ANALYSIS OF THE EFFICIENCY OF SOUND BARRIERS AS A METHOD FOR PASSIVE CONTROL OF TRAFFIC NOISE

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Abstract: In recent decades, the introduction of stricter environmental noise laws has resulted in a series of noise reduction measures of a different nature. These include urban planning measures such as the designation of noise-sensitive areas, regulations on vehicle speed limits or traffic restrictions, measures to improve the acoustic performance of vehicles, pavements and buildings, and the construction of noise barriers. The most used method to reduce noise on thoroughfares and highways is the installation of sound barriers that are constructed and constructed along the highway. There are three types of acoustic barriers, namely reflective, absorptive, and reactive. Absorbing barriers are opaque and contain a porous element that absorbs sound, such as fiber concrete and granulated concrete. Reflective barriers can be opaque or transparent and do not contain sound-absorbing material (concrete, cement, metal or wood) in their construction. Reactive barriers are opaque and are constructed to have cavities or resonators that are designed to absorb or reduce only certain frequencies that are part of the noise they are exposed to. Determining the effectiveness of noise barriers has attracted the attention of researchers over the past 40 years, and a wide variety of mathematical and experimental methodologies have been developed to assess it.

Keywords: *environmental noise, noise control, sound barriers*

INTRODUCTION

Experimental studies are based on different approaches related to the assessment of the effectiveness of sound barriers on the reduction of population anxiety (Nilsson, 2004), the effects of sound barriers on the quality of the urban environment (Young Hong, 2012), the measurement of noise propagation based on experiments with scaled models (Li, Q, 2020) and the measurement of the acoustic properties of real-scale barriers. Measurements of the acoustic properties of barriers are the most commonly implemented method and refer to the analysis of the effectiveness of barriers based on their different acoustic characteristics.

Many research studies address the intrinsic characteristics of barriers, such as sound absorption and insulation. Two types of measurement methods are commonly used to assess these properties: laboratory methods using a diffuse sound field in acoustic laboratories and field measurement methods.

Most of the research studies to date are based on the evaluation of the effectiveness of the barriers for the calculation of the loss factor after installation which is defined as the difference in the noise level before and after the installation of the barrier (Kotzen, 2014). Installation loss is an external characteristic of noise barriers, which depends mostly on site geometry, meteorological conditions, ground impedance, and the relative positions of the noise source and receiver. These factors are generally not independent of each other, so the total loss factor cannot be calculated by adding the partial loss factors after placing the barrier.

The international standard ISO 10847:1997 (Zhang, X, 2019) establishes two methods for assessing barrier efficiency through field measurements, namely the direct and indirect methods. The direct method is used when the barrier is not yet installed or can be removed. The noise level is measured before and after the installation of the barrier to determine the post-installation loss factor. In this method, adequate conditions must be ensured so that measurements before and after the installation of the barrier are carried out under equivalent weather and traffic conditions. The indirect method is used when the barrier is already installed and cannot be removed. In this case, the estimated noise level before the installation of the barrier is obtained by measuring a location considered equivalent to the location of the measurement. In the Republic of North Macedonia, sound barriers have been installed in several locations throughout the country, covering the major highways. In the capital city of Skopje, sound barriers have been installed at 2 locations, namely a reflective barrier at the transport center in the City Center and reflective and reactive barriers on the Ring Road for entering and exiting the city (Figure 1).

IMPLEMENTATION OF AN INDIRECT METHOD FOR ASSESSING THE PERFORMANCE OF SOUND BARRIERS

According to ISO 10847:1997, the indirect method implies an approach to be applied when the noise barrier is already installed at the designated location and cannot be removed in order to carry out field measurements according to the direct method. The indirect method is the only practical approach in the case of most new roads, where sound barriers are installed during road construction and therefore it is not possible to carry out a measurement before installation of the sound barrier under normal traffic conditions. This method was applied to assess the efficiency of two sound barriers that have already been installed in the city of Skopje, with the aim of providing insight into the degree of protection of the barriers from traffic noise, which turned out to be the dominant source of noise in the city. One location is the sound barrier at the Transport Center which is set up to protect a settlement from a busy street and intersection in the city center, as well as a railway that passes in the immediate vicinity, and the other on the Ringroad outside the city which is set up to protect a settlement from highway noise (Figure 1).

