ROADSIDE NOISE BARRIERS
A COMPUTERISED ACOUSTICAL COST-EFFECTIVENESS STUDY

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1. INTRODUCTION

Not so many years ago, the half joking comment by some road construction officers was, "Our roads don't make noise. Its the cars and trucks that make the noise. If you don't like the noise then quieten the vehicles." In the past, roadside noise barriers were not provided with new roads and highways.

Legislation has been in place for many years to limit the noise emitted by new motor vehicles. Australian Design Rules specify noise level limits that may be emitted by a new vehicles. However, the engineering means whereby vehicle noise may be further reduced has practical limits. More and more it is realised that even with well-designed engines, exhaust silencers, tyre treads and road surfaces, traffic noise levels often exceed acceptable environmental standards. This realisation, together with strong community reaction in some cases, has forced many road construction authorities to take positive action to reduce traffic noise by building roadside noise barriers.

Both Sydney and Melbourne now have many kilometers of roadside noise barriers lining the major routes in and out through the suburbs. The types are many and varied, but most are timber, concrete or glass reinforced cement (GRC).

The Roads & Traffic Authority of NSW (RTA) is currently spending considerable sums of money on roadside noise barriers as part of its routine noise control strategy. Day Design was commissioned by the RTA to model the Noise Reduction of six different types of Roadside Noise Barriers, obtain typical installed barrier costs from suppliers and to determine a rank order of acoustical cost-effectiveness for roadside barriers in typical situations. The final cost effectiveness comparisons in this study are made in terms of Dollars per linear metre of erected barrier versus Decibels of noise reduction.

Of the six roadside barriers under consideration in this study, the barrier with the best acoustical properties is undoubtedly the GRC. However, its price is the highest. The barrier with the worst acoustical properties is the treated pine timber barrier, but it has the advantage of costing only a fraction of the GRC. Which is the most economical in terms of decibels for dollars ? Which barrier is the most acoustically cost-effective ?

An earth berm provides a greater noise reduction than any other barrier of the same height because of its immense mass. Using an earth berm can actually save money where the earth from a nearby cutting must be disposed of. However the costs are so dependent on local conditions that we can not cost them. We have therefore eliminated earth berms from consideration in this study.

2.0 ROADSIDE NOISE BARRIERS UNDER CONSIDERATION

We have selected six typical but diverse commercial products, three being of the Reflective and three being of the Absorptive type:

DESCRIPTION	CONSTRUCTION
Reflective Barriers:	
* Abbco ribbed sheet steel	Double skin 0.6 mm sheet steel.
* Fanwall reinforced concrete	100 mm reinforced concrete.
* Treated pine timber	35 mm lapped pine timber planks.
Absorptive-Reflective Barriers:	
* dB Metal steel and mineral wool	1.2 mm steel, 100 mm F/G & perf.
* Durisol cement and wood wool	75 mm concrete & 85 mm wood wool.
* GRC cement and fibreglass	10 mm fibro cement 113 mm F/G.

Except for the treated pine timber barrier, the Sound Transmission Losses and Sound Absorption Coefficients of the above barriers were either provided by the manufacturers or established from text books. The treated pine timber barrier STL was determined by field measurements above and behind a 4 metre high barrier on the F3 Freeway. Data assumed in this study is given in Figures 2 and 3.

This study is not exhaustive. We have selected what seemed at the time to be a representative sample. Other barriers have come on the market too late to be included.

3. COST OF ROADSIDE NOISE BARRIERS

In order that barrier costs can be legitimately compared, we have asked each supplier to base his prices on one kilometre of roadside barrier, erected in normal ground within 20 kilometres of their manufacturing facility, and in barrier heights of 2, 4 and 6 metres. Posts must be capable of supporting the barrier against wind velocities that may occur once in 50 years in Sydney, (44 metre/sec). Prices in Dollars per Linear Metre are presented in Figure 7.

The sales allure of kilometres of roadside noise barriers and the effect of the recent recession have combined to make pricing more and more competitive. Whether or not the prices used in this study are realistic for the future is a matter of conjecture. However, updating the data and making new comparisons in the future will be a simple matter.

4. ACOUSTICAL PERFORMANCE OF ROADSIDE NOISE BARRIERS

By acoustical performance, we mean the predicted L_{A10} noise reduction at a receptor location due to the erection of a roadside barrier. The physical erection of long roadside barriers of various constructions and measurement of acoustic performance is a time consuming and expensive process. It was decided that a computer model could be used with sufficient accuracy to establish the comparative acoustical performance of a range of roadside noise barriers.

