveyed are 0.80 or very close to it.

6. Noise Behind a Barrier

The sound waves created by a vehicle moving along a highway will radiate outward in all directions. If there is no soundwall to protect a receiver, one of these directions will be along a straight line between the vehicle and the receiver. This noise is called direct noise, and the path along which it travels is the direct path. If a noise barrier is constructed between the vehicle and the receiver, the direct path will be obstructed. Instead, another noise path defined by a straight line from the vehicle to the top of the barrier, and originally destined to continue along an upward sloping straight line away from the vehicle, will now be "bent downward" (diffracted) by the top of the barrier to the receiver. Sound waves following the diffracted path will have less acoustical energy than those that followed the before-barrier direct path because the diffracted path is longer than the direct path. The difference between the direct noise (before barrier) and the diffracted noise (after barrier) is called "barrier attenuation." Within a certain range, the greater the angle of diffraction, the more attenuation can be expected. Explanations of perceived increases in noise at a particular distance due to noise barriers have sometimes centered on noise waves "going over the wall and coming back to the ground." This process is called "diffraction." Virtually all accepted noise barrier theories include the process of diffraction to predict barrier attenuation (noise reduction due to a noise barrier).

In general, the higher the barrier is, the more the noise will be attenuated. The process however, has diminishing returns, so that eventually when a barrier reaches a certain height, no significant additional noise reduction will be experienced by making the barrier higher.

Noise barriers are generally effective in the vicinity of highways; however, noise levels often approach ambient levels (the noise levels associated with normal day-to-day activities in the community) farther away from the highway. For obvious reasons, a soundwall cannot attenuate noise below these levels.

7. Sound Transmission Class (STC)

The Sound Transmission Class (STC) is a single number acoustical rating scheme introduced to facilitate comparison of sound transmission properties of different materials. This number is determined by specific laboratory testing as outlined in the ASTM Standard E90 and calculation procedures provided in ASTM Standard E 413. The STC rating correlates in a general way with the subjective impression of sound transmission for speech, radio, television, and similar sources of noise in offices and buildings. This classification is not appropriate to determine the traffic noise reduction or attenuation by a soundwall. The STC rating should only be used to compare the potential sound transmission loss properties of different materials. The exact traffic-noise reduction or attenuation provided by a given soundwall would depend on the location, shape, and dimensions of the barrier besides the material, and it should be determined by calculations or testing in the field.

Generally, the transmission loss of a material heavily depends on the material properties, particularly the mass or weight and density of the material. Note, the same weight can be attained by lighter and thicker, or heavier and thinner materials. The greater the density of the material, the thinner the material may be. Higher density materials normally yield higher sound transmission loss. Transmission loss also depends on the stiffness of the material.

Noise levels are combined logarithmically; therefore, when adding two noise sources that differ by at least 10 dB, the contribution of the lower noise level would be negligible in calculating the overall noise level. Since the FHWA noise prediction model operates under the assumption that the noise transmitted through the barrier will not contribute to the diffracted noise over the top of the barrier, and for the transmitted noise to become negligible, the transmitted noise should be at least 10 dB less than the diffracted noise. For this to be correct, the transmission loss of the barrier must be at least 10 dB greater than the barrier noise attenuation due to diffraction. For example, if the desired barrier attenuation is 10 dB, the transmission loss of the barrier material must be at least 20 dB. Figure B-1 shows the effects of insufficient transmission loss.

