APPLICATION OF NOISE PROTECTION WALLS ALONG ROAD "A" TRANSVERSAL IN SARAJEVO

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Summary

The research focuses on the efficiency of sound barriers in protecting against traffic-induced noise, with a specific focus on the example of barrier construction along the "A" highway in Sarajevo. The study aims to analyze the results of measuring daily and nightly noise levels at five different locations along the route, using standard methods and tools for noise measurement. The methodology involved constructing walls made of steel supporting columns and transparent panels of varying heights, and conducting control measurements of daily and nightly noise levels. The research results indicate that sound barriers are effective in reducing noise in the vicinity of roadways, especially during the daytime. However, nighttime noise values were slightly higher than the maximum allowable values, indicating the need for additional measures to control noise during nighttime hours. The importance of proper planning, construction, and maintenance of sound barriers is emphasized to ensure a better living environment for urban residents and reduce irritation caused by traffic noise.

Keywords: *traffic noise, urbanity, sound barrier, synthetic barriers, green barriers*

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1 INTRODUCTION

The primary source of noise in urban environments is traffic. Considering that traffic (road, rail, air) accounts for more than 80% of harmful sound occurrences, various measures have been developed over the years to protect or reduce noise emissions on roadways. Reductions in noise benefit nearby residential, commercial, and public areas by providing a better living environment, reducing irritation, and improving sound quality.

The most effective means of protection against traffic noise are sound barriers. Sound barriers are effective in shielding against excessive noise along roadways and can also limit the spread of dust and smog. Additionally, they provide a degree of privacy by shielding from the view of drivers and improve living conditions for residents and workers near roadways.

Sound barriers are characterized by excellent acoustic characteristics, resistance to high static and dynamic loads, corrosion, and weather influences. They are durable, easy to install, and maintain.

This paper will examine the application of sound barriers along the "A" highway in

Sarajevo, aimed at reducing the impact of traffic noise on surrounding residential units. The focus will be on the methodology of constructing the barriers and the results of control measurements of daily and nightly noise levels at five different locations along the route.

2 CONSTRUCTION OF SOUND BARRIERS ALONG THE "A" HIGHWAY IN SARAJEVO

After the construction of the "A" highway, which passes through two Sarajevo municipalities, Novi Grad and Ilidža, there arose a need for additional protection against traffic noise generated during its use, which undesirably affects the surrounding, mostly residential units. Noise protection is based on the installation of steel load-bearing HEA columns onto existing concrete walls, followed by the assembly and mounting of transparent noise protection panels. The height of the panels varies, depending on the height of the structures in front of which they are installed. Thus, we have different heights ranging from 1.5m, 2.0m, 2.5m, 3.0m, 4.5m, 5.0m, and 5.5m, depending on whether the panels are placed in front of individual houses or multi-story collective residential buildings, as depicted in Image 1.

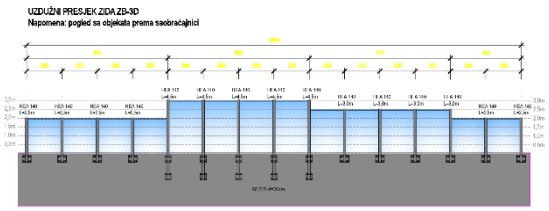

Image 1. Section of the longitudinal profile of the noise protection wall on the "A" highway

Depending on their height, the attachment points to the concrete walls will vary, either through one or two anchor plates. A draft of a section of the longitudinal profile of the wall is provided in Image 1. Besides the top crossbeam used for wall bracing, a mid-crossbeam is present on walls over 5.0m for additional stability.

By choosing this type of noise protection, not all noise is completely blocked but rather reduced to a more tolerable level. Effective barriers are considered those that reduce noise levels by 5 to 10 decibels. Traffic noise protection barriers reduce sound through absorption, transmission, and reflection back or by forcing sound to travel a longer path over and around the barrier. Therefore, the barrier must be sufficiently high and long, and the selected material must be strong and dense enough (at least 20kg/m2). Any material type is

equally effective in terms of sound insulation if it has this density.

