DESIGNING ROADSIDE NOISE BARRIER

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Abstract: Noise is the common problem in the residential area, whether it came from events, vehicles, construction sites, or urban area. The most affected residential area are usually the ones which adjacent to the highway or a road. When someone is overexposed from the noise, this could lead into many health problems. This is why a noise barrier is essential to be built along the road. problems regarding the noise barrier is that although the barrier can attenuates the noise from the traffic, there are other sound source, or in this case, noise source other than the traffic such as the airplane. This problem mostly happened on the residential ground around an airport. One of the solutions for these problems is by using vegetation as additional noise barriers. By doubling the barrier (noise barrier - vegetation) the attenuations will probably much higher, in accounts that the vegetation is much higher than the barrier so that if there are multiple floor buildings, the floors above will also provide with noise insulations. Although, it would be more appropriate to use acoustic treatments to the buildings. The other solution is that by using the concept of constructing a louver or cap atop the wall that is directed back toward the noise source. This concept follows the theory that such a design should inhibit shadow zone diffraction filling in sound behind the noise barrier.

Keywords: noise, sound, barrier, attenuation

Research Background

Noise is an unwanted sound. 'Sound which is disagreeable, discordant or which interferes with the reception of wanted sound becomes noise' (Cantrell, 1975). Each person has different understanding of the term 'noise'. Rock music will be noise to some people whom dislike rock music. However, rock music is a pleasant sound to some people.

Noise can be a critical problem in most area of work such as medical fields. Road noise is also one of the fields where noise control is essential because it is one of the most obvious impacts of daily road use. However, its effects are often given lower priority than the economic or other environmental impacts, usually because they are rarely visible and are difficult to determine the quantity of it. Yet many humans and animals that suffer chronic exposure to severe noise

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pollution are aware of its presence and it may cause major problems to them. That is why it is necessary to identify the sources of the noise pollution (mainly roadside noise), the acceptable levels of it, and a way to control the noise. On this paper, I will primarily focus on noise barriers as the main equipment to control the noise.

Road traffic noise depends on the amount of traffic, traffic speed, relative amount of trucks, bus, car, and motorbike traffic, and distance from the road to the receiver. There are 4 main sources of roadside noise pollution, which is:

a. Vehicles

b. Friction between vehicles and the road surface

c. Driver behavior

d. Construction and maintenance activity

Although, there are other factors that could contribute to noise pollution such as aircraft noise.

Vehicle noise comes from the engine, transmission, exhaust, and suspension. Poor machine condition caused by poor maintenance is also a contributing factor to this noise source. Some of the vehicles manufacturer already started to address this issue and trying to suppress the noise generated by the engine.

The friction of the tires with the pavement can cause road noise. It depends on the condition of the tires and the pavement but the highest level of noise can be attained when it's on high speed and during quick breaking. Regarding the driver behavior, it really depends on the driver itself. The noise caused can be either from the vehicles' horns, by the driver's playing loud music, or shouting at each other.

The construction and maintenance activity, on the other hand, doesn't contribute a tremendous amount of noise. The machinery (usually the heavy ones) is only used localized. That means it only contributed to one point of the road. Some countries such as Australia have done their construction and maintenance activity during nighttime (off-peak hours).

Problem Identifications

This research has few two problems which can be identified: first, how noise affects our quality of life? Second, what are the solutions for road noise problems?

Theoretical Discussions

Sound intensity is the most important factor in determining the "loudness" of a noise. It is usually measured in decibels (dB). This is a logarithmic scale. Each 10 dB increase in noise levels is equivalent to a doubling of the perceived loudness.

In practice, when noise measurements are taken it is the sound pressure levels that are being measured. The noise energy intensity is proportional to this sound pressure measurement. The audible range for people is about 0 – 120 dB. Above 120 dB, hearing damage will rapidly occur.

Because decibels are logarithmic units, sound levels cannot be added by ordinary arithmetic means. For example, the combined noise level from two equal sources (with twice the noise energy intensity of a single source) is 3 dB higher than the noise level from just one of these sources. Two compressors producing 75 dB each will combine to produce 78 dB, not 150 dB.

