Introduction

This policy is intended to serve as ODOT's standard practice for absorptive barrier use to ensure reflected noise does not degrade the performance of noise barriers at locations with parallel barriers. This policy is also intended to provide opportunities to minimize impact to receptors without a noise wall on the opposite side of the highway from a proposed barrier. This policy is an addition to the ODOT Noise Manual (2011) and will be incorporated in a manner similar to the Screening Analysis Procedures which were added in 2013.

Background

Research has indicated that when two noise barriers are located on opposite sides of a highway, the sound reflecting between the two barriers can lead to an increase in sound levels and thus a decrease in the effectiveness of the barriers. Absorptive noise barriers are designed to absorb more noise than they reflect. Under 23 CFR 772, federal traffic noise regulations, if a state highway agency chooses to use absorptive treatments as a functional enhancement of noise barriers, they must adopt a standard practice for using absorptive treatment that is consistent and uniformly applied statewide. ODOT's Noise Manual does not specifically address use of absorptive treatments, but does state in Section 7.5.5, in the discussion of parallel barriers, that "care should be taken to ensure that reflective noise does not degrade the performance of a wall, especially when anticipated noise reductions are small." The only method that the current policy includes to achieve this is to ensure that the width to height ratio between two parallel barriers is at least 10:1. However at some locations, placement of noise barriers is constrained by the location of the highway, drainage features, residences, and other considerations such that it's not possible to place barriers at the distance specification while also designing them tall enough to meet noise reduction goals. Furthermore, research conducted by the Transportation Research Board since the ODOT Noise Manual was last updated indicates that at certain distances from the roadway, reflected noise can exceed three decibels for ground level receivers even for a width to height ratio of 15:1. At a width to height ratio of 20:1, only receptors which were elevated nearer to the top of wall height, such as a second story balcony, experienced three decibels or more of reflected noise effects. This research is documented in NCHRP Report 791 in Chapter 12 and in Appendix K (2014).

Assessing Reflected Noise Effects of Parallel Barriers

In instances where parallel barriers are proposed to be constructed on both sides of a highway, the width to height ratio is the first thing to check to determine if analysis of reflected noise is required. In determining the width to height ratio, the average height of the taller barrier should be used. For example, if two parallel barriers on either side of a roadway are 12 feet tall and 18 feet tall respectively, and they are 360 feet apart, then the width to height ratio is 20:1.

When either of the following conditions exist, a parallel barrier analysis will be performed to consider the effects of reflected noise:

- Parallel barriers with a width to height ratio less than 15:1.
  OR

- Parallel barriers with a width to height ratio less than 20:1 where some of the benefitted residences are on an upper story of a building (second floor or higher)

In such cases, the parallel barrier function of the FHWA Traffic Noise Model (TNM) shall be used to assess the magnitude of the potential effects of reflected noise. Use of absorptive barrier materials will be considered to reduce reflected noise as outlined in the steps later in this section.

TNM has the capability to quantify reflected noise effects from parallel barriers. The parallel barrier function looks at a cross section of an already created TNM file. Each travel lane, both barriers, and receivers to represent the benefitted receptors shall be included in the cross section. The barriers and roadway surface in the cross section possess a variable called Noise Reduction Coefficient (NRC) which represents how reflective or absorptive a material is with respect to noise. An NRC of 0 means all noise is reflected, while an NRC of 1 means all noise is absorbed with none reflected.

If receptors on various floors of a building are benefitted, then, there must be a receiver to represent each elevation. Similarly, if there are two rows of benefitted receptors behind a barrier, it would be appropriate to represent each row with a receiver at the proper distance away from the barrier. In situations where barrier heights, number or placement of lanes, or other attributes of the cross section vary greatly along the length of the barriers, it will be necessary to use multiple cross sections in order to assess conditions for all of the benefitted receptors.

The following steps detail the process for this analysis. In order to eliminate the possibility of rounding error, the sound levels used for these calculations should be taken directly from TNM output without rounding to the nearest whole decibel.

Step 1. Determine Reflected Noise Effects of Reflective Barriers

The parallel barrier module of TNM shall be run with Noise Reduction Coefficient (NRC) = 0, for the roadway surface and the barriers. This represents the worst case effect of reflected noise and approximates conditions if reflective barriers such as concrete, are to be used. For each receiver location, the computed increase in A- weighted sound level (L_{eq}) will be reported in dBA.

Step 2. Compute Adjusted Sound Level for Reflective Barriers

The computed increases for the reflective barrier case are to be applied to each receptor to obtain an adjusted sound level. The adjusted sound level is the sound level with the proposed barrier plus the increase due to reflected noise obtained in **step 1**.

Step 3. Analyze Feasibility and Reasonableness of the Noise Barriers Considering Reflected Noise Effects with Reflective Barriers

Using the adjusted sound levels obtained in **step 2**, evaluate each barrier against the feasibility and reasonableness criteria in the ODOT Noise Manual.

