Noise Barriers as an Abatement Strategy

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Received 26 September 2017; revised 22 February 2018; accepted 14 May 2018

An attempt has been made in the present work to propose a systematic design methodology for the acoustic design of noise barriers. The nomograph method for the design of the noise barrier is presented. The methodology has been applied on a site in an urban area of Patiala city. A noise reduction of 8.5 dB(A) can be achieved by the installation of the noise barrier. The height of the barrier calculated with the nomograph method has also been verified by using the Fresnel number approach and empirical charts. The proposed methodology can be used for the systematic design of noise barriers with acoustic considerations.

Keywords: Traffic Noise, Noise Barrier, Acoustic Barrier Design, Barrier Nomograph, Fresnel Number

Introduction

The world is witnessing an unrelenting increase in the number of vehicles on the roads, leading to a significant rise in the traffic noise levels. The high noise levels have been shown to affect the health and well-being of a considerable section of society, especially those living in close proximity of highways and urban roads. In order to reduce the adverse effects of high traffic noise levels, the different strategies that can be followed are: decreasing the noise at the source, attenuating the noise during propagation or providing protection at the receiver. This is generally termed as the source-path-receiver concept. The noise abatement strategies can relate to noise control at the source or receiver. Another approach is to place barriers in the path of propagation of sound waves, i.e. between the source and receiver. These noise barriers are mainly of two types: artificial and natural. The noise barriers have been considered to be a cost-effective method for noise abatement. In the present work, the issue of adhocism that is adopted while making the barriers with some hit and trial approach, especially in the Indian traffic scene, has been addressed. The barriers are generally constructed or installed, and then the attenuation is measured. Sometimes, even that measurement does not happen. So, a systematic and scientific procedure to design the noise barriers based on acoustic considerations is necessary. The presented approach addresses this aspect of the barrier design. The paper is structured as follows: first, the principle of working of a noise barrier and some of the acoustical design considerations are presented in section 2; then, the proposed methodology for the acoustic design of a noise barrier and its application to a real life urban traffic scenario is presented in section 3; results and discussion are given in section 4 and finally, the conclusion is presented in section 5.

Materials and methods

Principle of a noise barrier

There is a reduction in the noise level due to the obstruction provided by a barrier. When a barrier is placed between a source and a receiver, the incident sound waves are either reflected back or get transmitted through the barrier. Some of the sound also reaches the other side of the barrier by diffraction. The area behind the barrier is known as the shadow zone, as the sound waves are not able to reach there. But the effectiveness of the barrier keeps on decreasing as the distance of the source or the receiver from the barrier wall increases. Some acoustic terms associated with a noise barrier are given below:

- Insertion loss: It is the difference in the noise level (in dB(A)) with and without the barrier at

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the receiver location, the noise level at the source remaining the same.

- Transmission loss: The logarithm of the energy ratios in front of the barrier and behind it is termed as Transmission loss, and is expressed in dB. The transmission loss depends on the barrier material, its density and the frequency spectrum of the noise source.

- Thin barrier: A thin barrier is one which attenuates the noise level by a single diffraction, e.g. a solid wooden fence or a free-standing wall.

- Thick barrier: A thick barrier is one which attenuates noise level by double diffraction, e.g. a building. If the barrier thickness, say \( t \), is greater than 3 m, then the barrier is considered to be thick for noise of all frequencies. If \( t \) is less than 3 m, then the barrier is still considered thick for noise components whose wavelength is less than \( t/5 \).

- Fresnel number: It is a dimensionless number used to represent the attenuation provided by a noise barrier. For a thin barrier, it is expressed as:

\[
F = \frac{2d}{\lambda}
\]

where \( F \) = Fresnel number,

\[
d = (A + B) - D
\]

(\( A, B \) and \( D \) are the path lengths from the source to the receiver[4]) \( \lambda = \) wavelength of the sound wave (m). The Fresnel number for a thick barrier is calculated as follows:

\[
F = \frac{2d}{\lambda}
\]

where \( d = (A + t + B) - D \)

\( t = \) thickness of the barrier

### Materials used for noise barriers

The places where such barriers are not possible, e.g. near airports, alternative measures like insulation of buildings or houses done by using special materials in houses walls, roof etc. or using double paneled windows with special glass have been adopted. Such insulation has been done in schools, hospitals etc. in different parts of the world. Different materials are used for construction of the barriers like concrete, steel, aluminium, polycarbonate or acrylic sheets, acoustic panels, wood panels with rubber coatings, hollow walls of composite material filled with crump rubber etc. The solid barriers have been reported to be more effective as compared to vegetation belts or barriers with gaps like fences. While planning a barrier at a location with high noise level, there are different aspects that need to be looked into. The following points should be considered while selecting a barrier:

- Effectiveness of the barrier in terms of acoustic considerations (e.g. the insertion loss)
- Structural strength of the barrier to withstand different loads
- Cost of barrier (material, labour, construction/installation, repair, maintenance)
- Ease of construction and maintenance
- Visual appeal / aesthetics, compatibility with the architecture of the place, tradition and culture.

