AN APPROACH FOR DESIGN OF NOISE BARRIERS ON FLYOVERS IN URBAN AREAS IN INDIA

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Abstract: Transport is a significant, often major source of environmental pollution consisting of noise and air. Noise pollution has become a major concern for communities living in the vicinity of urban roads and major highway corridors. In view of increasing noise levels along highways it has become essential to reduce the intensity of noise to acceptable limit by constructing noise barrier. To study the existing noise levels in the urban areas due to movement of vehicles, the entire city of Lucknow has been divided in different zones on the basis of different land use. Effect of other factors like type of terrain, speed of traffic, cross section of roads and traffic composition has also been considered during noise data analysis. In this paper noise levels on the fly over in front of Engineering College (IET Lucknow UP India) has been taken for study and a noise barrier for this location has been designed for predicted noise levels worked out using modified FHWA model. This model makes use of traffic data like volume, speed composition, slope, ground cover etc. A program in EXCEL was developed to work out barrier height using traffic and road geometry data. The height of noise barrier to reduce the noise level from 63.79 db to 55 db was found as 4.2 meters above the floor level of flyover.

Key words: noise barrier, FHWA model.

1. Introduction

Due to increase in number of vehicles and rapid urbanization of cities, noise level exceeds the permissible value. For many years noise barriers have been erected along major arterials to screen residential areas from high levels of traffic noise. Noise barriers for reduction of noise levels could be warranted for certain portion of road network (Mohan et al., 2002). Noise barriers can have a substantial effect on the visual environment of a highway and its surrounding environment. They are long continuous structures, often more than 15 feet high, made of various materials. They can significantly change the view of the road by blocking view of the roadside and creating a monolithic uniformity of walls instead changing urban scenery. Nonetheless, noise barrier may be highly sought after by neighborhoods as a means to reduce roads noise level. There are several models available to predict nose levels due to moving vehicles, however in earlier studies conducted for Indian environment FHWA model had shown good results (Shukla et al., 2008). The noise levels used for designing were the predicted levels using FHWA model (Shukla et al., 2009).

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1.1. Noise Standards

The ambient noise standards being followed in India for different types of zones are given in Table 1 (CPCB, 1991), similarly the noise level standards for residential areas in India given in Table 2 (CPCB, 1991).

Table 1

Ambient Noise Standards (India)

Sl. No	Area	Leq dB (A)	
		Day Time	Night Time
1.	Industrial Area	75	70
2.	Commercial Areas	65	55
3.	Residential Area	55	45
4.	Silence Zone	50	40

Table 2

Noise Level Standards for Residential Area in India

Sl. No	Location	Acceptable Noise Level in dB (A)
1.	Rural	25-35
2.	Suburban	30-40
3.	Residential	35-45
4.	Urban (Residential and Business)	40-45
5.	City	45-50

1.2. Factors Affecting Traffic Noise

The level of traffic noise depends mainly on the following factors (Attenborough, 1982):

- The Volume of the traffic;
- The speed of the traffic;
- The number of heavy vehicles in the traffic stream.

Generally, the loudness of traffic noise is increased by heavier traffic volume, higher speeds and greater numbers of heavy vehicles. Vehicle noise is a combination of the noises produced by the engine, exhaust, and tyres. The loudness of traffic noise is also increased by defective mufflers or other faulty equipment on vehicles. Any condition (such as a steep incline) that causes heavy laboring of motor vehicle engines also increases traffic noise levels. Traffic noise levels are affected by distance, terrain, vegetation, natural and manmade obstacles. Traffic noise is not usually a serious problem for people who live more than 150 m away from heavily traveled freeways or more than 30 to 60 m from lightly traveled roads. The most common traffic noise descriptors are L_{10}, L_{50}, L_{90} and Leq. L_{10} gives indication of the top end of the level range although it can be substantially less than the occasional peak. L_{90} corresponds to the background noise level in the absence of nearby noise sources. Leq is the equivalent continuous sound level, which contains the same quantity of sound energy over a definite time period as the actual time varying sound level (Harris, 1979).

