

Guidelines on Design of Noise Barriers



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Third Issue, December 2022

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1. Introduction

This booklet provides guidelines for the detailed design of roadside noise barriers including vertical & crank-top barriers, semi-enclosures, full enclosures and deck over. These roadside noise barriers are in general termed as Direct Technical Remedies. Their locations, dimensions, types and shapes are normally determined and defined in statutory Environmental Impact Assessment (EIA) studies or other non-statutory Noise Impact Assessment (NIA) studies etc.

This booklet intends to cover various aspects at the detailed design stage including determination of acoustic properties of noise barriers like transmission loss, material selection, some important tips at design and construction stages. However, it is not the intention of this booklet to cover calculation methodologies as these would have been dealt with during EIA and NIA studies.

Design engineers are reminded that during detailed design stage, sufficient space should be allowed for the erection of noise barriers. Without sufficient space, design options for noise barrier will be limited. As laid down in the ETWB TCW No. 36/2004, the noise barrier design proposal should be submitted to The Advisory Committee on the Appearance of Bridges and Associated Structures (ACABAS) for consideration of its aesthetic acceptability.

In recent years, the public has growing concerns about the cost and duration of noise barrier construction. To meet the public expectations, design engineers should take steps to develop cost-effective designs and to expedite construction process. Some of the measures are provided in this booklet for the design engineers' reference. The design engineers should also endeavour to explore other innovative designs and construction methods to shorten the construction period as far as possible.

Also, the reader is advised to make reference to the relevant design manuals currently adopted such as "Structures Design Manual for Highways and Railways, Highways Department, Government of the HKSAR", "Transport Planning and Design Manual, Transport Department, Government of the HKSAR", "Guidelines on Greening of Noise Barriers, Development Bureau, Government of the HKSAR", "Practice Notes No. BSTR/PN/003 Noise Barriers with Transparent Panels, Highways Department, Government of the HKSAR" and "Public Lighting Design Manual, Highways Department, Government of the HKSAR".

2. Design Considerations

The primary function of noise barriers is to shield receivers from excessive noise generated by road traffic. While the onus of mitigating road traffic noise lies with the road projects, noise barriers are considered the most reasonable noise mitigation measures available.

Many factors need to be considered in the detailed design of noise barriers. First of all, barriers must be acoustically adequate. They must reduce the noise as identified in the EIA and NIA studies. A proper design of noise barriers would need due considerations from both acoustic and non-acoustic aspects. Acoustical design considerations include barrier material, barrier locations, dimensions and shapes. However, they are not the only requirements leading to proper design of noise barriers.

The second set of design considerations, collectively labelled as non-acoustical design considerations, is equally important. As is often the case, the solution to one problem (in this case noise), may cause other problems such as unsafe conditions, visual blight, maintenance difficulties, lack of maintenance access due to improper barrier design and air pollution in the case of full enclosures or deck over. With proper attention to maintainability, structural integrity, safety, aesthetics, and other non-acoustical factors, these potential negative effects of noise barriers can be reduced, avoided, or even reversed.

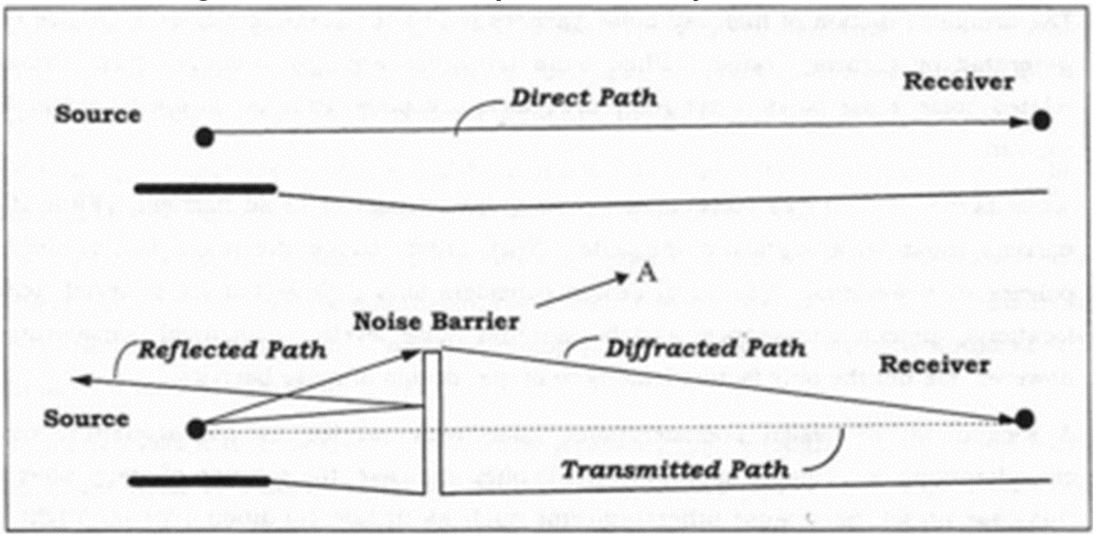
2.1. Acoustical Design Considerations

The material, location, dimensions, and shapes of noise barriers can affect the acoustical performance.

Figure 2.1.1 is a simplified sketch showing what happens to road traffic noise when a noise barrier is placed between the source (vehicle) and receiver. The original straight line path from the source to the receiver is now interrupted by the noise barrier. Depending on the noise barrier material and surface treatment, a portion of the original noise energy is reflected or scattered back towards the source. Other portions are absorbed by the material of the noise barrier, transmitted through the noise barrier, or diffracted at the top edge of the noise barrier.

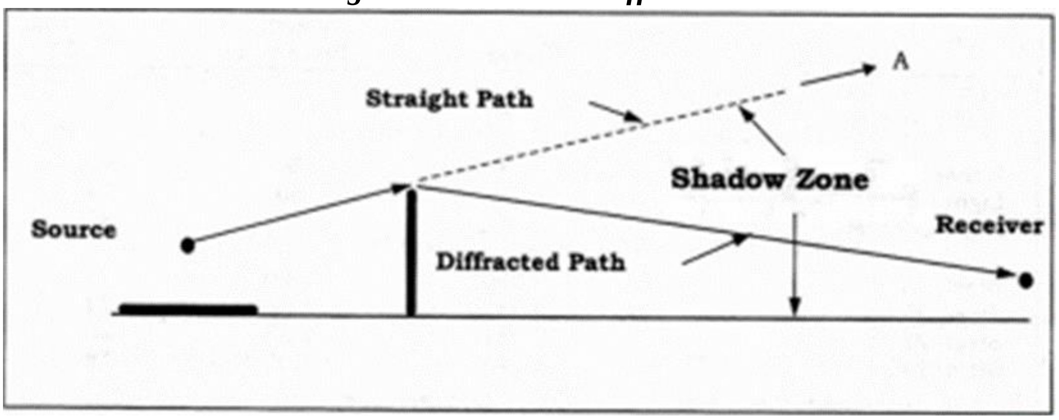
The transmitted noise, however, continues on to the receiver with a “loss” of acoustical energy (acoustical energy redirected and some converted into heat). The common logarithm of energy ratios of the noise in front of the barrier and behind the barrier, expressed in decibels (dB), is called the Transmission Loss (TL). The TL of a barrier depends on the barrier material (mainly its weight), and the frequency spectrum of the noise source.

Figure 2.1.1 Alteration of Noise Paths by a Noise Barrier



The transmitted noise is not the only noise from the source reaching the receiver. The straight line noise path from the source to the top of the barrier, originally destined in the direction of A without the barrier, now is diffracted downward towards the receiver (Figure 2.1.2). This process also results in a "loss" of acoustical energy.

Figure 2.1.2 Barrier Diffraction

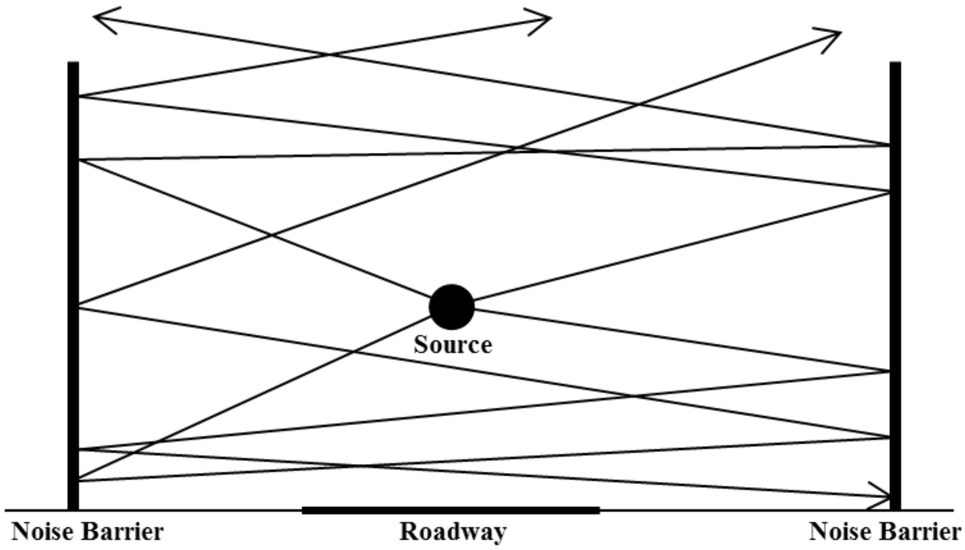


The receiver is thus exposed to the transmitted and diffracted noise. Whereas the transmitted noise only depends on barrier material properties, the diffracted noise depends on the location, shape, and dimensions of the barriers.

Where there are noise sensitive receivers on both sides of the road, parallel barriers could be used. However, sound reflected between reflective parallel barriers might cause degradations in the performance of each barrier due to the multiple reflections diffracting over the individual barriers (see Figure 2.1.3). In general, the distance between parallel barriers should be at least 10 times the average barrier height if only the reflective type is adopted.

Calculation of Road Traffic Noise (CRTN) published by the Department of Transport, Welsh Office, UK provides determination methods of reflection correction for parallel barriers. The factors of reflection correction include the relative height of barriers, horizontal distance between two barriers, height of reception point, horizontal distance from the top edge of barriers to reception point and the degree of inclination of reflecting barrier. The designers may consider the above factors to adjust the reflection correction for the noise prediction and optimize the design of parallel barriers.

Figure 2.1.3 Reflective Noise Paths due to Parallel Barriers



Absorptive type of noise barriers, either alone or in combination with the reflective type, could be used to avoid causing reflection of noise to these receivers. The same may also be required for barriers along the central median in case of a dual carriageway. In case where this is required, the lower portion of at least 2 to 3 meters should be of absorptive materials. The absorptive materials are normally more expensive and more difficult to be maintained than reflective materials. The designers are recommended to consider the application of absorptive and reflective materials for suiting various environmental and traffic conditions to achieve a cost-effective design.

Sometimes noise barriers cannot provide sufficient noise attenuation to the upper levels of high-rise buildings and thus enclosures may be required. If the enclosure is extended to cover the footway(s) as well, attention should be paid to the reverberation noise inside the enclosure. To reduce the noise disturbance on the pedestrians, it is recommended to limit the reverberation time inside the enclosure. Though there is no specific noise level standard applicable here, the general guideline to address reverberation noise is to specify the reverberation time at 500 Hertz to no more than 2 seconds.

2.2. Transmission Loss of Various Barrier Materials

All materials permit sound energy to pass through, although in varying degrees depending on the material and the frequency of sound. The attenuation of sound passing through a material is referred to as Transmission Loss (TL).

For a barrier to be fully effective the amount of sound energy passing through it must be significantly less than that passing over the top (or around the edge). When noise levels of two sources L_A and L_B are added, a difference between them larger than 10 dB adds less than 0.5 dB to the higher level.

For example: $L_A = 70$ dB $L_B = 60$ dB

$$L_{A+B} = 10 \times \log_{10} [\log_{10}^{-1}(70/10) + \log_{10}^{-1}(60/10)]$$
$$= 70.4 \text{ dB}$$

Thus, if the portion of sound transmitted through the barrier is 10 dB lower than that which goes over the barrier, the overall sound received is essentially determined by the energy travelling over the barrier.

For acoustical purposes, any material may be used for a barrier between a noise source and a noise receiver as long as it has a TL of at least 10 dB(A) greater than the desired noise reduction (i.e. Insertion Loss (IL) determined in the EIA or NIA studies). This ensures that the only noise path to be considered in the acoustical design of a noise barrier is the diffracted noise path, i.e. the path over (or around) the barrier.

For example, if a noise barrier is designed to reduce the noise level at a receiver by 8 dB(A), the TL of the barrier must be at least 18 dB(A). The transmitted noise may then be ignored, because the diffracted noise is at least 10 dB(A) greater and hence the noise propagation path must be over the barrier.

Table 2.2.1 gives approximate TL values for some common materials, tested for typical A-weighted traffic noise frequency spectra. They may be used as a rough guide in acoustical design of noise barriers. For accurate values, consult material test reports prepared by accredited laboratories.

Table 2.2.1

Material	Thickness mm	Surface Density kg/m^2	Transmission Loss* (TL) dB
Polycarbonate	8 – 12	10 – 14	30 – 33
Acrylic [Poly-Methyl-Meta-Acrylate (PMMA)]	15	18	32
Concrete Block 200x200x400 light weight	200	151	34
Dense concrete	100	244	40
Light concrete	150	244	39
Light concrete	100	161	36
Brick	150	288	40
Steel, 18 ga	1.27	9.8	25
Steel, 20 ga	0.95	7.3	22
Steel, 22 ga	0.79	6.1	20
Steel, 24 ga	0.64	4.9	18
Aluminium Sheet	1.59	4.4	23
Aluminium Sheet	3.18	8.8	25
Aluminium Sheet	6.35	17.1	27
Wood	25	18	21
Plywood	13	8.3	20
Plywood	25	16.1	23
Absorptive panels with polyester film backed by metal sheet	50 – 125	20 – 30	30 – 47

* Values assuming no openings or gaps in the barriers

In terms of noise reduction, the maximum value that can be achieved theoretically is 20 dB(A) for thin screens (walls) and 23 dB(A) for berms. A material that has a TL of 33 dB(A) or greater would therefore always be adequate for a noise barrier in any situation.

