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NOISE LEVEL MEASUREMENTS OF ROAD TRAFFIC AT DIFFERENT HEIGHTS IN RELATION TO THE NOISE SOURCE

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Abstract. *The paper provides an analysis of the results of noise levels originating from road traffic measured at different heights on the example of an eighteen-story solitaire in the Dušanovac, which is located along the traffic road Bulevar Franše d'Eperea in Belgrade (the former section of the E-75 Belgrade-Niš highway). Measurements were made simultaneously at three measuring points, on the second, tenth and eighteenth (last floor) of the solitaire.*

Key words: *noise, road traffic, heights, levels.*

1. INTRODUCTION

The paper presents an experimental approach to noise level measurements at different heights in relation to road traffic as a source of noise. The measurements included a statistical analysis of the noise levels during the 24-hour measurement period for consecutive 15-minute intervals in the zone of one of the noisiest and busiest traffic roads through Belgrade - Franše d'Eperea Boulevard (former section of the E-75 Belgrade-Niš highway). For this experiment, the highest solitaire was chosen along the mentioned road, in the Dušanovac, and the goal was to confirm or deny the fact that the highest noise levels are obtained in the places closest to the road. Based on these measurements, a comparative analysis of the results was given, which showed that high levels are also obtained at high altitudes that are quite far from the road.

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2. Description of the Measurement Procedure

A statistical analysis of the noise levels during the 24-hour measurement period, which originates from road traffic in the zone of the traffic road through Belgrade - Franše d'Eperea Bulevar, on which traffic takes place in two directions (towards the Mostar Interchange and towards Niš), was carried out in the outdoor environment at the measuring points MM1, MM2 and MM3 selected at different heights of the eighteen-floor high-rise building at the address 12 Ljermontova street in Belgrade.

The measuring points MM1, MM2, and MM3 are located on the terraces of the high-rise building on the second, tenth, and eighteenth floors [1], and a detailed description with the dimensions relevant to the measurements in question is given in the sketch in Fig. 1. Measuring point MM1 was chosen at a height of 6.4 m from the ground (second floor), measuring point MM2 at a height of 28.8 m from the ground (tenth floor) and measuring point MM3 at a height of 51.2 m from the ground (eighteenth floor), while their direct distances from the central axis of the road are 65.1 m, 71.8 m, and 84.2 m, respectively. The distance of the solitaire itself from the nearest edge of the road is about 51 m.

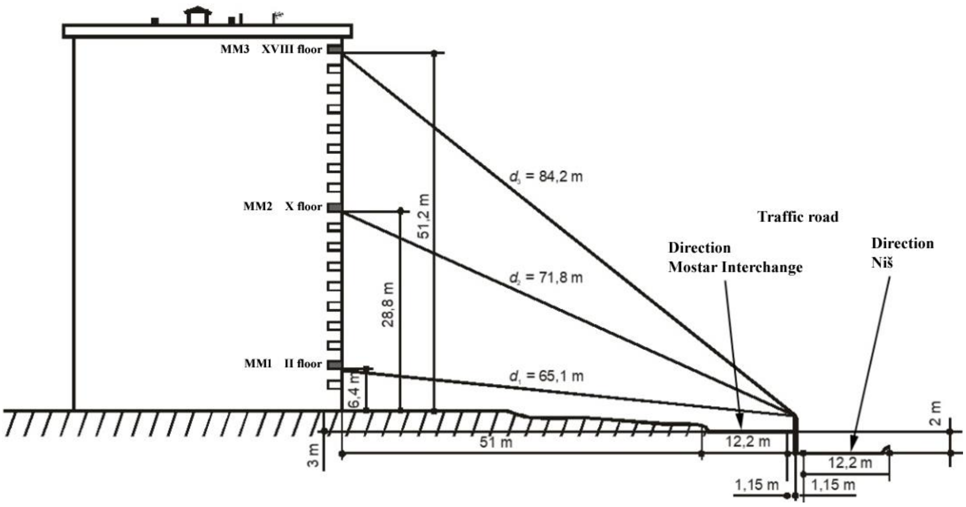


Fig. 1 Sketch of measuring points MM1, MM2, and MM3 and their position in relation to the noise source

3. Measurement Results

Noise level measurements at selected measuring points MM1, MM2, and MM3 were performed according to accredited methods [2,3].