The ISO standard specifies general criteria for measuring the effectiveness of barrier placement, including the acoustic environments of the measurement points, microphone positions, and noise source conditions. The standard also proposes generic principles to ensure and maintain sufficiently equivalent conditions between "before" and "after" measurements to enable accurate determination of the loss factor after barrier installation.

When using the indirect measurement method, it is necessary to select at least 3 measurement points, that is, a measurement point behind the barrier, a measurement point at an equivalent measurement location where no barrier is placed, and a measurement point in front of the barrier. According to the standard, in order to correctly choose a suitable equivalent measurement location and determine the estimated noise level before the installation of the sound barrier, it is necessary to ensure the same environmental conditions (meteorological and traffic conditions) at the two measurement points, where there are already installed sound barrier and where there is no protective sound barrier.

Defining these equivalent locations requires a close match in emission characteristics, relative positions of source, barrier and receiver, ground surface acoustic performance, terrain profile, infrastructure, reflecting surfaces and meteorological conditions. It is also necessary to ensure ground surface equivalence, which refers to the acoustic impedance of the ground along the source-receiver propagation path (i.e., ground cover acoustic features such as paved soil, vegetation, gravel, etc.) The ISO standard further requires that the environment in the 30 [m] distance region behind and to the side of the receiver positions be similar. To ensure the consistency and relevance of the results, measurements at both locations are preferably performed simultaneously.