Small adjustments in surface density to reach a preferred material gauge or a preferred construction thickness do not greatly affect the TL.

Similar to the practice in other countries, a material surface density of 10 kg/m^2 is typically sufficient but this should be reviewed on a case-by-case basis to meet the requirements of the project.

2.3. Reduction in Noise Barrier Performance due to Holes, Slits or Gaps

Sound "leaks", due to holes, slits, cracks or gaps through or beneath a noise barrier, can seriously reduce the barrier performance, and should be avoided. Any gaps represent segments of the barrier with zero Transmission Loss; that is, the gap can be considered to transmit 100% of the energy incident on it. Therefore, extra efforts should be spent at design and construction stages to avoid holes, slits or gaps, either with the adjoining panels, along the bottom edge or gaps for road traffic signs, lighting poles, fire hydrants, construction joints or expansion joints. See Figure 2.3.1 for examples.

While site specific situation warrants the provision of gaps like necessary opening of maintenance doors in a very long barrier or provision of access into special areas, special attention should be paid to provide overlapping of barriers etc. (also see section 4.5). In such cases, the sound transmission loss of the barrier is reduced by the amounts shown in Table 2.3.1 for various percentages of the barrier area comprising leaks.

If the noise barrier TL were reduced by at most 3 dB, the overall barrier performance will be reduced by at most 1 dB(A). It may be seen from Table 2.3.1 that the percent area occupied by leaks ranges from at most 1.5% of the total area for situations where the minimum TL requirement is 10 dB, to nearly zero for situations where the required barrier TL exceeds 20 dB. Thus, the significance of leaks increases dramatically where a high amount of noise barrier attenuation is needed.

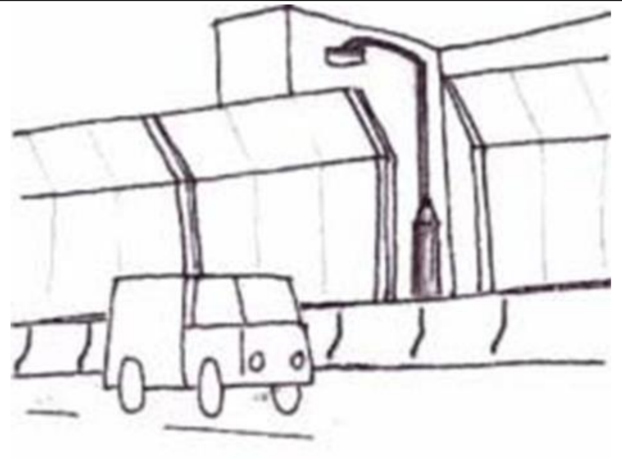
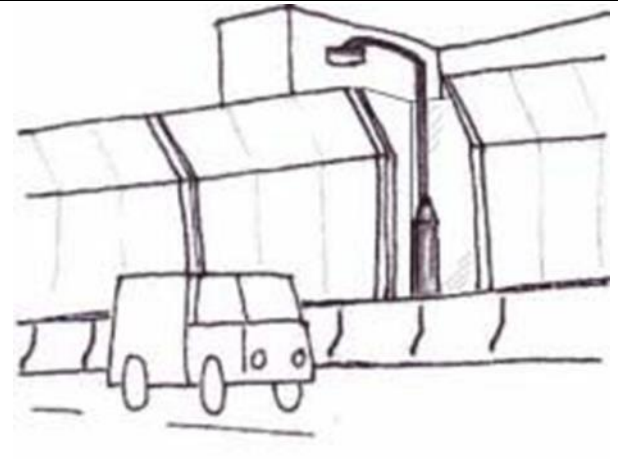
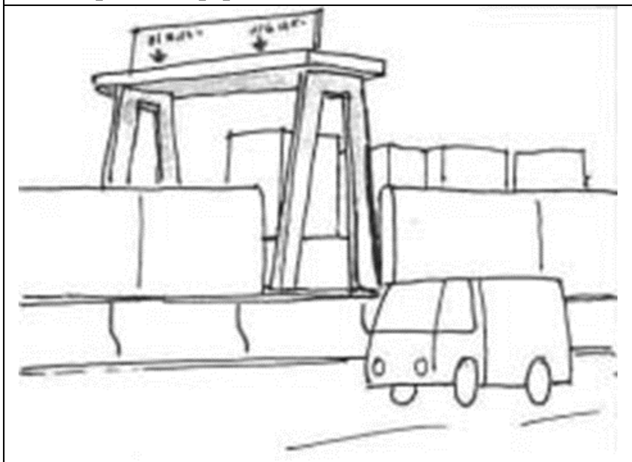
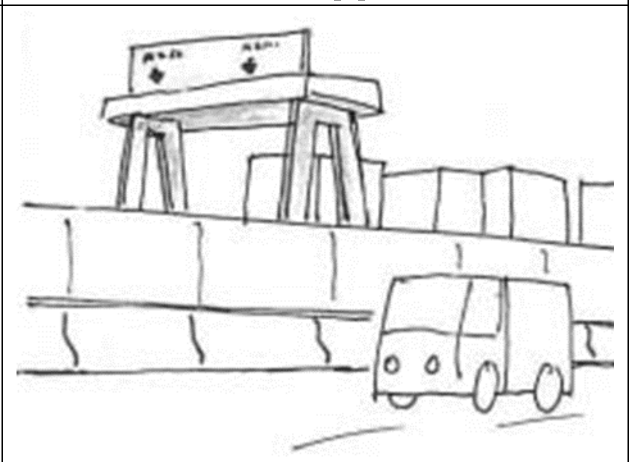
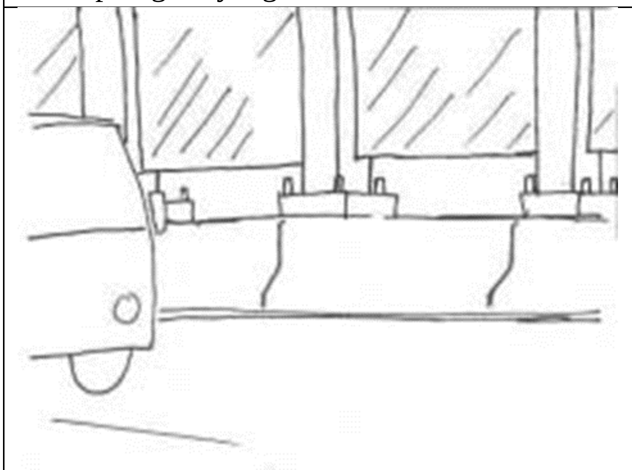
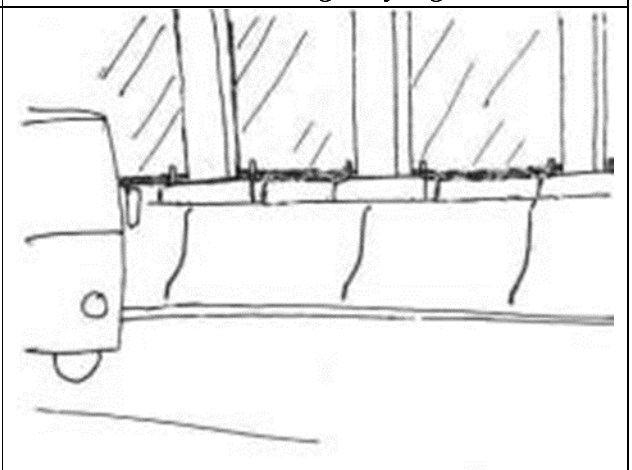
For noise barriers made of concrete or other "planks", the planks must be tongue-and-grooved, carefully lapped, or extremely well butted, to ensure a good air seal at joints. "Alternating boards", planks mounted on alternate sides of horizontal supports, should not be used.

Table 2.3.1 Reduction in Transmission Loss due to Leaks

% area occupied by leaks	Transmission Loss without leaks at 500 Hz			
	10 dB*	15 dB*	20 dB*	25 dB*
	↓ reduction in transmission loss, dB ↓			
50	10+	15+	20+	25+
25	10	15	20	25
13	8	12	17	22
6	5	10	14	19
3	4	7	11	16
1.5	2	5	9	13
0.78	1	3	6	10
0.39	1	2	4	8
0.20	0	1	3	5
0.10	0	1	1	4
0.05	0	0	1	2

* Required transmission loss for the proposed barriers

Figure 2.3.1 Examples of Gaps

DON'T	**DO**
	
▲ Gap at lamp post	▲ Recess formed at lamp post
	
▲ Gap at gantry sign	▲ Barrier continues at gantry sign
	
▲ Gap at bottom edge	▲ Gap at bottom edge filled with concrete and sealant

Therefore, to avoid reduction in acoustic performance of noise barriers, recess should be formed along the barrier to accommodate the street furniture or other interfacing structures such as bridge pier as far as possible. See Figure 2.3.2 to Figure 2.3.3. Sufficient space should also be allowed for the installation and maintenance of the street furniture. However, if this is not possible for whatever reason, an integrated design of the noise barrier may be required to accommodate the street furniture. See Figure 2.3.4. In case where space (headroom and side clearance), sight line and maintenance are permissible, traffic signs may be integrated with the noise barrier. Adequate horizontal clearance should be maintained to ensure sufficient sightlines could be provided as required in TPDM.

Figure 2.3.2 Recess for Sign Gantry Support

Figure 2.3.3 Recess for Bridge Pier

Figure 2.3.4 Integrated Design of Noise Barrier with Public Lighting

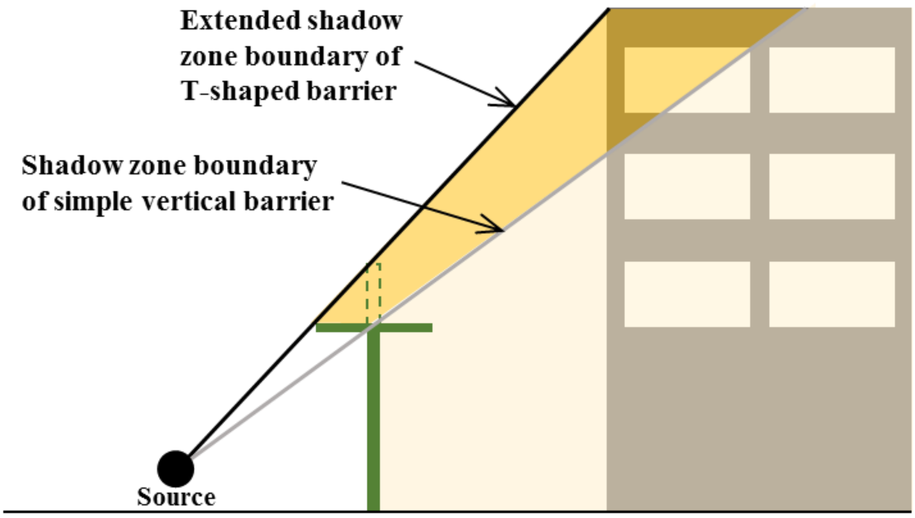
2.4. Barrier Shapes

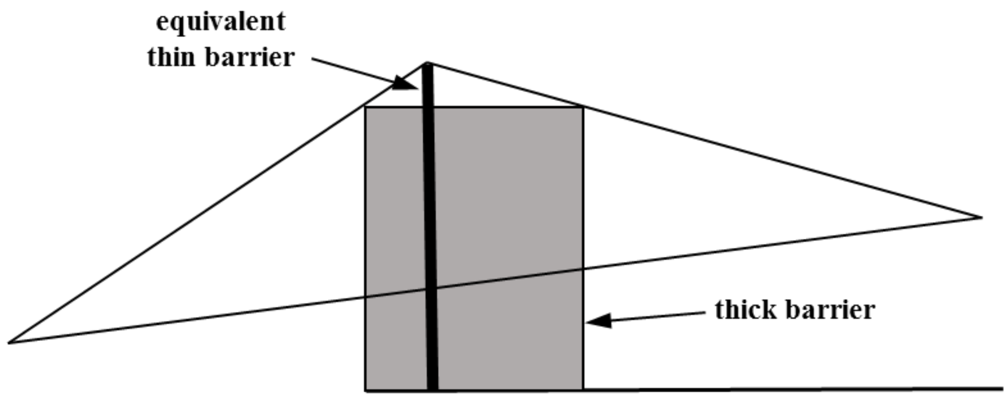
Calculation of Road Traffic Noise (CRTN), the methodology used in predicting road traffic noise in Hong Kong, assumes that a barrier has insignificant thickness, but diffraction over the top edge of a barrier is affected by its cross section. It may be appropriate to use an equivalent effective height for barriers which are very wide such as buildings. This can be estimated from the geometry as shown in Figure 2.4.1. Barriers with cross sections having corners and curved shapes are not as effective at reducing noise as those with sharp edges. Wedge shapes with internal angles greater than 90° and rounded shapes are the least effective. It may therefore be advantageous to use an acoustic screen on the top of a mound, to increase its effectiveness.

The effectiveness of a thin barrier of given height may be increased by bringing the diffracting edge nearer to the source of noise - thus increasing the path difference. Where a tall barrier is placed near to the carriageway, tilting the upper section towards the source can provide additional benefit. Increasing the number of diffracting edges can also improve attenuation considerably.

In most cases it will be relatively expensive to provide more than one barrier, however, by modifying the shape of the top edge of noise barrier, the shadow zone behind the screen can be enlarged with additional noise reduction as compared with the simple vertical barrier of same height. The shapes include T-shaped, Y-shaped, multiple-edge, tubular capping, etc. Given the same total height of barriers, the edge modified barriers can improve the noise attenuation by as much as 3 dB(A) in shadow zone compared to the simple vertical reflective barrier. In this connection, the height of barrier could be reduced. Such modifications may increase the wind loading on the barrier slightly, but probably by less than would occur if the barrier was made taller to achieve the same acoustic benefit.