The Sound Transmission Loss of a reinforced concrete barrier will be much greater than the Refraction Loss over the top, so that we can with confidence use the conventional Maekawa approach to calculate the barrier noise reduction. If in the interests of saving on costs, we select lightweight materials such as timber or sheet steel, the calculation of noise reduction is complicated by the sound energy transmitted through the barrier as well as over the top. If we then add a parallel barrier on the far side of the road we must add the reflected energy to the calculation. The problem is complicated by many other factors, not the least being the Australian requirement that trucks must have a vertical engine exhaust above the vehicle, which in many cases is approximately 3.5 metres above the ground.

The computer program (Softbar) that we have written for this project to calculate the noise reduction of a barrier at a receptor location takes account of:

* noise source heights of truck engines and vertical exhausts.
* percentage of heavy vehicles.
* typical traffic noise spectrum from 63 to 8000 Hz.
* height of barriers.
* sound refraction over the top of barriers.
* width of the roadway.
* distance from the barrier to the receptor location.
* altitudes of the road and the receptor location.
* sound reflection from roadside cuttings and parallel barriers.
* slope of the cutting wall.
* sound absorption of parallel barriers.
* sound transmission loss through the roadside barrier.

We have named this program SOFTBAR because it predicts the noise reduction of Soft (absorptive) faced as well as hard (reflective) roadside noise Barriers. Provided all barriers are assessed in the same way, the comparison in results should lead to a valid rank order of cost and acoustical effectiveness. We have taken a great deal of trouble to make the computer model as accurate as possible. We have also written a program based on the widely accepted UK CORTN 1988 method of traffic noise prediction which predicts the noise reduction of simple roadside barriers. Comparing the results by both models we find that SOFTBAR has the same order of accuracy as CORTN for simple reflective barriers, and a greater accuracy for dual and absorptive barriers.

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Figure 4. shows how the Day Design SOFTBAR prediction compares with the CORTN prediction for the simple Case 1. Both methods agree for a concrete barrier of height in excess of three metres. The noise reduction by barriers can be influenced by the Sound Transmission Loss of the barrier material, but CORTN does not provide for any variation in STL. The Softbar program predicts a lower noise reduction for a timber barrier than for a concrete barrier because it allows for the lower Sound Transmission Loss of the timber barrier. For barrier heights of three metres or less the CORTN method tends to overestimate the noise reduction because it assumes a source height of 0.5 metre, whereas Softbar allows for the higher source height of trucks.

To confirm the noise reduction of existing barriers and further check the accuracy of the computer models, the RTA had another firm of acoustical consultants, Wilkinson Murray Griffiths, carry out noise reduction measurements behind GRC and Treated Pine Timber barriers at the side of the F3 Freeway north of Sydney. The measurements were of a high order of accuracy, being subject to careful calibration procedures, and included L_1, L_{10}, L_{90}, and L_{eq} measurements in dBA and octave bands from 63 to 8000 Hz. Measurements were generally in accordance with the procedures recommended by the USA Federal Highway Administration Report FHWA-DP-45-1R (Reference 4).

We did note that the GRC absorptive barrier measurements gave an average L_{eq} noise reduction approx 1.7 dBA greater than was initially predicted by the preliminary Softbar program. We reasoned from this that the refraction of sound waves incident on the absorptive face of the GRC Barrier was creating a shadow zone noise reduction of approximately 2 dBA.

We are reluctant to draw this conclusion from field measurements having an accuracy of only +/- 1.5 dBA. However, available literature on Sound Absorptive Highway Noise Barriers also supports an excess attenuation of up to 2 dBA for barriers with an absorptive face.

Lawther & Hayek in a study for the National Cooperative Highway Research Program (USA) drew the conclusion that for single barriers "Generally, absorptive surfaces on barriers slightly improve barrier effectiveness ... Barriers with absorptive surfaces were predicted to have excess attenuations (in excess of those with hard surfaces), particularly in the barriers deep shadow ... At practical receiver ranges behind thin walls, the increment was not predicted to be large (ie, somewhere in excess of 2 dB at 50 feet and dropping towards 1 dB further out). These theoretical predictions have been substantially qualified by the gymnasium experiment" (Refer: 1.)