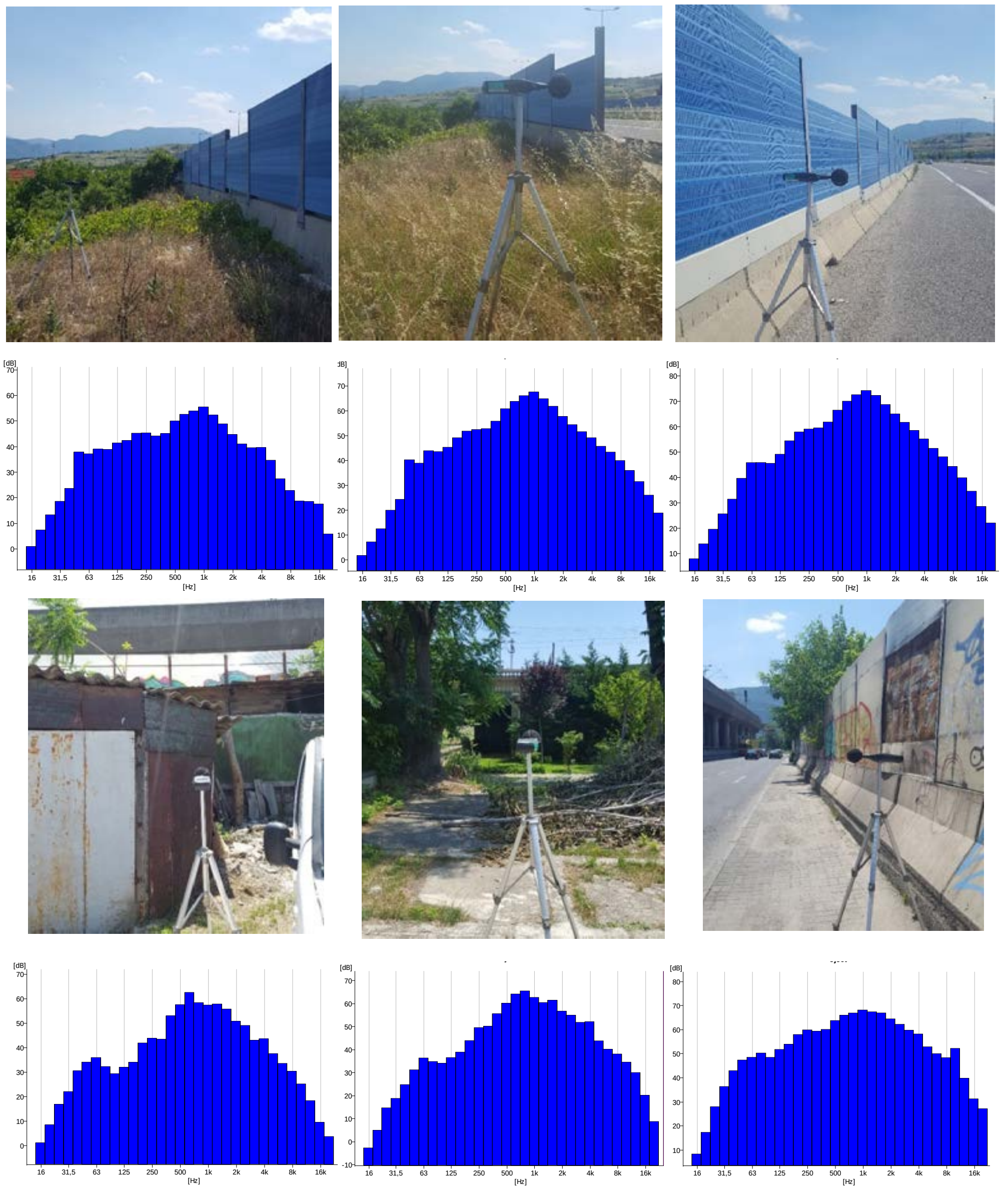

Figure 1. Measurement locations of sound barriers in the city of Skopje (top: Ringroad, bottom: in the City Center)

Most of the studies based on indirect methods use road traffic as a noise source. The ISO standard suggests that natural roadside noise be used as the sound source equivalence for the "before" and "after" measurements. The use of traffic noise has the obvious advantage of representing a natural source, but also the lack of describing fluctuations in traffic volume, speed and composition that can affect the accuracy of the results. The selected locations in the city of Skopje where sound barriers have been installed are exposed to an increased level of traffic noise, therefore the indirect method is an appropriate approach for determining their efficiency and assessing the degree of control and protection from traffic noise.

The ISO standard proposes general criteria that are a very general characterization of the open space behind the barrier, but there is no general standard for the locations of the receivers, that is, the measuring points. One of the key factors in using the indirect method is that the locations of the microphones relative to the noise source at the "before" and "after" positions should be identical, in terms of distance from the road and height above the road. Optional is the use of a reference microphone that takes into account the effect of possible fluctuations in the noise source, but it is assumed that possible fluctuations in the traffic during the measurements are not expected to significantly affect the results. The choice of these measurement points is largely determined by the possibility of finding equivalent locations to the "before" location. In most studies, microphones are placed at distances from the barrier that correspond to incremental doublings of the distance. The most common microphone height is 1.5 [m], although there are studies that consider additional heights that are similar to or higher than the barrier height (eg, 2, 4, 6 [m]).

RESULTS OF THE APPLIED METHOD FOR THE ANALYSIS OF THE EFFICIENCY OF SOUND BARRIERS

From the measurements carried out at the two selected locations in the city of Skopje, namely the ring road outside the city where sound barriers have been placed to protect the settlement from the noise from the highway and the location in the city center near the transport center where sound barriers have been placed to protect the settlement from noise from the street, intersection and railway line, results were obtained for the level of total noise caused by these sources. Namely, Figure 2 presents the results for the noise level in front of the sound barrier and behind the sound barrier of the Ring Road in the city. From the results, the differences in the noise level before and behind the barrier in the entire frequency range are noticeable, which indicates that the sound barrier has a major role in reducing the noise at this location.

What is notable is the significant difference of 14 [dB] in the noise level in front of and behind the barrier which is greatest at a frequency of 1 [kHz] which is considered dominant when it comes to traffic noise.