3 METHODOLOGY OF MEASUREMENTS

After the completion of construction work on the noise protection walls, in order to verify the achieved results, it is necessary to conduct control measurements following the selection of characteristic sites. In total, five different locations were selected, and measurements were conducted over three different days for both daytime and nighttime noise levels, all in accordance with the requirements of standard BAS ISO 1996-1:2005 and BAS ISO 1996-2:2008. Monitoring was carried out in compliance with the Law on Noise Protection ("Official Gazette of the Sarajevo Canton" No. 23/16) and the Law on Noise Protection of the Federation of Bosnia and Herzegovina ("Official Gazette of the FBiH" No. 110/12). Measurements were conducted at five locations according to the following Image 2.

Image 2. Position of measurement points

Measurements were conducted towards the sources of noise, lasting for 60 minutes for daytime noise and 30 minutes for nighttime noise, with monitoring of meteorological conditions.

The noise measurements were performed using an SVAN 977 noise measurement device from the Polish manufacturer SVANTEK, with a calibrator model SV 33, and a TFA meteorological station of the SINUS type. Data processing software used included SvanPC++3.3.26 and Supervisor 1.7.13. The devices are depicted in Image 3.

Image 3. Noise measurement device, calibrator, and meteorological station

4 MEASUREMENTS REPORT

As previously mentioned, measurements were conducted at 5 locations, with data regarding coordinates, altitude, and distance from the sound barrier provided in Table 1.

Table 1. Measurement Locations

Mjerno mjesto	N	E	NV (m)	Udaljenost od zvučne barijere (m)
MM 1	43°49'58.29"	18°20'12.58"	506	3
MM 2	43°50'4.57"	18°20'16.32"	506	9
MM 3	43°50'7.57"	18°20'21.13"	508	6
MM 4	43°50'8.47"	18°20'26.22"	510	4
MM 5	43°50'7.35"	18°20'29.37"	513	12

The abbreviations and units of measure used in the research are as follows:

- dB (decibel) - 1/10 Bel is a unit for measuring sound,
- dB (A) (decibel - A scale) is an international measurement scale of sound or noise level that takes into account the variability of the human ear,
- Leq dB (A) - (equivalent noise level) is the average energy value of variable noise equivalent to the continuous noise level measured over a duration of 15 minutes during periods from 06-22 [h] (daytime) and 22-06 [h] (nighttime),
- L_{max} dB (A) is the maximum value of measured noise in a given period,
- L_{min} dB (A) is the minimum value of measured noise in a given period,
- L_n dB (A) is the sound pressure level that is above the stated n% of the time within the measurement period,
- L1 dB (A) is the noise level exceeded 1% of the time within the measurement period.

During the measurements, noise generated by traffic on the "A" highway, traffic on secondary roads, and noise from surrounding settlements along the highway route was recorded. The equivalent noise level was recorded continuously for 60 minutes for daytime and 30 minutes for nighttime noise. Based on the measured noise levels, the relevant equivalent level is calculated and expressed in dB(A).

4.1 Measurement point MP1

Measurement point MP1 is located west of the roadway, in the immediate vicinity of a residential building on Hajrudina Šabanije Street. The measurement location is between the building and the sound barrier. The distance from the facade at the measurement site is 1.8 meters. The location of the measurement point is shown in Image 4, while Images 5 and 6 depict the measurement point and the noise protection wall.

Image 4. Depiction of measurement point MP1

Image 4. Depiction of measurement point MP1

The results of daytime and nighttime noise level measurements for measurement point MP1 are provided in Table 2, while Table 3 presents the meteorological parameters prevailing during the noise measurements. During the measurement period, the weather was clear and precipitation-free. The roads and surrounding ground were dry, making the soil conditions suitable for noise measurement. Image 7 depicts the noise measurement diagram for a 60-minute interval, while Image 8 shows the diagram of nighttime noise measurement for a 30-minute interval.

Table 2. Results of noise level measurements for measurement point MP1

Tabela 3.2. Rezultati mjerenja dnevnog i noćnog nivoa buke za mjerno mjesto MM 1

Parametar	Vrijednost	
	Dnevna buka	Noćna buka
Ref (min)	60	30
Leq dB(A)	56,3	50,7
Lmin dB(A)	39,7	34,0
Lmax dB(A)	83,7	67,6
L90 dB(A)	47,5	39,2
L50 dB(A)	56,3	47,6
L10 dB(A)	62,5	58,7
L5 dB(A)	63,9	60,5
L1 dB(A)	66,5	63,8

The meteorological parameters during the measurements were favorable.