2. Issues Related to Barrier

Issues which need to be addressed in the noise barrier design include:

- Aesthetic: To provide an attractive noise barrier that is complementary to and enhances the surrounding community and provides an improved urban image;
- Cost: To provide a barrier that has a reasonable cost to build as well as to maintain;
- Effectiveness: To estimate acoustic effectiveness of noise barrier in reducing sound level;
- Maintenance: To minimize maintenance cost of the barrier and plant materials and to minimize graffiti and potential legal/ liability problem;

- Acceptability: To create a barrier system that can gain the enthusiastic support of the surrounding community as well as various political decision making groups.

2.1. Design Aspects of Noise Barriers

Noise barriers are normally designed to provide the reduction in noise levels to the tune of 15-dBA at the receptor. To produce an effective sound shadow, a noise barrier should be dense and close to the road. Such kind of barriers can be adopted for flyover located in residential/silence zone in different metropolitan cities in the country.

2.2. Acoustical Design of Noise Barrier Height

Barrier attenuation is predicted as a function of Fresnel number, Eq. (1):

$$N = \frac{2 \cdot (A + B - C)}{\lambda} \qquad (1)$$

Where:

N - Fresnel number
A+B - Path length over the barrier
C - Path length through the barrier
l - the wavelength of the sound radiated by the source given by Eq. (2):

$$\lambda = c \cdot T \qquad (2)$$

where,

c - speed of sound propagation in m/s and
T - time period in sec given as $1/f$,
where f is frequency in Hz.

It is possible to compute Fresnel number and barrier attenuation for each frequency band. The parameters A, B and C are shown in Fig. 1.

However to save time, an effective frequency of 550 Hz is used for all vehicles. At temperature 20 °C, the speed of sound C is given by Eq. (3):

$$C = 20.04 \cdot (T^\circ + 273.16) \cdot 0.5 = 20.04 \cdot (20 + 273.16) \cdot 0.5 = 343 \ m/s \qquad (3)$$
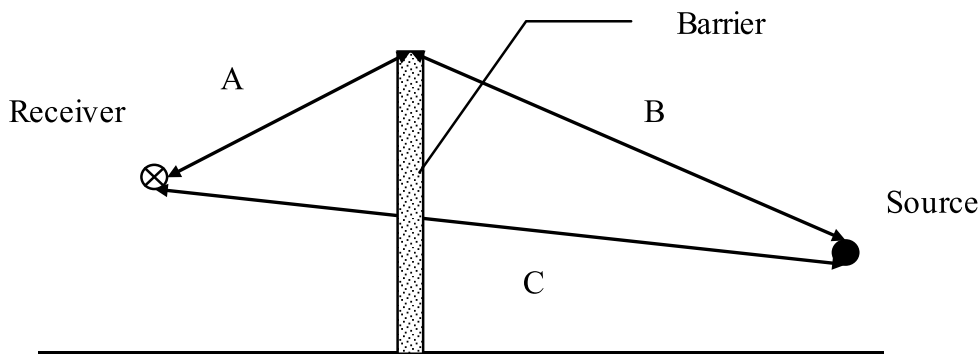
Fig. 1.
Geometry of Source, Barrier and Receiver to Establish the Barrier Attenuation

and the wavelength of sound at $f=500$ Hz is, Eq. (4):

$$\lambda = {}^{C}\!/_{f} = 343/550 = 0.624 \; m \, (4)$$

thus for $f=550$ Hz, we have Eq. (5):

$$N=2\cdot(A+B-C)/0.624 = \delta\cdot 3.21 \qquad (5)$$

$\delta=(A+B-C)$ - path length difference determined along the path defined by a particular source-barrier-receiver geometry.