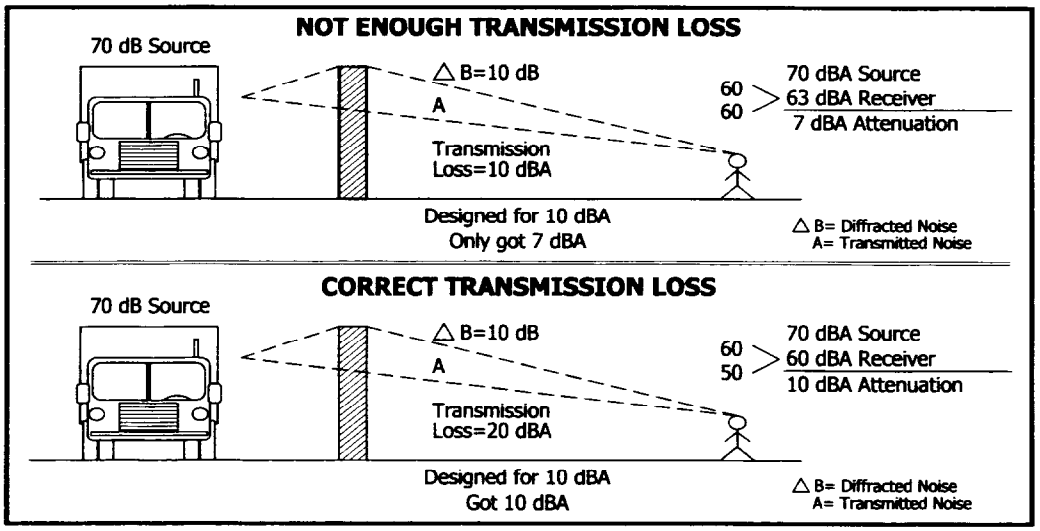

Figure B-1. Barrier Transmission Loss

Table A-1 presents a summary of STC evaluation criteria from different agencies. The required STC ratings for the surveyed agencies varied between 20 and 25 dBA. The basis for establishing the STC criteria is the diffracted noise attenuation of the soundwalls. The variation in values is due to the different criteria used; e.g., conceived achievable maximum noise reduction, average noise reduction for barriers in state, and expected noise reduction for soundwall systems. Most states noted that a 10 dB factor was added to the average noise reduction for barriers in the state or the desired barrier noise reduction to determine the required minimum STC rating for soundwalls.

The majority of soundwalls along highways provide a noise reduction between 5 to 13 dB. Occasionally, some soundwalls may provide noise reduction of up to 18 dB, depending on site-specific terrain condition, among other factors. In theory, soundwall materials with a transmission loss of 23 dB would lower the sound that would be transmitted through a majority of soundwalls to 10 dB below the noise that would be diffracted over the top of soundwalls with a maximum of a 13 dB achievable noise reduction. However, because an STC of 23 dB does not necessarily provide a transmission loss of 23 dB for traffic noise, an additional 2 dB factor of safety is recommended to ensure that the desired 13 dB reduction would be achievable. Therefore, materials with an STC of at least 25 dB would provide the necessary transmission loss to ensure that receptors behind the soundwall would only be exposed to the diffracted noise over the top of the barrier, and the desired reduction is achieved. Soundwall materials with an STC rating of at least 25 dBA should be acceptable for the State of Nevada.

Results of calculations for some projects may indicate that a noise reduction of more than 13 dBA can be achieved. Only materials that have an STC rating of 12 dB more than the achievable noise reduction will be included in that project's QPL. This approach will ensure that the noise transmitted through the soundwall will not jeopardize the overall noise reduction effects of the soundwalls.

Table A-1. STC and NRC Evaluation Criteria

Agency	Transmission Loss (TL or STC)	Noise Reduction Coefficients for Absorptive Material (NRC)
Caltrans	Expected Soundwall Reduction + 10 dB	Min. 0.85
Canada	Min. 20 dB	Min. 0.70
Civil Eng. Research Foundation	Min. 23 dB	Min. 0.80
Florida	Min. 20 dB @ 500 Hz	Min. 0.79
Maryland	Min. 20-25 dB	Min. 0.80
Michigan	Min. 25 dB	-
Minnesota	Min. 25 dB	-
New Jersey	-	Min. 0.85
Virginia	Min. 23 dB	Min. 0.80
Wisconsin	Min. 20 dB	Min. 0.80
Nevada (Existing)	Min. 35 dB	Min. 0.15
Recommended STC	**Min. 25 dB (for general QPL)** **Noise reduction + 12 dB (for project-specific QPL when more than 13 dB noise reduction is expected)**	**Min. 0.80**

1999 Structures LRFD Design Guidelines, revised, January 1, 1999, Florida State Department of Transportation. http://www.dot.state.fl.us/Structures/.

Arizona Department of Transportation Product Evaluation Policy, updated August 12, 1999. http://www.dot.state.az.us/ABOUT/atrc/pridedes.htm.

Certification Method of Acceptance for Noise Barrier Systems, February 1993, Wisconsin Department of Transportation.