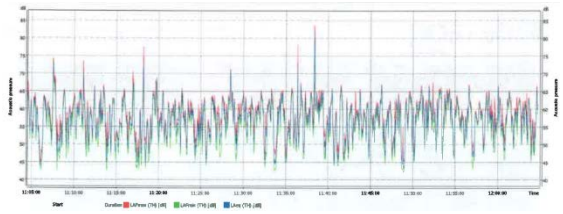

Image 6. Diagram of daytime noise measurement for measurement point MP1

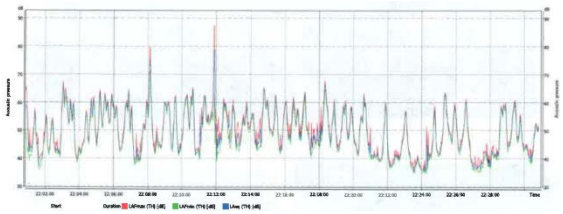

Image 7. Diagram of nighttime noise measurement for measurement point MP1

4.2 Measurement point MP2

Measurement point MP2 is located on Branislava Nušića Street on the west side of the A highway, next to the fence of a residential building. The location of the measurement point is shown in Image 9, while Images 10 and 11 depict the measurement point and the noise protection wall.

The results of daytime and nighttime noise level measurements for measurement point MP2 are provided in Table 4, while Table 5 presents the meteorological parameters prevailing during the noise measurements. During the measurement period, the weather was clear and precipitation-free. The roads and surrounding ground were dry, making the soil conditions suitable for noise measurement. Image 12 depicts the noise measurement diagram for a 60-minute interval, while Image 13 shows the diagram of nighttime noise measurement for a 30-minute interval.

Image 8. Depiction of measurement point MP2

Image 9. Depiction of the sound barrier at MP2

Table 3. Results of noise level measurements for measurement point MP2

Parametar	Vrijednost	
	Dnevna buka	Noćna buka
Ref (min)	60	30
Leq dB(A)	59,4	53,1
Lmin dB(A)	44,6	35,2
Lmax dB(A)	76,8	66,0
L90 dB(A)	51,7	41,8
L50 dB(A)	57,2	50,7
L10 dB(A)	62,7	60,9
L5 dB(A)	64,3	63,5
L1 dB(A)	67,8	67,5

The meteorological parameters during the measurements were favorable.

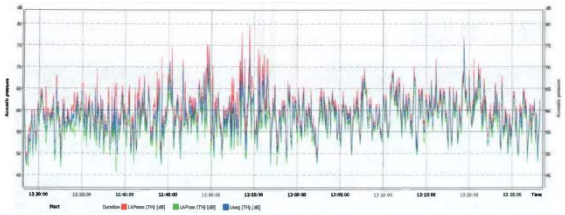

Image 10. Diagram of daytime noise measurement for measurement point MP2

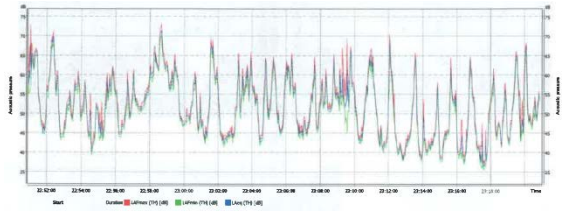

Image 11. Diagram of nighttime noise measurement for measurement point MP2

4.3 Measurement point MP3

Measurement point MP3 is located on Branislava Nušića Street on the west side of the A highway, next to the fence of a residential building. The distance from the sound barrier at the measurement site is 6.0 meters. The location of the measurement point is shown in Image 14, while Images 15 and 16 depict the measurement point and the noise protection wall.

The results of daytime and nighttime noise level measurements for measurement point MP3 are provided in Table 5, while Table 6 presents the meteorological parameters prevailing during the noise measurements. During the measurement period, the weather was clear and precipitation-free. The roads and surrounding ground were dry, making the soil conditions suitable for noise measurement. Image 17 depicts the noise measurement diagram for a 60-minute interval, while Image 18 shows the diagram of nighttime noise measurement for a 30-minute interval.

Image 12. Depiction of measurement point MP3

Image 13. Depiction of the sound barrier at MP3

Table 4. Results of noise level measurements for measurement point MP3

Parametar	Vrijednost	
	Dnevna buka	Noćna buka
Ref (min)	60	30
Leq dB(A)	57,6	51,5
Lmin dB(A)	43,8	37,0
Lmax dB(A)	66,6	63,4
L90 dB(A)	51,5	40,3
L50 dB(A)	56,8	47,0
L10 dB(A)	60,8	56,1
L5 dB(A)	61,8	57,7
L1 dB(A)	64,8	60,3

The meteorological parameters during the measurements were favorable.

