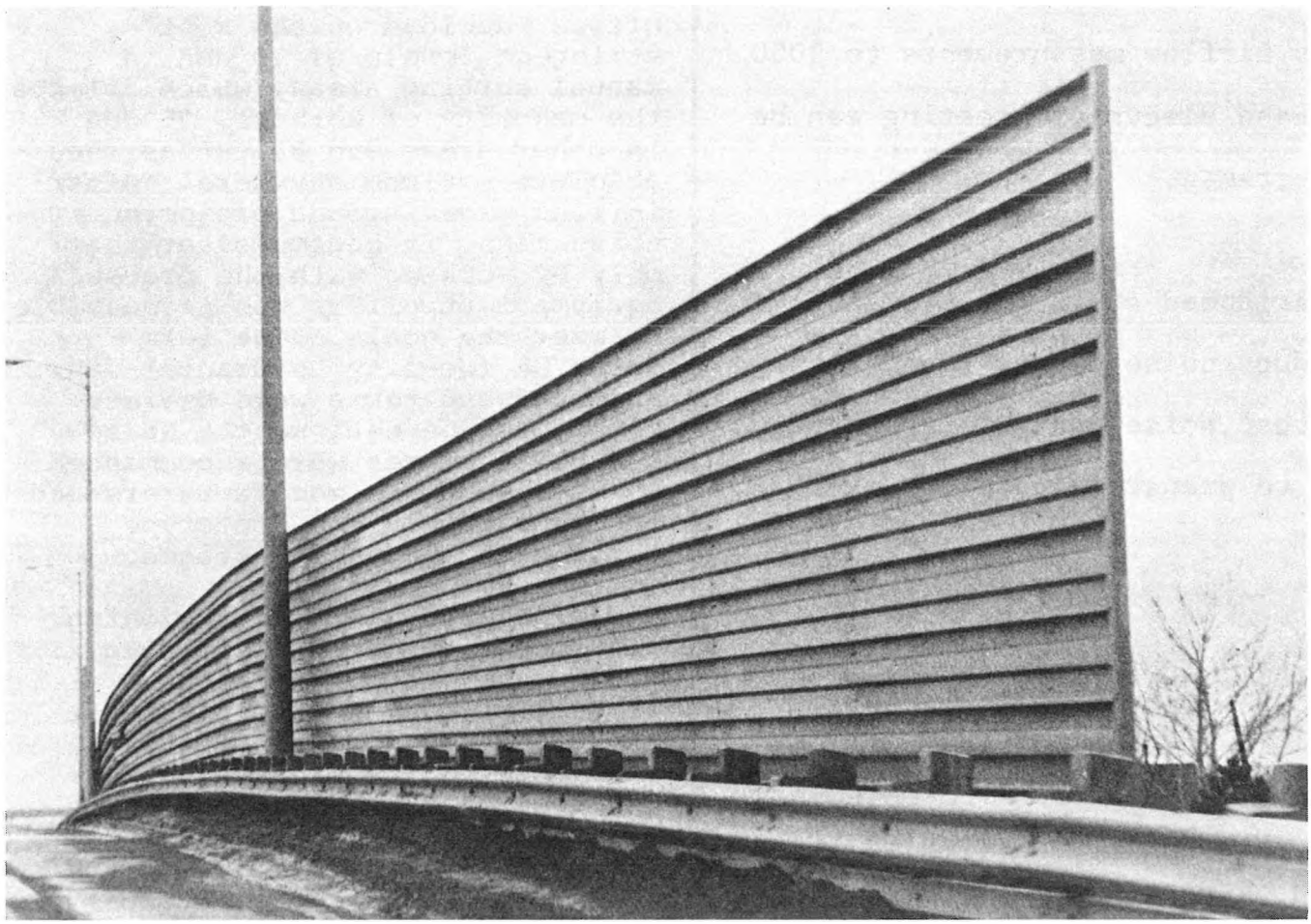
ONTARIO'S HIGHWAY NOISE BARRIER RESEARCH

Daryl N. May*
Wyle Laboratories
128 Maryland Street
El Segundo, California 90245

Ontario's Ministry of Transportation and Communications (MTC) has been involved in a highway noise R&D and implementation program to quieten the provincial freeway system in residential neighborhoods.

The program primarily involves noise barriers and pavement, because these two items are within provincial control. (The federal government regulates new vehicle noise.) The barrier construction program now has a $7.5m budget, making it probably the largest Canadian noise control program.

Ontario received this new impetus to its noise program as recently as 1975, when MTC called together representatives of the



*This work was performed while the author was in charge of noise research at the Ministry of Transportation & Communications, Ontario.

Ministries of Housing and Environment, and set up a committee (chaired by the author) to develop noise standards for freeways in residential areas.

With subsequent Cabinet endorsement, the committee's work became a major ingredient in Ontario's residential noise standards, which in this context essentially involve:

o MTC responsibility for freeway noise control where adjacent residential development precedes the freeway,

o Ministry of Housing responsibility (exercised with the advice of Ministry of Environment) for residential noise control where residential development postdates the freeway.

This paper reviews the major R&D and implementation achievements of the first, i.e., MTC, area of responsibility, with an emphasis on its noise barrier aspects. It has become clear from discussions and letters received in performing this work that other provinces and many American states have similar goals, and that our own contributions interested them. However, it was also clear that we had sometimes been too busy actually doing the work to share it. This paper's overview therefore emphasizes the publications available in the general literature or as MTC internal reports. (The latter are free from the Technology Transfer Office, R&D Division, MTC, 1201 Wilson Avenue, Downsview, Ontario M3M 1J8.)

MTC has researched barriers mainly as systems, emphasizing study of their optimum location, height, thickness, shape and materials, and verifying their acoustic and perceived benefits. These studies have been directed at improving the benefit/cost of the province's barrier construction program. Because of the large capital expenditures when highway barriers are constructed "by the mile," a relatively minor R&D expenditure can produce a big payoff. In approximate terms, MTC's $250,000 barrier R&D investment may have increased by 33 percent or more the benefits from the current $7.5m allocated for construction, which is equivalent to a 10:1 return on the research outlay. This ratio will improve further if, as seems likely, the construction budget is increased.

Although this paper emphasizes the R&D aspects of the program, some useful background reading on its administrative and construction aspects is in:

"Proceedings of Noise Barrier Seminar," Report 78-AC-16, Research & Development Division, Ministry of Transportation & Communications, Ontario, 1978.

The above report describes the different approaches taken for existing freeways ("retrofit" barriers) and new freeways ("new construction" barriers), and deals with the adoption of standard designs, contract awards, landscaping, construction, maintenance and monitoring of the overall program, and gives a brief overview of the acoustical aspects.

