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ACOUSTICAL PERFORMANCE OF NOISE BARRIERS ON RAIL TRANSIT SYSTEMS

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1. INTRODUCTION

Noise barriers are accepted throughout the world as noise abatement measures for transportation noise. Most countries have standard methods for design of noise barriers, especially for highways. For example, in the U.S., the Federal Highway Administration (FHWA) uses STAMINA/ OPTIMA[1] for optimizing heights of highway noise barrier segments. Determining the optimum lengths of noise barriers is generally handled through a process involving judgment and/or policy governing the minimum acceptable noise reduction for noise-sensitive properties. The procedure is simplified by assuming traffic is a continuous line source.

Rail transportation systems also use noise barriers for noise mitigation, and, like highway systems, have standard methods for determining heights.[2] However, determination of optimum lengths is difficult because trains are an intermittent source, with the capability of causing sudden increases in noise at receivers near the end of a noise barrier.

This paper describes a method for optimizing length for rail noise barriers based on time history of train noise. Harris Miller Miller & Hanson Inc. (HMMH) applied the method to the design of two noise barriers on the Red Line of the Massachusetts Bay Transportation Authority (MBTA) near Boston. The results confirm the applicability of the method.

2. DESIGN ISSUES

Performance Standard

For the MBTA design, the acoustical performance of the noise barriers was specified as follows:

For locations that qualify for noise abatement, exterior noise levels from *rail rapid transit operations should be brought down to a level no greater than 65 dBA Ldn at the standard measurement point of 5 feet above ground at the facade of the building. The minimum noise reduction of a noise barrier for train operations should be 10 dB, with a goal of achieving 15 dB, at the standard measurement point. This will ensure that the barrier provides a significant reduction of train noise.*

The length of the barrier should be established such that at residences close to the barrier endpoints, the noise time history when trains depart/approach the end of the barrier shows no more than a 3 dB increase/decrease from the fully shielded condition. The purpose of this requirement is to avoid sudden onset of sounds which could cause annoyance.

Barrier Design Model

HMMH used an analytical model for computing the noise time history of a train pass-by. The model is based on the sound propagation of an incoherent finite line source with dipole directivity.[3] A dipole directivity pattern is an approximation of the noise generated by the wheel/rail interaction, the dominant noise source on a moving rail car.

Height. Noise barrier models for determining the appropriate height given the location of sources are generally based on diffraction theory. These models assume long barriers, with the sound that reaches a receiver arriving across the top edge of the barrier and being diffracted downward into a "shadow" zone. The sound that enters the shadow is reduced in level by the diffraction, and the resulting barrier attenuation can be approximated by application of optical diffraction theory. Since the models for determining height are well-known, this paper focuses instead on the determination of optimum length.

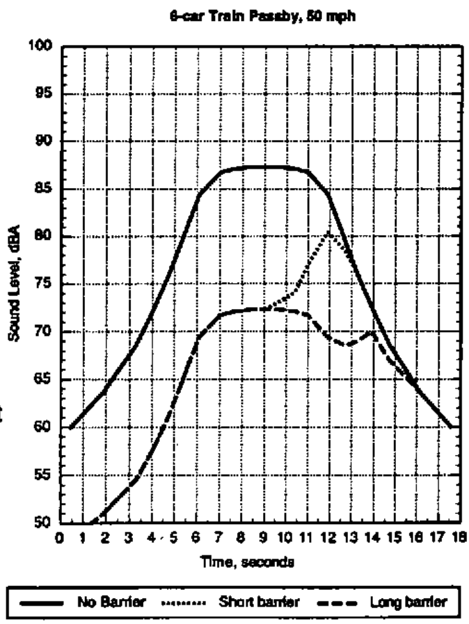

Figure 1 Time History at Receiver; Different Barrier Lengths

Length. An example of a length optimization procedure is shown in Fig. 1. Once the optimum height of a barrier is determined, it remains to define the start and end points of the barrier to provide adequate protection for receivers located near those points. An optimum length is determined when the noise time history at homes close to the barrier endpoints meets the performance standard where there is no more than 3 dB increase from the fully shielded condition. The train noise model described in Reference 2 allows for the calculation of the exact time history with and without a barrier. Optimization involves finding the point at which the length meets the criterion.

