National Cooperative Highway Research Program

RESEARCH RESULTS DIGEST

DIGEST 122 - NOVEMBER 1980

Noise Barrier Acoustical Parameters—Experimental Results

An NCHRP staff digest of the essential findings from the final report on NCHRP Project 3-26, "Theoretical and Experimental Investigations of Selected Noise Barrier Acoustical Parameters," by J. M. Lawther, S. I. Hayek, D. C. Tate, and M. A. Nobile, Applied Research Laboratory, The Pennsylvania State University, University Park, PA.

THE PROBLEM AND ITS SOLUTION

The increasing use of noise barriers along urban freeways, in particular, has drawn attention to the need for improved methods of predicting the effectiveness of barriers in reducing traffic noise intrusions on the area adjacent to the highway. Because substantial costs are associated with the construction of noise barriers, a careful evaluation of their potential effectiveness is required during the planning and design stages.

Currently available noise prediction procedures work reasonably well; however, in some cases noise measurements made before and after construction have indicated that the barrier did not perform as well as expected. Part of this difference is attributed to difficulties involved with making acoustic measurements in the field (e.g., problems with wind speed and thermal gradients); however, the accuracy of the prediction models themselves is also considered to be a contributing factor.

The overall objective of Project 3-26 was to provide needed information to improve existing noise barrier prediction models such as included in FHWA's "Noise Barrier Design Handbook," and NCHRP Report 174, "Highway Noise--A

Design Guide for Prediction and Control." Three specific aspects of the models were investigated: (1) the effects of ground absorption, (2) the relative effects of different cross-sectional shapes, and (3) the barrier surface absorption properties.

The research was conducted by Pennsylvania State University in two phases, and, in September 1978, NCHRP distributed the major findings from the first phase in Research Results Digest 105. That digest presented the results of a theoretical assessment of selected barrier characteristics, including cross-sectional shape and absorptive barrier coverings, as well as type of terrain cover. The theoretical findings from the first phase of this project required validation through controlled, laboratory experiments and through testing under actual field conditions. Laboratory tests were conducted in the second phase of Project 3-26 and the results are reported herein. Thus, Research Results Digests 105 and 122 provide a complete overview of NCHRP Project 3-26. Validation tests under actual field conditions were beyond the scope of this research but are being accomplished in a current FHWA project.

The specific objectives of the Phase II research were: (1) to conduct experimental tests of the validity of the theoretical models developed in the first research phase; (2) to identify those models that appear valid; and (3) to clarify the absolute and relative effects of terrain type, barrier cross-section, and barrier surface cover in determining the noise abatement performance of barriers. Experimental tests were conducted in a large gymnasium on the Pennsylvania State University campus to collect actual noise data to verify the Phase I theoretical model predictions. Research was limited to the testing of fabricated devices in an experimental design that was one-fifth the size of actual conditions; the noise source frequencies were also scaled to be consistent with the geometric layout. The wide frequency range of traffic noise and its spatial extension were both taken into account in the experimental design. Barrier cross-sectional shapes that were tested included thin walls, wedges, trapezoids, and parallel walls; and the tests were conducted under hard and grassy terrain conditions. Absorptive barrier coverings were also evaluated.

FINDINGS

The major findings of Phase II are described next under the headings of ground effects, barrier geometric effects, and barrier absorptive coverings. The Project final report contains a more detailed description of these findings, as well as numerous figures and tables showing the comparisons of theoretical predictions vs. experimental noise measurements. Note that, although the experiment was conducted in a one-fifth scale laboratory setting, dimensions given in this Digest are expressed as full scale values to aid in interpretation.

Ground Effects

The main area for improvement in current manuals is in the manner of dealing with terrain attenuation, both with and without a barrier present. Desirable modifications were fairly well demonstrated by the Phase II findings and relate to recognition of the differences in terrain loss as a function of the heights of the noise source and receiver.

Comparisons of insertion loss predictions (i.e., the reduction in noise level attributable to the barrier) using FHWA procedures with similar predictions that use the Project 3-26 models showed some instances of fair to good agreement, but also several cases with significant differences. Differences were greatest--as much as 3 to 5 dB for some hard ground cases and even more for some cases of absorptive ground--for high source heights representing truck traffic. The Project 3-26 models predicted the larger values of insertion loss in all cases of large differences. Analysis of the cases with substantial disagreement indicated that differences in treatment of terrain reflections were partly responsible, together with differences in the predicted values of the barrier diffraction coefficients.