1. Site Selection

There are two obvious phases in deciding barrier "placement": first you choose the site (as described here), then you choose the barrier for each site (see Section 2). These phases are not entirely separate, however, because it is necessary in analyzing a site's suitability to see how a barrier might perform there.

As part of the site selection process, MTC ranked over 100 sites across the province for the benefit/cost of the barriers that might be installed at each. This process involved:

o a preliminary determination of barrier length, alignment within the right-of-way, and height

o a benefit/cost model

o a computer prediction of "before and after construction" sound levels

o estimate of costs

o benefit/cost calculation for each site.

At this, the site selection phase, the determination of barrier length, alignment and height need only be preliminary. Barrier length was established by "eyeballing" the roadway and adjacent residences, terminating the barrier at a point beyond the limits of the more dense residential development; invariably this termination occurred at an "on" or "off" ramp. Barrier height was determined by calculating the predicted benefit/cost at a number of potential sites for barrier heights ranging from about 8 ft to 25 ft. The optimum barrier height from these calculations was 13 ft, which was also sufficient to satisfy our "minimum attenuation" criterion of 5 dB(A). The site selection process then used heights of 13 ft and 10 ft to show up any sites for which barrier height was so sensitive a determinant of performance that yet other heights should be considered.

Barrier alignment was determined by a parametric study, in which barriers were located variously at the highway edge-of-shoulder, right-of-way line, and an intermediate point. The relative elevations of highway, adjacent residences, and intermediate terrain were varied, and the calculations were performed for narrow and wide highways. One of the sets of geometries explored is shown in Figure 1.

The study concluded that:

o for flat terrain, or terrain in which the roadway and receivers are equally elevated but separated by a ditch or other depression, the best barrier location is near the receiver, i.e., near the residences

o for roadways raised above the right-of-way by 4 ft or more, the best barrier location is probably near the highway, but this should be verified by detail design

o for a depressed roadway, the best barrier location is near the receiver

o for terrain in which the roadway and receivers are separated by more elevated terrain, barrier location must be studied in detail. For elevations of the intermediate terrain that exceed the grade elevation by 2 ft or so, the best barrier location may be the raised intermediate point.

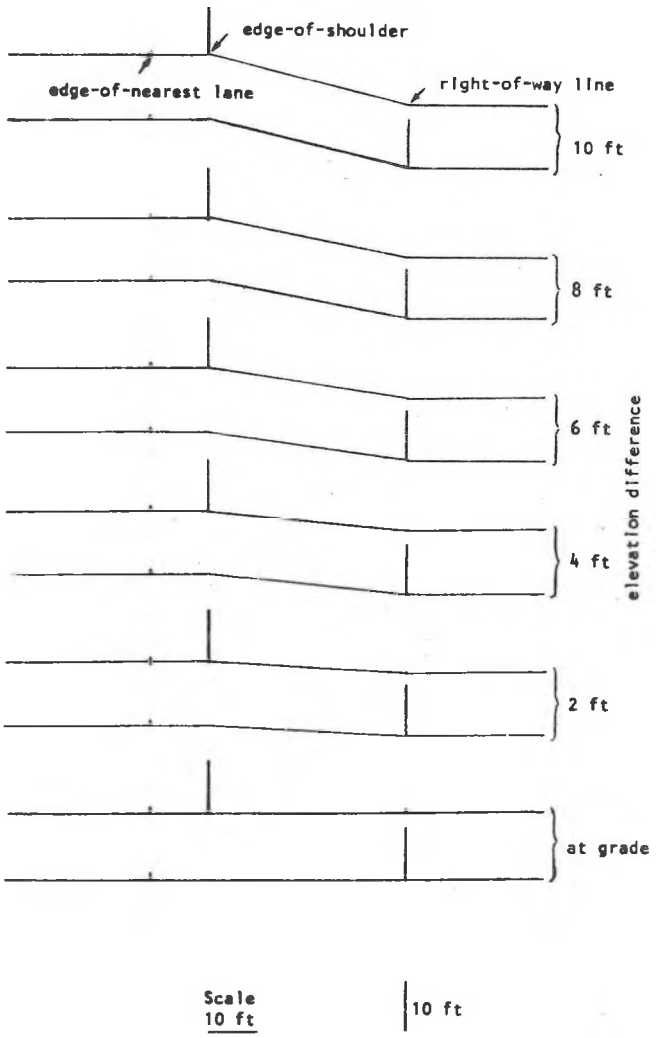


Figure 1. An example of some geometries investigated in a parametric study to preliminarily determine the best location of a barrier for site selection purposes. (For origin, see Section 1.)

Using these principles and an FHWA prediction program, sound levels were calculated outside the residences of representative homes up to several hundred feet from the highway - for all the sites, first without a barrier, then with a barrier of each of the two heights considered. The task was a major one, involving digitizing all relevant heights to take account of the three-dimensional features of the terrain. (Neglect of this can introduce large errors whenever elevations change.)

Together with cost estimates provided by the Highway Design Office, these sound levels were inputted to an MTC computer program to calculate benefit/cost. Benefit, in this instance, was modeled to consider

o the predicted barrier noise reduction at each home,

o the amount by which the without-barrier sound level exceeded a criterion sound level at each home, and

o the number of homes.

The ranking of candidate noise barrier sites by their predicted benefit/cost provides administrators with an objective way to allocate construction funds. They are then more able to resist the more influential, but not necessarily the most noise barrier-deserving residential pressure groups. The result also dilutes the tendency for the government in power to allocate construction on a political basis. By these means, a greater degree of benefit is achieved per dollar.

The most convenient references to this work are the one indicated in the introductory paragraphs, and:

C. Andrew and D. N. May, "Highway Noise Barrier Location for Maximum Benefit/Cost."

(1) Report 78-AC-03, Research & Development Division, Ministry of Transportation & Communications, Ontario, 1978.
(2) To be published, J. Sound Vibration, 1980 (with additional author M. M. Osman).

2. Acoustical Design

The term "acoustical design" here refers to the following geometric aspects of a conventional, i.e., wall barrier, design: height, length and alignment. (Structural aspects and new noise barrier shapes that enhance performance are described later.)

Designing the noise barrier takes place after a site has been selected for construction, and involves studying various options for height, length and alignment to maximize the benefit/cost. The calculation process involves the same computer tools as used for site selection (Section 1), but the process is refined by considering:

- o a great many different alignments and lengths, emphasizing those that the regional design office considers most practicable for that site, e.g., from a maintenance or aesthetic standpoint
- o every detail of the terrain elevation, which sometimes suggests a barrier should zigzag between the edge-of-shoulder and the right-of-way line to take advantage of local terrain elevation variations
- o different heights for different parts of the barrier
- o the refined costs of each candidate barrier, including site-specific costs such as to remove guide rail
- o the effects on the sound level of different pavement and terrain surfaces
- o the presence of any barrier on the opposite side of the highway.

