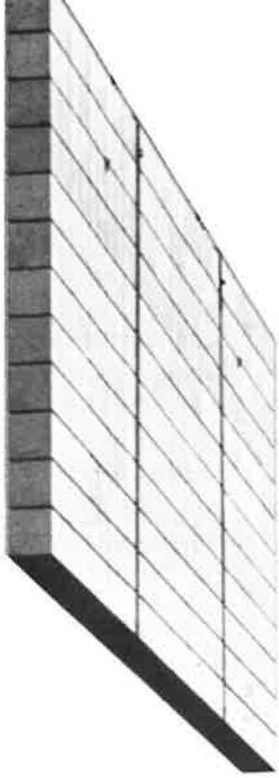

David K. Witheford

State of the Art TRANSPORTATION NOISE BARRIERS

Transportation noise has been making news lately, even headlines. For example, the issues involved in whether the Concorde will routinely land at Dulles and Kennedy Airports are far from being settled. Less dramatic and less loud than air transport noise, highway traffic-generated noise may yet have even greater impact. Highway noise affects more people.

Obviously, the public has become increasingly sensitive to such environmental matters. Clearly, it is this increasing public sensitivity to noise problems that requires highway engineers to learn about noise impacts, noise prediction, and noise control.

Some people might be surprised to find out that this learning process has been going on for some time. As a matter of fact, state highway engineers started supporting research on highway noise more than 10 years ago. The National Cooperative Highway Research Program launched its first noise project for the American Association of State Highway Officials in 1964. Since then, it has committed more than $600,000 of highway funds to noise research. We will soon start a new project on low-cost, prefabricated, and aesthetically acceptable noise barriers. And we recently received proposals on a $75,000 project entitled ***Investigation of Selected Noise Barrier Acoustical Parameters.***

Other current noise research is being conducted by the Federal Highway Administration. Highway noise studies are also being carried out as HPR projects by New Jersey, Virginia, and Washington.

Among the most recent products from noise research is a series of reports prepared for the Federal Highway Administration by Bolt, Beranek and Newman, Inc., on the subject of noise barriers. One of these, ***Noise Barrier Design Handbook,*** may soon be available (5). The most recent phase of NCHRP Project 3-7, ***Establishment of Standards for Highway Noise Levels,*** has produced a 6-volume final report (4). One of these volumes, ***Design Guide for Highway Noise Prediction and Control,*** is an update of the work published in earlier NCHRP reports.

These 2 sets of reports contain revised procedures for predicting the effectiveness of noise barriers. So, one

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aspect of the state of the art is that a new set of design procedures is emerging. Another is that research is still going on to improve both theory and practice. Another is that there is now and there will continue to be a good market for noise barrier construction. According to one source, more than $30 million/year may be spent for barrier construction on the federal-aid highway system.

Planning for Noise Control: Why Barriers at All?

When and where is the subject likely to come up? When and where should what kind of barriers be installed? How much should be spent on them? Who pays? What are the criteria? Questions like these call for different answers under different conditions.

Noise Control Measures

The only 3 ways to control highway noise impacts are by actions taken at the source, at the receiver, or at somewhere between the two.

Source treatments are in someone else's department, except for maybe the interaction between tire design and pavement texture. The U.S. Environmental Protection Agency and the vehicle manufacturers will sooner or later bring about reductions in vehicle noise output. Even so, it will still be a long time before the entire population of vehicles will be quietened enough to solve noise problems.

At the receiver, noise control means moving sensitive activities away from noise sources or else shielding them by modifications to buildings. Either solution is costly. It is hard to retrofit existing structures; however, better insulation (which is one feasible solution) can reduce not only noise but also energy requirements for heating and cooling.

Treatment between the receiver and the source can include costly design alternatives such as depressed or elevated highways. In the short term, at least, barriers are the most cost-effective treatment for most noise problems.

When and Where Needed?

Barriers can solve noise problems generated not only by new highways but by existing ones where traffic volumes grow and urban development tends to crowd in on rights-of-way. Because noise in the evening and at night is the least likely to be tolerated, urban residential areas are the most likely locations for noise barriers. Not just urban or suburban but even some rural locations may require treatment to reduce noise impacts. Furthermore, any highway, not just freeways, can generate excess noise. In short, barriers may be applicable almost anywhere.

Nevertheless, some limits to barrier applications can be established quickly. If the desired goal in noise attenuation is 5 dB or less, barriers may not be the cost-effective answer. If the desired goal is more than 20-dB reduction, barriers cannot realistically achieve it.

What Kind of Barriers?