Department of Transportation Noise Barrier System for Structures and Highways, January 1996, State of New York.

Effective Noise Barrier Solutions for TxDOT: A First-Year Progress Report, February 1996, Research Report 1471-1, Project 0-1471, Center for Transportation Research, Bureau of Engineering Research, The University of Texas at Austin.

Guidelines for Evaluating the Performance of Highway Sound Barriers, October 1996, Highway Innovative Technology Evaluation Center (HITEC), The Civil Engineering Research Foundation (CERF), Report 96-04.

Guidelines for the Evaluation of Noise Barrier Designs, 1991, Engineering Services Division, Minnesota Department of Transportation.

Guide Specifications for Structural Design of Sound Barriers, 1989 with Interim's through 1992, AASHTO.

Minnesota's Experiences with Noise Barrier Systems, Ronald M. Canner, Jr., Minnesota Department of Transportation.

Noise Barrier Product Evaluation Package, January 1998, California Department of Transportation.

Nevada Department of Transportation Research Manual, second revision November 1998, Prepared by the Research Division.

Noise Wall Design Criteria, January 1995, Illinois Department of Transportation.

Roadside Design Guide, January 1996, AASHTO.

Selection Guidelines for Noise Barriers, April 1998, Gary S. Figallo, Noise-Con 98, Ypsilanti, Michigan

Sound Barriers Design Criteria and Selection Procedure, July 1998, Pennsylvania Department of Transportation.

Sound Barriers Review Procedure, May 1997, Environmental Division, Virginia Department of Transportation.

Sound Wall Design Guideline, November 1992, California Department of Transportation.

Standard for Certification of Noise Barriers, November 1998, Canadian Standards Association.

Structural Design of Sound Walls with Emphasis on Vehicular Impact, September 1996, Research Report 1471-2, Project 0-1471, Center for Transportation Research, Bureau of Engineering Research, The University of Texas at Austin.

FHWA Noise Guidelines

PART 772 - PROCEDURES FOR ABATEMENT OF HIGHWAY TRAFFIC NOISE AND CONSTRUCTION NOISE

Authority: 23 U.S.C. 109(h), 109(i); 42 U.S.C. 4331, 4332; sec. 339(b), Pub. L. 104-59, 109 Stat. 568, 605; 49 CFR 1.48(b).
Source: 47 FR 29654, July 8, 1982; 47 FR 33956, Aug. 5, 1982, 62 FR 42904, unless otherwise noted.

Sec. 772.1 Purpose.

To provide procedures for noise studies and noise abatement measures to help protect the public health and welfare, to supply noise abatement criteria, and to establish requirements for information to be given to local officials for use in the planning and design of highways approved pursuant to Title 23, United States Code (U.S.C.).

Sec. 772.3 Noise standards.

The highway traffic noise prediction requirements, noise analyses, noise abatement criteria, and requirements for informing local officials in this regulation constitute the noise standards mandated by 23 U.S.C. 109(i). All highway projects which are developed in conformance with this regulation shall be deemed to be in conformance with the Federal Highway Administration (FHWA) noise standards.

Sec. 772.5 Definitions.

(a) Design year. The future year used to estimate the probable traffic volume for which a highway is designed. A time, 10 to 20 years, from the start of construction is usually used.

(b) Existing noise levels. The noise, resulting from the natural and mechanical sources and human activity, considered to be usually present in a particular area.

(c) L_{10}. The sound level that is exceeded 10 percent of the time (the 90th percentile) for the period under consideration.

(d) L_{10}(h). The hourly value of L_{10}.

(e) Leq - the equivalent steady-state sound level which in a stated period of time contains the same acoustic energy as the time-varying sound level during the same time period.

(f) Leq(h). The hourly value of Leq.

(g) Traffic noise impacts. Impacts which occur when the predicted traffic noise levels approach or exceed the noise abatement criteria (Table 1), or when the predicted traffic noise levels substantially exceed the existing noise levels.

(h) Type I projects. A proposed Federal or Federal-aid highway project for the construction of a highway on new location or the physical alteration of an existing highway which significantly changes either the horizontal or vertical alignment or increases the number of through-traffic lanes.

(i) Type II projects. A proposed Federal or Federal-aid highway project for noise abatement on an existing highway.

Sec. 772.7 Applicability.