Figure 2.4.1 Mechanism of Edge Modified Barrier and Thick Barrier

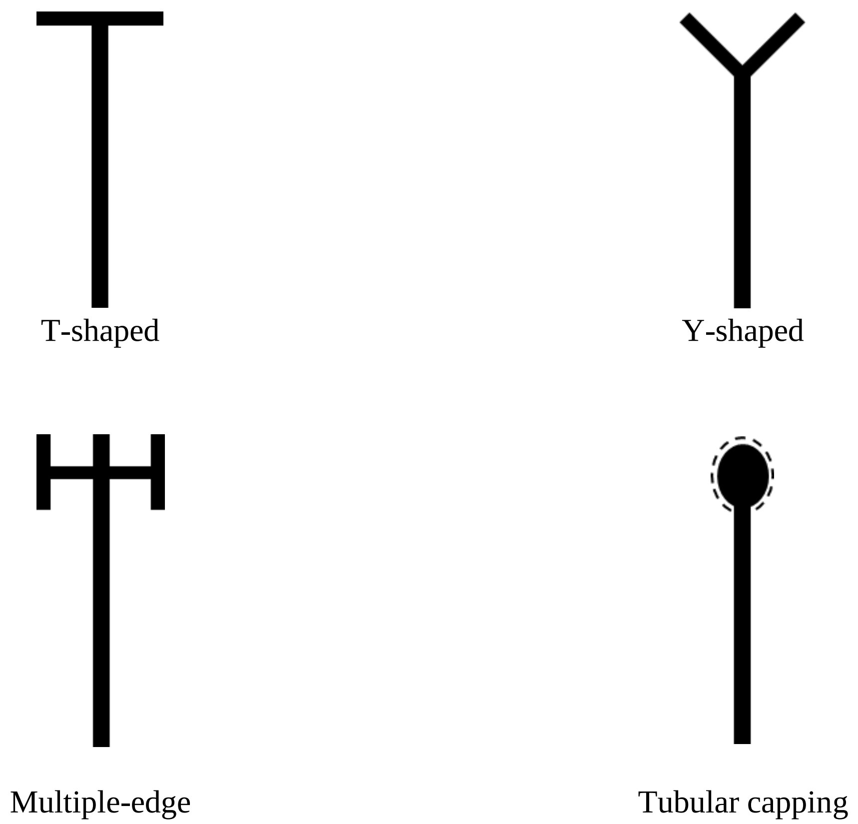




Representation of a thick barrier

Modifying the shape of the top edge of a noise barrier may improve/enhance the performance of the barrier without increasing the height and associated visual impacts. When adopting the edge modified barriers, sufficient space and proper access shall be considered for the maintenance or replacement of the panels at the top portion of edge modified barriers. If it is necessary to reach the top of the barrier for maintenance or replacement works, safe access with fall protection system should be provided. Due consideration should be given to the traffic condition and feasibility of lane closure for future maintenance. The designers should strike a balance between the performance, ease of maintenance and aesthetic when considering the appropriate shape of the top edge. The designers may make reference to "NZTA State Highway Noise Barrier Design Guide" in designing the top shape of noise barrier.

Figure 2.4.2 Edge Modified Noise Barriers



Barriers do not necessarily have to be of constant height - it may be cost effective to increase the height in the vicinity of isolated noise sensitive receivers and to reduce it between them. Some computer programs can optimise the profile of a barrier to screen such properties efficiently. Varying the height of the barrier may also help to alleviate the monotonous appearance of long lengths of barrier and may lessen the visual impact of the barrier as well.

While the position (relative to the carriageway) and height of the barrier have been fixed in the EIA study, the outlook is still open to the designer to refine. It is very often that only limited space is allowed at planning stage for noise barrier erection which not only imposes restriction on the choice of noise barrier design but also makes it impossible to soften the structure with landscape planting. If necessary, the designer should explore the feasibility of increasing the space required for the erection of noise barrier.

2.5. Choice of Materials

In general, roadside noise barriers could be divided into the following categories: -

- Reflective type – transparent and non-transparent
- Absorptive type – sound absorbent materials and possible finishes of absorptive panels
- Earth landscaped mound and retaining structures
- Mixed type – a combination of the above types

One of the key features in all structures is the material ultimately chosen. Despite the above categorization, the materials could largely be categorized as reflective and absorptive. The determination whether reflective or absorptive or the combination of both are already done in the EIA or NIA studies. In general, the following could be used:

- Steel (painted, galvanized, stainless)
- Aluminium
- Polycarbonate or acrylic sheets
- Concrete, brick or glass fibre reinforced concrete (GRC)
- Proprietary – made acoustic panels
- Landscaped earth berm

An acoustic panel is typically made up of a perforated cover sheet enclosing noise absorptive material (mineral wool or fiberglass inside and wrapped up with polyester film). An absorptive GRC noise barrier relies on noise absorptive material inside the GRC surface grill for noise absorption.

Each of these materials will have its special advantages and disadvantages and it is dependent upon the nature and requirement of a specific project to determine the suitability. As a general rule, the following should be noted:

- Except for absorptive GRC composites, acoustic panels and earth berms, all other materials to various degree reflect sound (i.e. reflective) to premises on the opposite side of the receiver to be protected;

- Metallic and transparent material can produce “glare” effects at certain incident angles;

- The appropriate surface treatment of polycarbonate must be chosen to avoid weathering, ultra-violet attack and consequent loss of transparency; and

- Non-transparent materials such as steel, aluminium and concrete normally require greater efforts in surface treatment to soften the visual impact.

2.6. Barrier Materials

The following sections give a brief introduction to various materials that could be used for the construction of noise barriers. The materials introduced are non-structural acoustic elements. The design of and the materials used in noise barriers shall be selected to ensure that factors such as aging/corrosion resistance, stone impact resistance, colour resistance and fire resistance etc. can satisfy the requirements specified in noise barrier standard BS EN 1794-1, BS EN 1794-2 and BS EN 1794-3.

2.6.1. Concrete

Concrete is used in various ways in the construction of noise barriers. Precast planks slotted into H shaped uprights provide a rapid means of construction and can be easily repaired. One form of proprietary concrete noise barrier is constructed from linked precast panels set at varying angles so as to obviate the need for separate post supports.

Table 2.6.1 Benefits and Considerations of Concrete Noise Barriers

Benefits	Considerations
• Impervious and therefore acoustically effective. • Low maintenance. • Durable and weather resistant. • Flexible in design and opportunity to use recycled materials that achieve environmentally friendly design. • Special designed surface features can be beneficially employed to reflect sound at a desired angle, away from noise sensitive receivers.	• Prefabricated concrete noise barriers are relatively expensive. • Concrete is heavy, making it more difficult to fix, particularly in retrofit situations and on existing structures. • Being completely solid, surface treatment of concrete by introducing aesthetic finishes are important. • Quality control should be ensured for concrete cast in-situ.

Figure 2.6.1 Examples of Concrete Noise Barriers

2.6.2. Metal

Metal noise barriers can be painted or coated in a wide range of colours. Steel is commonly used for supports. Sheet metal can be formed into lightweight hollow sections, which may contain fibreboard or mineral wool absorbent materials. A number of profiled barrier systems, comprising horizontal panels spanning between galvanized steel posts, are commercially available. The metal sheeting on one side may be perforated to allow noise to interact with absorbent material within, and the corrugated profile provides structural rigidity. Aluminium is often used in proprietary systems.

Table 2.6.2 Benefits and Considerations of Metal Noise Barriers

Benefits	Considerations
• Relatively high strength to weight ratio. • Easy to fix, facilitating the on-site installation. • Large panels may be easily erected with fewer supports.	• Metal panels have less aesthetic potential comparing to other materials. • Plants do not grow well next to sun-heated metal panels. • Expansion joints applied for expansion of metal panel in hot weather may cause an issue in maintaining the noise attenuation.

Figure 2.6.2 Examples of Metal Noise Barriers

2.6.3. Transparent Materials

Transparent materials allow light to properties or areas which would otherwise be placed in the shadow of the barriers. The transparent panels are usually made of PMMA, polycarbonate or glass. Transparent materials are noise reflecting and their use might therefore be restricted where reverberation would cause problems. Transparent panels may need to be protected from impact by errant vehicles. Consideration should also be given to the use of laminates, toughened glass, embedded mesh or other systems in order to control the spread of fragments in the event of damage. The design considerations for transparent panels, such as safety and fire resistance, and test requirements, including light transmittance, impact strength, etc. are given in the "Practice Notes No. BSTR/PN/003 – Noise Barriers with Transparent Panels".

Some transparent panels can become semi-opaque relatively quickly, either through superficial or material deterioration. It may be appropriate to make some allowance for this in specifying requirements. Grit can abrade surfaces - plastics are more vulnerable to this than glass.

Table 2.6.3 Benefits and Considerations of Transparent Materials

Benefits	Considerations
• Sunlight can penetrate and retain natural lighting behind the barrier. • Transparent panels can be used to reduce the visual impact of the tall noise barrier. • Tinted material may enhance the appearance. • Allow road users to locate themselves by providing views of the surrounding area.	• Bird collision measures should be provided. The transparent panels with pattern of thin opaque stripes can reduce bird collision issues. • Prone to vandalism. PMMA and polycarbonate panels could be damaged by fire, and glass could be damaged by strong impact. • Glare from reflections of the sun is a potential problem. • Regular cleaning would be required to maintain its transparency. The adoption of self-cleaning materials can be considered to reduce the need of maintenance. Its performance should be demonstrated. • Polycarbonate panels may become opalescent over time as it can absorb water, especially at exposed edges. • Oblique and narrow angle of view from the driving position and of the obscuring effect of supporting structures should be considered in the design

2.6.4. Plastics

Apart from their use in transparent panels, plastics have also been used in absorbent panels and for supporting planted systems. Plastics may be coloured as required, but colour may bleach in strong sunlight. Susceptibility to bleaching can be tested in a weatherometer. Ultraviolet (UV) light stabilizer additives or coatings can be applied to reduce the sensitivity of transparent plastic sheeting materials to sunlight. Plastics are prone to damage from fire and vandalism and some, e.g. polyethylene, become brittle after prolonged exposure to sunlight.

Figure 2.6.4 Examples of Plastic Noise Barriers

2.6.5. Recycled Materials

An increasing number of products are available which claim to be "environmentally friendly" by incorporating various recycled materials in their manufacture. Examples are: recycled plastics in supporting structures, waste materials from industrial processes in absorbers, sections of old tyres as planters, domestic waste transformed into compost. There may be limitations in the suitability of recycled products. The use of mixed scrap and surplus may affect choice of colour; eliminating contamination and reprocessing reclaimed materials will add to costs. It is important to establish whether the recycled product is comparable with new material and to ensure it will not tend to degrade more quickly.

2.6.6. Sound Absorbent Materials

Tests in a reverberation chamber (BS EN ISO 354 or similar) will produce a frequency response curve. It is desirable for absorption coefficients to be better than 0.8 at frequencies which are significant in the traffic noise spectrum. In general, the peak traffic noise frequencies lie between 500 - 1500 Hz. In some cases, tests may indicate absorption coefficients larger than 1. Although theoretically impossible, this can occur with highly absorbent materials where the shape of the product differs markedly from the ideal of a flat sheet. Some products are strongly tuned to prevent reverberation of low frequencies (100 - 300Hz). These are unlikely to prove useful in connection with high speed roads, but may be appropriate in urban centres where heavy vehicles will be stationary at junctions and accelerating in low gear.

Acoustic requirements should be specified for the whole noise barrier structure (including panels and supporting structure) and allowance should be made for a proportion of reflective supporting elements. An overall performance rating may be quoted for products, obtained by combining sound absorption coefficients in a similar manner to that described above for insulation performance.

Sound absorbent material may be fixed to a backing structure such as a framework of timber or steel, or the surface of a solid wall. Sound absorbent panels are often based on noise absorbent products developed for use in industrial environments and may be available in a range of colours. The aesthetic aspects including shape, colour and surface texture should be considered.

The case for using absorbent barriers in specific situations must be argued on the basis of their cost effectiveness, but where a high quality finish is already required, the additional cost of similar absorbent panels may not be excessive. The geometry of sound reflections may also permit the use of the absorbent material to be limited to that part of the surface where it will be most effective. Materials placed close to the carriageway can quickly become dirty and clogged with pollutants.

2.6.7. Alternative Materials

A variety of materials can be used in barriers including glass, acrylic and other synthetic materials, hollow sheet metal box sections and porous concrete.

2.7. Earth Berms and Retaining Structures

If a road construction contract would otherwise have surplus material, landscaped berms can be provided at negligible cost; at the same time the inevitable impact on the surrounding area of hauling the surplus material off site can be avoided. The design of berms should be compatible with the local landscape character and topography. The surplus material may only be suitable for gentle slopes and large quantities may be needed to achieve a significant amount of screening. Long roadside slopes are visually attractive but acoustically inefficient and increase landtake, which is always a constraint in Hong Kong. On the protected side, gentle slopes may serve other design objectives such as returning landscaped areas to agriculture.

Where insufficient land is available to construct earth berms high enough with natural slopes, geotextile reinforcement may be used to steepen slopes, but at the risk of being visually incompatible. Alternatively, retaining methods such as reinforced and anchored earth construction, gabions, concrete or timber cribs, and other proprietary support systems may be used to support the traffic face with advantage.

