CETRA$^{2010}$ 17–18 May 2010, Opatija, Croatia
First International Conference on Road and Rail Infrastructure

# TRAFFIC NOISE CONTROL USING SOUND BARRIERS

**Ivan Bolkovac, Marko Horvat, Hrvoje Domitrović**
*University of Zagreb, Faculty of electrical engineering and computing, Zagreb, Croatia*

## Abstract

Traffic noise is one of the main elements that contribute more and more to noise pollution of the environment due to the increasing growth of traffic intensity. As a result, the need has arisen to increase the level of protection from this noise for both the people and the environment in areas located in the vicinity of the most frequent routes such as highways and major city streets. Various methods of noise protection can be applied, e.g. the displacement of roads, which can be difficult to implement, or the construction of physical barriers. There are several types of physical barriers, such as sound barriers, embankments, green belts, etc. and the choice of the appropriate type is guided with factors like location, size, acoustic properties (absorption and reflection coefficient), resistance to external influences (waterproofness, stability at high speed winds, temperature changes, etc.), cost effectiveness, ease and speed of construction and also aesthetics. The main advantage of sound barriers is a high level of protection that can be achieved at a minimum cost in a short time through appropriate design and choice of materials required for construction. Various types of sound barriers are available and can be placed in different ways, depending on the fore mentioned factors. In this paper we will show different types of sound barriers and various ways of setting them for particular situations. The construction of a real sound barrier will be presented.

## 1 Introduction

Modern residents are faced with an ever increasing number of vehicles and traffic volume in the immediate vicinity of their homes, and as a consequence of this trend ever increasing noise pollution levels. Noise created by increasing traffic has an impact on the psycho-physical condition of a man, and thus his health and everyday life. Value of the annual increase of noise levels by about 1dB at year/20 [1] is of particular concern. The aim of this paper is to draw attention to this growing problem and emphasize the means to mitigate the problem since it can not be solved completely - abolishing modern transport is not possible.

### 1.1 Noise

The noise is, by definition, any sound effect that interferes with man's work or rest, hence, noise is any unwanted sound. To make sound be declared as noise, it must have sufficient intensity, must be isolated from other sounds, and sufficiently audible. In certain conditions, however, a relatively quiet sound can be declared as noise if it interferes with man's activities. Although noise is a subjective category, there is an agreement on the vast majority of cases about which sound stimuli can be classified as noise. Noise sources can be natural or artificial [2]. While natural resources can generate very intense noise, their impact on the general population is usually not studied as much as numerous man-made noise sources, mainly concentrated in urban areas. The latter category definitely includes the noise of traffic.

## 1.2 Noise effects on humans

Numerous studies have shown that the noise has an extremely negative impact on the humans [2]. It is scientifically proven that noise causes a variety of psychosomatic disorders depending on the intensity and length of exposure to noise:

- noise to 50 dBA interrupts sleep;
- up to 60 dBA causes smaller psychological disturbance;
- 60 to 90 dBA causes severe psychological and neurovegetative disturbances, increase in blood pressure, rapid breathing, increases in the number of red blood cells and disturbances in the regulation of blood sugar;
- above 90 dBA causes hearing damage;
- above 120 dBA causes pain.

## 1.3 Traffic noise

Today's traffic is necessary for the functioning of society, so the public often close their eyes to the undeniable harmful effects that it causes - one of them is noise pollution. Traffic is very complex because the source of the noise depends on a variety of factors: the number and type of vehicles, their speed, road surfaces, engine type, weather conditions etc. Traffic noise is particularly pronounced near the routes with higher traffic frequency. Regardless of the size of the vehicle, the sources of traffic noise can be divided into several categories [1]

- engine noise (depending on the type of motor, rpm and load)
- intake system noise (depending on engine type, mode, load and speed, type of air filter and dampener)
- exhaust system noise (depending on pressure in the cylinders and the diameter of the valve)
- fan noise (depending on the cooling system and how it is set)
- tire noise (depending on the road surface, construction of the tire and vehicle speed)

With modern cars engine noise and intake/exhaust noise are significantly reduced compared to previous generations, but there is an increase in tire noise due to different mixtures of tire rubber as well as harsher pavement surface (because of safety) [1]. The influence of individual components also depends on vehicle speed and tire noise is more dominant at greater speed. Average noise levels for certain motor vehicles are:

- 70 dBA for cars
- 85 dBA for trucks
- 90 dBA for motorcycles, trams and trains
- 100 dBA for small aircraft
- 120 dBA for large aircraft

According to the American standard, OSHA 1910.95: Occupational Noise Exposure Standard (U.S. Department of Labor) from 1995 the majority of traffic vehicles are above the value specified as safety limit for 8-hour exposure to noise.