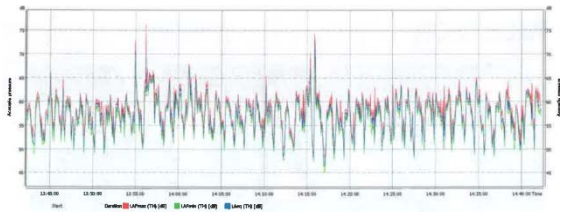

Image 14. Diagram of daytime noise measurement for measurement point MP3

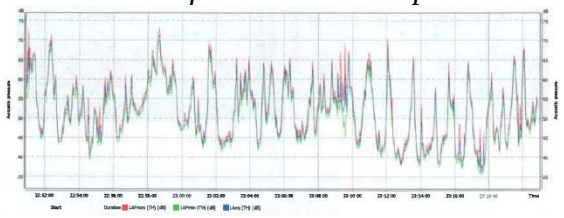

Image 15. Diagram of nighttime noise measurement for measurement point MP3

4.4 Measurement point MP4

Measurement point MP4 is located on Ramiza Salčina Street in the immediate vicinity of a residential building. The distance from the sound barrier at the measurement site is 4.0 meters. The location of the measurement point is shown in Image 20, while Images 21 and 22 depict the measurement point and the noise protection wall.

The results of daytime and nighttime noise level measurements for measurement point MP4 are provided in Table 8, while Table 9 presents the meteorological parameters prevailing during the noise measurements. During the measurement period, the weather was clear and precipitation-free. The roads and surrounding ground were dry, making the soil conditions suitable for noise measurement. Image 22 depicts the noise measurement diagram for a 60-minute interval, while Image 23 shows the diagram of nighttime noise measurement for a 30-minute interval.

Image 16. Depiction of measurement point MP4

Image 17. Depiction of the sound barrier at MP4

Table 5. Results of noise level measurements for measurement point MP4

Parametar	Vrijednost	
	Dnevna buka	Noćna buka
Ref (min)	60	30
Leq dB(A)	59,1	52,6
Lmin dB(A)	39,5	34,3
Lmax dB(A)	71,3	66,1
L90 dB(A)	50,7	40,1
L50 dB(A)	60,9	53,7
L10 dB(A)	65,8	61,9
L5 dB(A)	66,8	63,3
L1 dB(A)	69,1	65,5

The meteorological parameters during the measurements were favorable.

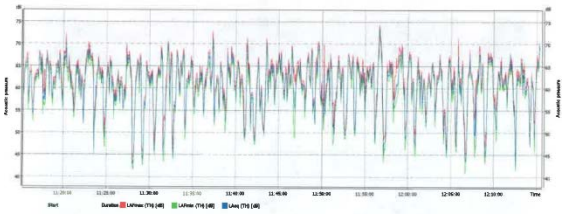

Image 18. Diagram of daytime noise measurement for measurement point MP4

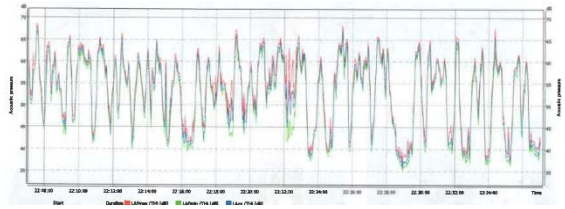

Image 19. Diagram of nighttime noise measurement for measurement point MP4

4.5 Measurement point MP5

Measurement point MP5 is located on Branislava Nušića Street, on the eastern side of the A transferzale. The distance from the sound barrier at the measurement site is 12.0 meters. The depiction of the measurement point location is shown in Image 24, while Images 25 and 26 depict the measurement point and the noise protection wall.

The results of daytime and nighttime noise level measurements for measurement point MP5 are provided in Table 10, while Table 11 presents the meteorological parameters prevailing during the noise measurements. During the measurement period, the weather was clear and without precipitation. Roads and surrounding terrain were dry, making the ground conditions suitable for noise measurement. Image 27 shows the noise measurement diagram for a 60-minute interval, while Image 28 displays the nighttime noise measurement diagram for a 30-minute interval.