Figure 2.7.1 Concept of Earth Berms

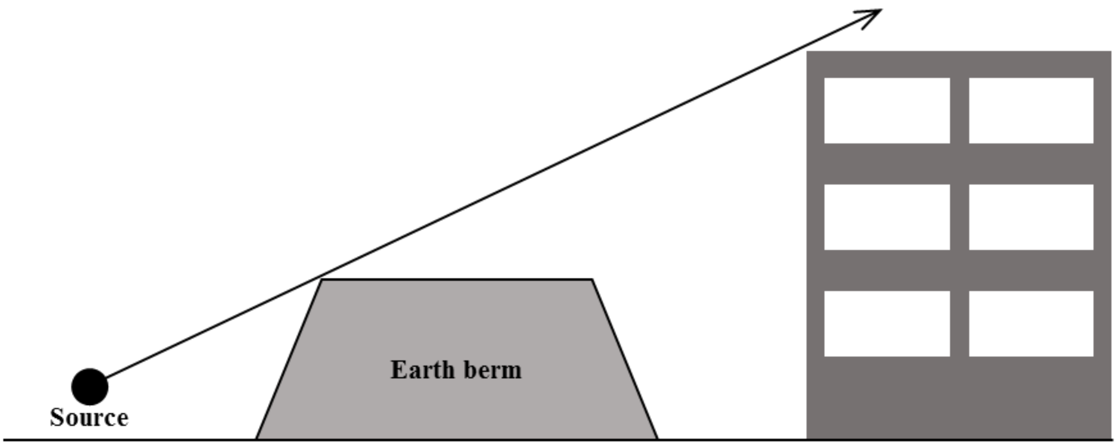


Figure 2.7.2 Example of Earth Berms

2.8. Non-acoustical Considerations

While standard guidelines on ventilation, lighting, visual impact and drainage requirement specifically for noise enclosure are not available, the designers are recommended to principally specify that agreements on requirements from Electrical & Mechanical Services Department, Lighting Division of Highways Department, Landscape Division of Highways Department, Bridges and Structures Division of Highways Department and Drainage Services Department should be sought.

Some other important issues including firefighting and emergency access requirements for road users as well as nearby residents should have already been considered during EIA or NIA. Nevertheless, designers should not overlook these during detailed design stage.

2.8.1. Safety/Vehicle Impact

Whenever there is a likelihood of a noise barrier being struck by an errant vehicle, failure of the noise barrier caused by vehicle impact is a potential roadside hazard. Noise barrier should be protected from the impact of errant vehicles by a vehicle restraint system. For the details on the criteria for the provision of safety barrier fences and the spatial requirements for the safety barrier fences, guidance given in TPDM Volume 2 Chapter 3.9 should be referred. The requirements for the horizontal clearance from a carriageway to an obstruction including any railing barrier are given in TPDM Volume 2 Table 3.5.2.1.

Where rigid barriers or parapets are adopted to shield the noise barrier, adequate clearance should be provided to accommodate the zone of intrusion occupied by tall vehicles during collision. Alternatively, where space is limited, say less than 1.5m, concrete profile barrier can be integrated with the noise barrier.

Sometimes safety barrier fences at the access openings of the noise barriers are discontinuous. This can be hazardous to motorist when vehicles collide with the safety barrier fence at the access opening. To avoid such issue, a continuous beam barrier with sufficient clearance to the noise barrier structure should be provided. If space is limited, a continuous concrete profile barrier integrated with the noise barrier could be provided. In that case, the access openings could be installed on top of the concrete profile barrier.

Other potential traffic hazards, for example, the upstream end of noise barriers could be prone to frontal collision by an errant vehicle, should also be considered. The designer should refer to TPDM on the design requirements and/or protection measures to mitigate the traffic hazards.

Where noise barriers are required to be installed on bridge structures, these should only be combined with a parapet if the assembly has been designed to accept the consequences of vehicle impact. Materials and finishes for attached noise barriers need to allow for the considerable distortions of metal parapets under impact. A freestanding noise barrier vulnerable to vehicular impact should be located behind vehicle parapet with adequate clearance for it to deflect upon impact.

The risk associated with noise barriers on flyovers falling onto vehicle/pedestrian paths upon impact by vehicles should also be considered in the design. Additional catching devices such as laminated panels or panels with embedded filaments or mesh should be provided as appropriate. Further requirements are set out in the “Practice Notes No. BSTR/PN/003 Noise Barriers with Transparent Panels” published by the Highways Department.

Impact load assessment is required to ensure adequate structural capacity of the noise barrier against vehicular impact. The guidance of impact load assessment is given in Appendix F of “Structures Design Manual for Highways and Railways”.

2.8.2. Fire Resistance and Emergency Access

Noise barriers, particular transparent type, are subjected to fire hazards. In the case of noise barriers whose elements, whilst having the fire retardant properties as required, are nevertheless combustible, either the posts must be non-combustible and function as a fire barrier, or a length of at least 4 metres made of non-combustible elements shall be inserted in every 100 metres of noise barrier. Full enclosure type exceeding 230 metres may need to comply with road tunnel fire safety requirements set out in the “Codes of Practice for Minimum Fire Service Installations and Equipment and Inspection, Testing and Maintenance of Installations and Equipment” published by the Fire Services Department. Emergency access/exit points are also required for roadside barriers and barriers erected along the central reserve to assist evacuation. Attention should be paid to the design of these doors so as to avoid sound leakage and these doors should be kept closed under normal circumstances. (Also see section 4.5.) Advice from relevant authority should be sought on the frequency of these emergency access/exit points. If necessary, a risk assessment should be conducted to evaluate the anticipated risk associated with the noise enclosure.

2.8.3. Lighting Considerations

Lighting inside noise enclosures should be uniform and should avoid glare and flicker effects whilst the switch-on time of artificial lighting during daytime should be minimized. The Lighting Division of the Highways Department, and the "Public Lighting Design Manual" should be consulted / referred to as appropriate for the design of lighting conditions inside noise enclosures.

2.8.4. Maintenance Considerations

Chapter 4 would give a full and detail account of maintenance considerations.

2.8.5. Construction and Installation

The contract drawings should show methods of fixing noise barriers to structures, which ensure that gaps below the bottom edge of the barrier are avoided.

The drawings should also show the position and height of the noise barrier and where applicable, the position of gates, also the fittings required and the proposals for treatment at gaps to maintain the acoustic attenuation. The length and position of noise barriers behind any gap should ensure that there is adequate deviation of the noise path from the carriageway to any sensitive receiver being protected by the noise barrier. It should be noted that additional width may be required on embankments to install panels behind the barrier line where gaps are required.

High productivity construction method such as off-site prefabrication, multi-trade integration and module maximization shall be considered. The on-site construction of foundation and off-site prefabrication of noise barrier modules can be conducted concurrently. The prefabricated noise barrier modules, consist of barrier panels and structural frames, will be delivered to the construction site for installation. The joint of modules can be simplified by maximizing the use of bolt connection. In this connection, the overall construction efficiency could be improved by saving time in the process of manufacturing, assembly and installation. Under off-site fabrication, quality of noise barrier components and safety can be improved. The construction waste could be reduced as well to achieve sustainable and environmentally friendly construction.

For the delivery of noise barrier modules by land transport, the size of each noise barrier module should be designed not to exceed the limit as given in the Road Traffic (Traffic Control) Regulation 55 of Cap. 374G. For the loading of vehicles, the requirements are given in the "Code of Practice for the Loading of Vehicles". If a load of width exceeds 2.5 metres, application of wide load permit should be required in accordance with the "Guidelines on Application for Wide Load Permit" published by the Transport Department.

2.8.6. Structural Considerations

The guidance on the structural design of noise barriers/enclosures is given in the "Structures Design Manual for Highways and Railways". The designers are recommended to carry out value engineering assessment to achieve cost-effectiveness and shorten the construction period. For instance, cross beam may be provided to connect the parallel cantilevered barriers to form an integrated structure which is similar to the structural form of noise enclosure. The portal frame structure with pin support at the column base can efficiently transform the lateral load into push-and-pull vertical forces on both sides of the foundation. Therefore, the working loads acting on the foundation could be minimized to optimize the foundation design. The overall construction time and cost of the foundation could be reduced. Although the integrated form structure may bring benefits to the construction of foundation, the designer shall also assess the overall construction cost of noise barriers with a view to achieving an economical design. Minimum headroom shall be provided according to "Structures Design Manual for Highways and Railways". The stability of the whole system shall be carefully checked under vehicular impact. Some pin supports may be replaced by rigid base support to provide more overall robustness, if considered appropriate. In addition, maintenance access to the cross beam shall be provided as far as practicable to avoid extensive road closure during maintenance.

Figure 2.8.6(a) Integrated Structural Form for Parallel Noise Barriers

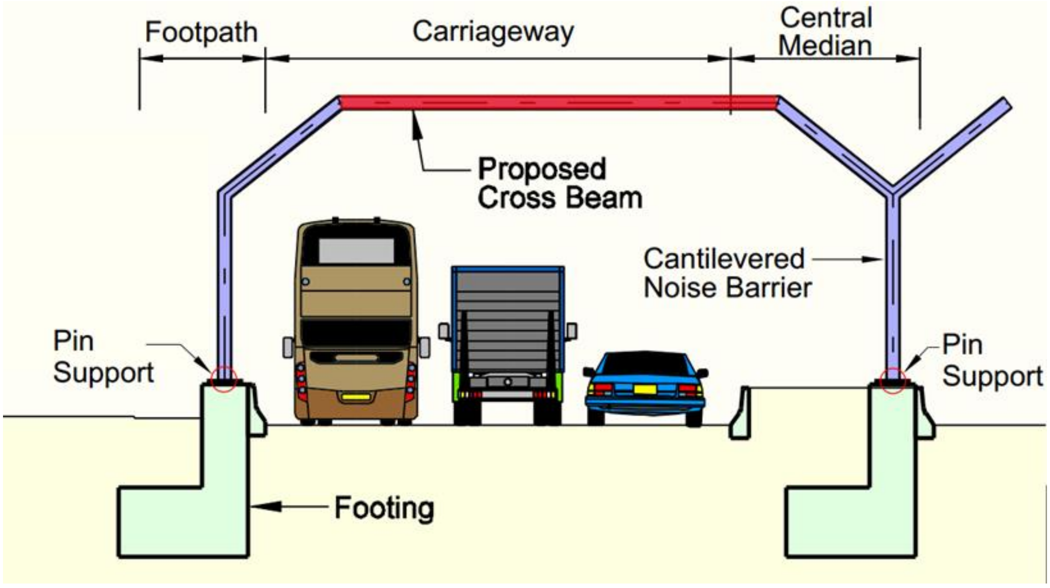


Figure 2.8.6(b) Example of Pin Support at Column Base, at Po Shun Road, Tseung Kwan O

Note: Pin support at column base allows the base moment to be released and re-distributed to the cross beam and the connecting columns. The bending moments in cross beam and the connecting columns would be increased, while the overall working loads in foundation could be minimized.

The key considerations for the structural design of noise barriers include design working life, adoption of design wind pressure, vehicle impact assessment, structural materials and deflection due to wind pressure.

(a) Design Working Life

In general, design working life is the assumed period to be used for its intended purpose with anticipated maintenance but without major repair being necessary. Noise barriers are designed to only mitigate the effects of traffic noise for noise sensitive receivers near the high speed roads or expressways. Repair of noise barriers, in general, will not cause major disruption to traffic compared to other highways structures, such as bridges. Therefore, the design working life of noise barriers are 50 years.

(b) Adoption of Design Wind Pressure

The typical design wind pressure and pressure coefficients are given in the "Structures Design Manual for Highways and Railways". As the configurations of noise enclosures vary widely, the pressure coefficients given in the design manual may not be applicable. In order to achieve an economical design, the designer may consider to carry out wind tunnel tests to determine suitable pressure coefficients for the noise enclosure design.

(c) Vehicle Impact Assessment

In the design of noise barriers/enclosures against vehicular impact, the designer should formulate the strategy for the structure against accidental actions according to the "Structures Design Manual for Highways and Railways". The overall structural integrity of the noise barriers/enclosures should be maintained following the vehicular impact, while local damage to a part of support or other structural components can be accepted.

(d) Structural Materials

In Hong Kong, steel is usually used as the structural components of noise barriers. The super-structure is supported by sub-structures such as mini-piles foundation or footings. With a view to achieving a cost-effective design, a value engineering assessment is recommended to be carried out in the considerations of project life-cycle cost, construction time and maintenance. Some advanced materials such as high strength structural steel and ultra-high strength tensile bar can be considered in the design of noise barrier structures.

(i) High Strength Structural Steel (Grade S690 Steel)

Most of the structural components of noise barriers/enclosures are steel with grade S355 or S275. High strength structural steel such as grade S690 steel has been developed and adopted in various industries such as construction, shipbuilding, machinery and lifting equipment. Grade S690 is a high yield strength structural steel produced in compliance with the acceptable material standard adopted in Mainland China, Australia, Japan, United State of America and British versions of European Union Standards, such as EN 10025-6. The additional rules for the structural design using high strength structural steel are given in BS EN 1993-1-12.

The strength of grade S690 steel is increased by about 90% as compared with grade S355 steel. The overall use of materials and self-weight of structures can be minimized, which can further reduce the loading and scale of the supporting sub-structure. Reduction in size/weight of steel can also improve the aesthetic of noise barriers/enclosures by adopting lighter/slimmer elements, and facilitate the handling of material that improve the efficiency and safety in construction. Albeit the material cost of grade S690 steel is higher than that of grade S355 steel, the reduction in use of material can minimize the overall project initial cost and carbon footprint for material fabrication. The adoption of grade S690 steel in the fabrication of the Double Arch Steel Bridge of the Cross Bay Link at Tseung Kwan O reduces the use of steel by about 30%.

Only built-up sections are available for the structural components if grade S690 steel is adopted in noise barrier structures. Prefabrication of steel sections from steel plates by welding in factory is required. The requirements/standards of welding procedure, tests and consumables are specified in the BS EN 1090-2.

(ii) Ultra-high Strength Tensile Bar

Mini-pile is commonly adopted as the foundation for noise barriers in Hong Kong due to its high flexibility in construction. It is suitable for piling works in congested urban areas. Steel bar with 50mm diameter grade 500 is normally used for mini-pile foundation. In order to maximize the structural capacity of each mini-pile, ultra-high strength tensile bar with 63.5mm diameter in grade 555, grade 690 and grade 830 can be adopted in mini-pile design. The design provisions of these ultra-high strength tensile bars are specified in ASTM A615/A615M, A706/A706M and A1035/A1035M respectively. The ultra-high strength tensile bars were also adopted in previous projects under the Highways Department, Drainage Services Department and Water Supplies Department.

Mini-pile using ultra-high strength tensile bar can provide a higher structural capacity. The number of mini-pile can be reduced to expedite the foundation construction. As such, the construction time and cost of foundation can be reduced. Trial piles may be required to justify the pile performance. Other than the strength of rebar, the pile capacity would also be affected by numerous factors, including the length of pile, rock socket length and geological profile. The designer should take into account the above factors when considering the use of ultra-high strength tensile bar to achieve a cost-effective design.