### Design considerations

The design of noise barriers needs consideration of both acoustic and non-acoustic aspects. The acoustic aspects include: material of barriers, shape and dimensions, location etc. The non-acoustic design considerations are also important. Some of them are: safety, maintainability, ease of access, structural strength, aesthetics and compatibility.

#### Acoustic design considerations

Acoustic design of a noise barrier implies calculating the height of a barrier based on acoustic considerations to achieve the desired attenuation at the receiver end, located at some distance. When a noise barrier is placed between source and receiver, the sound is reflected back or it is absorbed by the barrier material. The rest of the sound waves are transmitted through the barrier or they are diffracted from the top edge of the barrier and reach the receiver end but with a reduced acoustic energy. The noise also reaches the receiver through a diffracted path. The receiver is thus exposed to both the transmitted noise as well as the diffracted noise. As stated earlier, the transmitted noise depends on the barrier material and density, the diffracted noise depends on the barrier design, i.e. the shape, dimensions, location etc. The barriers are also classified on the basis of above discussions, as reflective type, absorptive type or a combination of both. When there is a noise-sensitive region on the opposite side of the barrier (on other side of the road), then reflective type barrier is avoided or a combination of reflective and absorptive type is used, so that the noise is not reflected back towards the other end.

#### Acoustic design of a noise barrier (Nomograph method)

Acoustic design of a noise barrier by the nomograph method implies calculating the height of
the barrier to attain the desired value of attenuation (in terms of dB(A)) at the receiver end located at some distance. In order to propose the methodology for the acoustic design of the noise barrier, the nomograph method has been used and is explained in this section. The procedure is valid for moderately high volume of freely flowing traffic on infinitely long, straight and level roadway. A site was identified on a busy urban road near a temple in the Patiala city having high traffic noise level (with $L_{eq}$ 75 dB(A)). The desired acceptable noise level at such sites as per the standards is 67 dB(A). Attenuation of around 8 dB(A) is therefore required. The temple has an existing boundary wall of 1.4 m height, 22.86 cm (9 inch) thickness and 17 m length with iron grills on top. If a noise barrier is continuous, free of cracks and holes, and fairly dense, then the noise energy transmitted through the barrier is likely to be insignificant when compared to the noise energy that reaches the other side of the barrier by diffraction. If the mass per unit area of the barrier exceeds 20 kg/m$^2$ then the sound transmission through a barrier is found to be negligible for a typical automotive traffic noise spectrum. A schematic diagram showing the dimensions of the road site is presented in Figure 1. A plan view of the proposed barrier is also given. It can be seen that the temple wall (17 m length line) is subtending an angle of 154° at the receiver location located inside the temple, assumed at a distance 2.0 m behind the wall. In this method, a nomograph given in Figure 2 has been used to find the barrier height. The different steps that are used in this nomograph method are described below:

- First, the desired attenuation is found by subtracting the existing traffic noise level at the site from the desirable/acceptable noise level for the category given in standards. In this standard chart/table the acceptable noise levels are defined for schools, hospitals, churches, libraries, residential areas, hotels etc.
- From this desired barrier attenuation (upper right portion of the nomograph, Figure 2), a vertical line is dropped up to the angle subtended curve.

![Figure 1](image)

**Fig.1 — Schematic diagram of the road segment near the temple site along with a plan view of the barrier**
A horizontal line is drawn from the above point to the pivot line, meeting the pivot line at point D.

Then a line is drawn from the L/S line (it is the ‘line of sight’ line, shown in Figure 3, obtained by joining the source to the receiver; the source is assumed at a height of 0.5 m from the ground, in the middle of the road, the receiver at a height of 1.2 m from the ground) to the point D (of previous step) and extended up to the Turn C line to meet at point C.
The corresponding point on the lower L/S line is joined with the ‘barrier position’ point (barrier position is the length TR in Figure 3) and extended up to Turn A, meeting at point A.

A vertical line is drawn from point A meeting the curve from point C at point E (shown in Figure 2).

From point E, a horizontal line is drawn up to Turn B to meet at point B.

The point B is connected to the corresponding point on the left L/S line, thus intersecting the barrier break line in a point. This is the required ‘barrier break’ value, which is further used to calculate the barrier height, using Figure 3.