Careful acoustical design on this basis results in fine-tuning the benefit/cost above the value produced in the preliminary site selection analysis. It is also evident in this process what mistakes could have been made without the computer design method: the barrier design options sometimes include a reasonable looking design which might have been selected using traditional, i.e., eyeballing, design methods, but which would perform abominably if it were built. MTC's current approach has so far avoided committing such design to construction.

The best references to this task are those in the introductory paragraphs and in Section 1.

3. New Shapes

The conventional barrier, which is simply a wall, is commonly known to be less effective than a berm of similar height. However no comprehensive investigation has been performed on the many other barrier shapes, i.e., cross-sections, which might also offer performance gains.

To fill this void, MTC developed a scale model facility in which barrier shapes could be easily and inexpensively varied.

Since the materials in a noise scale model facility must exhibit similar absorption coefficients at the model frequencies as the materials they represent do in real-life, a range of locally-available model materials had to be researched. These are described in:

M. M. Osman, "MTC Scale Model Facility for Transportation Noise Problems: Materials Choice and Validation for Scale Modelling," Report 77-AC-4, Research & Development Division, Ministry of Transportation & Communications, Ontario, 1977.

(This work parallels similar studies, using complex impedances, at the University of Calgary and National Research Council, Ottawa.)

The facility was used to explore the performances of the noise barrier shapes shown in Figure 2. In this figure, the circled numbers indicate the improvement in insertion loss exhibited by the various barrier types over that of a conventional barrier. Of particular interest was the fact that T-profile barriers exhibited a performance that was not only better than that of a similar-height conventional barrier, but also better than that of a similar-height, similar-width rectangular cross-section barrier. This is illustrated in Figure 3. It was found that the thickness of the T cap should also be kept as small as possible. To provide an additional performance gain, the top of the T can be treated with a sound absorptive material.

The source-barrier-receiver geometries which generated these results are detailed in the references given below. They occurred in the category of source-barrier-receiver geometry labeled (a) in Figure 4. This is, of course, the most common barrier situation.

The work also investigated other, less common situations: (b) and (c) in Figure 4. A significant "double-barrier degradation" was observed for situation (c), which warned against constructing double barriers, especially on narrow roadways. However, facing the barriers with sound absorptive material

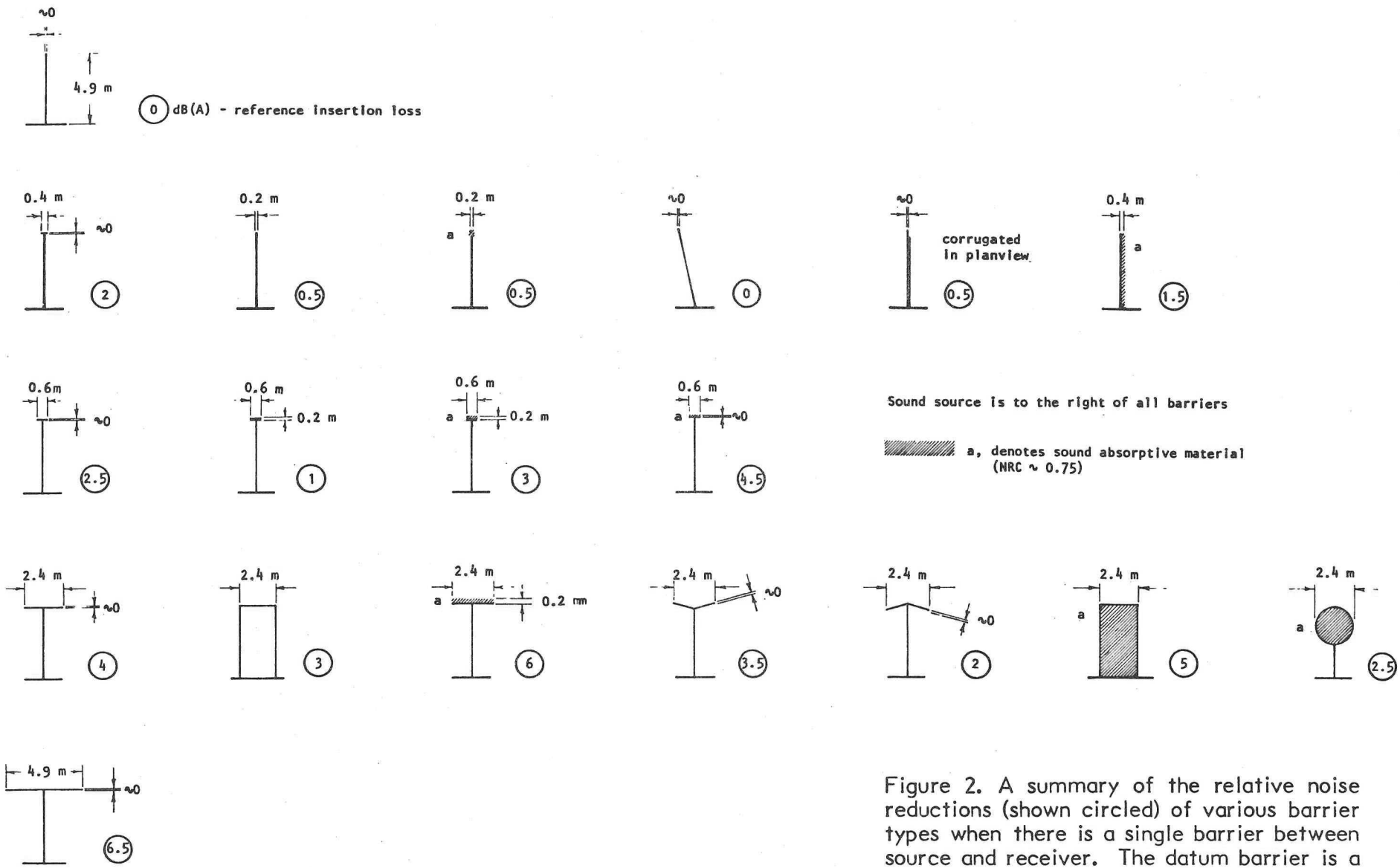


Figure 2. A summary of the relative noise reductions (shown circled) of various barrier types when there is a single barrier between source and receiver. The datum barrier is a conventional, knife-edge top wall given the reference noise reduction here of 0 dB. (From scale model studies, see Section 3.)