For freestanding barriers where the Fresnel number is positive, the barrier attenuation is given by Eq. (6) and Eq. (7):

$$D = 10 \, log\left[\left(\frac{1}{\phi_R - \phi_L}\right)\left(\frac{1}{\sqrt{10}}\right)\int_{\phi_R}^{\phi_L} \frac{tanh^2\sqrt{2\pi N cos\phi}}{\pi N cos\phi}\, d\phi\right]$$

for $0 \leq \text{Ncos}\phi < 5.03$ $\qquad$ (6)

$$D=20 \text{ for Ncos}\phi > 5.03 \qquad (7)$$

The variation of the Fresnel number with corresponding barrier attenuation is plotted Fig. 2. It is clear from the plot that as the Fresnel number increases, the barrier attenuation increases. In Excel program the height of barrier is varied in steps and the barrier attenuation provided due to this height has been calculated. Finally the barrier adjustment is added to the existing Leq value of the noise to bring the noise level to the acceptable level.

3. Input Data Requirement

The program uses the following geometries to be entered in the dialog box:
- Source height above roadway (m);
- Distance from source to barrier (m);
- Distance from barrier to receptor (m);
- Left angle subtended by the barrier (radians);
- Right angle subtended by the barrier (radians);
- Height of barrier above road way (m);
- Receptor height with respect to road way (m).

4. Barrier Adjustment

The placement of obstruction between the highway and the observer will shield the observer and therefore lower the sound level. The barrier attenuation is computed by using an incoherent line source model for each vehicle type.

The noise reduction caused by barrier depends on two factors:
- The path difference of the sound wave as it travels over the barrier compared with direct transmission to the receiver;
- The frequency content of the noise.

Optical-diffraction theory has been applied to establish the sound attenuation loss caused by the presence of a straight solid wall.

Barrier adjustments for a given class vehicles are given by Eq. (8):

$$\Delta_{barrier} = \begin{cases} 0 & \text{for} \quad \text{Ncos}\phi < -0.1916 \\ 10 \, log\left[\left(\frac{1}{\phi_R - \phi_L}\right)\left(\frac{1}{\sqrt{10}}\right)\int_{\phi_L}^{\phi_R} \frac{tan^2\sqrt{2\pi|Ncos\phi|}}{2\pi|Ncos\phi|}\, d\phi\right] & \text{for} -0.1916 \leq \text{Ncos}\phi < 0 \\ 10 \, log\left[\left(\frac{1}{\phi - \phi}\right)\left(\frac{1}{\sqrt{10}}\right)\int_{\phi_L}^{\phi_R} \frac{tanh^2\sqrt{2\pi Ncos\phi}}{\pi Ncos\phi}\, d\phi\right] & \text{for} \quad 0 \leq \text{Ncos}\phi < 5.03 \\ 20 & \text{for} \quad \text{Ncos}\phi > 5.03 \end{cases}$$

where,

$\Delta_{barrier}$ - Barrier Adjustment
Φ_L - Angle measured from the perpendicular to the left ends of the barrier in radians;
Φ_R - Angle measured from the perpendicular to the right ends of the barrier in radians.

5. Design of Barrier for Location at Engineering College (IET Lucknow)

5.1. Site Details

A flyover on a railway crossing was constructed in the year 2006 connecting NH 24 (Lucknow Sitapur road) to NH 28 (Lucknow Faizabad road) on ring road (now named as NH 24 A). Institute of Engineering & Technology (IET) is located close to this bridge. The site is without any traffic control device. At the end of this bridge there is a four legged intersection distributing traffic towards NH 28 and residential areas of Aliganj and Jankipuram carrying heavy traffic. A field study regarding the land use, traffic volume, traffic speed and other features around the bridge was carried out to determine the height of proposed noise barrier for construction in future to bring down the noise levels under the permissible limits. The traffic volume study was done categorizing the vehicles in seven different classes as under given in Table 3 below.