Image 20. Depiction of measurement point MP5

Image 21. Depiction of the sound barrier at MP5

Table 6. Results of noise level measurements for measurement point MP5

Parametar	Vrijednost	
	Dnevna buka	Noćna buka
Ref (min)	60	30
Leq dB(A)	55,3	48,9
Lmin dB(A)	44,0	32,6
Lmax dB(A)	59,9	60,3
L90 dB(A)	49,9	40,2
L50 dB(A)	54,2	47,1
L10 dB(A)	58,7	54,3
L5 dB(A)	60,3	55,8
L1 dB(A)	66,3	59,1

The meteorological parameters during the measurements were favorable.

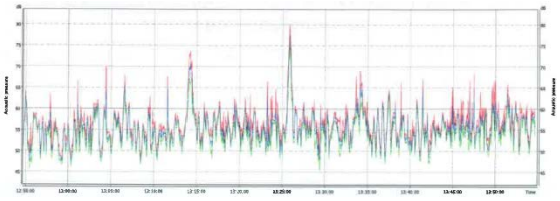

Image 22. Diagram of daytime noise measurements for measurement point MP5

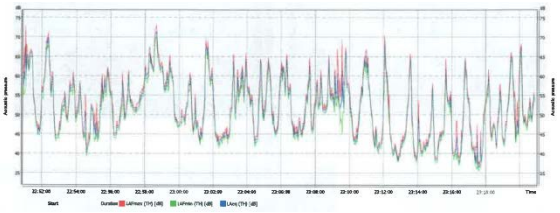

Image 23. Diagram of nighttime noise measurements for measurement point MP5

5 REVIEW OF MEASUREMENT RESULTS

In Table 12, the results of all measurements are presented for both the daytime and nighttime variants. Subsequently, the maximum permissible noise levels specified in the Law on Noise Protection of the Sarajevo Canton ("Official Gazette of the Sarajevo Canton" no. 23/16) for Zone IV, as indicated in Table 13, are provided. Zone IV encompasses commercial, business, residential, and residential areas along traffic corridors, as defined by the Spatial Plan of the Sarajevo Canton (2003-2023).

Table 7. Measurement results and maximum permissible values

Mjerno mjesto	Izmjerene vrijednosti						Najviše dozvoljene vrijednosti nivoa buke			
	Dan			Noć			Zona	Dan	Noć	L1 dB(A)
	Leq dB(A)	U dB(A)*	L1 dB(A)	Leq dB(A)	U dB(A)*	L1 dB(A)		Leq dB(A)		
MM 1	56,3	± 2,4	66,5	50,7	± 2,9	63,8	IV	60	50	75
MM 2	59,4	± 2,4	67,8	53,1	± 3,3	67,5	IV	60	50	75
MM 3	57,6	± 2,4	64,8	51,5	± 3,4	60,3	IV	60	50	75
MM 4	59,1	± 2,4	69,1	52,6	± 2,9	65,5	IV	60	50	75
MM 5	55,3	± 2,4	66,3	48,9	± 2,9	59,1	IV	60	50	75

Table 8. Permissible noise levels in different zones

Tabela 1.1. Dozvoljeni nivoi vanjske buke u različitim zonama

Područje (zona)	Namjena područja	Najviše dozvoljeni nivo vanjske buke (dBA)		
		15 min Leq		Vršni nivo
		Dan	Noć	L1
I	Bolničko, lječilišno	45	40	60
II	Turističko, rekreacijsko, oporavilišno	50	40	65
III	Čisto stambeno, vaspitno-obrazovne i zdravstvene institucije, javne zelene i rekreacione površine	55	45	70
IV	Trgovačko, poslovno, stambeno i stambeno uz saobraćajne koridore, skladišta bez teškog transporta	60	50	75
V	Poslovno, upravno, trgovačko, zanatsko, servisno (komunalni servis)	65	60	80
VI	Industrijsko, skladišno, servisno i saobraćajno područje bez stanova	70	70	85

CONCLUSION

Measurement uncertainty U is provided as an expanded measure of uncertainty for a confidence level of 95% and a coverage factor k=2. Correction of results due to residual noise is not determined as the total noise level from all sources was measured.

Based on the measurement results, considering the measurement uncertainty, it is concluded that the daytime noise at the measurement locations does not exceed the maximum permissible noise values for Zone IV where the measurement was conducted during the day, while for the nighttime regime, the measured values are slightly higher than the maximum allowable values.

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