## 1.4 Traffic noise mitigation options

There are several noise mitigation options as described below [3]:

- Distance
- Tunnel/cut and cover
- Cutting
- False cuttings/earth mounds
- Barriers – bio barriers/vertical/cantilevered
- Combined solution
- Quiet surface (porous asphalt/whisper concrete)
- Insulating

In this paper the emphasis is put on sound barriers, or to be more specific, absorbant sound barriers.

## 2 Sound barriers

Sound barriers are purpose made obstacles that are placed in and around areas that must be protected from traffic (or any other kind of) noise. They can be of various types, design and materials depending on the objective that needs to be achieved. There are several assesments that influence noise barrier design [3]: acoustic assesment, landscape assessment and asessment of visual intrusion. The combination of these factors (as well as some others including, but not limited to, climate, safety, etc.) determins the final solution chosen. Although acoustic properties of the barrier are the most important factor one must not ignore the other two because ot their impact on the enviroment they must be adopted to that enviroment [3]. If this is not the case adverse effects can be a result. When the wrong type of barrier is constructed , which degrades landscape character and diminishes landscape quality it will inspire local animosity, and where this is allowed to happen the public's perception of any acoustic benefit is noticeably reduced [3].

### 2.1 Acoustic properties of sound barriers

### 2.1.1 Insertion loss

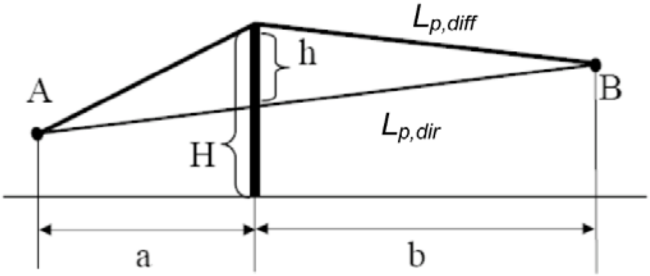

**Figure 1** Direct and difracted sound path beyond the barrier

If A is source of the noise (i.e. a car), B is the reciever, H is the barrier height, $\lambda$ is the wavelength of sound, $L_{p,dir}$ is direct ray towards B and $L_{p,diff}$ is diffracted ray towards B then we can define Fresnel number N as:

$$N = 2\frac{L_{p,diff} - L_{p,dir}}{\lambda} \tag{1}$$

In that case insertion loss (IL) can be calculated as in (2) and (3) depending on the value of N [3].

$$IL = 5 + 20\log\frac{\sqrt{2\pi N}}{\tanh\sqrt{2\pi N}} (dB) \text{ for } -0.2 < N < 12.5 \tag{2}$$

$$IL = 24(dB) \text{ for } N > 12.5 \tag{3}$$

The above formulas only applies to single vehicles at their closest point to the reciever and more complex expressions are available to describe the performance of a barrier for a stream of traffic [3].

### 2.1.2 Reflective vs absorbant barriers

The two main types of sound barriers are absorptive and reflective type (they can be used in combination). Allthough both type of barriers usually have sufficient direct transit sound attenuation the main difference is what is happening with the sound energy that is entering the barrier. In reflective barriers this energy is reflected at the appropriate angle while at the absorbant barriers this energy is dissipated in the absorbent material. This difference has implications on barrier construction and placement. Combination of this two types can be used to circumvent their limitations and achieve optimal solution.

## 2.2 Barrier placement

For the optimum performance of the sound barrier it is desireable to place it as close to the source of the noise (in this case, road), as possible. This is true if both reciever and source are at the same level or if the source is elevated (i.e. on a viaduct) [3]. This is not valid if the source (road) is in a cutting or where a raised landform separates them. Here, the barrier is best placed at the top of the cutting slope [3]. In case of multiple lane roads or highways it can happen that the height of the barrier is not sufficient enough because of the distance between the barrier and the farthest lane. If that is the case special care must be taken and the best and most efficient solution selected since just increasing the height of the barrier will have limited effects [3]. It should be noted that the type of the barrier will aslo influence positioning. In case of reflective barriers one must take special attention to the direction of the reflected sound since it can have a negative impact on the barrier performance. One solution is to put the barriers at an appropriate angle to the incident sound.