Rapin carried out octave band sound level measurements behind a single barrier screening a heavy truck, with and without an absorptive facing on the roadside of the barrier. He concluded, "This data indicates a decrease in levels of about 1 to 4 dB when the truck is behind the absorptive wall, compared to the reflective wall" (Refer: 2.)

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Bowlby and Cohn using their computer model with an absorptive barrier having a Noise Reduction Coefficient (NRC) of 0.65 estimated a barrier noise reduction improvement of 2.1 dBA when compared with parallel hard reflective barriers of the same height. (Refer: 3.)

In consideration of the abovementioned research by others, and the results of L_{10} octave band sound level measurements made on this project, we have made an adjustment to the software model that provides up to 2 dBA barrier attenuation in excess of that calculated by the Maekawa formula for a high NRC sound absorptive barrier such as the GRC or dB Metal barriers. Following this modification to the Softbar program, we found that both the GRC and timber barrier noise reduction measurements made by WMG were generally within +/- 1 dB(A) of the Softbar computer predictions.

5. HORSES FOR COURSES

If noise sensitive premises are located at say 100 metres on one side of the road only, an inexpensive timber, sheetmetal or lightweight concrete reflective barrier would obviously be more cost effective than an expensive sound absorptive barrier. On the other hand, if there are noise sensitive premises within say 30 metres on both sides of the road, barriers with a high sound absorption and a high sound transmission loss such as the more expensive Durisol, GRC or dB Metals may well be a better selection.

In order that useful comparisons may be made in such disparate roadside configurations, we have made the acoustical cost-effectiveness comparisons for Five Configuration Cases as illustrated in Figure 1.

6. RANK ORDER OF ACOUSTICAL COST-EFFECTIVENESS

We have calculated the noise reduction in dBA for each of six typical construction barriers, in heights of 2, 3, 4, 5 and 6 metres. We have then taken the budget prices ($ per Linear Metre) given by the barrier suppliers and calculated the acoustical cost-effectiveness for the range of barrier heights in terms of Dollars per Decibel (dBA). The results have been graphed for each of the six roadside barrier configuration cases. We have included the Noise Reduction and Cost Effectiveness graphs for the typical dual barrier configuration Case 3. in Figures 8 and 9.

7. CONCLUSION

The following conclusions have been reached by considering the Cost-Effectiveness graphs for each roadside configuration case.

Case 1.

If the required noise reduction does not exceed 13 dBA, then any of the six barrier constructions will be adequate. To achieve this noise reduction, an absorptive barrier would need to be about 3.5 metre high and a reflective barrier would need to be about 4.5 metre high.

In absolute terms, a 4.5 metre high reflective barrier would cost about $350 to $500 and a 3.5 metre high absorptive barrier about $800 to $900 per linear metre. Both would achieve the same noise reduction in the Case 1 configuration. We conclude that simple reflective barriers are more cost effective than the more complex absorptive barriers for such applications.

Cases 2, 3 & 4.

These three cases are all similar, in that a parallel reflecting surface, either in the form of another barrier or a roadside cutting, increases the incident sound energy. Increasing the height of a cutting can reduce the acoustical effectiveness of a roadside noise barrier.

In such cases the absorptive barrier performs better than the reflective barrier, but the difference is not as marked as may be expected. Even for 4 to 6 metre high barriers, the difference in noise reduction between absorptive and reflective barriers is 2 to 4 dBA. In most cases increasing the height of the reflective barrier by 1.5 metre will give the same acoustical performance as the absorptive barrier. Please refer to Figure 8.

In absolute terms, a 5 metre high reflective barrier would cost about $400 to $700 and a 3.5 metre high absorptive barrier about $850 to $950 per linear metre. For such medium height barriers the reflective barrier is more cost effective.

In these configurations the limiting noise reduction for 6 metre high barriers is about 17 dBA. For such barriers the Sound Transmission Loss quality of the barrier is of great importance, and the selection is limited to either reinforced concrete or the more expensive absorptive barriers. The question of whether to use a 7 to 8 metre high reflective barrier or a 6 metre high absorptive barrier to achieve 17 dBA noise reduction is beyond the scope of this study. When barrier heights reach these levels, considerations of safety in high winds and aesthetics may well outweigh cost considerations.

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CASE 5.

In this Case, at the highest receptor position 4, the nearside barrier is more or less ineffective in reducing noise. The farside barrier will reduce noise for receptor position 5, but increase the noise at position 4 due to reflection. Sound reflected from the farside barrier may well become the more dominant factor in controlling the overall noise level at the receptor location 4. An absorptive farside barrier will reflect about 2 to 3 dBA less noise than a reflective farside barrier.