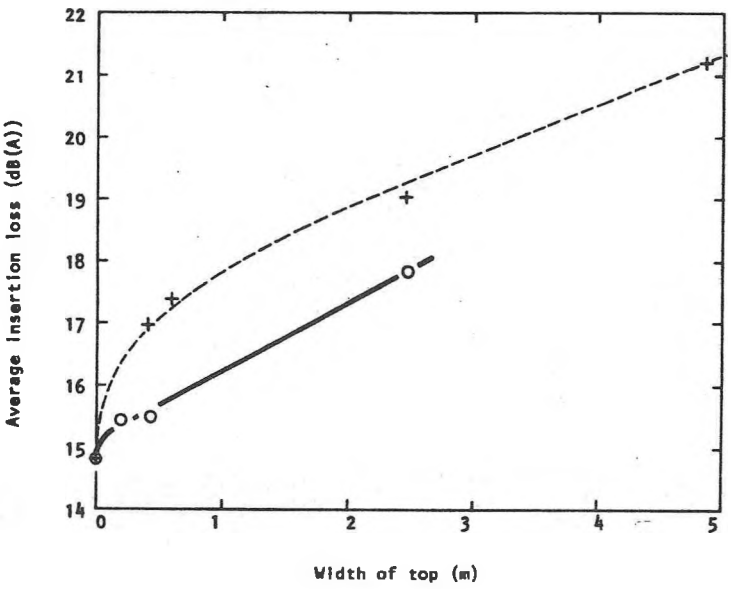
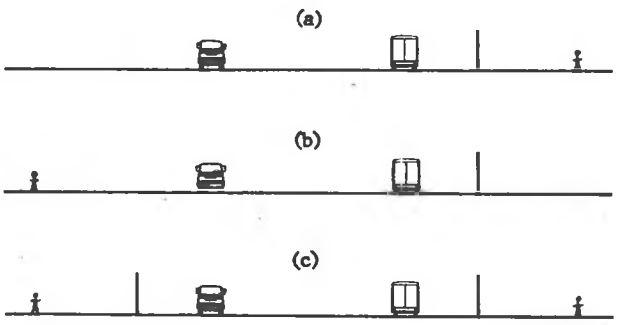


Figure 3. Noise reduction ("average insertion loss") as it varies with the width of top for T-profile barriers in the upper curve, and wide rectangular cross-section barriers in the lower curve. For T-profile barriers with cap widths up to 0.6m (2 ft), the average growth of noise reduction with cap width is 4.1 dB(A)/m. This compares well with the growth rate of 2.0 dB(A)/m as one increases the height of a conventional barrier in a similar test situation. The T-profile barrier may therefore hold promise. (From scale model studies, see Section 3.)

Figure 4. Three source-barrier-receiver situations of relevance.



lessened this degradation. Since this was foreseen from theory, the durability of real-life, i.e, full-scale, materials was simultaneously investigated (see Section 4).

The references to the scale model, noise barrier shape investigations are:

D. N. May and M. M. Osman, "Highway Noise Barriers: New Shapes."

(1) Report 79-AC-06, Research & Development Division, Ministry of Transportation and Communications, Ontario, 1979.
(2) To be published, J. Sound Vibration, 1980.

Full-scale validation of some of these results was also obtained. See the appropriate reference in Section 7.

4. Durability of Sound Absorptive Materials

A wealth of information exists about sound absorptive materials for indoor use, but outdoor use of such materials is fairly rare. To establish the outdoor durability properties of nine types of these materials, MTC ran the following tests:

o The samples were attached for 9 months (through winter) to a wooden noise barrier erected just behind the guide rail of the Queensway freeway in Ottawa

o The sound absorption coefficients of most of the materials were measured before and after the above-mentioned weather exposure, in order to see if there were any significant changes in their values

o Four accelerated durability tests were run in the laboratory.

The results of such studies are, of course, only presentable in considerable length, occupying more space than available here. However, a number of adequately durable materials were found. A full-scale, mile long barrier was constructed in Toronto of one material, made of chemically mineralized and neutralized organic softwood shavings, bonded together under pressure with portland cement.

These results will also be of relevance in other applications, including an MTC-developed use on high-rise balconies (see Section 11.1).

A. Behar and D. N. May, "Durability of Various Sound Absorbing Materials for Highway Noise Barriers."

(1) Report 79-AC-01, Research and Development Division, Ministry of Transportation & Communications, Ontario, 1979.
(2) To be published, J. Sound Vibration, 1980.

continued on page 16

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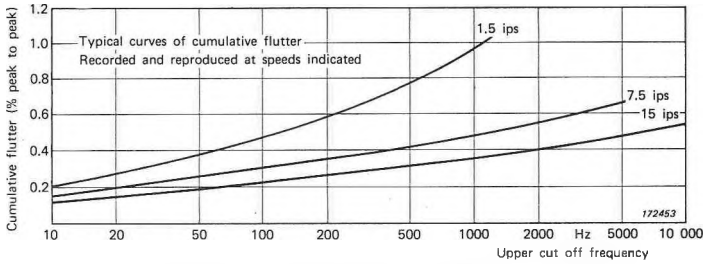
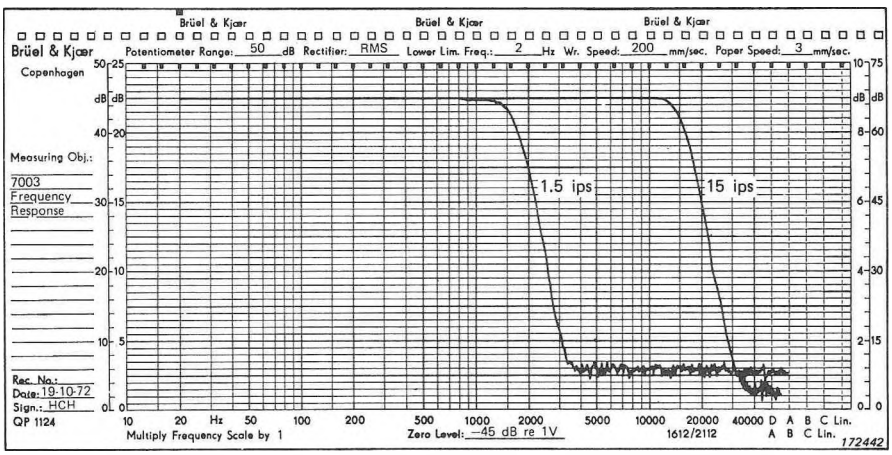