## 2.3 Barrier lenght

Lenght of the barrier must also be taken into account since the sound is difracted not only a the top of the barrier but also at the barriers side edges. This is why it is reccommended that an angle of view of 160° [3] is covered by barriers. This can be reduced if bent edges are used at the end of the barrier [3].

# 3 Sound barrier “Tišina 1”

## 3.1 Physical and acoustic properties

Measured sound barrier was “Tišina 1” which is an absorbant-type of sound barrier built almost entirely of wood with a mineral wool as an absorbent material. Face of the barrier can be seen in Figure 2. Measurements conducted in certified laboratory [5] puts the barrier in the following classes:

- according to the norm HRN EN 1793-1:1999. “Tišina” can be classified as Class A2 [5]
- according to the norm HRN EN 1793-2:1999. “Tišina” can be classified as Class B3 [5]

## 3.2 Resistance to elements

Inspection and measurements conducted in licenced laboratories ZIDI [6] and IGH [7] concluded that “Tišina” sound barrier is:

- sufficiently resistant to elements and durable for a perod of minimum 10 years [6] while expected durability is in the range of several decades with the proper maintenance [6].
- in compliance with the norm HRN EN 1794:2001 regaridng fire resistance and can be calssified as Class 1 [7]

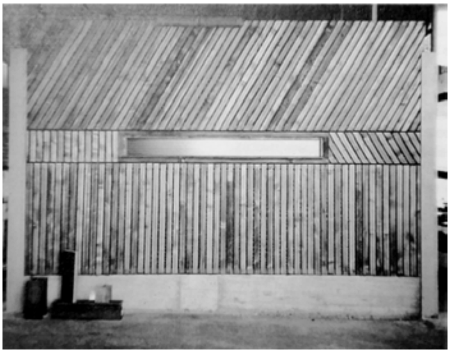

Figure 2 "Tišina 1" sound barrier

# 4 Measurement setup

## 4.1 Description of the measured sample

Sample "Tišina 1" was constructed of three panels set on a concrete foundation 40cm high. Upper and lower panels were 110cm high and the middle panel was 30cm hgh. Width of all panels were 4m. Panels were set into stell "H" carriers which were 16x16cm in cross section and 260cm high. Total surface of the measured sample was 12.06 $m^2$ while the surface of the panels alone were 9.75 $m^2$. Total mass of the construction was 281 kg while the panels alone were 28.86 kg/$m^3$ in density.

## 4.2 Measurement method

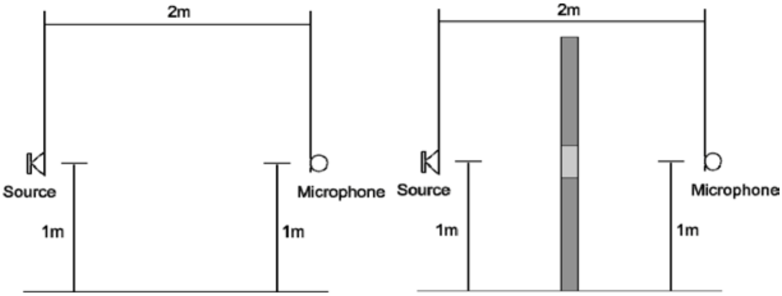

Figure 3 Measurement setups with and without measured barrier

During the development phase, sound insulation measurement were performed using impulse method with the use of following instruments: CROWN TEF System 12+, TOA P-75 D amplifier and TOA 360W speaker. Measurement was performed in two parts. In the first part speaker and microphone were set at the distance of 2m. Impulse response (ETC diagram) was then measured using TEF 12+. In the gained diagram marker was set on the time of arrival of the incident sound. This was done to determine delay needed between the signal generator and analyzing filter. After this setup no further adjustions were made on the measurement equipment. In the second part measurements of the level change of the inicdent sound depending on the frequency of the generator. Thus two TDS diagrams were aquired and in both cases speaker and microphone were 2m apart. Two setups can be seen in the Figure 3. In the first case there was no obstacle between them while in the second case measurement sample was set in between. Difference between first and second case gave sound attenuation of the measured sample at a particular frequency. Measurements were performed in the frequency range between 80 Hz and 3.2 kHz. Surround noise level was less than 43 dBA and measured sound intesitiy was 10 dB or more above background noise.