(e) Deflection

Deflection on noise barrier/enclosure structures is mainly induced by wind pressure. The general deflection limits given in the National Annex to BS EN 1993-1-1 are specified for steel structures of buildings and they may not be suitable for noise barriers/enclosures. The designer should take into account:

- The effect on surrounding structures;
- Road safety; and
- Flexibility of acoustic element

when deciding the appropriate deflection limit for noise barriers/enclosures.

2.8.7. Ventilation

Ventilation is an environmental concern in noise enclosures. Solid panels without openings are good at sound attenuation but they will incur ventilation and air pollution problems due to the blockage of air passage. Acoustic louvre can be adopted on noise enclosures, which are extended to cover the footpath(s) or public transport facilities, such as bus lay-bys inside the noise enclosure, as a mitigation measure for ventilation or air quality issue.

Dust and grime may be accumulated on the surface of acoustic louvres depending on their location and weather conditions. Periodic cleaning would be required by using water or mild detergent. For the removal of stubborn stains and graffiti, the cleaning process and frequency should be carried out in accordance with the instructions from the manufacturer to avoid damaging the noise attenuation performance.

Detailed testing may be required to ascertain the noise reduction and ventilation performance of acoustic louvres adopted on noise barriers to achieve a cost-effective design.

Figure 2.8.7 Example of Acoustic Louvres in Noise Enclosures, on Wong Chu Road, Tuen Mun

Note: The highlighted part in Figure 2.8.7 shows the acoustic louvres installed on noise enclosures.

2.8.8. Sustainability

In accordance with Development Bureau Technical Circular No. 2/2015, renewable energy technologies should be incorporated in infrastructure projects as far as reasonably practicable. The photovoltaic (PV) technology should be adopted to reduce the carbon footprint and achieve a sustainable design. PV technology should be adopted for new infrastructures involving open spaces or flat surfaces with unshaded solar exposure area greater than 1,000m^2.

PV panels can be installed on the noise barriers or the roof of noise enclosures to generate renewable energy. In view of the high failure rate and maintenance demand of batteries, PV system with battery storage is not recommended. According to the abovementioned Technical Circular, PV system with electricity grid connection is preferred.

In general, road lighting operates at night-time only. The power generated in day-time by the PV system cannot be utilized efficiently by road lighting. The designer may consider connecting the PV system to other Electrical and Mechanical (E&M) systems with day-time electricity loads, such as subway lighting. In case the PV system is connected to the public lighting system, the designer shall submit to and seek approval from the Lighting Division, Highways Department, on the detailed design of the PV system.

When adopting PV panels in the design of noise barriers/enclosures, the PV panels should be unshaded from adjacent structures, buildings and trees to optimize sun exposure. The performance of PV panels would be influenced by their orientation and inclination. The designer should take them into account when considering the optimal location for the installation of PV panels.

The transparency of noise barriers/enclosures with PV panels should be considered by striking a balance between allowing sufficient sunlight to pass through for road safety and generating enough electricity. Typically, it is recommended that the PV panels should have at least 50% light transmittance. The designer should refer to the “Public Lighting Design Manual”, Development Bureau Technical Circular No. 2/2015 or other relevant technical document issued by the Electrical and Mechanical Services Department or the power companies when designing the PV system.

Frequent cleaning of PV panels should be conducted to avoid accumulation of dust which affects their performance. Self-cleaning coating can be applied on the surface to facilitate the cleaning purpose. Each PV panel should be of appropriate weight and size so that it can be easily handled or removed by maintenance workers with simple tools. Sufficient space should be provided for accommodating pillar box for PV system as well.

In order to ensure the operation safety of the PV system, the project offices should allow appropriate safety facilities and protection facilities to protect the electrical workers and the related electrical installations on the distribution system or the electricity grid under normal and emergency situations.

From past experience, it is difficult to maintain and replace the PV cell as the model of PV cell changes rapidly. The latest model is usually incompatible with the existing model. If replacement for one cell is required, the whole panel may need to be replaced due to incompatibility, which will result in a high maintenance cost. The designer should strike a balance between life cycle cost and energy saving when considering the adoption of PV panels on noise barriers/enclosures.

The maintenance and management responsibility for the PV system to the electricity grid should be clearly demarcated and seek agreement with relevant department(s) at the very early design stage. The designer should work out the maintenance matrix to identify the maintenance agents for the components of the PV system installations, such as PV panels, associated electrical installations and supporting structures.

3. Aesthetical Aspect

According to the Environmental Impact Assessment Ordinance (EIAO), direct technical remedy should be given wherever practicable to remedy or compensate for adverse noise conditions brought about by a new road scheme. The form of direct technical remedy represents any form of direct screening, which includes e.g. earth mounding, barriers and enclosures that can be incorporated into the road design.

This Guidelines intend to provide guidance on how the aesthetical impact brought by the roadside barriers could be minimised by the appropriate choice of the form and materials used. The noise barrier design proposal should be submitted to The Advisory Committee on the Appearance of Bridges and Associated Structures (ACABAS) for consideration of its aesthetic acceptability.

3.1. Overview

There is no dispute that the roadside barriers erected would protect residents living next to roads from excessive traffic noise. However, the roadside barriers itself could also affect the aesthetical perception of both road users and residents. In a broad sense, a new road scheme changes the visual quality of the area through which it runs as perceived by the people who live and visit the area. This is partly due to presence of the road and its structures and mainly because the road is man-made, and its alignments, materials, signs, lighting and traffic can be out of character with the rest of the landscape. Thus, the amount of visual intrusion of a road is dependent on the quality and type of landscape through which it runs.

The visual impact of roadside barriers on adjoining communities, as well as on motorists is a major consideration in the design of roadside barriers. A tall roadside barrier placed close to the low-rises could have severe visual effect as a tall barrier creates unwanted shadows and blocks panoramic views. On the motorist side of the barriers, the emphasis should be on the overall form of the barrier, its colour and texture. Small details will not be noticed at normal highway speeds. However, the emphasis should be on avoiding a tunnel effect through various forms, and visual treatment. Landscaping can be used effectively to accomplish this. It is always a challenge to design an aesthetically pleasant roadside barrier that can protect residents in the vicinity.

The cost-effectiveness of noise barriers should be extended beyond its acoustic performance-to-price ratio to include the long-term aesthetic interests. The design should find the most agreeable compromise between acoustic functionality, costs and aesthetics.

3.2. Elements to be Considered

3.2.1. Architectural

The appearance of barriers would be governed by the choice of the “form”, which can be regarded as “the broadly perceived shape of an object”. In view of the linear nature of the noise barrier, simple plan vertical shape appears to be monotonous and creates a wall effect. The visual quality can be enriched through manipulation of the linear form, such as segmentation, curving and articulation of the surface texture and colour.

The overall appearance of barriers could be further articulated through applying of architectural concepts such as scale, profile, proportion, balance, rhythm and repetition (not in any priority order). Such considerations are particularly useful where tall or extensive lengths of barriers are required in urban areas and where it may be desirable to break down the scale of an otherwise monolithic feature by using combination of contrasting materials. In laymen term, the concepts could generally be interpreted as: -

(a) Scale, Profile, Proportion and Balance

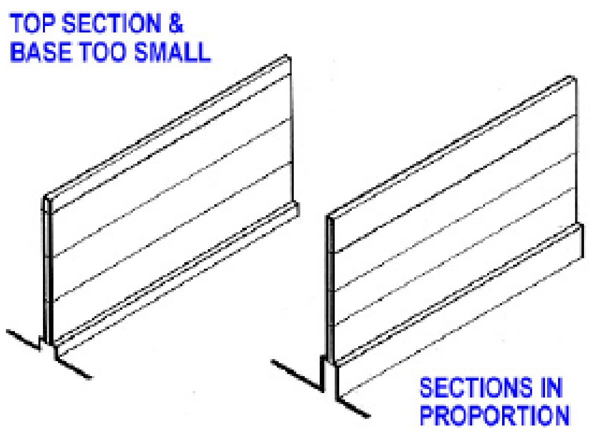
The scale of noise barriers is primarily determined by the noise source and position of noise sensitive receivers. The profile of barriers may vary considerably and is often an aspect that can be changed for the aesthetic effect. Curved or cantilevered barriers are generally slightly lower than vertical barriers, fulfilling the same noise mitigation function and having better acoustic properties.

Table 3.2.1(a) Recommendation on Architectural Design

Practices to Encourage	Practices to Discourage
• If space permits, step the barrier. This creates interest, limits reflection and if enough space exists it may create toe-planter space. • Support posts should be as thin as possible. • Emphasized posts (i.e. posts that are visually more prominent) may be used to break monotony. • Curved forms are visually more interesting.	• Avoid making every post an emphasized post. For visual interest, a hierarchy and rhythm can be created if posts are aesthetically emphasized at regular intervals. • Avoid vertical walls that impinge and dominate over pedestrians. • Emphasizing top edges are generally only applicable to solid walls to better articulate its form. With transparent panes, it is preferable not to emphasize the top edge, keeping it light and open.

Proportion is another critical part in the aesthetic design of noise barriers. Proportion refers to the relative size relationship between different elements of a noise barrier. Most significant is the relationship between the base, middle and top sections of a barrier. In general, the base needs to be viewed as a foundation that it should be thicker and shorter than the middle and top section. To have a better appearance of a barrier, the thickness of supporting columns should be minimized as much as possible, especially on a clear barrier, while always maintaining the necessary safety considerations.

Figure 3.2.1(a) Top, Middle and Base Proportions

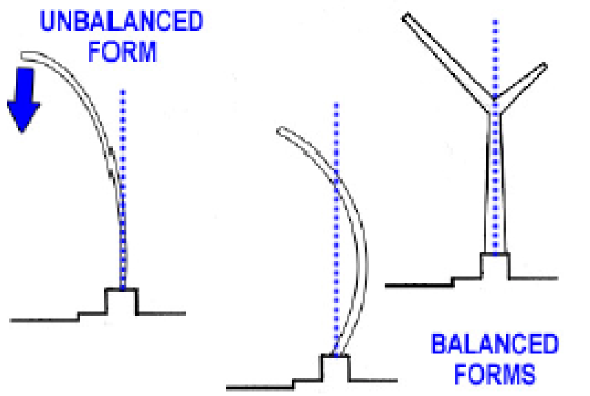


Top, middle and base properties

Short top section and large base

Balance refers to the visual weight of barriers around its axis which affects the appearance, especially for curved or cantilevered barriers.

Figure 3.2.1(b) Balanced and Unbalanced Forms



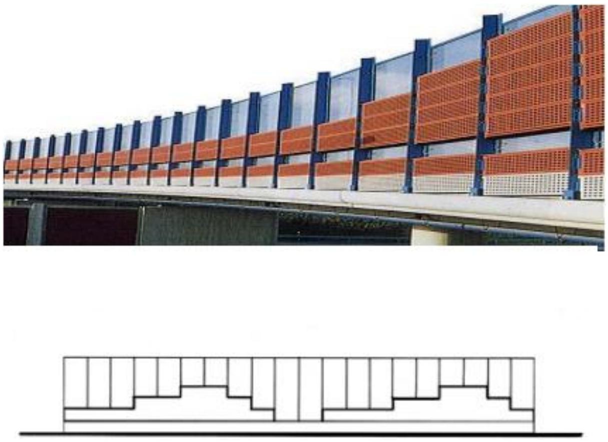
Balanced and unbalanced forms

Balanced road profile

(b) Rhythm and Repetition

Rhythm is an important design technique created by the repetition of design elements at various intervals. It adds an extra sense of harmony to simple repetition and creates a new level of interest for the viewers, especially for the visual receivers moving past at speed. In the aesthetic design of noise barriers, rhythm can be created by using the repetition of the barriers' columns. Emphasized columns may be adopted for this purpose.

Figure 3.2.1(c) Examples of Rhythm applied on Noise Barriers



Asymmetrical rhythm

Rhythm using splayed angles

Rhythm using colour

To reduce the visual impacts of barriers, it is often useful to design the solution appropriate to their locality. The linear barriers could either be broken down, for example, by using alternative solid and transparent panels, by using colour variations or plantation to soften the sharp edges of barriers. Therefore, designed solutions are preferable than mass produced barrier systems.

Table 3.2.1(b) Recommendation on Rhythm and Repetition

Practices to Encourage	Practices to Discourage
• Keep rhythm simple and easy to view at an appropriate scale. The scale of rhythm should be related to the speed of visual receivers moving past, i.e. the faster the speed, the longer the wavelength or frequency.	• Avoid to overdo the use of colours when creating rhythm.

3.2.2. Visual Impact

Barriers would no doubt affect the aesthetic perception of road users and people living there which to certain degree termed as visual impact. The fundamental is to design the barriers with appropriate scale and character compatible and matches with the local environment. If it is not possible to design a barrier that blends into the local environment, the aim should be to reflect some of its features such as materials, colours, textures and shapes, in a form of barriers which has aesthetic appeal, without being dominant in the field of view. Sometimes, transparent panels may be used to lighten the overall impact, either to create "windows" which partially restore views, or along the top section of a barrier to reduce its apparent height.

Table 3.2.2 Recommendation on Visual Interest

Practices to Encourage	Practices to Discourage
• Motifs can be added at a scale and position appropriate to all relevant viewers, such as pedestrians and drivers. • Motifs, patterns and line-work may be completely abstract or completely realistic. • Textural lines may run diagonally to remove reference to the long linear length of the barrier. Varying angles of diagonals may also be used to add even more interest.	• Textures and colours should not compete for attention. Gaudy colours may negate the effects of a refined textural finish. Colours, if any should be subdued if imprints are used. • Lines may be wavy or straight but nothing in-between. For visual appeal lines, they should not all be the same thickness – they should have some hierarchy of detail.

Figure 3.2.2 Application of Lines Pattern

3.2.3. Compatibility with Local Features

To some extent, local residents would tend to accept the barriers which have relationship with its surroundings and are compatible with the appearance of the adjacent neighbourhood.

