Are Earth Berms Acoustically Better Than Thin-Wall Barriers?

J.J. Hajek

The two most common highway noise barrier structures are earth berms and thin-walls. Yet the relative acoustical performance of these barriers is not well understood. Previous analytic, scale-model, and full-scale studies, comparing the acoustical effectiveness of thin-walls with that of berms and wedges, are reviewed. Additional data obtained by full-scale measurements, and in particular by a 1:16 scale-model study, are presented. The source-barrier-receiver geometry and model materials used were selected to simulate typical highway situations. Preliminary results indicate that, contrary to a recommendation in the Federal Highway Administration Highway Traffic Noise Prediction Model, thin-wall barriers and earth berms of the same height are about equally effective in reducing noise. In addition, the acoustical effectiveness of combining a wall with an earth berm was found to be quite similar to that of using thin-wall barriers alone. The practice of erecting relatively low walls on top of earth berms was found to be acoustically sound.

Reflective thin-walls, earth berms, and combinations of the two, are the most common highway noise barriers. Their relative nonacoustical aspects, such as cost, maintenance, right-of-way requirements, and aesthetics, are well understood (1), but their relative acoustical performance is not so clear. Whereas some highway noise prediction methods assume that they perform equally (2,3), the widely used Federal Highway Administration (FHWA) Highway Traffic Noise Prediction Model (4) asserts that earth berms provide 3 dB(A) higher insertion loss than do thin-walls of the same height. This difference in acoustical performance has been attributed to absorption or edge effects.

The higher insertion loss assumed for earth berms could lead to an important consequence: If the shape of the earth berms (presumably the cause of the increase in the insertion loss) is changed by erecting a thin-wall on its top, the 3-dB(A) benefit provided by the berm top may be lost. Figures 1 and 2 show two wall-berm combinations. Such combinations are quite common in many states. Relatively low walls have been added to improve performance in comparison with earth berms alone. But do they?

This concern is illustrated in Figure 3, which is based on our results from scale-model testing. Details of the scale-model testing, such as instrumentation, methodology, and additional results, are discussed later in this paper. For now, Figure 3 is intended only to illustrate the effect of mounting a thin-wall atop a barrier with an absorptive top.

According to Figure 3, mounting a thin-wall atop a highly absorptive barrier can actually reduce insertion loss. Only after the thin-wall is raised to the height of 1.2 m is the reduction in the insertion loss—caused by violating the absorptive cylindrical shape—recovered by the increase in barrier height. The question arises, Can the same phenomenon occur if a thin-wall barrier is erected atop an earth berm?

This question has become acute in Ontario since a proposal was made to build a thin-wall, approximately 2 m in height, atop an existing 3-m-high earth berm. The berm is already providing some insertion loss (about 6 dB(A)), so the rate of increase in the insertion loss with additional barrier height would be about 1.5 dB(A)/m. However, the desired 3-dB(A) increase in the insertion loss is not expected from adding
Table 2. Barrier shapes evaluated.

<table>
<thead>
<tr>
<th>Barrier Height (m)</th>
<th>Type</th>
</tr>
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<tbody>
<tr>
<td>3</td>
<td>Conventional barrier with vertical, reflective-surfaced walls 0.16 m thick</td>
</tr>
<tr>
<td></td>
<td>Earth berm (rounded)</td>
</tr>
<tr>
<td></td>
<td>Earth berm with distinct edges on top</td>
</tr>
<tr>
<td>4.9</td>
<td>Conventional barrier with vertical, reflective-surfaced walls 0.16 m thick</td>
</tr>
<tr>
<td></td>
<td>Earth berm (rounded)</td>
</tr>
<tr>
<td>0.3-1.8</td>
<td>Conventional barrier atop 3-m-high earth berm</td>
</tr>
<tr>
<td></td>
<td>Conventional barrier atop 3-m-high berm with sound-absorptive top</td>
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Barrier Height of 4.9 m

The acoustical performance of three different 4.9-m-high barriers—namely, a conventional thin-wall barrier, an earth berm, and a wall-berm combination—is compared in Figure 5. The source is in the fifth lane, 2.4 m aboveground, as detailed in Figure 4.

The insertion loss (i.e., the difference in sound level between the situations with and without the barrier, with no change in ground cover and source-receiver geometry) obtained for the three barrier shapes was quite similar; the lowest overall insertion loss was measured for the earth berm. The lower insertion loss provided by the earth berm in comparison with that of the thin-wall of equal height has been reported earlier (6) (Table 1) and can be tentatively attributed to two factors:

1. Sound waves diffracted into the shadow zone can also reach a receiver by reflection from the ground (29). In the case of earth berms, diffracted waves may also be reflected from the slope of the berm in the shadow zone.

2. Tilting the slope of a wedge while keeping its top at the same position alters its insertion loss because the position of the image source, with respect to the slope, shifts. As the wedge is spread out more (i.e., as the angle of tilt increases), the position of the image source shifts toward the base of the wedge and thus sound levels in the shadow zone increase. This is shown schematically in Figure 6.

The negative effect of these two factors on insertion loss is mitigated by the sound-absorptive properties of the berm surfaces and by the scattering and absorption losses taking place along the berm top.

No systematic difference between the conventional thin-wall barrier and the wall-berm combination was observed.

Barrier Height of 3 m

Insertion losses measured for 3-m-high barriers—a conventional barrier, an earth berm, and an earth berm with an "artificially" high sound-absorptive top—are shown in Figures 7 and 8. The two berms were identical except for a urethane foam used on the top of the absorptive berm. As mentioned before, the earth berm was completely covered with a special fiberboard material to simulate grass cover.