## 5 Results

Results obtained can be seen in the table and figure below.

**Table 1** Measurment results

| f(Hz) | Sound level without barrier | Sound level with barrier | Difference |
|---|---|---|---|
| 100 | 93.3 | 75.5 | 17.8 |
| 125 | 85.1 | 70.4 | 14.7 |
| 160 | 91.6 | 73.6 | 18 |
| 200 | 92 | 74.4 | 17.6 |
| 250 | 91 | 73.9 | 17.1 |
| 315 | 93.1 | 69.1 | 24 |
| 400 | 90 | 68.7 | 21.3 |
| 500 | 92.4 | 64.3 | 28.1 |
| 630 | 92 | 63 | 29 |
| 800 | 91.3 | 59.5 | 31.8 |
| 1000 | 93.5 | 56.2 | 37.3 |
| 1250 | 94.9 | 56.1 | 38.8 |
| 1600 | 92.9 | 56.2 | 36.7 |
| 2000 | 91.9 | 56 | 35.9 |
| 2500 | 92 | 54 | 38 |
| 3150 | 93.7 | 53.2 | 40.5 |

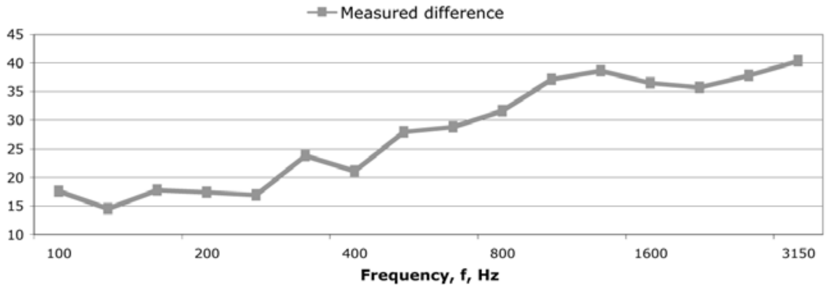

**Figure 4** Measurement results

According to this results and according to the norm HR EN 1793-2:1999. “Tišina 1” can be classified as Class B3 which was validated in a licensed laboratory [5].

## 6 Conclusion

In this paper, out of several possible noise mitigation options, noise mitigation by use of sound barriers is shown, as well as mechanical and accoustic properties of a sound barrier "Tišina 1" which complies to Class A2 regarding it's absorbant properties and Class B3 for it's insulation properties. Acheved characteristycs of the "Tišina 1" sound barrier were controlled during development phase by proprietary measurement procedures and confirmed by official measurements in licensed laboratories. Exceptional mechanical and fire resistant properties as well as durability of the "Tišina 1" barrier combined with the use of eco-friendly materials (wood) can confirm that one element can combine all the desired characteristics regarding sound absorbtion and insulation while at the same time blend seamlessly into surrounding enviroment.

## References

[1] Golubić, J.: Promet i okoliš, Fakultet prometnih znanosti, Zagreb, 1999.

[2] Simonović, M.; Kalić, D.; Pravica, P.: Buka- štetna dejstva, merenje i zaštita, Prosveta, Niš, 1982.

[3] Kotzen, B.; English, C.: Enviromental Noise Barriers, E & FN Spoon, London, 1999.

[4] Attenborough, K.; Ming Li, K.; Horoshenkov, K.: Predicting Outdoor Sound, Taylor & Francis; 1 edition, December 4, 2006.

[5] Vuić, T.; Šilhard-Mihaljević, S.: Izvještaj o ispitivanju br. 2900-1375/04, IGH d.d., Zagreb, 2004.

[6] Turkulin, H.;Jambrekovic, D.: Stručno mišljenje o kvaliteti i postojanosti tehničkog rješenja drvene zvukobrane cestovne ograde "Tišina", Broj 262/2004, ZIDI, Šumarski fakultet Sveučilišta u Zagrebu, Zagreb, 2004.

[7] Vuić, T.; Šilhard-Mihaljević, S: Izvještaj o ispitivanju br. 2900-1230/04, IGH d.d., Zagreb, 2004.