Measurements were made during two working days in a period of 24 hours. Statistical analysis was performed for successive 15-minute intervals with frequency weighting A and time weighting Fast, while the following noise levels were monitored: $L_{\mathrm{Aeq,15min}}$, $L_{\mathrm{AF5,15min}}$, $L_{\mathrm{AF10,15min}}$, $L_{\mathrm{AF50,15min}}$, $L_{\mathrm{AF90,15min}}$ and $L_{\mathrm{AF95,15min}}$.

All measurements were performed in automatic mode with sound level meters manufactured by Rion, Japan, models NL-18, NL-32, and NA-28, and the processing of the obtained results was done in the software SLC ver 2.1.

All measurements were taken with a windscreen. The windscreen did not affect the noise level measurement results.

Measurements were made during the daytime (day) and nighttime (night) reference time intervals. The day includes the time period from 06.00 to 22.00, and the night from 22.00 to 06.00. The measurements were started on Wednesday, October 21, 2009, at around 11.30 am and ended on Thursday, October 22, 2009, at about the same time. In this way, the day is divided into two intervals: from the beginning of the measurement until 22.00 and from 06.00 of the next date until the end of the measurement period. The night has one interval: from 22.00 to 06.00 of the next starting date.

During the period in which the measurement was performed, there was a lot of traffic in the area of the measuring points in both directions of the traffic road - towards the Mostar Interchange and towards Niš, in two-day and one-night intervals lasting 1 hour (4 × 15 minutes). Vehicles are grouped as light (car, van, pickup), heavy (truck, small truck, and bus), and motorcycles, and the number of vehicles is presented in Tab. 1.

Table 1 The total number of vehicles in both directions that passed the traffic road on October 21, 2009, in front of the measuring points at the specified intervals

Vehicles type	Day interval 11:30-12:30			
	11:30-11:45	11:45-12:00	12:00-12:15	12:15-12:30
Light	1212	1069	1043	1234
Heavy	150	97	130	126
Motocycles	4	4	4	4
	Day interval 16:30-17:30			
	16:30-16:45	16:45-17:00	17:00-17:15	17:15-17:30
Light	1433	1260	1238	1425
Heavy	64	74	95	89
Motocycles	6	5	4	10
	Night interval 22:30-23:30			
	22:30-22:45	22:45-23:00	23:00-23:15	23:15-23:30
Light	585	607	497	466
Heavy	35	43	35	32
Motocycles	1	0	4	2
	Total in all intervals			
Light	12069			
Heavy	970			
Motocycles	48			

All the results of the statistical analysis are presented in diagrams and tables as follows. For each measuring point, the measurement diagram is presented in the corresponding figure (Fig. 2 for MM1, Fig. 3 for MM2, and Fig. 4 for MM3) showing the measured equivalent continuous sound pressure levels values $L_{\mathrm{Aeq,15min}}$ and statistical parameters $L_{\mathrm{AF5,15min}}$, $L_{\mathrm{AF10,15min}}$, $L_{\mathrm{AF50,15min}}$, $L_{\mathrm{AF90,15min}}$ and $L_{\mathrm{AF95,15min}}$ during the period of 24 h.

Under each diagram, there are three tables with a unique label for the measuring point (Tab. 2 for MM1, Tab. 3 for MM2, and Tab. 4 for MM3). For each measuring point individually, the tables on the left show the equivalent continuous sound pressure levels for the day or night during the 24-hour measurement period, total calculated values L_{day} and L_{night}, as well as the total number of measurements in the given measurement period. In the tables on the right below the same diagrams, the highest values of the parameters are shown $L_{AF5,15min(max)}$ and $L_{AF10,15min(max)}$, as well as the smallest values $L_{AF90,15min(min)}$ and $L_{AF95,15min(min)}$ during the same measurement period. The tables below show the rounded total calculated values from the left table for the day L_{day} and for the night L_{night}.

On the diagrams with the measurement results of statistical noise analysis, the day and night intervals are marked with circles. The calculation of the equivalent level was made for the exact belonging of the measurement interval to the day or night measurement period, so that the interval (less than 5 min) that started before 22.00 is fully included in the daytime, and the measurement interval started before 06.00 in the night.