There is an inverse square relationship between sound intensity and distance. So noise from a point source such as an individual vehicle will increase by 6 dB if the distance to the receiver is halved. Similarly, if the distance is doubled the noise level will fall by 6 dB.

In practice, however, factors such as the intervening ground surface, surrounding topography, wind, temperature gradients, rain, snow, fog and sound reflection will modify this inverse square law.

‘Road traffic noise is often best treated as a line source, comprising a number of point sources. Depending on the intervening ground surface (hard or soft), noise from such a line source will increase by between 3 dB and 4.5 dB if the distance to the receiver is halved, rather than 6 dB as described above.’ (Roads and the environment: A handbook, 1997)

In general, the sound power level is the one used for measuring the noise (background noise). The loudness is expressed by using Spectral Weighting, an A-Weighted value instead of B or C weighted value because A-Weighting presumably more precise for calculating hearing sensitivity. A-Weighting are widely used in environmental and occupational acoustics, as well as when assessing potential hearing damage and other noise health effects, when a single number representing the amount of sound is required. A-weighted values usually expressed by dBA.

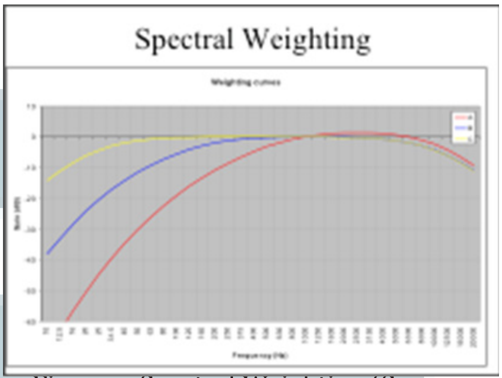

Figure 1. Spectral Weighting (Source: Densil Cabrera, Loudness)

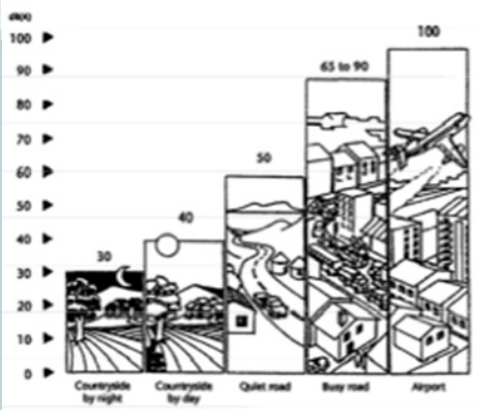

Figure 2. The Audible Range of The Acoustic Pressure (Source: Roads and the environment: A handbook, page 159, 1997)

The audible range of the acoustic pressure (SPL) is expressed in dBA. By looking into the figure above, we can identify the scale of the sound level shows that calm environments correspond to a level of 30 to 50 dBA. Above 70 dBA the sound becomes very disruptive and could cause severe problems it’s continuously expose to the ears.

We can perceived the acoustic energy during the period of observation by measuring Equivalent sound pressure level (Leq), the steady sound level that, over a specified period of time, would produce the same energy equivalence as the fluctuating sound level actually occurring. The Leq of noise during the period 8 a.m. to 8 p.m. can be written as Leq (8 a.m. – 8 p.m.) or Leq (12hr). Noise levels during nighttime are generally lower than the daytime except in the case of especially high traffic during nighttime with a high percentage of heavy goods vehicles.

According to the 'Environmental Criteria for Road Traffic Noise' (ECRTN), there are three Leq measurements that are commonly used. These measurements are:

a. Leq (15hr), noise level between 7 am – 10 pm

b. Leq (9hr), noise level between 10 pm – 7 am

c. Leq (1hr), the highest 10% hourly noise level between 7 am – 10 pm or 10 pm – 7 am, whichever is relevant to the particular criterion in question.

Australian and international experience has shown that for continuous traffic flows the L10 (1hr) and Leq (1hr) noise descriptors are related as follows:

Leq (1hr) = L10 (1hr) – 3 dBA

These measurements can be done by using a Sound Level Meter. Besides Leq, there are some noise descriptors, which are essential to state the noise.