The above procedure is illustrated below, with the actual measurements on the site. A line diagram showing the elevation view of the source, receiver and barrier is presented in Figure 3. The point S represents the source, assumed at a height equal to the exhaust level (generally 0.5 m). The point D is assumed to be in the middle of the road, i.e. the centre line of the meridian. The point R represents the receiver (behind the temple wall; RC is taken as 1.2 m above the ground). EF corresponds to the height of the barrier required, at the position of the existing temple boundary wall. The general steps for calculating the barrier height from given barrier attenuation from the nomograph (shown in Figure 2) are applied and illustrated below:

- Drop a vertical line from 8.5 dB(A) barrier attenuation (upper right portion of nomograph) point to the 154° subtended angle curve.
- (*8.5 dB(A) is the desired attenuation (75 dB(A) – 67 dB(A); an extra 0.5 dB(A) is added as a safety margin or to account for any error/s).

- From the above point (step 1), draw a horizontal line up to the pivot line, to intersect it in a point, say D.

- Join the point corresponding to 11.32 m on the right L/S line to the point D on the pivot line and extend it up to turn C to intersect in a point, say C.

- From the lower L/S line, join the 11.32 m point with the barrier position (P) and extend up to Turn A line in a point A.

- Draw a vertical line from point A to meet the contour line from point C. This point is named E.

- From E, draw a horizontal line to meet the Turn B line in point B.

Join the point corresponding to 11.32 m on the left L/S line to the point B. The point where this line intersects the ‘Barrier break in L/S’ line gives the value of ‘Barrier break’. The barrier break in the present case comes out to be 1.17 m (ET in Figure 3). It corresponds to a barrier height of 2.25 m. (The point E in Figure 3 can be found by drawing a locus line parallel to the line SR, at a distance equal to the barrier break value. The point where this line intersects the vertical line through F, is the point E. The value of EF can be measured, which is the required barrier height). Other dimensions are given in Figure 3. In the present case, the height of the temple boundary wall needs to be increased from 1.4 m (existing height) to 2.25 m to achieve the desired attenuation.

**Results and Discussion**

The methodology presented above can be used for systematically calculating the barrier height, with acoustic considerations. Another approach that can be used either to calculate the barrier height or to verify the height obtained by the above method, is the ‘Fresnel number’ approach. The details of Fresnel number have already been explained in the previous section. The application of the same in the present case is described below. The different dimensions of the source to receiver path lengths (with the assumption of a thin barrier) along with the calculations used for finding the value of the Fresnel number are presented below:

\[ A = 9.46 \text{ m}, \quad B = 2.26 \text{ m}, \quad D = 11.32 \text{ m} \]

\[ d = A + B - D = 9.46 \text{ m} + 2.26 \text{ m} - 11.32 \text{ m} = 0.40 \text{ m} \]

For a sound frequency of 500 Hz

\[ \lambda = 0.686 \text{ m} \]

\[ F = \frac{2d}{\lambda} = 1.16 \]

Now, the barrier attenuation that can be achieved corresponding to the above Fresnel number is looked up in an empirical chart. The attenuation that can be achieved for the given barrier, with the Fresnel number 1.16, lies between 9 dB(A) and 10 dB(A). A frequency of 500 Hz has been considered for the present calculation. The attenuation achieved is higher for higher frequencies, as can be observed from the formulas and the standard charts. So, it can be observed that the results obtained by both the methods (i.e. Nomograph and Fresnel number approach) are matching fairly well, and may be used
independently or simultaneously to gain a fair deal of confidence to get started with the initial design of the barrier with acoustic considerations. After ascertaining the height of the barrier, attention can be turned to decide the other design considerations like the barrier material, surface finish, aesthetics etc. The civil engineering design which also takes into consideration the load calculation and the composition of material which is required to construct the barrier wall can be further taken up. The construction of the barrier must ensure that it does not have any cracks or gaps and the surface mass is at least 10 kg/m². In the present work, the design of the noise barrier is limited to determining the height of barrier to achieve a desired attenuation based purely on acoustic considerations. The literature indicated the scope was limited to addressing the issue of ad hocism that is adopted while making the barriers with some hit and trial approach, especially in the Indian traffic scene. The barriers are generally constructed or installed, and then the attenuation is measured. Sometimes, this measurement is also not done. So, a systematic and scientific methodology, based on acoustic considerations, for the design of noise barriers is necessary. The presented approach addresses this aspect of the barrier design.

Conclusions

The application, different types and some of the basic acoustic design principles associated with traffic noise barriers have been presented in this work. A nomograph based approach for the design of a noise barrier with acoustic considerations has been given. The application of the same to a real urban traffic scenario has been presented. An attenuation of 8.5 dB(A) can be achieved with the proposed height of the noise barrier. The results have also been verified by using the Fresnel number approach and empirical charts. The presented approach can be used by civil engineers, acoustic engineers, academicians, researchers and other stakeholders. The limitation of the approach is that the construction of a barrier may not always be feasible due to space and other restrictions at the site. In such cases, other suitable options need to be explored.

Acknowledgement

The valuable comments of the reviewers which have helped in raising the standard of the paper are highly appreciated. All the support and resources offered by the Mechanical Engineering Department, Thapar Institute of Engineering and Technology, Patiala, are sincerely acknowledged.

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