Typical cumulative inherent noise and flutter characteristics



Typical frequency response curves of a measurement channel of Type 7003

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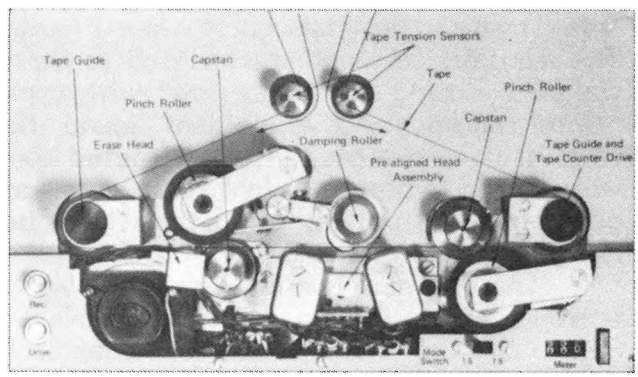

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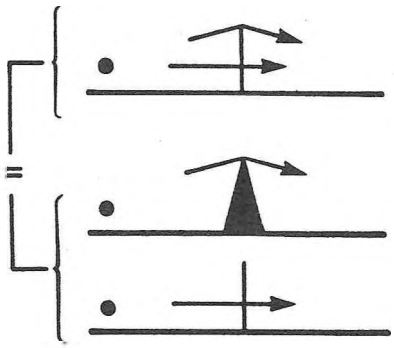


Figure 5. The two transmission paths important in noise barrier work can be treated separately.

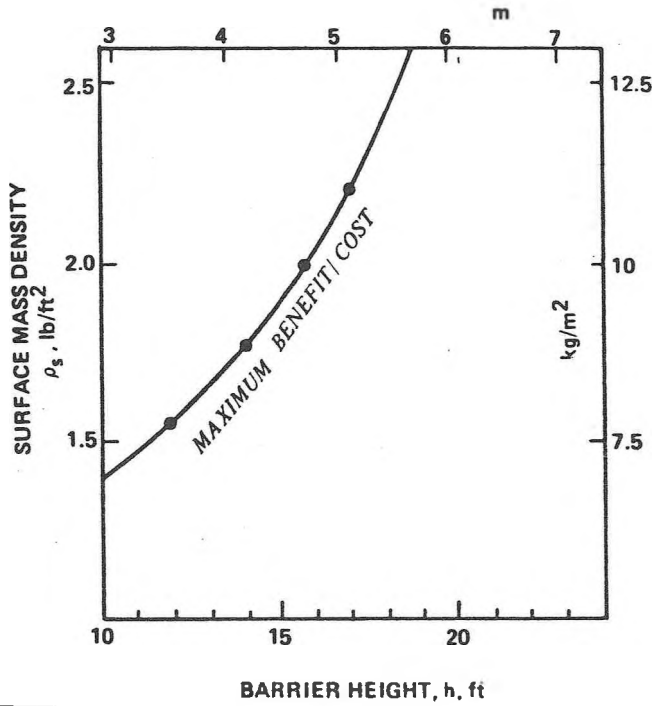


Figure 6. The optimum surface density for the panels in a steel noise barrier as a function of barrier height. (See Section 5.)

5. Barrier Weight

In the instances when barrier weight has been considered in barrier design, a panel surface weight density of 4 lb/ft^2 has become accepted as the minimum acoustical requirement.

MTC was able to revise this requirement downwards, to about 1.5 lb/ft^2 (for all materials except wood). This was achieved with a theoretical analysis, backed up by laboratory transmission loss tests (see Section 6) and full-scale barrier measurements (see Section 7).

The theoretical study considered the noise diffracted over the barrier, and the noise transmitted through it - see Figure 5. The transmitted sound was related to barrier weight by using the "mass law" with appropriate regard for the incident sound field from traffic sources. The diffracted sound was related to barrier height for a worst-case geometrical situation, using traditional barrier prediction methods.

The optimum barrier weight for various barrier heights (shown for steel barriers in Figure 6) was then found by considering actual and estimated costs for various height and weight structures. A barrier built to these principles theoretically achieves the highest overall performance at least cost. However, this is usually only true of steel barriers. (Where other materials are used, nonacoustical requirements generally dictate the weight.) MTC's steel barriers are, however, by far the least expensive, durable barriers of any we have heard of. They cost one-third to one-half what some other agencies' similar-height barriers cost. Their cost has been held roughly constant, despite inflation, for over 5 years by successively applying these and other design refinements.

The study now needs extension by considering not just panel weight, but also the structural concerns that arise when panel weight is reduced, since these can cause the barrier post spacing to be reduced. Barrier post spacing is also an important cost factor.

D. N. May, "The Optimum Weight of Highway Noise Barriers."

(1) Report 78-AC-14, Research & Development Division, Ministry of Transportation & Communications, Ontario, 1978.

(2) Proceedings of Conference on Highway Traffic Noise Mitigation, Los Angeles, California, December 11-15, 1978, published by U. S. Department of Transportation, Washington, D. C., 1979.

(3) To be published, J. Sound Vibration, 1980.

6. Use of Damping Material

The efforts to design lightweight barriers described in Section 5 led to considering other techniques to minimize cost. One such technique was to achieve the desired structural transmission loss (TL) by paring down the weight and adding a sound damping material to restore the TL.

This was tested using a steel barrier structure and a spray-on damping material, by measuring the TL with and without the

material.

A cost analysis showed savings in barrier panel material costs of between 7 and 23 percent, depending on the assumptions taken into the calculations. Further research seemed justified by these results.

A. Behar and D. N. May, "Vibration Damping Compound as a Means to Reduce Steel Noise Barrier Cost."

(1) Report 78-AC-11, Research & Development Division, Ministry of Transportation & Communications, Ontario 1978.
(2) Presented at the 50th Anniversary Meeting of the Acoustical Society of America, Cambridge, Massachusetts, June 11-15, 1979.
(3) To be published, J. Sound Vibration, 1980 (with amended title).

7. Full-Scale Barrier Noise Reduction

The noise reduction produced by a barrier is measured to confirm that the barrier performed. The need for this goes beyond precautionary monitoring of the program, and is mainly to learn how to prevent repeating mistakes in future designs. Predictions of barrier performance are by no means precise, and measurements assist in their development.

There are many pitfalls in making barrier noise measurements, since even small measurement variations may be a significant proportion of the noise difference one is trying to detect. There is no standard for barrier noise measurements, though ANSI is working on one (with MTC and NRC input).

The standard MTC measurement procedure is to measure the noise behind the barrier and, simultaneously, at a "control location." This takes place before the barrier is built and after, at identical positions and similar times of day. The control location is usually situated near the highway, but beyond the limits of the barrier, where it is used to indicate any changes in highway sound level that occur from one measurement occasion to another. The measured insertion loss of the barrier is then "normalized" by correcting for any source strength variations that are observed.