Step 4. Determine whether Absorptive Barriers Should be Considered

If the results of Step 3 show that either barrier is not both feasible and reasonable considering the effects of reflected noise, then absorptive barriers should be considered in **Step 5.**

Additionally, IF

- the computed increase due to reflected noise for any benefitted receptors is greater than or equal to 3 dBA,

OR

- there are benefitted receptors that would no longer be considered benefitted considering the effect of reflected noise,

THEN absorptive materials should be considered regardless of whether the reflective noise walls would still be feasible and reasonable. **Continue to step 5.**

But, IF

- reflected barrier effects are less than 3 dBA at all benefitted receptor locations,
- AND the barrier is feasible and reasonable even considering the effects of reflected noise,
- AND the barrier still provides at least 5 dBA reduction to all receptors originally identified as benefitted,

THEN further consideration of using absorptive noise barriers is not required and the analysis is concluded. **Skip to step 8.**

Step 5. Analyze Reflected Noise Effects with Absorptive Barriers

To determine how much reflected noise would be present if absorptive barrier materials were used, another parallel barrier model run should be created with all attributes the same as the ones in **step 1**, except that the NRC for barrier surfaces should be changed from 0 to 0.7 to represent the use of absorptive materials for the barrier.

Note: This can be completed with multiple values, but the first iteration should be always be NRC=0.7. If NRC=0.7 is later deemed not effective enough at reducing reflected noise, NRC=0.8 should also be tested. Several products are available with NRC=0.8 and a greater number still are available with NRC=0.7 or greater.

Step 6. Compute Adjusted Sound Level for Absorptive Barriers

For a given value of NRC, apply the computed increases in sound level due to reflected noise to each receiver. The adjusted sound level for absorptive barriers is the sound level with the proposed barrier plus the increase due to reflected noise found in **step 5**.

Step 7. Analyze Feasibility and Reasonableness Considering Reflected Noise Effects with Absorptive Barriers.

Using the adjusted sound levels obtained in **step 6**, evaluate each barrier against the feasibility and reasonableness criteria in the ODOT Noise Manual.

Step 8. Draw Conclusions and Document the Parallel Barrier Analysis

There are three possible outcomes, each of which lead to a different conclusion:

A. Both barriers are feasible and reasonable regardless of whether absorptive materials are used.
B. Both barriers are feasible and reasonable only if absorptive materials are used.
C. Even if absorptive barriers are used, one or both barriers are not feasible and reasonable.

A.) If both barriers are both feasible and reasonable, for the reflected noise worst case, and the absorptive case, then the differences between the two should be documented. The project team will choose between reflective or absorptive materials for noise barriers at this location.

B.) If both barriers are feasible and reasonable with absorptive materials, but one or more barriers are not both feasible and reasonable with reflective materials, then absorptive materials shall be used for both barriers. The documentation should recommend that the barrier materials meet or exceed the value of lowest NRC which was used for the analysis that showed the barriers were feasible and reasonable. For example, if a barrier of 0.7 is shown to accomplish this, then the recommendation would be that barrier materials with NRC greater than or equal to 0.7 must be used on both barriers.

C.) If the adjusted sound levels in for the NRC = 0.7 case do not conclude that the barriers are feasible and reasonable in **step 7**, then **steps 5-7** should be repeated with NRC =0.8. If the barriers with NRC = 0.8 are feasible and reasonable, then the recommendation would be that materials must have an NRC of 0.8 or greater. If for any reason the barriers with NRC 0.8 are not found to be feasible and reasonable, then the barrier design may need to be revisited to include more height or length, but in most cases a barrier with NRC 0.8 or greater should limit reflected noise to the point that it does not interfere with performance of the barriers.

Documentation of this analysis is to be included either within the Final Noise Wall Design Memorandum or as a standalone memorandum. It should include a figure showing each cross section and tables documenting the adjustments to the sound levels at each receptor and the re analysis of feasibility and reasonableness. TNM files are to be included electronically as part of the documentation of the analysis.

Reflected Noise from a Single Barrier

Reflected noise off of a single noise barrier has not been shown to cause significant increases in sound level for receptors on the opposite side of the highway. The theoretical maximum impact of reflected noise is a doubling of acoustic energy, or a 3 dBA increase, which is the smallest change in sound level that a typical human ear can perceive. In reality, not all sound is reflected to the other side even using concrete barriers. The measured difference due to reflected noise has rarely been more than 1-2 decibels. While a 1-2 dBA increase may be too small a difference to hear, when combined with an increase in sound level over time due to construction of additional lanes, shifting of traffic closer to residences, or even just increases in traffic volume over time, these increases can accumulate.