(a) Type I projects. This regulation applies to all Type I projects unless it is specifically indicated that a section applies only to Type II projects.

(b) Type II projects. The development and implementation of Type II projects are not mandatory requirements of 23 U.S.C. 109(i) and are, therefore, not required by this regulation. When Type II projects are proposed for Federal-aid highway participation at the option of the highway agency, the provisions of Secs. 772.9(c), 772.13, and 772.19 of this regulation shall apply.

Sec. 772.9 Analysis of traffic noise impacts and abatement measures.

(a) The highway agency shall determine and analyze expected traffic noise impacts and alternative noise abatement measures to mitigate these impacts, giving weight to the benefits and cost of abatement, and to the overall social, economic and environmental effects.

(b) The traffic noise analysis shall include the following for each alternative under detailed study:

(1) Identification of existing activities, developed lands, and undeveloped lands for which development is planned, designed and programmed, which may be affected by noise from the highway;

(2) Prediction of traffic noise levels;

(3) Determination of existing noise levels;

(4) Determination of traffic noise impacts; and

(5) Examination and evaluation of alternative noise abatement measures for reducing or eliminating the noise impacts.

(c) Highway agencies proposing to use Federal-aid highway funds for Type II projects shall perform a noise analysis of sufficient scope to provide information needed to make the determination required by Sec. 772.13(a) of this chapter.

Sec. 772.11 Noise abatement.

(a) In determining and abating traffic noise impacts, primary consideration is to be given to exterior areas. Abatement will usually be necessary only where frequent human use occurs and a lowered noise level would be of benefit.

(b) In those situations where there are no exterior activities to be affected by the traffic noise, or where the exterior activities are far from or physically shielded from the roadway in a manner that prevents an impact on exterior activities, the interior criterion shall be used as the basis of determining noise impacts.

(c) If a noise impact is identified, the abatement measures listed in Sec. 772.13(c) of this chapter must be considered.

(d) When noise abatement measures are being considered, every reasonable effort shall be made to obtain substantial noise reductions.

(e) Before adoption of a final environmental impact statement or finding of no significant impact, the highway agency shall identify:

(1) Noise abatement measures which are reasonable and feasible and which are likely to be incorporated in the project, and

(2) Noise impacts for which no apparent solution is available.

(f) The views of the impacted residents will be a major consideration in reaching a decision on the reasonableness of abatement measures to be provided.

(g) The plans and specifications will not be approved by FHWA unless those noise abatement measures which are reasonable and feasible are incorporated into the plans and specifications to reduce or eliminate the noise impact on existing activities, developed lands, or undeveloped lands for which development is planned, designed, and programmed.

Sec. 772.13 Federal participation.

(a) Federal funds may be used for noise abatement measures where:

(1) A traffic noise impact has been identified,

(2) The noise abatement measures will reduce the traffic noise impact, and

(3) The overall noise abatement benefits are determined to outweigh the overall adverse social, economic, and environmental effects and the costs of the noise abatement measures.

(b) For Type II projects, noise abatement measures will only be approved for projects that were approved before November 28, 1995, or are proposed along lands where land development or substantial construction predated the existence

of any highway. The granting of a building permit, filing of a plat plan, or a similar action must have occurred prior to right-of-way acquisition or construction approval for the original highway. Noise abatement measures will not be approved at locations where such measures were previously determined not to be reasonable and feasible for a Type I project.

(c) The noise abatement measures listed below may be incorporated in Type I and Type II projects to reduce traffic noise impacts. The costs of such measures may be included in Federal-aid participating project costs with the Federal share being the same as that for the system on which the project is located, except that Interstate construction funds may only participate in Type I projects.

(1) Traffic management measures (e.g., traffic control devices and signing for prohibition of certain vehicle types, time-use restrictions for certain vehicle types, modified speed limits, and exclusive land designations).

(2) Alteration of horizontal and vertical alignments.

(3) Acquisition of property rights (either in fee or lesser interest) for construction of noise barriers.

(4) Construction of noise barriers (including landscaping for aesthetic purposes) whether within or outside the highway right-of-way. Interstate construction funds may not participate in landscaping.

(5) Acquisition of real property or interests therein (predominantly unimproved property) to serve as a buffer zone to preempt development which would be adversely impacted by traffic noise. This measure may be included in Type I projects only.