The microphones in the area behind the barrier are typically 15 ft away from reflecting structures, and are at a number of heights up to 20 ft, the main one being 4 ft high. The position of each is noted very precisely, and photographed, to ensure that "before" and "after" measurements are made in the same place. They are connected to digital sound level monitors which report the A-weighted sound levels rounded to the nearest decibel. The many statistical descriptors of relevance to traffic noise are recorded, with most emphasis being placed on L_{eq}. Each measurement period is 30 minutes, and it is the practice to measure at several points for this period of time rather than at just a few points for longer. Therefore the results are usually averaged over a number of points (e.g., "first row homes," "second row homes") to characterize the performance of the barrier.

Since ground cover and weather affect barrier performance, these are noted for future reference. A miniature weather station provides the latter.

An example of the microphone locations for a barrier measurement are given in Figure 7. In this instance, a concentration of measurement positions occurred immediately behind a 500 ft barrier test section that was variously altered so as to be (a) absorptive, (b) reflective, and (c) T-profiled. These particular measurements confirmed some of the scale-model results described in Section 3.

Some examples of relevant publications are given below. The first is of interest because it deals with the special test section described above; the second validated the use of lightweight barrier structures (see Section 5); and the third contains measurements showing that noise amplification can indeed occur on the opposite, i.e., unprotected, side of the highway, though it amounts to only about 1 dB.

D. N. May and M. M. Osman, "The Performance of Sound Absorptive, Reflective, and T-Profile Noise Barriers in Toronto."

(1) Report 79-AC-07, Research & Development Division, Ministry of Transportation & Communications, Ontario, 1979.
(2) To be published, J. Sound Vibration, 1980 (with amended title).

D. N. May, "Noise Barrier Attenuation - Highway 401 South Side, Dixon Rd. to Kipling Ave., Toronto," Report 77-AC-09, Research & Development Division, Ministry of Transportation & Communications, Ontario, 1977.

D. N. May, "Noise Barrier Attenuation - Highway 417 North Side, Melrose Ave. to Loretta Ave., Ottawa," Report 78-AC-13, Research & Development Division, Ministry of Transportation and Communications, Ontario, 1978.

8. Perceived Benefit from Psychoacoustic Studies

For planning purposes in barrier site selection, and also for design purposes, highway agencies need a model for barrier "benefit." Benefit in this usage must consider not just noise reduction, but also the sound level from the highway before a barrier is built. This enables a planner to decide, for example, whether a 75 dB(A) site should receive a barrier giving 8 dB noise reduction, before a 70 dB(A) site at which the same barrier would give 11 dB noise reduction.

At present such decisions are made either arbitrarily or by an empirical benefit model such as Ontario uses (see Section 1). To try to establish a benefit model on a scientific basis, a laboratory experiment was performed in which 82 subjects judged the benefit of a noise barrier by listening to 32 tape recordings of before-barrier and after-barrier traffic noise. The resulting 2624 perceived benefit judgments were related by regression analysis to the barrier attenuation, the before-barrier traffic sound level, and a music background level, all of which had been varied over the 32 tapes. Prediction equations were developed for barrier benefit in terms of these sound levels.

The result of this analysis is shown in Figure 8, which allows barrier benefit, on a scale of 0-10, to be determined once the barrier noise reduction (attenuation) and before-barrier sound level are known.

An unexpected finding was that barrier benefit was highest when before-barrier sound levels were lowest; it appeared that people judge barrier benefit in terms of barrier attenuation first, and the quality of their auditory environment after a barrier is installed second, preferring a barrier that solves their noise problem to an equally-attenuating barrier that does not.

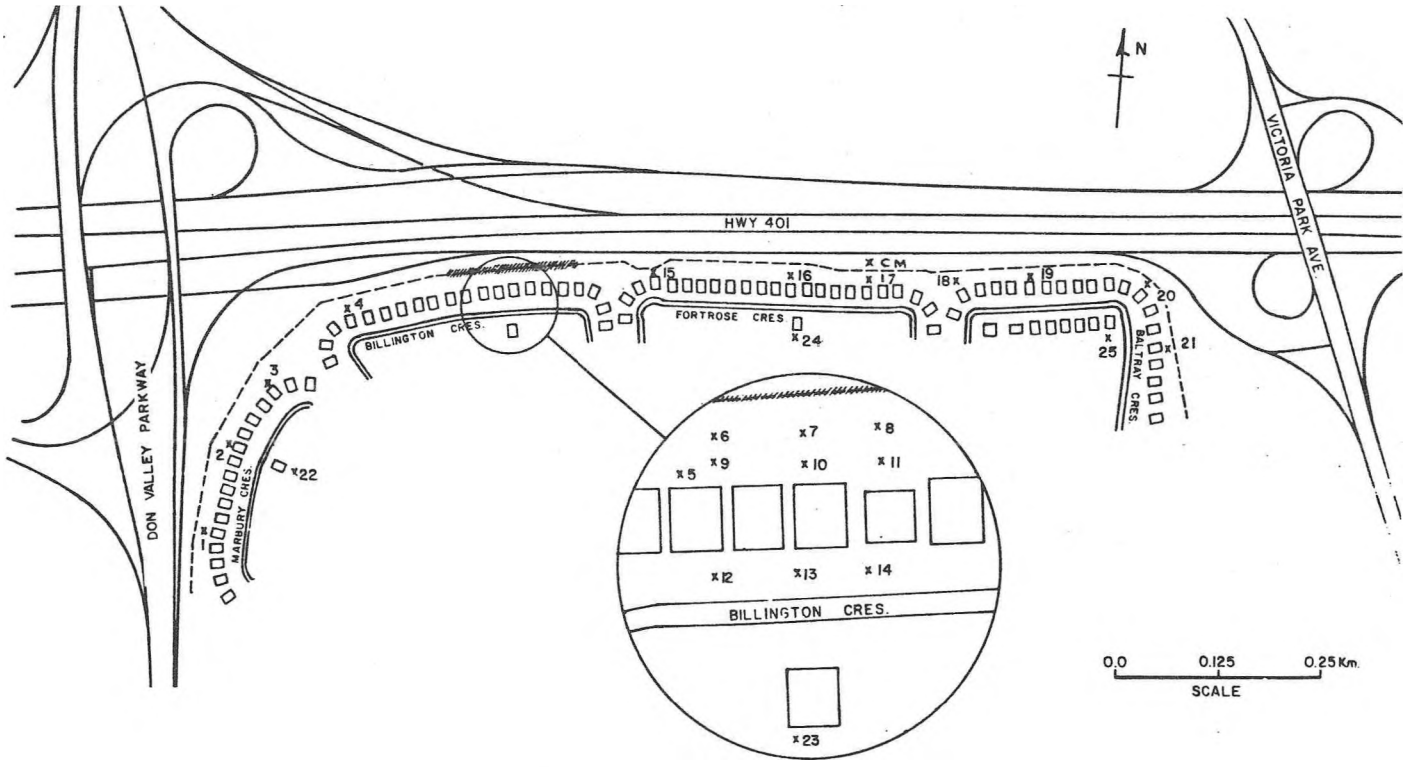


Figure 7. The measurement points for a noise barrier survey in Toronto. The barrier is shown by the dashed line. A special test section is shown hatched. The measurement points are shown by an (x) and either a number or CM (for control measurement). This particular control measurement was 20 ft high to avoid the influence of the barrier.