Table 3
Identified Vehicle Categories for Study at Engineering College (IET Lucknow) Flyover

Sl. No	Vehicle Categories
1.	Car/Jeep/Van
2.	Mini Bus/Mini truck
3.	Bus
4.	2-Wheeler
5.	Truck
6.	Tractor/Trailor
7.	3-Wheeler

Traffic volume count data collected for both directions as given in Table 4 and 5, similarly classified traffic speed count data collected for both directions is given in Table 6 and 7.
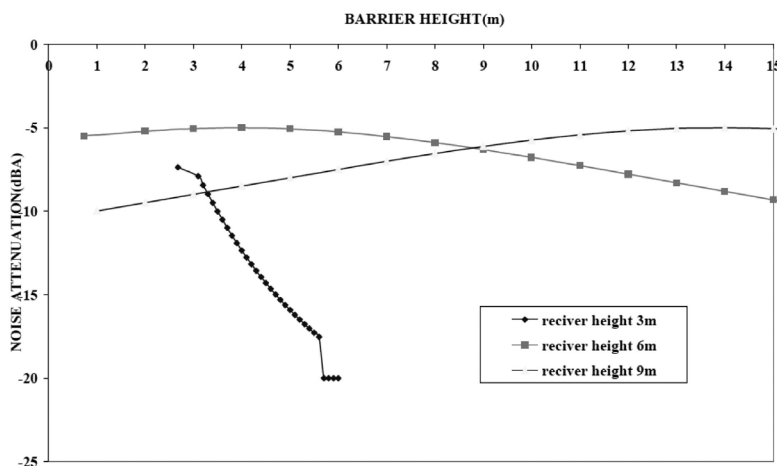
Fig. 2.
Barrier Height and Noise Attenuation for Receiver at Different Heights

Table 4
Traffic Volume (veh/h) at Engineering College (IET) Flyover Direction 1

Time	Car/Jeep	2-Wheeler	Mini Bus/ Mini Truck	Bus	Truck	3-Wheeler	Tractor/ Trailor
8.00-9.00	85	210	23	2	56	45	10
9.00-10.00	87	275	20	1	62	56	11
10.00-11.00	111	199	19	4	66	54	9
11.00-12.00	151	205	22	3	67	65	12
12.00-13.00	170	188	23	8	81	34	12
13.00-14.00	159	199	29	3	75	76	10
14.00-15.00	110	201	30	3	77	78	12
15.00-16.00	150	212	18	6	72	98	6
16.00-17.00	177	245	24	8	70	102	11
17.00-18.00	200	269	28	5	78	65	3
18.00-19.00	234	254	42	8	120	145	10
19.00-20.00	240	301	45	3	186	56	12

Table 5
Traffic Volume (veh/h) at Engineering College (IET) Flyover Direction 2

Time	Car/Jeep	2-Wheeler	Mini Bus/ Mini Truck	Bus	Truck	3-Wheeler	Tractor/ Trailor
8.00-9.00	112	117	23	4	48	88	8
9.00-10.00	120	200	30	5	54	46	6
10.00-11.00	145	211	24	12	53	34	10
11.00-12.00	140	345	85	12	158	48	8
12.00-13.00	155	345	74	24	90	71	7
13.00-14.00	95	212	33	9	51	67	13
14.00-15.00	110	300	67	14	39	89	9
15.00-16.00	95	234	78	23	30	45	13
16.00-17.00	70	212	63	30	87	34	13
17.00-18.00	50	212	91	9	78	54	1
18.00-19.00	85	213	83	18	40	67	11
19.00-20.00	191	256	122	30	94	45	13