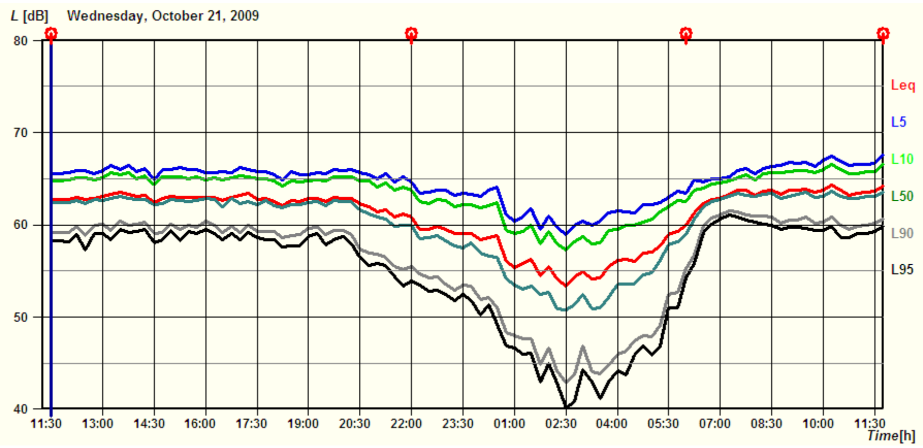


Fig. 2 Statistical noise levels analysis at the measurement point MM1

Table 2 Calculated values at the measuring point MM1 L_{day} and L_{night} and measured statistical levels $L_{AF5(max)}$, $L_{AF10(max)}$, $L_{AF90(min)}$ and $L_{AF95(min)}$

No.	Day L_{day}	Night L_{night}	Day No. rec.	Night No. rec.
	dB (A)			
1	62.7	57.6	42	32
2	63.3	–	23	–
Total	63.0	57.6	–	–

No.	Period	L_{5max}	L_{10max}	L_{90min}	L_{95min}
		dB (A)			
1	Day	66.4	65.6	55.1	53.3
2	Night	64.6	63.7	42.8	40.1
3	Day	67.6	66.6	55.2	54.2

L_{day} = 63 dB (A)
L_{night} = 58 dB (A)

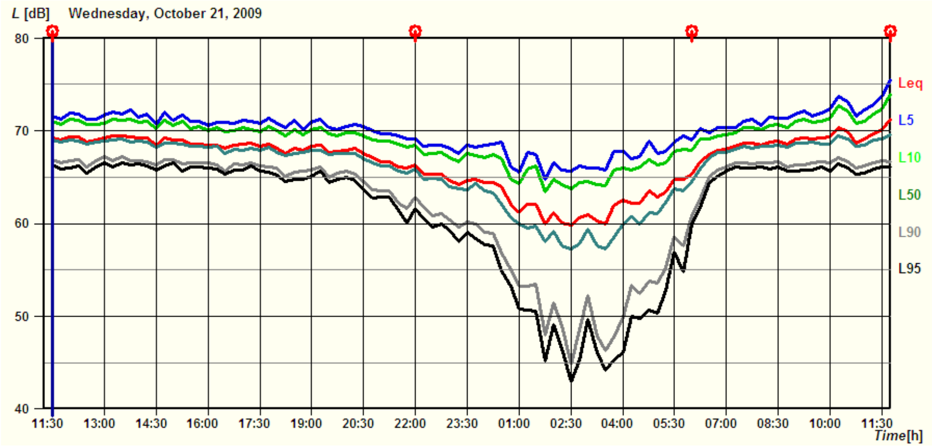


Fig. 3 Statistical noise levels analysis at the measurement point MM2

Table 3 Calculated values at the measuring point MM2 L_{day} and L_{night} and measured statistical levels $L_{AF5(max)}$, $L_{AF10(max)}$, $L_{AF90(min)}$ and $L_{AF95(min)}$

No.	Day L_{day}	Night L_{night}	Day No.	Night No.
	dB (A)		rec.	rec.
1	68.4	63.3	42	32
2	68.9	–	23	–
Total	68.7	63.3	–	–

No.	Period	L_{5max}	L_{10max}	L_{90min}	L_{95min}
		dB (A)			
1	Day	72.2	71.3	61.6	60.1
2	Night	69.4	68.4	44.8	42.9
3	Day	75.5	73.9	60.8	59.9

L_{day} = 69 dB (A)
L_{night} = 63 dB (A)