As a general rule, the character of the neighbourhood should be looked into to provide a checklist of its distinguish elements. For example, in the urban context, the design of a barrier needs to capture something of the neighbourhood, such as the prevalence of a particular material or style in buildings; for a leafy suburb, a barrier incorporating planting might blend in more readily. Alternatively, the design of a barrier in the vicinity of a local point such as a group of high-rise blocks might best echo the visual dominance of that image. For the rural and new town situation, it is preferable to have a 'natural' form to harmonise the local vicinity. The use of earthworks and planting should be developed to create a visual impression which seems to preserve the rural.

Table 3.2.3 Recommendation on Increasing Compatibility with Local Features

Practices to Encourage	Practices to Discourage
• Noise Barriers adjacent to pedestrian activities should reflect a scale and level of articulation appropriate to these observers. • Local architectural, cultural or heritage theme should be referred to in noise barrier aesthetic design. • Adoption of visually recessive dark earth tones can be considered in a natural environment.	• New architectural theme is not recommended to an area that already has one. • Direct colours copying from the immediate environment is not recommended if they are too bold or gaudy or if transposed directly as a coloured transparent panel.

3.2.4. Coordination with Road Furniture

In general, priority of design should be given to the protected side since the purpose of a barrier is to protect the environment enjoyed by the people. However, the design of barriers must take into account the visual effects of the traffic sides, recognising their role as a backdrop to the motorists' view of the road.

Efforts would always be spent in the design of roads and bridges to ensure that their visual impact is acceptable. However, the visual unity is often spoiled by uncoordinated elements such as road signs, lighting columns, gantries, safety fences and parapets. The design of a roadside barrier should complement the engineering design of the road and therefore needs to be developed as part of an overall concept. Consideration of visual impact early on in the design process will help designers to avoid unnecessary conflicts. The designer should also take note of the compatibility of the rhythm of various elements along the road to determine the suitable module for the barrier.

There are several advantages to be gained from identifying a suitable module for a barrier that will help to coordinate it with other elements. As well as being cost effective in terms of installation and maintenance, the repetition of units can create a sense of order and harmony which is conducive to road safety.

Figure 3.2.4 Coordination with Street Furniture

Lighting attached to noise barrier

3.2.5. The Protected Side

A barrier can drastically change the outlook for residents, who in addition to a loss of view, may also suffer loss of daylight. A barrier is experienced by the residents as a feature which perhaps dominates the space, and such impact would remain unchanged unlike the impact of variable traffic volumes. A designer can provide a barrier which minimizes this potential intrusion by using attractive materials which display in plan and elevation. Planting incorporated within the barrier design will soften its overall impact by imparting a more natural character and relieving the monotony of a horizontal skyline.

3.2.6. The Road User's Side

The road user experiences a length of barrier for a very short space of time and will nearly always view the design at an oblique angle. The road user in general will perceive only a broad impression of the design, its pattern of colour and its contrast with the surroundings. The driver in particular will absorb a very limited amount of visual information because of vehicle speed and concern for other traffic on the road.

Barriers over 3 metres high substantially conceal the view of existing landmarks from the road, but they can also conceal visual clutter which might otherwise distract the attention of drivers. Where barriers are needed over considerable lengths in urban and semi-urban areas, their appearance should be designed to avoid monotony. Features which create a monotonous appearance are the unrelieved face of a barrier constructed from a single material, and a stark and unvaried horizontal top. Surveys of drivers in Holland have indicated that a view which is unchanging for 30 seconds is monotonous; this suggests that changes in design every half mile, or approximately 800 meters, are desirable for long barriers adjacent to a high speed road.

Variation in the type of barrier, changes in its longitudinal profile, and transparent panels over structures, will all act as visual signposts helping drivers to recognise where they are along the route. Changes should be introduced at natural "break points" and care should be taken to ensure that barriers complement or even enhance the road users' broad picture of the road.

3.2.7. The Impact of Tall Barriers

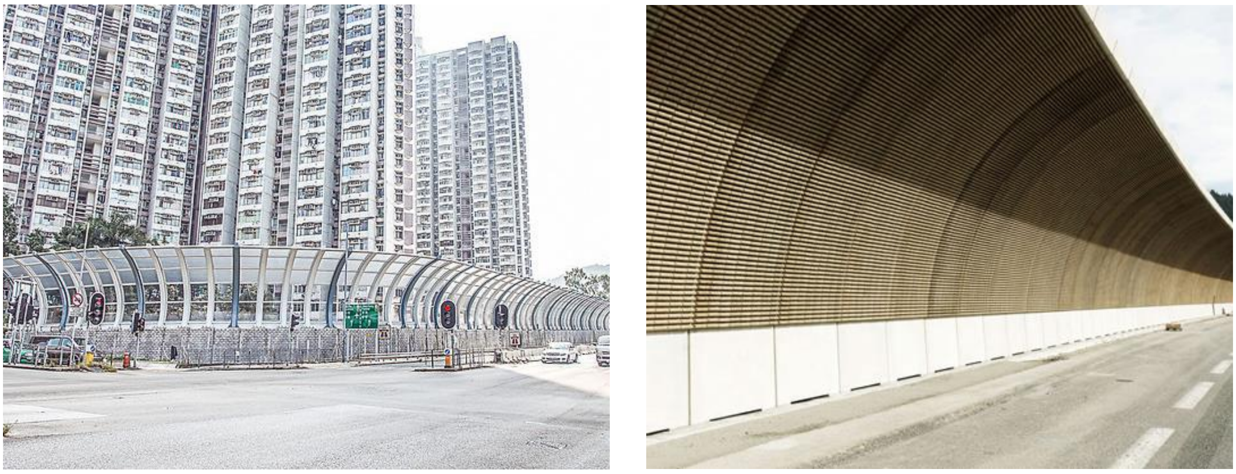
In urban areas in particular the Hong Kong situation, a straight barrier is often called to protect the high-rises next to roads. However, tall barriers tend to be out of scale and proportion to its surrounding and associated structures. The resulting vertical surface may in fact be visually more incompatible with an urban environment. A careful study of the areas requiring protection should be carried out to determine whether the barriers would be acceptable as a dominant feature in the protected area, or whether they should be subordinate to the existing townscape elements. It is always useful to include breaking down the scale of the barrier structures to fit the scale and character of the surroundings, as evidenced by the size and the appearance of the adjoining buildings and their component parts.

The scale of the barrier can be reduced by providing alternative solid and transparent panels and together with the introduction of set back or recessed panels, or by the arrangement of elements on the facade of the barrier, so that these component parts (such as the structural frame and the infill panels) would harmonise with the pattern of the surroundings. The sensitive choice of colours will also help to integrate the barrier with its setting. In some areas the barrier could take the form of a facade, as a new feature designed to enhance the character of townscape.

In some cases, a cantilever barrier is built instead of a very tall barrier. The cantilever barrier is one which cantilevers out towards and above the roads. Visually, it could minimise the impact as it would reduce the overall barrier height. However, a substantial section of materials must be avoided to protrude over the carriageway of the road. From residents' point of view, the cantilever barrier could diminish the impact on the viewer from outside because the top part curves away from the viewers and hence appears lighter. The top section should also be avoided to be seen as too substantive. Some good design could blend the cantilever with the scenic surroundings.

Figure 3.2.7 Examples of Cantilevered/Curved Barriers

Cantilevered Barriers



Curved Barriers

3.2.8. Use of Transparent Barriers

Where a barrier is required to provide noise protection to properties in close proximity to the highway there are likely to be adverse effects due to the loss of view, loss of daylight, and enclosure effects. The loss in the quality of the view and the need for light will need to be assessed for each property affected by a tall barrier alongside the road, and the design of the barrier should be adjusted to mitigate these adverse effects. Measures to be considered include the incorporation of transparent panels coordinated with the windows of properties behind the barrier.

Transparent barriers can also be used as a more general means of reducing the prominence of the barrier as perceived both from the protected side and from the new road. A reduction in impact can be achieved by incorporating transparent panels at regular intervals along the barrier, or by glazing the top part of the barrier (typically one-third of the height) to reduce its apparent height and dominance. When using transparent panels in noise barriers, specific pattern may be added onto the transparent panels to avoid bird collision. For instance, the "2 x 4" rule pattern that the horizontal stripe with a maximum spacing of 2 inches (50mm) or the vertical stripe with a maximum spacing of 4 inches (100mm) can be adopted. Colour of visual markers/stripes shall be provided as much contrast as possible.

Panel angling is an alternative method to avoid bird collision. The transparent panel can be angled at 20 to 40 degree from the vertical to reduce reflection from the sky and surrounding environment. The angled panel may also minimize the collision force to reduce the avian mortality.

Figure 3.2.8(a) Barriers with Transparent Panels

Figure 3.2.8(b) "2 x 4" Rule Pattern

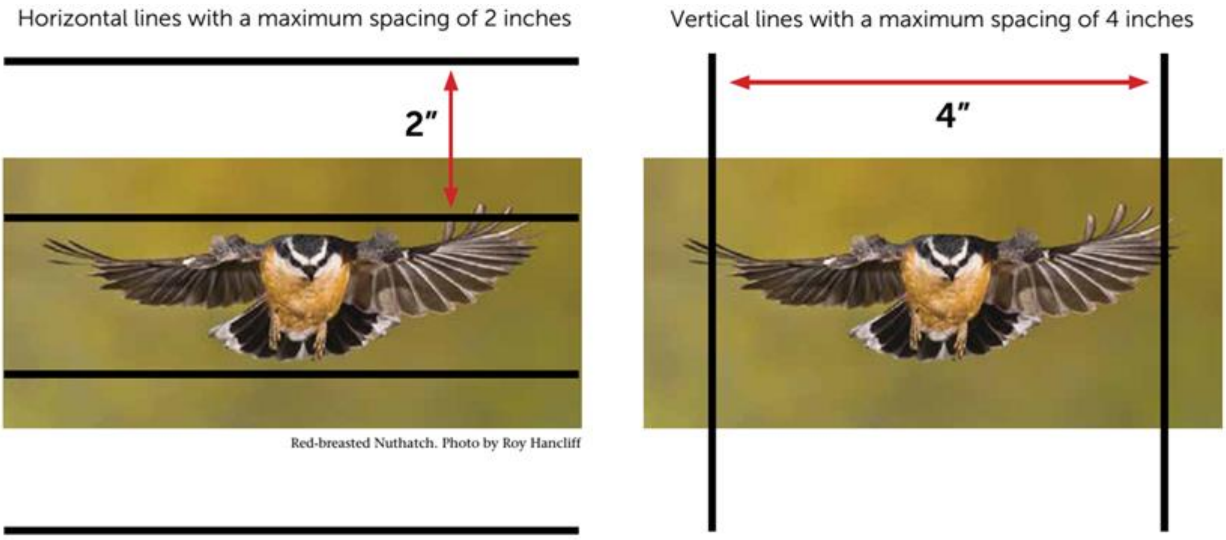


Figure 3.2.8(c) Example of Angled Noise Barrier Panel

3.2.9. Use of Colour and Material

Many barrier systems comprise acoustic panels which can be produced in a range of colours. It is of general consensus that the appearance of a barrier can be toned down to help it merge with its surroundings, or made to stand out as a striking and highly visible addition to the environment by the use of colour. The choice of material and colour should be compatible with the site context. For example, using cooler blue / grey shades at the top of a barrier and warmer brown green earth colours near planters to blend into natural environment settings, or using similar colour and appropriate proportion of material to echo with adjacent developments would help to reduce the monotonous looking. This variation in colour tends to reduce the apparent height of a tall barrier at the roadside. Colour graduation may be less effective at some distance, where the barrier appears in silhouette.

The local setting for the barrier should determine whether it is appropriate to add a splash of colour to an otherwise drab scene. The use of bright colours to create a feature should be careful. They are most effective when restricted to key parts of the barrier, for example, to emphasise its structural form. Large areas of strong colour on a barrier can result in an unpleasantly bright rather than attractive appearance. Also, use of shiny and clear surfaces can create a high-tech appearance. However, it should be taken into consideration from preventing reflection of undesirable light.

Table 3.2.4 Recommendation on Use of Colour and Material

Practices to Encourage	Practices to Discourage
• A variety of materials, especially between solid and clear materials, is preferable as it creates visual interest and may be read as different elements which help to break up the dominance of a tall barrier. • Valuable panoramic views should be preserved by using clear panels. Consideration should also be given to preserving a sense of privacy if the site requires it. • Curved surfaces or decorative etchings on clear panels can be adopted to minimize reflection of undesirable light. The design of curved surfaces or decorative etchings should be standardized to facilitate the repair or replacement of individual structure in future maintenance. • The choice of material and colour should be compatible with the site context.	• Coloured clear panels should generally not be adopted if viewed against the sky as these colours are made vibrant by light passing through. If viewed against the sky, upper panels should be clear. If the environment is dull or industrial like, then colours may add interest but this should be done with caution or by a professional designer. • Use of solid materials should be avoided if undesirable dark shadows are created or in the congested space since this may add to its sense of enclosure. • White, shiny or metallic colours should be avoided if barriers are in reflection of glare-causing positions.