The results in Figures 7 and 8 are based on the source height modeled 1.2 and 2.4 m aboveground, respectively. Both figures show that the 3-m-high conventional thin-wall barrier again slightly outperforms its earth berm counterpart. The replacement of the grass-covered top by the more absorptive top improved the berm performance by about 2 dB(A) for the source-barrier-receiver geometries used. This suggests that the absorptive material on the barrier top may be a more important influence of diffraction than the barrier shape.
Wall-Berm Combination

The effect of mounting a thin-wall conventional barrier atop an earth berm is shown in Figure 9. The height of the conventional barrier ranged from 0.3 to 1.8 m; the source-barrier-receiver geometry used is shown schematically in Figure 9 and is detailed in Figure 4.

Figure 5. Comparison of different 4.9-m-high barriers with source in fifth lane 2.4 m above ground.

Figure 6. Effect of tilting the slope of a wedge: (left) small angle of tilt and (right) large angle of tilt.

Figure 7. Comparison of different 3-m-high barriers with source in second lane 1.2 m above ground.
Figure 9 shows that insertion loss increased with the increased height of the thin-wall barrier atop the earth berm. The insertion loss shown is average for 12.2, 24.4, and 36.6 m behind the barrier (the source is in the fifth lane, as shown in Figure 4). The rate of increase in insertion loss was not quite uniform, being somewhat lower initially. Nevertheless, the erection of a thin-wall atop an earth berm consistently improved the insertion loss of the earth berm alone.

A different picture emerges if the thin-wall is mounted atop the berm with the sound-absorptive top as in Figure 10. (Source and receiver are 1.2 m above grass-covered ground, and the receiver is 12.2 m behind the barrier.) For the geometry used, this structure provides about 3 dB(A) higher insertion loss than its earth berm counterpart. Mounting a thin-wall atop the absorptive-topped berm does not initially increase insertion loss, since the beneficial effect of the absorptive top is lost and is not fully recovered by the increase in the total barrier height. However, as the height of the thin-wall increases to about 1.2 m, the effect of the absorptive top diminishes and the combination of the wall and the absorptive-topped berm and the combined wall and earth berm perform equally.

CONCLUSIONS

The following conclusions, based on the data presented in this paper, are intended mainly to stimulate interest in the relative acoustical performance of the two most common barrier shapes: reflective thin-walls and earth berms.

1. Reflective thin-walls, earth berms, and the
combination of the two are about equally effective (in terms of insertion loss) provided the berm is covered by grass or similar material. Actually, for the majority of source-barrier-receiver geometries investigated in the scale-model study, a slightly lower insertion loss [usually less than 1 dB(A)] was measured for earth berms than for thin-walls of the same height. This difference may not have practical significance since it also depends on the sound-absorbent properties of the material used to model the grass-covered ground.

2. The acoustical performance of an earth berm can be increased by placing sound-absorbent material on its top. On the other hand, placing bicycle paths or walkways on earth berms that serve as noise barriers would make the top reflective and should be avoided.

3. The erection of relatively low thin-walls atop earth berms is acoustically justified since it increases the insertion loss beyond that of earth berms alone.

4. Research on the effect of barrier shapes should be continued, and full-scale testing should be emphasized. An improvement of several dB(A) attributable to barrier shape may be considered significant since the insertion loss provided by barriers in the field is usually in the 5- to 10-dB(A) range.

REFERENCES

Quality Control for Environmental Measurements

EARL SHIRLEY

A general overview of the quality assurance program for environmental measurements practiced by the California Department of Transportation is presented to illustrate current practice. The discussion, which is general rather than detailed, places the program in perspective and concentrates on equipment used to measure noise and air pollutants and the associated instrumentation and procedures for calibration. A quality assurance program is necessary to ensure the validity and reliability of environmental measurements. Traceability of instrument calibration to an authority such as the National Bureau of Standards is important. The program involves fairly complex instrumentation systems and requires expert technical personnel and good documentation.

One of the fundamental responsibilities of management is the establishment of a continuing program to ensure the reliability and validity of any measured test value. The California Department of Transportation (Caltrans) has been following such a program for a number of years to provide assurance that test data involving materials such as asphalt, soils, and concrete are valid. To achieve this, the department has been participating in national programs sponsored by organizations such as the American Society for Testing and Materials, the Materials Reference Laboratory of the American Association of State Highway and Transportation Officials, and the Cement and Concrete Reference Laboratory of the National Bureau of Standards (NBS) and has been carrying out its own quality control program.

The addition of environmental testing responsibilities to Caltrans' normal duties brought about a need for a quality assurance program (QAP) in those areas also. Specifically involved were test data relating to air quality, water quality, and noise and vibration. Some of the benefits that would result from such a program were seen to be

1. Increased confidence in decisions based on environmental data;
2. A solid, defensible position in the event of litigation involving environmental data;
3. Uniformity in techniques and procedures for the use of instruments and their calibration and for data analysis; and
4. Unqualified acceptance of Caltrans test results by other organizations.

With the need for a QAP identified, it was necessary to decide on the program type and scope that would best fit Caltrans needs. Three basic alternatives were examined:

1. Develop a full "standards laboratory" capability in-house;
2. Make use of equipment manufacturers' regional service centers, or
3. Develop an in-house capability similar to that of a manufacturer's regional service center.

The first alternative was judged to be too costly. For example, the noise portion would require either the rental or the construction of an anechoic chamber. It was also felt that full-scale testing of environmental measurement equipment in accordance with American National Standards Institute, U.S. Environmental Protection Agency (EPA), and NBS procedures was neither cost effective nor necessary for Caltrans operations.

The second alternative, based on previous experience, would lead to long "turn-around" times (up to three months) and tend to discourage regular calibration. In addition, since most of the regular