Three conditions are shown as examples in Fig.1: no barrier, short-length barrier, and long barrier. The short-length barrier allows too much of the train to go unshielded and results in a "jump" of 8 dB in the noise level as the train passes the end of the wall. Because the increase in sound level is much more than 3 dB, the short-length barrier in the example would not meet the criterion established for the project. The long barrier, on the other hand, is longer than it needs to be to meet the criterion.

3. RESULTS

Barriers Constructed

The noise barriers designed using the time history models were completed in 1995. Both barriers were brick walls located as close to the near track as safety and practicality would permit. The distance is typically 8 feet from the near rail. Tops of the walls are 10 feet above the top of rail.

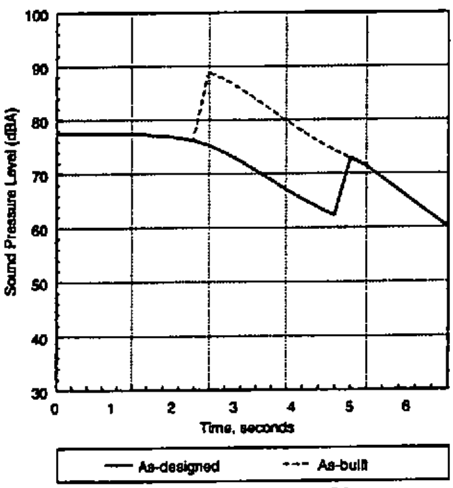

Figure 2 Predicted Noise Signatures near End of Barrier

Calculations showed that the heights of walls could have been approximately 2-feet less with sound absorption on the track-side surface of the wall, but a cost saving was not demonstrated.

After completion of construction, HMMH conducted a follow-up study to document the acoustical performance of the noise barriers based upon a comparison of the measured noise reductions with the performance goals.

The noise barriers generally met the performance goals in the neighborhoods of concern. However, due to site constraints, one of the noise barriers was not built with the length that was originally designed. Consequently, this segment provides a test case for the model used to determine optimum length.

Barrier Length Recalculation

The noise time history model was used to recalculate the effect the actual barrier had on the noise experienced near the end of the barrier (Fig.3).

Calculated time histories of train passbys show the designed length would have had a minimal increase in sound pressure level as the train appeared from behind the barrier, but the built barrier would be expected to show an increase of nearly 10 dB. Moreover, the calculations indicated that the sound exposure level (SEL) from the as-built barrier would be approximately 6 dB more than originally projected. Data from the post-construction measurement program were reviewed to verify the effect.

Measurements

A noise measurement program was performed in the neighborhoods protected by the sound barrier walls in order to check the barrier performance with the goal. Although specific time signatures of passing trains were not obtained, the effect of the shortened noise barrier can be determined by comparison of the measured and predicted day-night sound levels (Ldn) at the specified location near the end of the wall. As described above, the SEL from the as-built barrier is projected to be 6 dB higher than the originally designed barrier. Consequently, the Ldn would also be 6 dB greater than projected. The measured levels and the projected levels are shown in Figure 4. Note the original design conforming to the length defined by the performance standard was projected to provide a 15 dB noise reduction at the specified location, but the shortened as-built barrier was expected to provide 9 dB reduction. The actual reduction was 8 dB at this location, thereby suggesting the validity of the model.

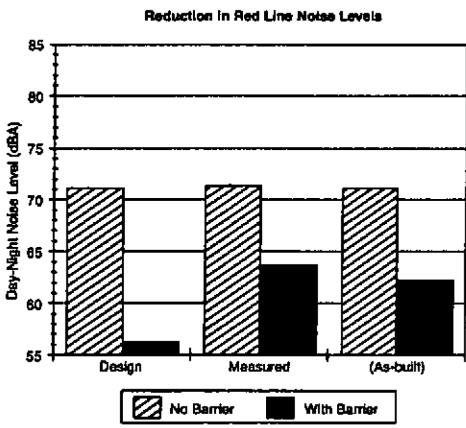

Figure 3 Noise Barrier Acoustical Performance

4. ACKNOWLEDGMENTS

This work was performed by Harris Miller Miller & Hanson Inc. as a subcontractor to Sverdrup Corporation, under contract to the Massachusetts Bay Transportation Authority in Boston. The noise barriers were constructed as part of an ongoing noise abatement program by the Authority.