(6) Noise insulation of public use or nonprofit institutional structures.

(d) There may be situations where (1) severe traffic noise impacts exist or are expected, and (2) the abatement measures listed above are physically infeasible or economically unreasonable. In these instances, noise abatement measures other than those listed in Sec. 772.13(c) of this chapter may be proposed for Types I and II projects by the highway agency and approved by the Regional Federal Highway Administrator on a case-by-case basis when the conditions of Sec. 772.13(a) of this chapter have been met.

Sec. 772.15 Information for local officials.

In an effort to prevent future traffic noise impacts on currently undeveloped lands, highway agencies shall inform local officials within whose jurisdiction the highway project is located of the following:

(a) The best estimation of future noise levels (for various distances from the highway improvement) for both developed and undeveloped lands or properties in the immediate vicinity of the project,

(b) Information that may be useful to local communities to protect future land development from becoming incompatible with anticipated highway noise levels, and

(c) Eligibility for Federal-aid participation for Type II projects as described in Sec. 772.13(b) of this chapter.

Sec. 772.17 Traffic noise prediction.

(a) Any traffic noise prediction method is approved for use in any noise analysis required by this regulation if it generally meets the following two conditions:

(1) The methodology is consistent with the methodology in the FHWA Highway Traffic Noise Prediction Model (Report No. FHWA-RD-77-108)*

(2) The prediction method uses noise emission levels obtained from one of the following:

(i) National Reference Energy Mean Emission Levels as a Function of Speed (Appendix A).

(ii) Determination of reference energy mean emission levels in Sound Procedures for Measuring Highway Noise: Final Report, DP-45-1R*.

(b) In predicting noise levels and assessing noise impacts, traffic characteristics which will yield the worst hourly traffic noise impact on a regular basis for the design year shall be used.

Sec. 772.19 Construction noise.

The following general steps are to be performed for all Types I and II projects:

(a) Identify land uses or activities which may be affected by noise from construction of the project. The identification is to be performed during the project development studies.

(b) Determine the measures which are needed in the plans and specifications to minimize or eliminate adverse construction noise impacts to the community. This determination shall include a weighing of the benefits achieved and the overall adverse social, economic and environmental effects and the costs of the abatement measures.

(c) Incorporate the needed abatement measures in the plans and specifications.

* These documents are available for inspection and copying as prescribed in 49 CFR Part 7, Appendix D.

TABLE 1 - NOISE ABATEMENT CRITERIA

[Hourly A-Weighted Sound Level – decibels (dBA)[1]]

Activity Category	Leq (h)	Description of Activity Category
A	57 (Exterior)	Lands on which serenity and quiet are of extraordinary significance and serve an important public need and where the preservation of those qualities is essential if the area is to continue to serve its intended purpose.
B	67 (Exterior)	Picnic areas, recreation areas, playgrounds, active sports areas, parks, residences, motels, hotels, schools, churches, libraries, and hospitals.
C	72 (Exterior)	Developed lands, properties, or activities not included in Categories A or B above.
D	--	Undeveloped lands
E	52 (Interior)	Residences, motels, hotels, public meeting rooms, schools, churches, libraries, hospitals, and auditoriums.

STATE OF NEVADA
DEPARTMENT OF TRANSPORTATION
Environmental Services Division

TRAFFIC and CONSTRUCTION NOISE ABATEMENT POLICY

The noise standard is outlined in the United States Code of Federal Regulations 23 CFR 772 "Procedures for Abatement of Highway Traffic and Construction Noise" as adopted on April 1, 1972 under the authority of 23 USC 109 (h,i). All highway projects which are developed in conformance with this regulation shall be deemed to be in conformance with the Federal Highway Administration's (FHWA) noise standard. The definitions used in this Noise Abatement Policy are the same as those found in 23 CFR 772.

NDOT has adhered to the noise standard since February 1973 and the following reflects revisions to the policy which have been observed by the Department since April 1, 1996.

1. A traffic noise analysis is performed for highway projects on a new location, or the physical alteration of an existing highway which significantly changes either the horizontal or vertical alignment, or increases the number of through traffic lanes. The analysis is performed for developed lands and undeveloped lands when development is planned, designed, and programmed. Development will be deemed to be planned, designed, and programmed if a noise sensitive land, such as a residence, school, church, hospital, library, etc., has received a building permit from the local agency with jurisdiction at the time of the noise analysis.