L10 is the noise level exceeded for 10% of the particular time period. This descriptor is used in the assessment of noise from construction activities and industry.

L90 is the noise level exceeded 90% of the time during the period of interest. It is commonly called the "background" noise level.

The L90 level should always be reported in any noise level measurement study, as it is the descriptor for background noise used by environmental agencies in construction and industrial noise assessment.

Lmax is simply the maximum noise level recorded during a defined period of time.

Design of Roadside Noise Barrier

One way to reduce the noise from the road environment is to use an acoustic barrier such as walls and mounds. It provides immediate reductions in road

Figure 3. The Acoustic Effectiveness of a Barrier (Source: RTA, page 17, 2001)

traffic noise at the shielded properties once barrier construction is complete. This noise barrier must break the lines-of-sight between the noise source (road traffic) and the receiver (i.e. the residential area). However, in some cases, lowering the barrier may cause better results. 'The acoustic effectiveness of a barrier depends on its density, height, length, and location.' (RTA, 2001)

Noise barrier attenuations

Reduction in sound level	Reduction in acoustic energy	Degree of difficulty to attain
5 dB(A)	70%	Simple
10 dB(A)	90%	Attainable
15 dB(A)	97%	Very difficult
20 dB(A)	99%	Nearly impossible

Figure 4. Noise Barrier Attenuations (Source: RTA, page 17, 2001)

The higher the barrier (from the point of the lines-of-sight) and the closer its location to the source or the receiver, the greater the noise attenuation provided.

The barrier needs to have a sufficient length. Roadside barriers usually have to provide shielding along an appreciable length of road to be effective.

If we applied it with the appreciable length, roadside barriers can be efficient in providing attenuation to groups of residences, but it will not be cost effective for single structures and may be ineffective where openings are required for driveway access.

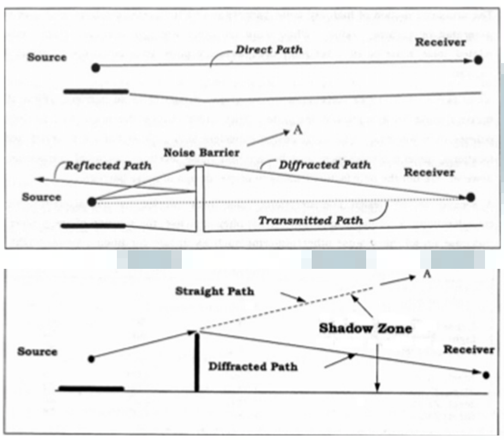

Figure 5. Noise Barrier (Source: Guidelines on Design of Noise Barriers, Government of Hong Kong, 2003)

The physical heights of barriers can usually be reduced if the pavement is lowered. 'Opportunities for taking advantage of this should be examined during the earliest stages of planning for new roads.' (RTA, 2001)

Combinations of earth mounding and lower height noise walls can reduce the scale and potential visual impacts of fabricated barriers, especially in conjunction with landscape treatments.

Noise walls have been constructed using timber, precast concrete panels, lightweight aerated concrete, fiber cement panels, transparent acrylic panels and profiled steel cladding. Dense vegetation screen planting can also be used as noise barriers. It will have visual and privacy benefits such as psychological benefits, but it provides only minor acoustic attenuation, about 1 dBA for a 10 m depth. For significant noise attenuation, a solid barrier (earth mounding, noise wall, cutting, etc) is required. By using two or more barrier types can maximize the effectiveness of it. For building with more than 2 levels, the noise barriers provides reductions to the traffic noise only at lower levels of the building, where the facade insulation are needed for the upper floors of the building.

Currently, Australia applies 2 to 3m in height for the barrier's height, which can achieve attenuation up to 10 dBA. However, increasing the attenuation more than 10 dBA, let's say 15 dBA, is extremely difficult and it's not practical. It is possible to make the barrier attenuation up to 15 dBA by making the barrier up to 8 m tall but to make that kind of attenuation; the cost will be very high. The technique that has already been applied in Australia and throughout the developed world is based on the pioneering work of Maekawa (1968) and Kurze (1974). This technology is based on simple algorithms that describe the combined effects of sound transmission loss through a barrier in conjunction with the diffraction of sound over (and in some cases around) the barrier. Some enhancement from this technology has been done by the US department of Transportation, Federal Highway Administration (FHWA) Traffic Noise Model (TNM). However, this technology still has the same problem, which is the high cost for constructing a higher barrier.