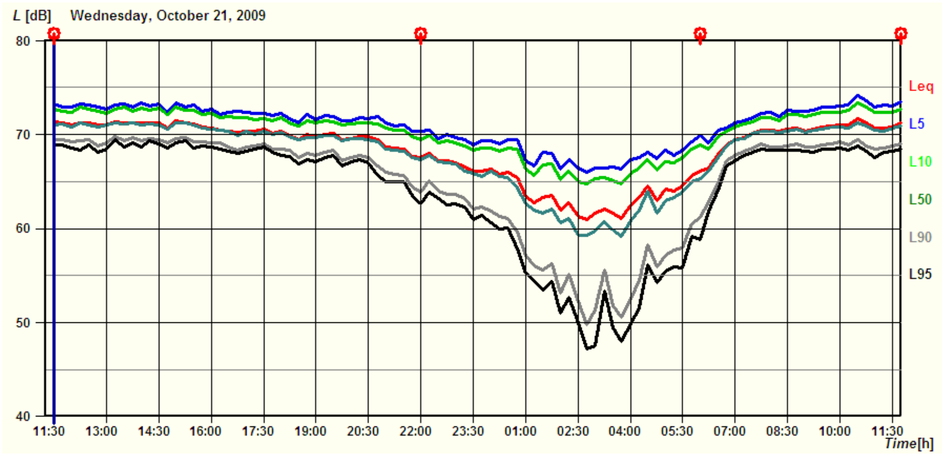


Fig. 4 Statistical noise levels analysis at the measurement point MM3

October levels $L_{AF5(max)}$, $L_{AF10(max)}$, $L_{AF90(min)}$ and $L_{AF95(min)}$

No.	Day L_{day}	Night L_{night}	Day No. rec.	Night No. rec.
	dB (A)			
1	70.4	64.8	42	32
2	70.3	–	23	–
Total	70.4	64.8	–	–

No.	Period	L_{5max}	L_{10max}	L_{90min}	L_{95min}
		dB (A)			
1	Day	73.4	72.9	63.9	62.6
2	Night	70.5	69.9	49.8	47.2
3	Day	74.2	73.4	61.2	58.8

L_{day} = 70 dB (A)
L_{night} = 65 dB (A)

3.1. Comparative analysis of noise levels by measurement points

In Fig. 5, a comparative diagram of measured values $L_{Aeq,15min}$ at different heights at measuring points MM1, MM2, and MM3 during a period of 24 h is presented, while in Tab. 5 a comparative table of total calculated values at the same measuring points and for the same time period was presented.

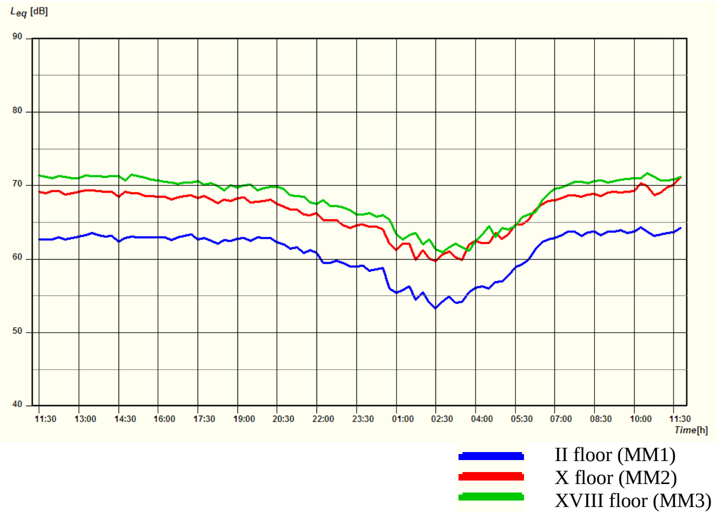


Fig. 5 Diagram of the comparative analysis of the noise level at different heights by measurement points MM1, MM2 and MM3

Table 5 Comparative results of calculated values L_{day} and L_{night} by measuring points

Measuring point mark	Measuring point height (m)	L_{day} (dB (A))	L_{night} (dB (A))
MM1	6.4	63	58
MM2	28.8	69	63
MM3	51.2	70	65
The total number of counted vehicles of all categories		10780	2307