Figure 3.2.9(a) Use of Colour and Material

Preservation of valuable panoramic views by using clear panels

Minimize reflection of undesirable light by using curved surfaces

Create a thematic design by using classic materials and colours

The use of contrasting materials

Figure 3.2.9(b) Typical Sun Angles and Reflections from Cantilevered and Enclosed Barriers

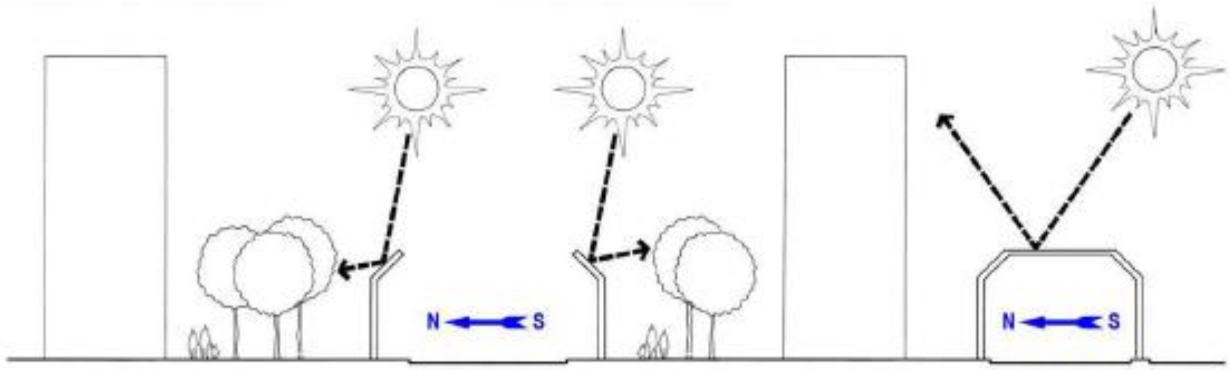
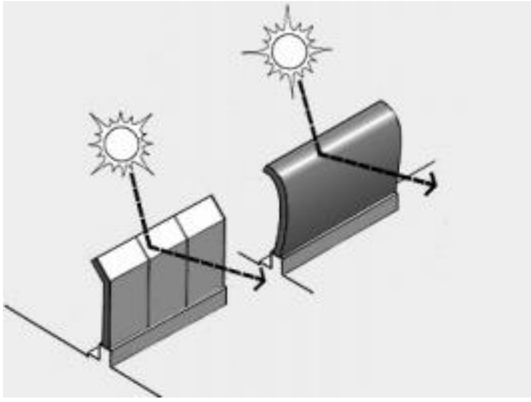


Figure 3.2.9(c) Light Reflection on Flat Surface and Curved Surface



3.2.10. Use of Vegetation

Planting can often be used to soften and enhance the appearance of a barrier, providing variation from season and in different daylight conditions. In view of the harsh roadside environment, the selected plant species shall be hardy and drought tolerant for long-term maintenance. The project proponents should refer to "Guidelines on Greening of Noise Barriers" issued by Greening, Landscape and Tree Management Section of Development Bureau for the design of greening on noise barriers to achieve the greening effect in a cost effective and sustainable manner with due considerations of the key aspects on "Effectiveness", "Maintenance", "Safety" and "Sustainability". Sufficient planting space shall be allowed for the sustainable growth of shrubs, climbers or appropriate plants. The project proponents shall ensure early consultation with relevant maintenance authority on the proposed vegetation and obtain the prior agreement before further processing the project proposals.

At-grade greening is preferable for its larger soil volume, better moisture retention and more available space for root growth. It is commonly adopted at roadside and/or central median in Hong Kong. When adopting at-grade greening, the underground structures or utilities near the greening zone should be identified to avoid any conflicts between the provision of at-grade greening and maintenance of underground structures or utilities. In addition, low-growing plant should be considered to ensure sufficient sightline to traffic due to the concern of safety. Safe access for maintenance should be provided as well.

In respect of vertical greening panels (e.g. small planting cups attached to vertically placed panels), as observed from the past trial installations of the vertical green panels on the noise barriers along footpaths and high-speed roads, it should be noted that there had been maintenance constraints which led to the unsatisfactory growing conditions of vegetation on the vertical greening panels as identified below:

(i) The small planting cups of the vertical greening panels hindered healthy plant growth in the long run;

(ii) the plants were prone to disease and fungal attack under the harsh and dusty environment (e.g. high-speed roads) leading to rotting of plants;

(iii) the difficulty of conducting maintenance works for vertical greening panels erected at higher level (e.g. 2 metres or more above ground level);

(iv) the need of implementing frequent temporary road closure for the horticultural maintenance works for vertical greening panels installed along carriageway; and

(v) the possibility of deterioration of the irrigation system under harsh environmental and the high maintenance effort required for inspection and maintenance.

The project proponents should only consider the use of vertical greening panels when they are satisfied that the proposal can satisfactorily overcome the above problems and meet the associated high maintenance commitment required for routine horticultural maintenance of the planting.

Figure 3.2.10(a) Examples of At-grade Greening

Figure 3.2.10(b) Examples of Vertical Greening

3.2.11. Modifications to Barrier Designs

Small variations in the alignment of the barrier, such as stepping or zig-zags, may have only a marginal effect on noise attenuation, and so they can be used to create a more attractive design, particularly on the protected side. They can also assist the establishment of planting to soften the appearance of the barrier.

Figure 3.2.11 Zig-zags Barrier

3.2.12. Noise Barriers on Road Structures

Some noise barriers may be located on the road structures such as bridges and viaducts. Space is limited and all elements add visual weight to an already bulky structure. Close-up pedestrian views are usually not common to barriers on elevated structures. Views of the bridges are often from a distance or from the road itself. In addition, if greening of noise barrier is adopted, adequate space for maintenance access, accessibility for plants and soil replacement, water pressure, pipe work and finding appropriate wind-tolerant plants should be considered.

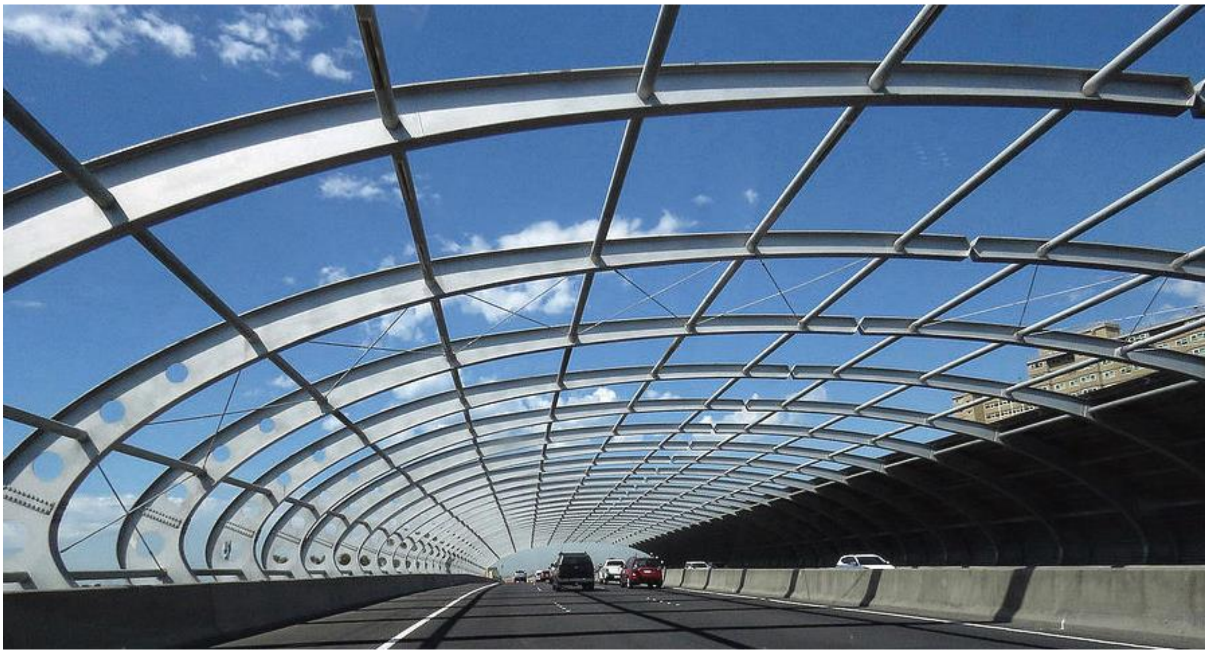
Table 3.2.5 Recommendation on Noise Barriers built on Road Structures

Practices to Encourage	Practices to Discourage
• Barriers built on structures should be designed as an integral part of the structure. The profile curves of the structure should be carried through into the barrier. • Colours should match the context or structure. Graded colours from dark at the bottom to light at the top may be used to reduce the barrier's scale and visual 'weight'. • Simple clean lines and avoidance of visual complexity and visual clutter.	• Barriers should not be seen as an appended element. • A new architecture or aesthetic, different to the elevated structure, should not be introduced.

Figure 3.2.12 Examples of Noise Barriers built on Road Structures

Simple noise barrier attachment

Colours used to accentuate the bridge



Parabolic shapes create a hi-tech thematic design

3.3. Approach

The following principles should form the basis of the first considerations for barrier designs: -

a) Barrier appearance should be considered initially from the view point of those living alongside the road. Barriers should as far as possible reflect the characters of the local neighbourhood and should preserve or even enhance the quality of the environment for local residents.

b) As far as possible, barriers should be designed so that it is not apparent to the road users or to those who live alongside the road that there is actually a barrier there.

c) Barriers from the motorists' view point should reflect the character of the locality through which the road passes in order to provide a sense of place. However, if extensive lengthy barriers are necessary, the designer should apply appropriate design concepts to add visual interest in order to avoid a monotonous appearance.

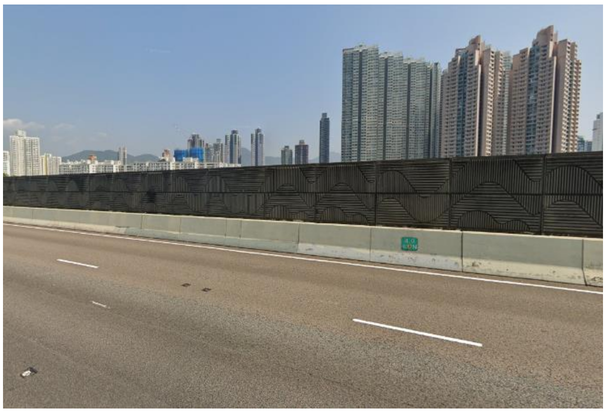
In general, the size of barriers will largely be determined by requirements for noise attenuation. Considerations of structural stability, safety and maintenance will also influence their appearance. However, this still leave a considerable amount of freedom to vary the form and finish to reflect the character of the neighbourhood through which the road passes. The use of materials and structural forms appropriate to the adjacent landscape and the application of architectural principles to the design of barriers will reduce their visual impacts.

3.4. Experience of Adopting Different Forms of Mitigation Measures in Local/Overseas Context

3.4.1. Straight Solid Barriers

Concrete or other solid materials could be used for short barriers. To reduce the visual impact, features or patterns could be added on the surface of barriers.

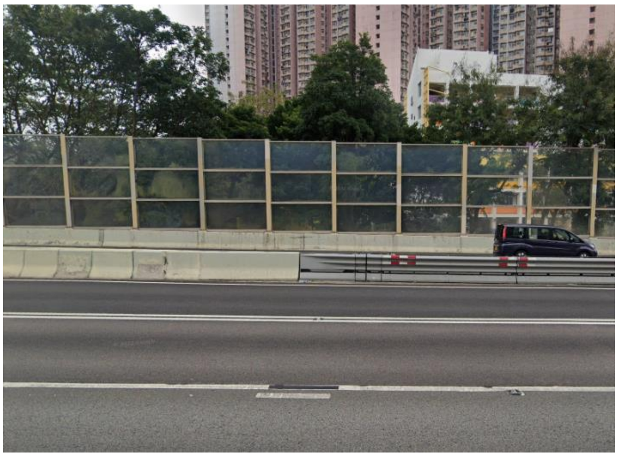
Figure 3.4.1 Examples of Straight Solid Barriers



3.4.2. Straight Barriers with Transparent Panel

For very tall barriers, it is useful to have transparent panels at the top to reduce the visual impact.

Figure 3.4.2 Straight Barriers with Transparent Panels



3.4.3. Barriers with Combination of Transparent Panels and Solid Panels

A combination of transparent and solid panel would lighten the visual impact and at the same time maintain the attractiveness by using colourful panels.

Figure 3.4.3 Transparent and Solid Panels

3.4.4. Semi-enclosure

To minimize visual impact, transparent panel should be considered on both sides.

Figure 3.4.4 Transparent Panel in Semi-enclosure

3.4.5. Earth Mound

An earth mound is an obvious solution to noise pollution in country side because it can be made to fit in with the landscape more naturally than any vertical structure, especially as it can support planting which greatly improves its appearance in most rural contexts. The amount of space which an earth mound requires is a major constraint as it requires more land than vertical barriers.

Figure 3.4.5 Example of Barrier Sitting on top of an Earth Mound

3.4.6. Vegetated Barriers

A number of 'green barrier' systems have been developed which use living plant material in conjunction with soil-filled supporting structures up to 4m high. In most cases, these need careful maintenance including irrigation in dry weather. If plants wither due to lack of water or disease, the barriers lose their visual appeal and may not be easily restored. In the longer term, well-established living barriers may need to be rebuilt if the planted material causes the supporting structure to deteriorate. Any consideration of this type of barrier should take into account of the appropriateness of the planted species to the locality and to their maintenance requirements.

Particular attention should be paid to the safety issue for carrying out maintenance works to vegetation adjacent to an expressway. Designers should consult and agree with Transport Department, Hong Kong Police Force, Highways Department and the landscape maintenance party early at the design stage on a particular arrangement for future maintenance.

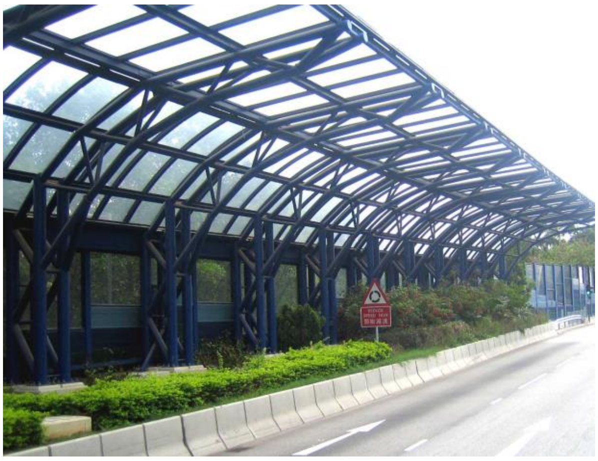
Figure 3.4.6 Vegetated Barrier

3.5. Examples to Enhance the Appearance of Noise Barriers

There are some examples of noise barriers in Hong Kong and overseas to help enhance the appearance of noise barriers.