In the end, these are some considerations that needs to be think about when designing a roadside noise barrier:

a. Aesthetics

b. Cost

c. Effectiveness

d. Maintenance

e. Safety

Simple Shapes

The development of noise barrier until today incorporates various arrangements, which come in a range of design formats. One of the examples of this is the simple shaped barrier such as the T-shaped barrier. This T-shaped barrier had a uniform capping fitted such that the cross sectional shape of the barrier typically became like a T. The attenuation is increased due to the increased effective height shown below.

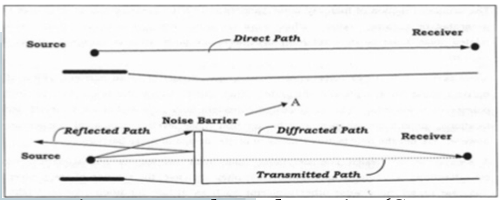

Figure 6. T-shaped Barrier (Source: Samuels, Recent Developments in the design and performance of road traffic noise barriers, 2001)

There are some variants of this design. One of the examples is the multiple edged barriers. According to Crombie (1988), Hajek and Blaney (1984), Hasabe (1988), Iida (1984), and Watts (1992), this barrier can deliver small but useful increases in attenuation of around 2 to 3 dB, compared to conventional barriers.

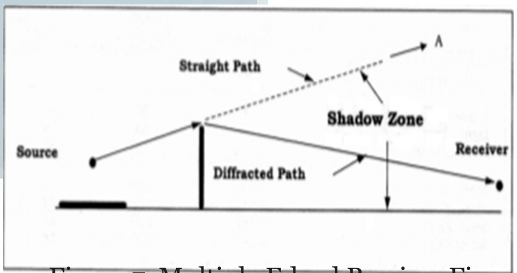

Figure 7. Multiple Edged Barriers Figure 5. T-shaped Barrier (Source: Samuels, Recent Developments in the design and performance of road traffic noise barriers, 2001)

Amram and Masson (1992) applies more complex shapes to the barrier. They suggested that the attenuation increases in the order of 3 to 5 dBA are possible with these barriers. This findings has been confirmed in the results of Shima (1998), Watts (1994 and 1996), and Watts and Morgan (1996).

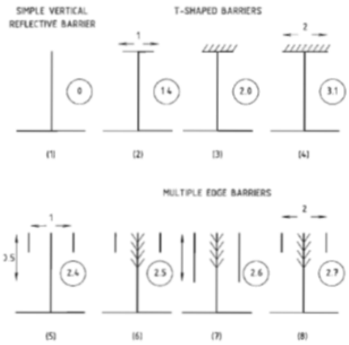

Figure 8. Complex Shapes (Source: Samuels, Recent Developments in the design and performance of road traffic noise barriers, 2001)

Absorbing Edge Barriers

This type of barrier achieves a gain in attenuation by the attachment of a sound-absorbing device on top edge of the barrier. It could typically take the form of an earth mound covered in soft vegetation. With this kind of barrier, an attenuation of 1 or 2 dB are possible. Recently there has been some work involving the use of absorptive cylinders to provide additional absorption. The barrier is similar to the figure above with the addition of the absorptive cylinders along the top of the barrier (Fujiwara 1989, Yamamoto). Fujiwura and Furuta (1991) suggested that the increased attenuation from such barriers is in the order of 2 to 3 dBA. Although the results are almost satisfactory, there is more work to be done. One of the examples is the design for the absorptive cylinder units.