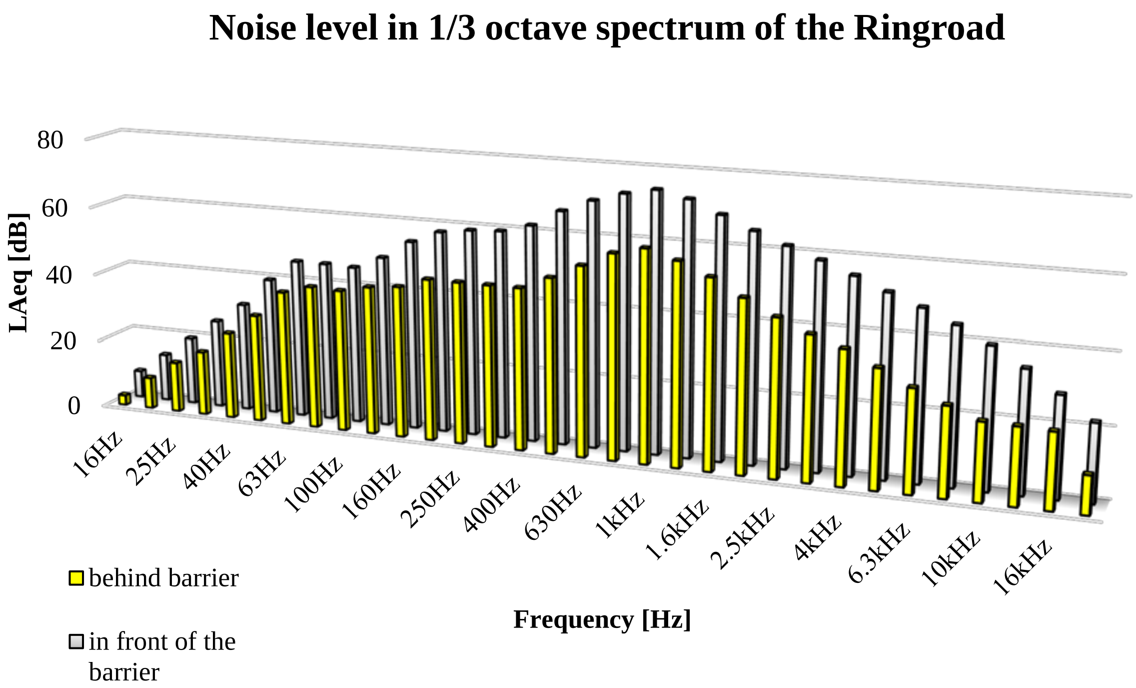

Figure 2. Results of the measured values for the noise before and behind the barrier placed on the ring road in the city of Skopje

Figure 3 presents the results of measured noise levels in front of and behind the sound barrier at the City Center location. The differences in noise levels in [dB] are obvious, but here you can also notice pronounced differences at other lower frequencies such as 31.5 [Hz] where the difference is approximately 18 [dB] and at higher frequencies such as 16 [kHz] where the difference reaches 28 [dB]. This difference in the discrepancies in the noise levels at different frequencies in one and the other location is probably due to the fact that other sources of noise are present in the location in the city center in addition to traffic (dominant source of noise from construction activities was observed, noise from barking of dogs, as well as noise from railway traffic), while at the measuring location of the ring road the dominant source of noise is only traffic.