Figure 3.5.1 Examples to Enhance Appearance of Noise Barriers/Enclosures

Noise barrier with fewer/without sub-frame at Island Eastern Corridor near Taikoo, Hong Kong



Noise barrier with greening at Castle Peak Road near Tsing Lung Road, Hong Kong

Noise enclosures with a curved and rippling design at Kai Tak, Hong Kong

Noise panel with a wide range of colours and shapes at Nahariya, Israel

4. Maintenance

4.1. Design Consideration

Noise barriers should be designed so that they require minimal maintenance other than cleaning. Concrete or masonry walls require little or no maintenance during the desirable service life of 40 years, but transparent sections need frequent cleaning and might well need replacing during their service life. Careful design can prevent the need for on-site modifications or other damage during construction that might considerably reduce the life of noise barriers. For example, hammering of panels for fitting into place could cause damage and should be prohibited. Therefore, design should be done carefully with due consideration of the practicability in construction. Plastic panels should incorporate resistance to the effects of ultra-violet light. Surfaces and joints should not include dirt or moisture traps or other details liable to cause rust staining. The effects of weathering on colour and of rainwash on accumulated surface grime should also be considered.

It may be necessary to provide access from the protected side for maintenance purposes and where there is a right of way for pedestrians or cyclists. This may render a barrier vulnerable to vandalism and the choice of form and materials should take this factor into account. It may be appropriate for pedestrian and cycle paths to be lit; where painted surfaces are required, polyamide based finishes will enable easier removal of graffiti. Materials for noise barriers should possess good fire retardant properties. Though there is no specific requirement of service life, noise barrier material manufacturer is, however, required to guarantee for at least 10 years on properties such as colour resistance, stone impact resistance, aging and corrosion resistance, light transmission, fire retardant properties etc.

4.2. Design Consideration

In order to minimize the need for maintenance, attention should be paid to the selection of materials used in the construction of noise barriers. The quality of materials used should be appropriate to the location. For example, barriers built in relatively inaccessible locations or in areas likely to be subject to extreme weather conditions will need more durable components than those which can be more easily maintained or are in relatively sheltered positions. Care should be taken over design details in order to eliminate possible moisture traps which would encourage rot or chemical attack. Alloy and metal fittings should be carefully selected to avoid differences in electrochemical potential which would accelerate corrosion. Plants selected for use in conjunction with a noise barrier should generally be of hardy species which require a low level of maintenance.

4.3. Cleaning

With the passage of time, barrier surfaces may become stained by contaminants such as water-splash from the road surface, airborne grime, bird droppings, honeydew or sap from overhanging trees. Concrete or masonry noise barriers may not need cleaning in certain locations as the surfaces would be washed by rainwater and their textured finish may control staining. Flat surfaces, however, will require regular cleaning as contamination will be more apparent and will detract from the appearance of the barrier. High pressure water jets mounted on purpose built tankers, or hand washing with brushes and low pressure water are suitable treatments.

The frequency of cleaning required will depend on the degree of contamination that occurs. Water splash contamination can be reduced by distancing the barrier from the edge of the carriageway, although this will have the drawback of reducing its effectiveness in attenuating the road traffic noise. Effective road surface drainage will also reduce splash effects by preventing puddles from forming. Bird dropping staining can be controlled by the use of design details or chemical repellents that deter birds from perching on the barrier. A very thin wire at a height of about 50mm along the top edge of the barrier will help to prevent birds from resting, thus control bird droppings. Trees and other overhanging vegetation may need trimming or cutting back to prevent abrasion and marking of the barrier. Transparent noise barriers will need to be cleaned more frequently than other types because they will show any contamination more readily or surface treatments can be used. Proprietary-made self-cleansing panels could also be considered where its use is justified.

Purpose-made vehicles fitted with water tanks, hoses, brushes and access platforms would reduce the cost of cleaning barriers but long lengths of barrier will be required to justify the necessary investment. In the short term, access platforms can be used to reach the far sides of barriers in order to carry out cleaning and other maintenance. Noise barriers erected near to the carriageway may require lane closures during maintenance; traffic management will be especially important for access to any barriers in the central reserve. Their use is not encouraged, but zero maintenance barriers (self-cleaning, impact resistant) would be appropriate in this location.

Similarly, it would be difficult to clean panels at the curved formed and the outside of noise barriers erected on high level structures, as such zero maintenance barriers should be used.

Self-cleaning coating can be applied on the surface of panel to facilitate the cleaning process and act as a special treatment to the surface of PMMA sheet to minimize the graffiti issue.

The cleaning performance of a self-cleaning panel depends on the availability of rainwater and it will be affected during dry season. For the aspect of economic design, the designer should consider the location of installing the self-cleaning panel to maximize its effectiveness. The long-term maintenance cost between general cleaning and coating replacement should be compared when considering the use of self-cleaning panel.

Trial test for self-cleaning panels have been conducted to demonstrate its performance. The designers may consult with the Highways Department for the information of the trial testing of self-cleaning panel if it is intended to adopt in the noise barrier project.

4.4. Other Maintenance Tasks

In addition to cleaning, other maintenance tasks include:

a) Tightening joints and fixings after initial construction. This should take place at the end of the construction maintenance period.

b) Painting or treatment of metal surfaces. This requirement can be reduced by using anodized aluminium, galvanized or weathering steel. But colours may need to be refreshed periodically if they are an important element in the design.

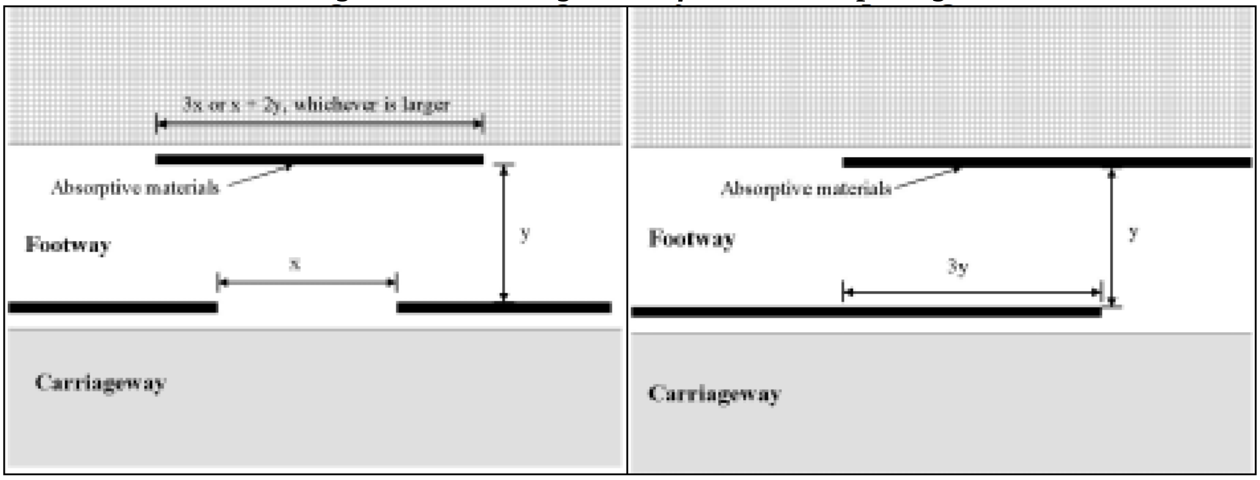
c) Periodic maintenance of planting - weeding, replacement of withered plants and, if necessary, watering to secure the proper establishment of the vegetation in the initial period, followed by periodic thinning, or pruning as necessary. (Barriers composed of living material retaining earth require a more intensive management regime.)

4.5. Access

The need for future maintenance should be taken into account when deciding on the form of a noise barrier. Safe maintenance accesses should be provided such that inspection and maintenance at touching distance could be achieved. Where it will need to be inspected from time to time, screen planting should be placed with sufficient space to permit easy access. Doors or gaps should be provided at reasonable intervals, say about 200m intervals to give access for the maintenance of both the noise barrier and any planting behind the noise barrier. Where possible, these access points should be located to provide access to any traffic control and communications equipment.

Where access point is to be provided for pedestrian but doors are not practical, then, another section of parallel barrier should be provided in front of the access point to avoid degradation of the acoustic performance. One face of this barrier should be provided with absorptive materials to avoid multiple reflections between parallel barriers. The length of this additional barrier should be at least several times of the width of the gap/opening (3x) or as a rough guide, x + 2y, where x is the width of the gap and y is the spacing of the two barriers, whichever is larger. See the figure below for different arrangements at the opening. The exact length required should be worked out during detailed design stage having considered standard acoustical principles and practices.

Figure 4.5.1 Arrangement of barriers at opening



Some locations such as bridges and viaducts might be inaccessible for maintenance of noise barrier. The use of specialized equipment might be necessitated to clean both sides of a transparent noise barrier panel. Working area will be required for erecting platform or parking of vehicle with hydraulic lifting platform that can reach both sides of the noise barrier for carrying out the maintenance works. Adequate working space for maintenance of all noise barriers shall be provided. In addition, the designer should take into account the temporary traffic arrangement (TTA) that might be required during the maintenance of noise barrier.

For noise enclosures, fixed access ladders can be provided for access to the roof for maintenance. Security guard/cover should be provided on ladders to prevent unauthorized access.

Figure 4.5.2 Access ladders on noise enclosure

If integrated structural form with cross beams is intended to connect the parallel noise barriers, maintenance access to the cross beams shall be provided as far as possible to avoid extensive road closure during maintenance. Such structural form may not be recommended at such locations in which future maintenance works would have major concerns on traffic impact due to temporary lane/road closure.

4.6. Safety

Working at height is always required for the inspection and maintenance of noise barrier /enclosure. Lifting platform is normally adopted for the maintenance of noise barrier and vertical panel of noise enclosure. If direct access to the roof of noise enclosure is needed for the maintenance of roof panel. Fall protection measures should be provided to ensure the safety of workers.

There are various types of fall protection measures such as guardrail system and fall arrest systems. The designer should determine the appropriate fall protection measures for noise enclosure. The designer may make reference to relevant design standards for the planning and design of fall protection measures.

Figure 4.6.1 Examples of fall protection measures

Guardrail system on noise enclosure

4.7. Vandalism and Graffiti

Vandalism and graffiti issues are the concerns in maintenance of noise barrier. In general, the design of noise barrier should prevent unauthorized access such as provisions of security mesh fences and vegetation. For anti-graffiti measures, adopting planting to shield the structural components and use of textured surfaces may be considered. Self-cleaning coating is another approach to facilitate the removal of graffiti from PMMA panel.

Figure 4.7.1 Graffiti issues on noise barrier

5. Checklist

The following are some of the points which should be considered when the Contractor's design is checked:

(i) The intensity for wind load and calculations for acoustic performance.

(ii) The quality of the materials proposed to be incorporated in the barrier, particularly those, if any, that are not included in the Material Specifications.

(iii) That the structural grades of materials used are in accordance with those quoted in the calculations.

(iv) The supply, transportation and storage of noise barrier materials. Workmanship, particularly any pre-installation treatment required and the method of fixing.

(v) That the acoustic properties are maintained by the avoidance of gaps, including gaps due to shrinkage or thermal movement.

(vi) Easy replacement of parts following accidental or wilful damage.

(vii) Security of components and nature of materials used to discourage wilful damage.

(viii) Maintenance access is provided at appropriate location.

5.1. Checklist of Significant Issues

Issues		Consideration
A. Effectiveness	A1.	Is there any opening or gap that would reduce the Transmission Loss?
	A2.	Is there any residual noise impact at the noise sensitive receivers?
	A3.	Will the presence of the structure reflect sound excessively?
	A4.	Is the size and alignment optimized for maximum noise benefit?
B. Structural Integrity	B1.	Can the design withstand design loading conditions?
	B2.	Is the probability of fallen parts from the structure minimized by design (e.g. by provision of catching or locking device to prevent fallen parts?)
	B3.	Is alternative structural form, high-strength material or other innovative technology could be adopted to improve cost-effectiveness?

Issues		Consideration
C. Compatibility with the Environment	C1.	Has visual impact been softened?
	C2.	Is the design compatible with the characteristics of its immediate environs?
	C3.	Can the structure be designed to create a positive identity for the neighbourhood?
	C4.	Is there space allowed for landscape planting?
	C5.	Is the module of the noise barrier compatible with the rhythm of other elements such as street lighting along the road or unit length of parapet of elevated structure?
	C6.	Is anti-bird collision facility provided if the transparent panels are adopted?
D. Maintenance	D1.	Is the material capable of providing a pleasant visual impression by regular maintenance?
	D2.	Is the design such that it facilitates maintenance, either by machine or by manual labour?
	D3.	How often will replacement of parts be necessary?
	D4.	Is there any special requirement for access?
	D5.	Has a practicable arrangement been agreed with all relevant parties for carrying out maintenance works to vegetated barriers?
	D6.	Have fall protection measures been provided to reduce the risk of falling from height?
E. Safety	E1.	Will the structure become a hazard upon a crash, or a fire by breaking into splinters or by producing toxic fumes?
	E2.	Is the design safe on traffic engineering grounds?
	E3.	Will the structure obstruct fire engine/emergency access?
	E4.	Has head-light glare been minimized?
F. Ventilation	F1.	If the structure is an enclosure (or semi-enclosure), has the capability of natural (or forced) ventilation been checked?
	F2.	If the structure is intended to serve other purposes, has the ventilation load been taken into account?

Issues		Consideration
	F3.	Is there sufficient space between the noise barrier and the building to enable natural/sufficient ventilation of the lower floors of the building behind the noise barrier?
G. Lighting	G1.	If the structure is an enclosure, have openings been provided at sidewalls and/or roof to allow daylight penetration in order to save energy cost?
	G2.	What would be the operation hours of artificial lighting and has it been taken into account in the design?
	G3.	If the structure is a vertical noise barrier, has recess or adequate space behind or in front of the barrier been allowed for the installation and maintenance of road lighting column?
	G4.	If the structure has a cantilever arm, will it affect the road lighting system?
H. Installation	H1.	Is light weight installation preferred?
	H2.	Will the method of installation bring about the least amount of traffic congestion?

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