5. REFERENCES

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PRACTICAL CONSEQUENCES TO BE OBSERVED WHEN SHIELDING AIRCRAFT NOISE OF GROUND TEST RUNUPS

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The maximum noise of ground test runups is emitted when maximum take off thrust is applied. Many modern aircraft engines with high bypass ratios however need mostly non-turbulent conditions for the inlet airflow of the engine at high power conditions.

Under runup conditions in the free field it is always possible to turn the nose of the aircraft against the wind direction. This is not possible if the aircraft is situated within a shielding facility which must be directed in a prefixed axis direction. So cross winds or even rear winds must be accepted during ground test runups within such shielding devices.

The aerodynamic situation around buildings is well known since many years. So it is known that sharp edges of walls and ceilings cause considerable additional turbulences in a turbulent atmosphere.

Sometimes simple walls have been erected in order to shield the aircraft noise, but it was found that stall effects may happen in cross wind or rear wind situations at even low wind velocities when test runups with high power setting of the engine are made within such enclosures.

Though take-off power has only seldom to be applied during test runups of modern engines, it must be prevented that additional turbulences are lead towards the inlet of the engine when high power is applied. A strong connection between the airflow conditions of the surrounding atmosphere and the danger of engine stall effects caused by the shielding construction has been found some years ago if shielding facilities are used in cross wind or rear wind situations.

It cannot be accepted that restrictions of the usability of a noise shielding facility turn out just in cases of high aircraft noise emissions when the maximum noise ought to be reduced with maximum effect. Therefore the possibilities to combine suitable airflow conditions for the inlet of jet engines with the optimal acoustical shielding effect of a building surrounding the noise sources have been studied during the last years.

In special aerodynamic model tests it was found out that the reason for stall effects of simple wall enclusures were turbulences caused on top of the walls and coming down towards the region in front of the engine inlet causing high pressure variations in that area, thus preventing a constant airflow into the engine. If the whole facility would be roofed, this effect certainly would be eliminated. The roof also gives much additional advantage for the acoustical shielding effect which may be low with simple walls just in cases when weather conditions make sound propagation over large distances possible. But as a total enclosure of the aircraft comes out to be very expensive it will always be tried to maintain at least one side of the enclosure mostly open. This is usually possible, as around large airfields there are normally areas where housing districts are situated some kilometers away. Noise reduction is not necessary in that direction. In these cases it is a big advantage if the aircraft might roll in and out by the open side.

On the other hand, additional measures remain to be necessary under many wind conditions in these cases in order to prevent turbulences which are not desired and do not occur under free field conditions.

As in any case of application the local conditions are different, an extensive special evaluation has to be made first to look for the necessary acoustical shielding effect. This effect must have its maximum in direction to the nearest situated housing district. But already from the beginning, these evaluations have to be combined with a study of the main wind directions and the main occurance of high wind velocities. The surrounding conditions, as high maintenance buildings in the neighbourhood or other factors influencing the atmospheric turbulances around the enclosure have also to be taken into consideration. As a result, the most favourable axis direction for the shielding facility can be proposed. Furthermore a model of the facility, including the whole surrounding situation, has to be examined in order to look for remaining problems which might influence the usability. If necessary, additional measures will be taken in order to solve these problems.

By this way, in optimizing the acoustical and aerodynamic conditions and fitting them to each other, it is possible to reach a usability comparable with the situation of runups in the free field under high power engine conditions and independent of the wind direction. Of course it also must be achieved that the facility can be used by all types of aircraft whether their engines are mounted at the wings, at the rear or at different heights above ground.