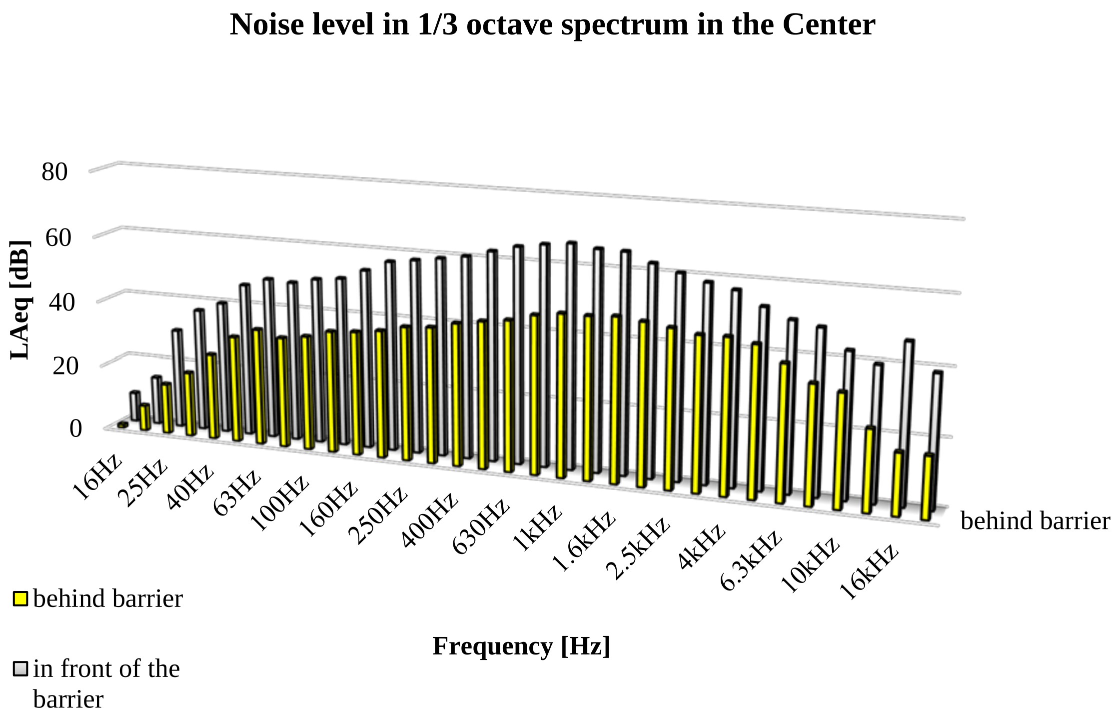

Figure 3. Results of the measured values for the noise in front of and behind the barrier placed in the Center of the city of Skopje

CONCLUSIONS

The conducted analyses that were presented in this chapter indicate that among the many factors that increase the level of noise in the city of Skopje, one of the most influential is road traffic noise. The noise map of the selected area in the city of Skopje "Debar Maalo" represents a really important first step for future work in the whole city to deal with the problem of noise pollution. Traffic noise mapping technology is convenient because it allows, through easily accessible collection of traffic flow data, to provide a visual representation of the noise situation and the distribution of the noise level across the area, particularly focusing on the traffic noise problem. On the other hand, the validation of this methodology using a conventional methodology based on acoustic measurements provides a good solution for a better understanding of the causes of sound pollution and the impact of traffic noise in the total noise level. The discrepancies in the noise levels during the night and daytime hours that were ascertained are due to the difference in the noise sources in the night period of the day in relation to the day and evening period. This may lead to the conclusion that traffic density at night is lower, but other sources such as human speech or music may be dominant. Therefore, additional analysis of the presence of different types of noise sources and their impact should be done in order to provide a more accurate insight into the noise situation in the area.

On the other hand, the most commonly applied solution to the problem of increased noise level caused by road traffic is the installation of sound barriers where necessary in order to protect a certain neighbourhood that is significantly exposed to noise, and in the city of Skopje such sound barriers have been installed only in a few locations. According to the research conducted in this chapter, the barriers installed in the city show a solid performance with a noise reduction rate of more than 10 [dB] in the entire frequency range. What was observed from the conducted analyses of the results at both locations is that the sound barriers show better characteristics at higher frequencies, while they show a lower rate of sound intensity reduction at lower frequencies. From here it can be concluded that sound barriers are an appropriate solution where protection is needed from traffic noise that is dominant at frequencies of 1 [kHz] and higher, but for locations where various sources of noise occur at lower frequencies, their application is not sufficient for complete noise protection and control. For this purpose, the research work is directed towards the development of systems for active sound control, the purpose of which is to deal with and control low-frequency sounds, which are often a source of unpleasant sound in the environment in addition to traffic noise.

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