Barriers can take several forms. They may be earth mounds, wide bands of vegetation, or combinations of both. Or they may be walls of many types of materials, from simple and inexpensive to high-priced materials designed with architectural elegance. Or barriers may be a combination of earth forms, walls, and landscaping. The answers depend on the criteria chosen, the location to be treated, and the ability to pay.

Criteria for Planning and Design

Whatever barriers are to be provided, several factors must be considered. Can the design goal in noise attenuation be met? Is the cost affordable on a total cost basis and reasonable on a dollar cost per decibel of attenuation achieved? How well are the following considerations accommodated: durability, maintenance, traffic safety, snow removal, and aesthetics?

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Who Pays for Noise Barriers?

The question of who pays for noise barriers should probably not determine the when, where, and how of noise barriers, but in the real world it does. Experience shows that the costs are borne by a variety of agencies and groups. For example, if a project is part of new Interstate highway construction, the funding may be on a 90-10 basis. Minnesota is a pioneer in one way of generating state funding for barriers. One percent of its Department of Transportation income from state fuel taxes, or roughly $1 million/year, is now mandated for noise abatement on metropolitan Interstate freeways.

Michigan offers another kind of example. An earth-berm barrier along I-75 in Troy was built and paid for by a neighborhood association. The variable assessments on homeowners, based on distance from the highway, raised $50,000. The association was provided a permit by the state to build on the right-of-way and then hired a contractor to build the barrier. Clearly, if the needs are great enough, there are ways to pay for barriers.

Objections to Barriers

Planners need to be aware that there can be objections to noise barriers: They are often considered unattractive by the adjacent community; they may tend to aggravate the air pollution problem on the right-of-way; they may increase the severity for run-off-the-road accidents if too close to the roadway; they lose their effectiveness in hilly terrain; and they provide little benefit for upper floors of multistory structures close to the right-of-way. Early awareness of such considerations may prevent the installation of less-than-successful barriers. Some barriers may even be too successful, as in this case: "The highway noise barrier works great. Now we can hear the airplanes again."

Noise Barrier Theory

Noise barriers work because they alter the path that sound follows between its source and the receiver. Instead of moving on a direct path, sound will be reflected off a barrier, transmitted through it, and diffracted over it. Reflected sound is not usually a problem. Sound transmitted through a barrier should not be a problem either, if the barrier is dense enough. That leaves sound diffracted over the barrier to be controlled. Thus, the height of the barrier is the major determinant of its effectiveness.

The control is related to total path length difference between source and receiver with and without the barrier. Small differences in path length (up to just 30.5 cm or 1 ft) will achieve from 7- to 10-dB attenuation. A 1.5-m (5-ft) difference can create a 15-dB reduction. Path length difference must be 6 m (20 ft) or more to produce the maximum practical attenuation of 20 dB.

The key parameters in calculating the effect of a barrier are line of sight distance between receiver and source, break in the line of sight made by the barrier,

1 Air placing of concrete for experimental noise panels shows example of surface textures possible. When positioned above the noise path, walls like this have substantially cut decibel levels.

2 Effective noise-reducing materials include precast panels, plastered fencing, earth, steel, and wood. Almost any solid will do the job if it is tall enough to intercept the noise path.

3 Building of noise walls usually involves standard masonry and standard placement techniques. One new technique uses prefabricated block panels in sections up to 3.7 m high and 6.1 m long.

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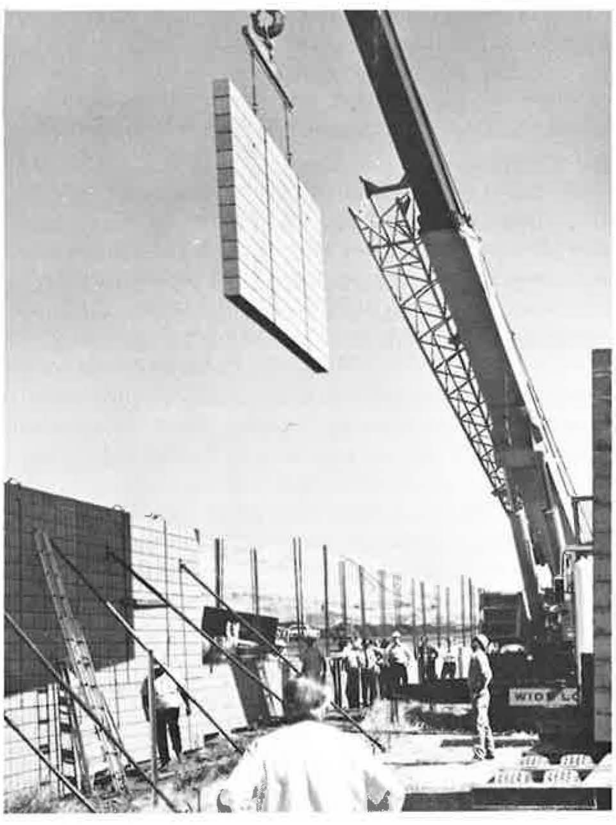