An aspect of ground reflection phenomena heretofore largely neglected in highway noise modeling is the effect of the change in ground surface characteristics due to the transition from the hard pavement surface to the absorptive terrain. The effect of this surface discontinuity was estimated to be significant for automobile sources separated from the pavement edge by two or more lane widths, while, for truck sources, little effect was found. The theoretical model that was used in Project 3-26 to study propagation over such discontinuities agreed fairly well with experiment at high receiver positions but did not do so at low receivers.

Barrier Geometric Effects

Differences in barrier cross-sectional geometry, initially thought to require more detailed treatment in the models, were not found to significantly affect performance for commonly used barrier configurations, beyond the effects already accounted for in the models. Project 3-26 used complex and exact models for propagation over hard thin walls and wedges; these models predicted noise-level values in good agreement with experiment. A less rigorous model for the hard trapezoidal barrier also did fairly well, though not at levels just below the line of sight. For the parallel wall barrier, the theoretical predictions suggested greater differences than could be confirmed through the laboratory experiments. This discrepancy is unfortunate because test results on such barriers indicated that they are at least 2 to 3 dB better than other geometries considered. The attenuating potential of parallel walls (and of walls with similar superstructure) requires further investigation.

Barrier Absorptive Coverings

Generally, absorptive surfaces on barriers slightly improve barrier effectiveness. In the first phase of Project 3-26, barriers with absorptive surfaces were predicted to have excess attenuations (in excess of those with hard surfaces), particularly for receivers in the barrier's deep shadow (i.e., at short range and well below the line of sight from the traffic). For receivers not so deep in the shadow, the increment of excess attenuation due to barrier absorption was predicted to diminish. At practical receiver ranges behind thin walls, the increment was not predicted to be large (i.e., somewhat in excess of 2 dB at 50 ft and dropping towards 1 dB further out). There was one instance in which predictions indicated a large increment in excess attenuation due to barrier absorption. This was the case of a gently sloping barrier, like a wedge, near the pavement edge. In such cases a rather general increase in excess attenuation of 3 to 5 dB was predicted in the shadow region, over and beyond that which would result from a hard thin wall. These theoretical predictions have been substantiated qualitatively by the gymnasium experiment.

APPLICATIONS

In their present form, the findings of this research have limited value for direct application in highway design practice. However, the performance characteristics of various barrier types under different terrain conditions determined in this project should be extremely useful to the FHWA and others who are involved with the development and modification of noise prediction techniques. The results of the scale-model tests performed in Project 3-26 are serving as the basis for study under actual field conditions in a current FHWA study being conducted by the Pennsylvania State University. Further, the model developed in the NCHRP research will be fully considered in future revisions of the FHWA's procedures and incorporated where appropriate.

The theoretical base that has been established in the ground-effects investigation can be used to modify the treatment of terrain loss and barrier effects in highway noise prediction methods. However, the assumptions regarding the level terrain and the absence of environmental effects may be significant limitations on the applicability of the findings in many locales and conditions. Thus, predictions from the models developed in Project 3-26 will have to be supplemented or modified to account for rough terrain, wind, thermal gradients, and other field conditions.

The theoretical results from the models developed in this research for cross-sectional geometric shape and the experimental measurements agree within 2 to 4 dB of predictions based on the FHWA Highway Noise Prediction Manual. The similar performance characteristics of the wedge, trapezoid, and thin wall barriers indicate that use of one barrier model to treat all these geometries is a reasonable approach.

The final report of this project treats highway barrier absorptive coverings in a fairly rigorous manner. The complexity of the models is too great, however, for general use in a highway noise prediction model. Some simplified adaptation of the rigorous models would have application in future versions of the FHWA prediction manual. Nonetheless, from the absorptive covering tests, it can be concluded that berms and slopes on cuts and fills should be planted with absorptive material such as grass or other vegetation with densely packed root interstices to improve their performance as noise barriers.

FINAL REPORT

The final report of this project will not be published in the regular NCHRP series. A copy of the agency's final report may be purchased from University Microfilms International, 300 North Zeeb Road, Ann Arbor, Michigan, 48106; or may be obtained, on a loan basis, by written request to NCHRP. A separate project report, "Model for Acoustic Propagation Over Ground--Theory and Experiment," describing the technical aspects of the prediction model, is also available on a loan basis from NCHRP.