If there are receptors on the opposite side of a highway from a noise barrier, which are located at a distance less than 10 times the height of the barrier, and either of the following are true, the project team may elect to use absorptive barrier materials to avoid or minimize impact to the affected receptors:

- The design year build condition sound levels are predicted to exceed the Noise Abatement Approach Criteria (NAAC) at the receptors.
- The receptors are expected to experience 3 dBA or greater increase in sound levels from existing to design year build conditions

Consistent Barrier Appearance

Absorptive materials may also be used as part of an effort to have noise walls with consistent aesthetics along a highway corridor. For example, if some walls associated with a project must be absorptive to avoid problems with reflected noise, the Project Team may elect to use the same materials in order to maintain a consistent appearance with other noise walls along the corridor.

Documentation of Decisions

In many cases as defined above, the final decision of whether to use absorptive materials to use will be made by the ODOT Project Manager. However, in parallel barrier situations where reflective barriers would not meet feasible and reasonable criteria when the effects of reflected noise are considered, then absorptive barriers must be used to avoid compromising the effectiveness of the abatement.

Decisions made as a part of the processes outlined in this policy are to be documented with an Absorptive Barriers Decision Document filled out by an ODOT Noise Specialist in coordination with the project team and signed by the ODOT Project Leader. Any commitments to use absorptive materials must also be documented in the special provisions of the construction contract.

References

Federal Highway Administration (FHWA). *Procedures for Abatement of Highway Traffic Noise and Construction Noise*. 23 CFR Part 772. July 2010.

Federal Highway Administration (FHWA). *Highway Traffic Noise Analysis and Abatement: Policy and Guidance.* January 2011.

Federal Highway Administration (FHWA). *Traffic Noise Model (TNM)*. Version 2.5. April 2004.

Harris Miller Miller & Hanson Inc.; Bowlby & Associates, Inc.; Environmental Accoustics; Grant S. Anderson; Douglas E Barrett. (2014). NCHRP Report 791: Supplemental Guidance on the Application of FHWA's Traffic Noise Model (TNM). Transportation Research Board, National Cooperative Highway Research Program. Washington D.C.: National Academy of Sciences.

Oregon Department of Transportation (ODOT, 2011). *Noise Manual*. July 2011.

Project Name________________
Key Number_______

ODOT's Absorptive Noise Barrier Policy describes when Absorptive Barriers are required for use, when the project team may choose to use them, and when they do not need to be used. This form is intended to document decisions whether to use absorptive materials for Noise Barriers. There are three separate parts to the form. The applicable part should be filled out when the following situations exist:

A. The project will build parallel barriers along a section of a highway
B. The project will build a barrier with receptors on the opposite side of the highway that will not have their own noise wall
C. Project team wishes to use absorptive materials for a barrier for aesthetic purpose (to keep a consistent appearance with other barriers)

If a noise wall is proposed but none of the above cases apply, this form is not required. An ODOT Noise Specialist should complete the form in coordination with the project team and the form is to be signed by the ODOT Project Leader.

Section A. Parallel Barriers on either side of the highway

Names of Barriers____

What is the width to height ratio (distance between barriers: height of taller barrier)?

☐ <10:1 / ☐ between 10:1 and 15:1 / ☐ between 15:1 and 20:1 / ☐ >20:1

Are second floor receptors present? ☐ Yes / ☐ No

If parallel barrier analysis in TNM was completed, answer the following

Are both barriers feasible and reasonable with reflective barriers? ☐ Yes / ☐ No

Are both barriers feasible and reasonable with absorptive barriers? ☐ NA / ☐ Yes / ☐ No

Are absorptive barriers required for use based on reflective barriers failing to be feasible and reasonable? ☐Yes / ☐ No

Do other conditions exist that the project team may decide to use absorptive barriers?

Computed increase due to reflected noise is 3 dBA or greater? ☐Yes / ☐ No

Benefitted receptors which lose benefit due to reflected noise? ☐Yes / ☐ No

Based on considering reflected noise from these parallel barriers, mark the type of materials that will be used and why.

☐ Absorptive, required by policy

☐ Absorptive, project team decision

☐ Reflective, project team decision

☐ Reflective, based on width to height ratio, analysis of reflected noise not required

If absorptive materials are to be used, indicate the value of Noise Reduction Coefficient (NRC) the materials must meet or exceed? NRC = (☐ 0.7 / ☐ 0.8)

Section B. Barrier with receptors on opposite side of the highway

Name of Barrier ____

Are there receptors across the highway from a proposed barrier at a distance from the barrier of less than 10 times the height of the barrier? ☐Yes / ☐ No

If yes, do any of the following conditions exist where a project team has the option to use absorptive barriers?

Do any of the receptors exceed the NAAC ☐ Yes / ☐ No

Do any of the receptors experience a 3 dBA increase from existing to Build ☐ Yes / ☐ No

Document whether absorptive materials (NRC 0.7 or greater) will be used and why

☐ Yes, Project Team Decision

☐ No, Project Team Decision

☐ No, Criteria not met

Section C. Use of Absorptive materials to keep consistent appearance with other barriers

Name of Barrier____

Justification to use absorptive barriers to maintain consistent appearance with other barriers (please describe nearby barriers and why they are of absorptive material):

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____
____

ODOT Project Leader Signature Date

_________________________________ ____________________