Table 6
Traffic Speed (km/h) at Engineering College (IET) Flyover Direction 1

Time	Car/Jeep	Mini bus	Truck	Bus	2-Wheeler	3-Wheeler	Tractor/Trailor
8.00-9.00	43.23	37.5	32.63	40.6	33.63	31.32	19.5
9.00-10.00	40.81	36.75	30.13	38	30.56	27.33	18.7
10.00-11.00	41.62	30.41	34.52	40.12	31.6	29.46	20.53
11.00-12.00	40.51	33.16	32.21	33.77	31.76	32.56	19.76
12.00-13.00	44.85	32.53	30.21	35.46	32.89	28.26	18.53
13.00-14.00	44.89	40.5	32.6	43.5	33.73	29.23	21.74
14.00-15.00	45.53	40.41	30.1	40.6	30.15	24.25	22.3
15.00-16.00	40.46	34.75	33.12	31.25	32.26	33.55	23.5
16.00-17.00	40.61	31.6	32.45	32.43	36.55	33.7	20.7
17.00-18.00	41.7	32.7	33.45	32.3	32.2	30.96	21.37
18.00-19.00	42.5	31.7	30.6	31.6	32.9	31.16	22.65
19.00-20.00	50.0	33.6	32.6	40.1	29.9	30.33	23.67

Table 7
Traffic Speed (km/h) at Engineering College (IET) Flyover Direction 2

Time	Car/Jeep	2-Wheeler	Mini Bus/Mini Truck	Bus	Truck	3-Wheeler	Tractor/Trailor
8.00-9.00	43.23	41.23	32.45	33.43	40.21	31.24	18.23
9.00-10.00	41.22	33.56	37.23	32.53	34.59	31.36	20.5
10.00-11.00	35.78	32.7	28.00	25.25	33.5	30.73	22.32
11.00-12.00	31.21	3152	32.4	31.22	31.62	30.32	16.7
12.00-13.00	39.13	34.27	30.67	31.00	30.17	31.15	21.51
13.00-14.00	37.52	32.58	30.59	43.66	31.26	30.35	19-67
14.00-15.00	32.6	33.44	43.8	33.5	30.82	31.45	18.72
15.00-16.00	34.42	33.42	32.81	32.23	30.66	20.4	21.57
16.00-17.00	36.25	31.00	30.00	30.25	30.75	26.88	22.1
17.00-18.00	35.23	36.64	34.42	29.62	32.46	28.42	18.93
18.00-19.00	41.38	33.93	31.00	34.3	30.1	27.5	17.81
19.00-20.00	38.56	36.23	31.2	34.89	32.56	31.56	22.53

5.2. Land Use

This location is in residential zone.

5.3. Site Geometry

Geometric data collected from site and its layout with the proposed flyover is presented in Fig. 3.

For calculating the height of noise barrier input data was entered in designed Excel sheet and hourly Leq for 12 hr data was calculated. Leq values calculated at Engineering College (IET) at both the receptors are shown in Table 8.

Knowing hourly Leq values the appropriate height of barrier was determined by trial and error method.

From the program developed the height of barrier above the pavement is calculated as 4.2 m.

6. Conclusion

The paper analyzed the existing noise levels in the urban areas due to movement of vehicles. Therefore, the entire city of Lucknow has been divided in different zones on the basis of different land use. Effect of other factors like type of terrain, speed of traffic, cross section of roads and traffic composition has also been considered during noise data analysis. In this paper noise levels on the fly over in front of Engineering college (IET Lucknow UP India) has been taken for study and a noise barrier for this location has been designed for predicted noise levels worked
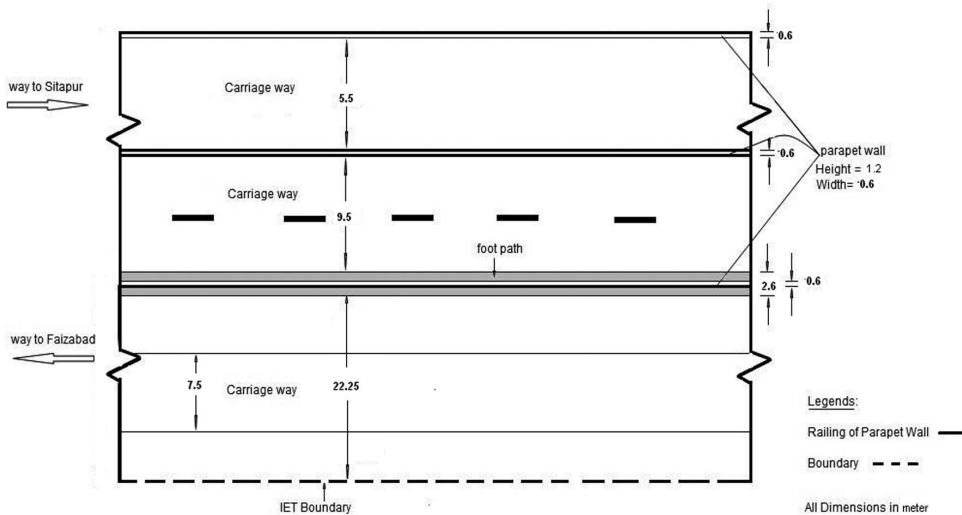
CROSS SECTION SHOWING DETAILS OF FLY-OVER ON NH-24 (at Engineering College IET Lucknow)