Figure 8. A psychoacoustical study into barrier perceived benefit produced this result in terms of barrier noise reduction and before-barrier sound level. (See Section 8.)

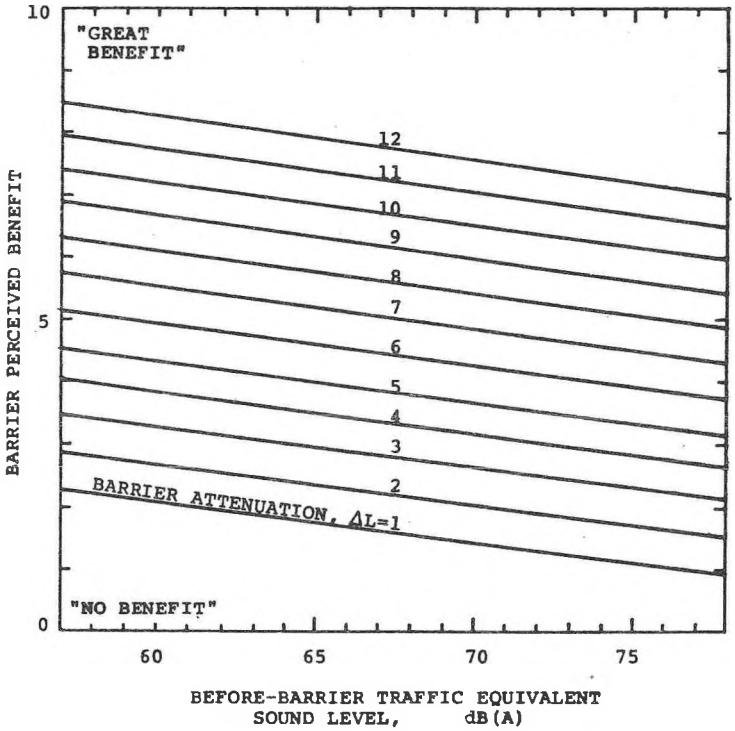
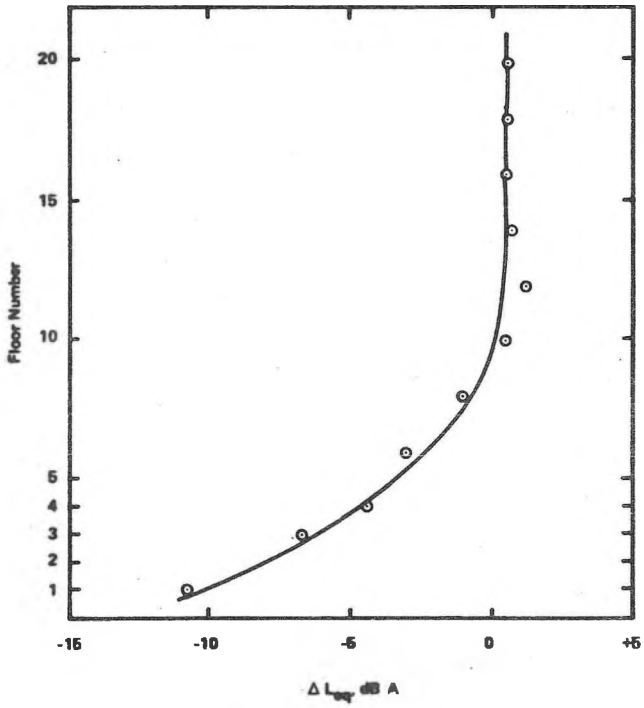


Figure 9. How sound level increased with height in a Toronto high-rise, 260 ft from a 15-lane freeway. L_{eq} is here the equivalent sound level measured 8 ft out from the building on the floor shown minus the simultaneously measured equivalent sound level 50 ft from the highway edge-of-pavement at a height of 4 ft above the ground. (This difference removes the effect of source strength variations such as arise from traffic flow irregularity.) Floors are spaced 9 ft apart. Floor 1 is at ground level. See Section 11.1.



The implications of a barrier benefit model which predicts decreasing benefit with increasing before-barrier sound level must be assessed by user-agencies for themselves. Such a model suggests that the sites most severely impacted by traffic noise may be the ones that should receive them last (unless the attenuation of the barriers is sufficient to solve rather than just alleviate the noise problem). However, it may be more tenable as public policy to mitigate the most severe problems rather than solve the less severe ones. In this case the value of this benefit model is limited to pointing out the real feelings the public apparently have when a noise barrier is erected: their concern for the high level of residual sound level after the barrier is constructed may be voiced by renewed complaints at a later date.

D. N. May and M. M. Osman, "Highway Noise Barrier Perceived Benefit."

(1) Report 79-AC-05, Research & Development Division, Ministry of Transportation & Communications, Ontario, 1979.
(2) To be published, J. Sound Vibration, 1980.

9. Perceived Benefit from Social Surveys

Social surveys provide the final test of barrier success or failure. Those MTC undertook or commissioned all confirmed that residents were well-satisfied with their barrier.

The first survey cited below showed that most of the benefit accrued in the first

row of homes. This survey also provided revealing indications of nonacoustical benefits from barriers, e.g., in reducing such things as dust and dirt, headlamp glare, salt spray, and trespassing by stranded motorists.

The second survey cited below tended to confirm the psychoacoustical result in Section 8 that residents valued a noise barrier most when before-barrier traffic sound levels were high rather than very high.

Further details of these and other interesting findings may be obtained from the survey reports:

C. Andrew and K. Sharratt, "Privacy Fence: A Survey of Public Reaction to the Privacy Fence Located Along Highway 401 within Metro Toronto Between Victoria Park and Warden Avenues," Research & Development Division, Ministry of Transportation & Communications, Ontario, 1976.