   A traffic noise analysis may be required by the National Environmental Policy Act of 1969 (NEPA). This can occur when a project is not a Type I project but does, in itself, create a traffic noise impact. Such projects must be dealt with on a case-by-case basis in accordance with NEPA.

2. Local officials will be kept informed of potential traffic noise impacts to land adjacent to a proposed highway project early in the planning process to protect future noise sensitive land development from becoming incompatible with traffic noise levels. This will be accomplished through environmental documents, noise study reports, and public meetings.

The "date of public knowledge" is when the public is officially notified of the adoption of the location of a proposed highway project. The date of public knowledge shall be the date a project's environmental analysis and documentation is approved; i.e., the date of approval of CEs, FONSIs, or RODs. After this date, NDOT is still responsible for analyzing changes in traffic noise impacts, when appropriate, but NDOT is no longer responsible for providing noise abatement for new development which occurs adjacent to the proposed highway project. Provision for such noise abatement becomes the responsibility of local communities and private developers.

3. Traffic noise abatement measures are considered when the predicted traffic noise levels for the design year approach or exceed the Noise Abatement Criteria (NAC) as identified in the noise standard, 23 CFR Part 772. NDOT defines the term "approach" as 1 dBA less than the NAC.

   Mitigation measures to reduce traffic noise impacts will also be considered when the predicted traffic noise levels substantially exceed the existing noise levels. NDOT has defined the term "substantially exceed" as 15 dBA. The absolute noise level and predicted change will be considered in the reasonableness evaluation, as discussed below.

4. A wide range of criteria is used to determine the overall reasonableness, such as (1) the amount of noise reduction provided; (2) the number of people benefited; (3) the cost of the abatement; (4) the views of the impacted residents; (5) the absolute noise levels; (6) the change in noise levels; and (7) the timing and consideration of development along the highway, and the feasibility (engineering factors) of noise abatement. FHWA directs that noise abatement measures must achieve a substantial noise reduction. NDOT considers a barrier that mitigates at least 5 dBA for the first row of residents, and 3 dBA for the second row of residents as a substantial noise reduction.

   A cost analysis will be prepared to evaluate the cost/benefit ratio of different abatement measures. NDOT uses the 1992 national average of $10,000 per resident and the current Nevada demographics average of residents per residence or a minimum of 1.5 residents per dwelling, to assess barrier economics.

   In determining the reasonableness and feasibility of noise abatement, NDOT will meet with the impacted residents and present a brief program on highway traffic noise to explain and demonstrate the characteristics of highway traffic noise, the effects of noise barriers in attenuating traffic

noise, and the types of noise barriers that may be considered. As available, specific details location, length, height, aesthetic treatment, landscaping, maintenance, drainage, safety; etc., of noise barriers being studied will also be provided in addition to a discussion of alternatives to barrier construction.

NDOT will then solicit the views and opinions of the impacted residents and make a preliminary determination on the reasonableness and feasibility of noise abatement. After completion of final design, NDOT will meet again with the impacted residents to present final barrier design details and solicit the residents' final views and opinions on barrier construction. NDOT will then make a final determination on the reasonableness and feasibility of noise abatement.

5. Procedures to minimize construction noise impacts, while considering traffic impacts, will continue to be addressed on a project by project basis.

6. The Department intends to establish a matching program to retrofit existing impacted locations with noise mitigation. Prioritization of impacts includes the number of people affected, severity of impact, duration of impact, whether residences were built before or after the roadway was planned, cost benefit derived from mitigation, and availability of any local matching funds. The funding for this program will be limited to an annual appropriation of state highway funds as approved by the State Transportation Board.

7. There may be extenuating circumstances where unique or unusual conditions warrant special consideration of highway traffic noise impacts and/or implementation of noise abatement measures. These circumstances could involve areas such as (1) those that are extremely noise-sensitive, (2) those where severe traffic noise impacts are anticipated, or (3) those containing Section 4(f) resources. Extenuating circumstances will be considered on an individual project basis.

This policy has been reviewed during fiscal year 1996 and has been determined to be consistent with all current federal regulations.

DIRECTOR_____

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