In this situation sound absorptive barriers will provide the greatest noise reduction with the least barrier height for receptor positions 1 to 4, also causing the least noise increase due to reflection at position 5. Even though overall costs may be greater, an absorptive barrier would often be selected for such an application.

The aim of this study was not to stifle competition by saying this barrier is "good" and this barrier is "bad", but rather to give the Roads and Traffic Authority of NSW an objective means of comparing barriers, and determining the best application for certain types of roadside barriers. If certain barriers are identified as not being acoustically cost-effective in this study, it may be countered that appearance, longevity or other factors which are not considered by this study, may be of more importance.

8. ACKNOWLEDGMENT

We are indebted to the NSW Roads and Traffic Authority for commissioning us to carry out this study, and to our colleagues at Wilkinson Murray Griffiths for their cooperation in taking accurate sound level measurements at selected locations near GRC and Treated Pine Timber barriers along the F3 Freeway.

9. REFERENCES

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(4) "Sound Procedures for Measuring Highway Noise: Final Report" USA Federal Highway Administration Report FHWA-DP-45-1R.

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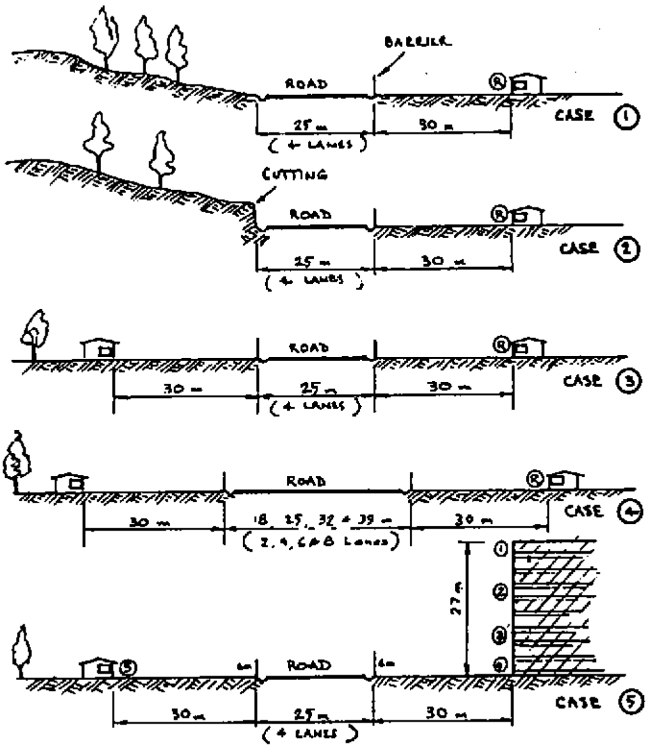

FIGURE 1.

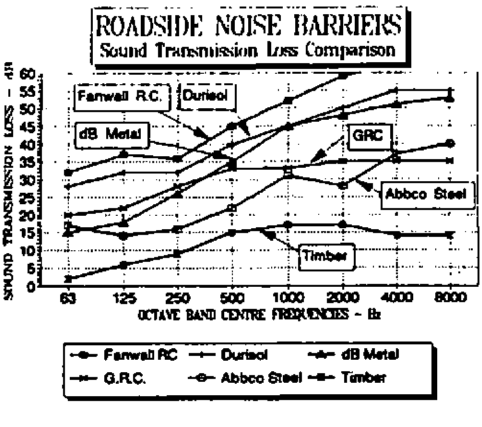

FIGURE 2.

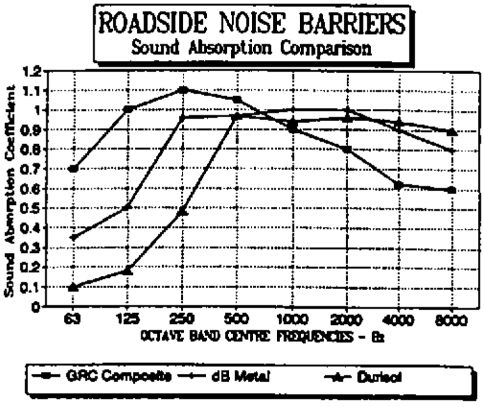

FIGURE 3.

ROADSIDE NOISE BARRIER COST EFFECTIVENESS