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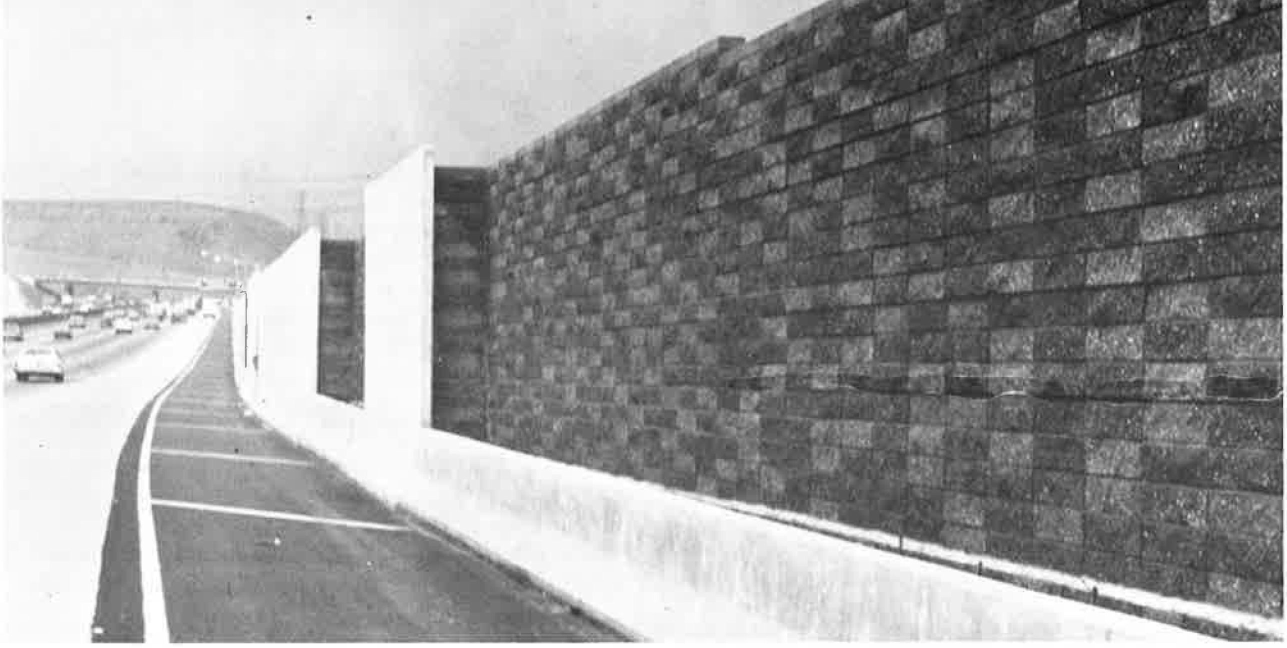

Decorative brick structure, featuring staggered setbacks to relieve the unbroken line of the barrier, results in an attractive and functional screen.

position of the barrier with respect to source or receiver (the shorter of the 2 distances), and angle subtended by the barrier ends. These 4 parameters need to be determined before the new process is used for arriving at the barrier attenuation. The process provides a nomograph solution and a computer program to predict the attenuation to be achieved.

These new procedures are improvements over the methods given in both the Transportation Systems Center guide (10) and the NCHRP reports 117 and 144 (2, 3). The ranges of application have been defined differently, and other refinements (like the treatment of truck versus automobile noise sources and the ground loss effects) have been made to produce more accurate predictions.

Design Procedures

The new FHWA handbook (5) contains 83 pages under the subject of design procedures plus many more pages devoted to sample problems and examples. The suggested design procedure lists 9 steps to follow:

1. Determine noise reduction goals,
2. Define site characteristics,
3. Determine geometrical alternatives,
4. Identify additional barrier treatments,
5. Select design options,
6. Define cost factors,
7. Assess functional characteristics,
8. Select barrier, and
9. Design barrier.

The following are some useful ideas or tips for designers to consider.

1. Use the vertical cross section of the roadway to advantage in determining the barrier setback locations. That is, place the barrier where its wall height is lowest yet still achieves the desired break in the line of sight.