Fig. 3.
Existing Flyover Geometry

Table 8
Calculated Values of Leq for Design of Barrier at Engineering College (IET Lucknow)

Time (Hrs.)	Noise Level (L_{eq}) dB (A)	
	Direction 1	Direction 2
7:00-8:00 AM	75.47	73.8
8:00-9:00	76.27	72.99
9:00-10:00	77.68	69.88
10:00-11:00	76.97	72.52
11:00-12:00	77.12	74.19
12:00-1:00 PM	76.62	72.44
1:00-2:00	76.75	72.45
2:00-3:00	76.14	73.66
3:00-4:00	76.19	75.69
4:00-5:00	75.68	74.58
5:00-6:00	75.16	75.31
6:00-7:00	76.23	76.05
7:00-8:00	75.45	75.8

out using modified FHWA model. This model makes use of traffic data like volume, speed composition, slope, ground cover etc. A program in EXCEL was developed to work out barrier height using traffic and road geometry data. The height of noise barrier to reduce the noise level from 63.79 db to 55 db was found as 4.2 meters above the floor level of flyover.

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PRISTUP PROJEKTOVANJU OGRADA ZA ZAŠTITU OD BUKE NA NADVOŽNJACIMA U GRADSKIM SREDINAMA U INDIJI

Arvind Kumar Shukla

Sažetak: Saobraćaj je značajan, često glavni uzročnik komunalne buke i zagađenja vazduha. Pitanje komunalne buke je od velike važnosti za zajednice koje žive u blizini gradskih saobraćajnica i glavnih koridora. S obzirom na porast nivoa buke duž auto-puteva od suštinskog značaja je smanjenje intenziteta buke na prihvatljiv nivo izgradnjom ograda za zaštitu od buke. Za potrebe ispitivanja postojećeg nivoa buke koju generišu vozila u gradskim sredinama, grad Laknau je podeljen na više zona prema prostornom planu grada. U radu su analizirani i drugi faktori: tip terena, brzina saobraćaja na deonicama, poprečni presek puteva i tip vozila u saobraćaju. U ovom radu, predmet proučavanja je stepen buke na nadvožnjaku ispred Engineering College u Lankau, a ograda za zaštitu od buke na ovoj lokaciji projektovana je u odnosu na predviđene nivoe buke ustanovljene primenom modifikovanog FHWA modela. Ovaj model koristi saobraćajne podatke kao što su intenzitet, slaganje brzina, nagib, pokrivenost terena niskim rastućim biljem, itd. Razvijen je program u Excel-u kojim se definiše visina ograde na osnovu ulaznih saobraćajnih parametara, kao i geometrijskih karakteristika drumske saobraćajnice. Na osnovu dobijenih rezultata, utvrđeno je da visina ograde na kojoj bi se stepen buke smanjio sa 63,79db na 55db iznosi 4,2m iznad podnog nivoa nadvožnjaka.

Ključne reči: ograda za zaštitu od buke, FHWA model.