Longitudal Profiled Edge Barriers

Wirt (1979) originally suggested that improvements in barrier performance could be obtained by application of a longitudal profile to the top edge of a barrier. The theory behind this suggestion also involves the creation of a destructive interference sound field. He tested this via laboratory based scale model tests on both flat and topped and pointed saw-tooth top profiles that were known as "Thnadners". The results were that improvements in attenuation are between 1.5 to 4.0 dBA. There are some debates whether "Thnadners" barriers exhibited poorer performance than conventional barriers of the same height. But there is no proof that the arguments have undergone some experiments regarding the two barriers.

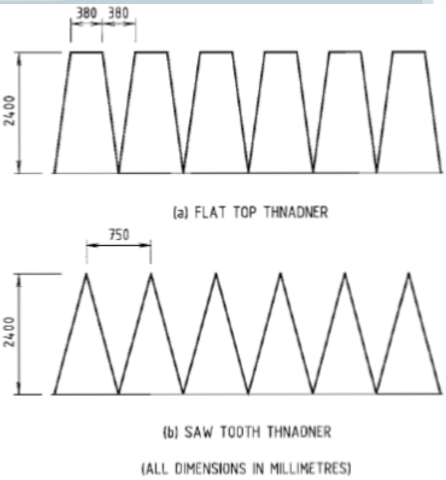

Figure 9. Two Barriers Experiment (Source: Samuels, Recent Developments in the design and performance of road traffic noise barriers, 2001)

Random Edge Barriers

There are some investigations by Ho (1995A, 1995B, 1997), Ohm (1997), Rosenberg and Busch-Vishiniac (1997) and Meniunou (1998) regarding similar types of barrier to the Longitudal Profiled Edge Barriers, where the profile applied to the top of the barrier is random in shape. The theoretical concept of this is that the sound is diffracted over the top of a barrier. However, this type of barrier doesn't quite perfect due to the coherence of the sound diffracted over the barrier acts to set an upper limit on the attenuation performance of the straight edged barrier. To overcome this problem, the theory suggests that the barrier is to be redesigned so as to interfere with the coherence of the diffracted sound, which resulting the increase of attenuation performance of the barrier.

There is also some effort to apply active noise control technology to the design and operation of traffic noise barriers. Ohnishi (1998) has been developing an active noise control device, known as an Acoustical Soft Edge (ASE). The device is fitted to the barrier, where each device is controlled individually and may be tuned to specific frequency ranges.

Problems regarding Noise Barrier Design & Solutions

Although there are some guidelines regarding the design of the noise barrier supplied by the Road and Traffic Authority (RTA), there are no standards for noise barrier design in Australia. Europe and Hong Kong has been developing the standards for noise barrier. The EN (European Standards) has grouped the standards for Highway noise barriers under the standards EN 14388 (2005) – Road traffic noise reducing Devices – Specifications. This standard covers acoustic, non-acoustic and long term performance, but not aspects such as resistance to vandalism or visual appearance. For product conformity, that is for a noise barrier to be considered for the European highways market the standard requires that the barrier product would need to have been assessed and categorized in accordance with the required parts of EN 1793 for acoustic performance and the required parts of EN 1794 for non-acoustic performance (mechanical, structural, environmental and safety).

Some of the problems that can be a problem are:

a. Cost of design, construction and maintenance

b. Aesthetic impacts for motorist and neighbors

c. Necessity to design custom drainage that the barrier may interrupt.

From the acoustical point of view, the problem that could happen is that if the barrier only covers the first floor of a building, additional treatment will be needed for the other floors noise insulation. This will bring the cost problem more urgent due to the fact that the higher the barrier so does the cost to build the barrier. Other problems regarding the noise barrier is that although the barrier can attenuates the noise from the traffic, there are other sound source, or in this case, noise source other than the traffic such as the airplane. This problem mostly happened on the residential ground around an airport.

One of the solutions for these problems is by using vegetation as additional noise barriers. By doubling the barrier (noise barrier - vegetation) the attenuations will probably much higher, in accounts that the vegetation is much higher than the barrier so that if there are multiple floor buildings, the floors above will also provide with noise insulations. Although, it would be more appropriate to use acoustic treatments to the buildings. The other solution is that by using the concept of constructing a louver or cap atop the wall that is directed back toward the noise source. This concept follows the theory that such a design should inhibit shadow zone diffraction filling in sound behind the noise barrier

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