2. For less visual impact, place the barrier 4 or more times its height away from the receiver.

3. Avoid gaps and holes in a barrier because they reduce its effectiveness.

4. Note that although a close-in receiver may determine a barrier's height a distant receiver may determine its length.

5. Consider combining a berm with a wall to offer safety benefits, less visual impact, less sound reflection, and lower cost.

Barrier Costs

Barrier costs vary greatly not only because of the materials used but because of site characteristics as well. Right-of-way availability, availability of material for earth berms, and extent to which community aesthetics may dictate material selections, all influence final cost estimates.

Generally, though, barriers will cost less than other alternatives designed to reduce noise impacts. The NCHRP report (4) shows some figures for comparison and also contains data on the cost of selected barrier installations. The variability is considerable. Costs for typical barrier heights could range from $98/m ($30/ft) to more than $328/m ($100/ft). For wall construction, masonry and wood would be cheapest, steel the most expensive, and concrete in between. Earth berms should typically fall in the range of $66 to $164/m ($20 to $50/ft), exclusive of right-ofway costs.

The alternative of vegetation strips also does not come cheaply. Dense plantings reduce noise transmission by 3 to 5 dB/30 m (100 ft) of width. Even apart from right-of-way costs, the cost of planting at the needed widths might not differ much from that for a wall.

Construction Examples

California, Michigan, and Minnesota, among others, have a great deal of experience in noise barrier construction.

CALIFORNIA

A concrete block barrier built in Fairfield in 1972 cost only about $98/m ($30/ft). Such barriers can be combined with a berm, and the slopes leading up to the barrier can be landscaped with flowering plants and shrubs. As an alternative, panels of textured materials can be used to make low-cost barrier construction more attractive. California has tested various stucco-treated panels and even transparent Lexan plastic panels; in the latter case, the clear plastic was impossible to maintain in a clear condition.

MICHIGAN

Michigan has built 1 wooden barrier that is 4 m (13.5 ft) high and 823 m (2,700 ft) long and achieves an attenuation of 11 dB compared with the no-barrier case. This barrier cost $181,000 or about $220/m ($67/ft). A more attractive but also more costly barrier was built on I-71 at Southgate. This is an aluminum-coated steel wall, also 4 m (13.5 ft) high, on a berm set back 10 m (30 ft) and 533 m (1,750 ft) in length. It cost $190,000, or $364/m ($111/ft), for its predicted 10-dB attenuation. In contrast, a 11 450-m^3 (15,000-yd^3) earth berm in Kalamazoo cost only $41/m ($12.50/ft). It achieves a 7- to 9-dB attenuation. This 3-m (10-ft) mound, with its high point 20 m (66 ft) back from the pavement, was built to shield a school and lends itself well to landscaping treatment. Another earth-mound built by a neighborhood association in Troy cost more, but it provides sufficient height to shield the second floor level of the adjacent houses.

MINNESOTA

More elegant than any of the preceding examples is a precast concrete panel wall built in Minnesota in an urban area abutting I-35. Some of the sections are 6-m (20-ft) high. Where the barrier faces a local street, the flat wall appearance is broken up by variable panel heights, varying setbacks, and changes in the texture of the wall surface. At the backs of residential properties, it permits quite attractive landscaping.

Even wooden walls can be made visually appealing. Minnesota has used a green stain that eventually faded to the natural wood color, applied vertical battens to introduce some variability in texture, and planted trees and shrubs to break up the solid appearance. Costs for this kind of treatment, with wall heights ranging between 1.5 and 5.8 m (5 and 19 ft), are on the order of $328/m ($100/ft).

Selected Readings

Two FHWA and NCHRP reports have already been mentioned, and several other recent publications merit review. One is Transportation Research Circular 175, ***Highway Traffic Noise Prediction Methods,*** which mainly discusses noise models and theory (9). A second is the 1975 World Survey of Current Research and Development on Roads and Road Transport, prepared by the International Road Federation, which contains a summary report by Behrens and Barry on European experiences (8). The same report has been recently reprinted by FHWA. Third, the Minnesota status report of the Interstate noise abatment program (8) will interest anyone concerned with noise barrier design problems.

Summary

In the field of noise barriers, the times are changing. Pressure is increasing to build noise barriers. Funding for them is likely to increase. And a published body of experience is being developed that will aid designers in effectively solving the growing number of problems. Designers can benefit not only from better design methods but also from the experience of those who have already been building barriers.

Clearly noise barriers will continue to be needed, at least until vehicles become quieter, at those locations where attenuation in the range of 5 to 20 dB is desired. Some current research may lead to further improvements in predicting noise impacts and to further improvements in cost-effective designs. But the basic tools are here now, ready to be picked up.

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