F. Schliewinsky and M. J. Adams, "Analysis of Noise Barrier Impact on Dissatisfaction with Freeway Annoyances," Research & Development Division, Ministry of Transportation & Communications, Ontario, 1979.

10. Education and Public Relations

Two useful publications in a noise barrier construction program are (a) an explanation of design principles, and (b) an audiovisual program.

An easily followed report showing how barriers work, the importance of adequate length, how to calculate noise reduction in simple situations, how "leaks" degrade performance, etc., was found invaluable. It was issued to regional engineers within the agency, and to many members of the public who wanted to do-it-themselves when they saw MTC barriers being constructed elsewhere.

An audiovisual program was produced for regional engineer use at public "drop-in" centers. Its noise effects cautioned the public not to expect too much from barriers, and its visuals gave them a good idea of what barriers look like.

D. N. May and J. J. Hajek, "Design Principles for Highway Noise Barriers," Research & Development Division, Ministry of Transportation & Communications, Ontario, 1975.

A. Behar and D. N. May, "Highway Noise Barriers - an Audiovisual Program," Reports 78-AC-10A (Users' Guide) and 78-AC-10B (Slides and Tape), Research & Development Division, Ministry of Transportation & Communications, Ontario, 1978.

11. Associated Highway Noise Research

Given in brief here is a summary of MTC highway noise research that was closely associated with the noise barrier program.

11.1 High-Rise Balconies

High-rises are not protectable by noise barriers. Moreover our measurements showed a noise increase with height due to the absence of the ground attenuation that protects low level structures - see Figure 9. To provide high-rise occupants with a way to reduce noise in this important recreational area, the use of sound absorptive treatment was tested on balcony surfaces - with satisfyingly substantial results; see Figure 10.

D. N. May, "Freeway Noise and High-Rise Balconies."

(1) Report 77-AC-2, Research & Development Division, Ministry of Transportation & Communications, Ontario, 1977.

(2) J. Acoust. Soc. Am. 65(3), 699-704, 1979.

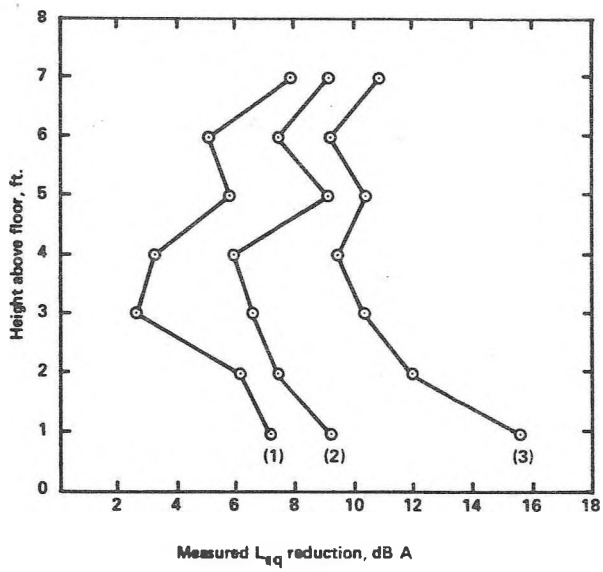


Figure 10. The substantial noise reduction produced on a 17th floor balcony by adding sound absorptive linings to (1) ceiling only, (2) ceiling and back wall, and (3) all surfaces. See Section 11.1.

11.2 Sound Level Prediction

MTC's highway noise prediction models have been highly regarded at Transportation Research Board conferences, due partly to the substantial data base of careful measurements from which they were drawn.

J. J. Hajek, "Ontario Highway Noise Prediction Method," Report RR 197, Research & Development Division, Ministry of Transportation & Communications, Ontario, 1975.

J. J. Hajek, "An L_{eq} Traffic Noise Prediction Method."

(1) Report 78-AC-04, Research & Development Division, Ministry of Transportation & Communications, Ontario, 1978 (first printing, 1976).
(2) Presented at the Annual Meeting of the Transportation Research Board, Washington, D. C., January 1977.

11.3 Psychoacoustical Tests of Noise Descriptors

Noise descriptors like L_{eq} and L_{10} have sometimes been criticized for a supposed inability to adequately describe traffic noise with unusual time-varying properties. A psychoacoustical study was therefore performed using a wide range of sound level standard deviations for the tape-recorded noises presented to subjects. Intrusive noises like gear changes and clearly distinguishable individual truck pass-bys were featured.

The results showed that L_{eq} was a better descriptor than other descriptors, including those which considered the sound level standard deviation. It could, however, be slightly improved by adding a term containing the number of truck gear changes. However, this addition did not seem warranted for freeway noise situations.

C. Andrew and D. N. May, "A Laboratory Study of Annoyance Due to Traffic Noise and the Choice of Noise Descriptors."

(1) Report 77-AC-1, Research & Development Division, Ministry of Transportation & Communications, Ontario, 1977.
(2) Presented at the 94th Meeting of the Acoustical Society of America, Miami, Florida, December 1977.

11.4 Pavement-Tire Noise Reduction

Pavement-tire noise reduction in association with noise barriers adds up to considerable noise alleviation potential, all within the ability of the government to provide.

MTC's research in pavement/tire noise has:

o Identified a quiet type of transverse grooving for use in restoring the skid-resistance of worn concrete pavements, and a very quiet open-graded, carpet seal mix asphalt pavement

o Developed a near-tire measurement technique

o Highlighted the relative influence of tire type and pavement type in influencing sound levels

o Developed a roadside measurement technique using a two-way analysis of variance to indicate how pavement noise level differences reduce with increasing distance from the highway.

Relevant references are:

J. J. Hajek, "Influence of Pavement Surface Textures on Highway Noise."

(1) Research & Development Division, Ministry of Transportation & Communications, Ontario, 1975.
(2) Presented at the Annual Meeting of the Canadian Acoustical Association, Toronto, October 1975.

D. N. May and M. M. Osman, "Noise from Retextured & New Concrete & Asphalt Road Surfaces."

(1) Research & Development Division, Ministry of Transportation & Communications, Ontario, 1978.
(2) Proceedings of Inter-Noise '78, San Francisco, California, May 8-10, 1978.

M. M. Osman and D. N. May, "Relative Influence of Pavement Texture and Tire Type on Pavement/Tire Noise."

(1) Report 79-AC-08, Research & Development Division, Ministry of Transportation & Communications, Ontario 1979.
(2) Proceedings of the International Tire Noise Conference, Stockholm, Sweden, August 28-30, 1979.
(3) Presented at the Society of Automotive Engineers Congress and Exposition, Detroit, February 25-29, 1980, Paper 800282 in SP 456, available from SAE, Warrendale, Pennsylvania.

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