4. The Obtained Results Comment

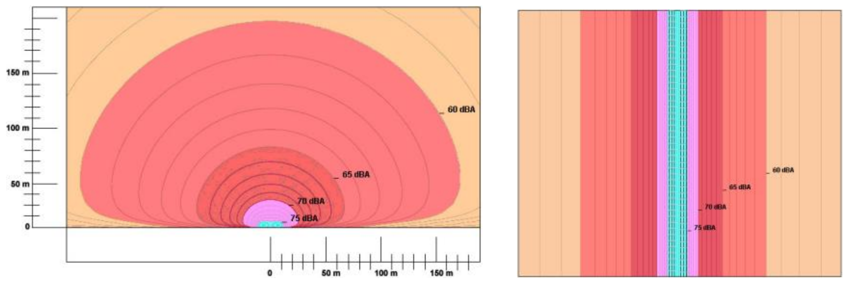
As for the purposes of this experiment, the measuring points were carefully selected so that they were evenly spaced from each other every 22.4 m in height and the same vertical plane and axis in relation to the noise source, that is, the traffic road in question, and that the measurements on them were carried out at the same time, there are provided the same conditions for the noise source at all measurement points and the results are completely comparable.

From the comparison diagram of the equivalent continuous sound pressure levels $L_{\mathrm{Aeq,15min}}$ measured at different heights (MM1, MM2 and MM3) given in Fig. 5 as well as from the table of calculated values for the day L_{day} and night L_{night} given in Tab. 5, it can be seen that the level of noise originating from road traffic on the observed section of the traffic road increases with the increase in height.

Also, it is noticeable that a greater noise level jump with the increase in height was recorded on the lower floors, namely 3 dB (A) during the day and 5 dB (A) during the night between the second and tenth floors, while on the higher floors a noise levels jump of 1 dB (A) for the day and 2 dB (A) for the night between the tenth and eighteenth floor.

The reason why the level of noise originating from road traffic in this case and on this terrain of the selected section increases with the increase in height can be found in the topographic influence of the terrain itself, but also in the direction of the propagation of the acoustic energy radiation of vehicles. Although the emission of acoustic energy from vehicles depends on several superimposed sources, the dominant influence is caused by motor sources that arise during the mechanical excitation of the engine itself as well as the combustion process, and the radiation of which spreads upward in most vehicles, due to the position of the engine itself.

The reason why the increase in road traffic noise level is higher at lower heights can be found in models and analyzes where such a source is considered as point or linear, as is the case with the calculation model shown in Fig. 6 [4], where it can be seen that the sound decreases slowly with increasing height at lower distances from the source, and then due to the square of the distance it already loses a lot of sound power at higher/longer distances from the source.



a) point source noise model b) line noise source model

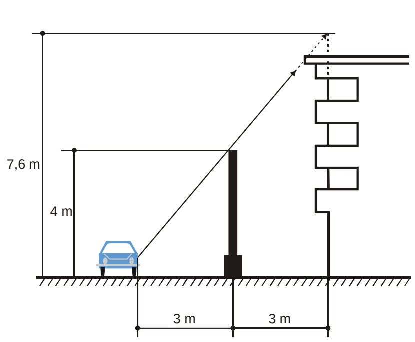
Fig. 6 A model of the distribution of noise levels originating from road traffic for height $h = 3$ m according to [4]

5. CONCLUSION

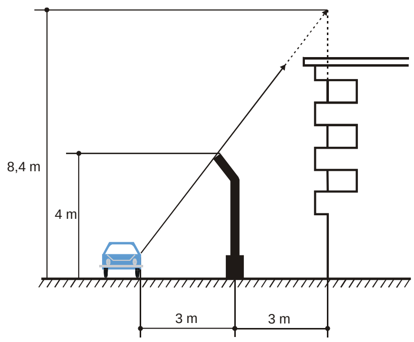
Based on the presented measurement results, it is concluded that the direction of propagation of sound energy of road traffic is more dominant towards higher heights, that is, floors.

Also, due to the slow decrease of the noise level with close distance from the sound source (up to about 50 m, which is the height of the eighteenth floor in our case), that is, the road where there is heavy traffic, the constant level of which is about 75 dB according to existing research and models (for h = 3 m), the proposal is to find a solution for noise protection on higher floors in solitaires located next to the big traffic roads through further research.

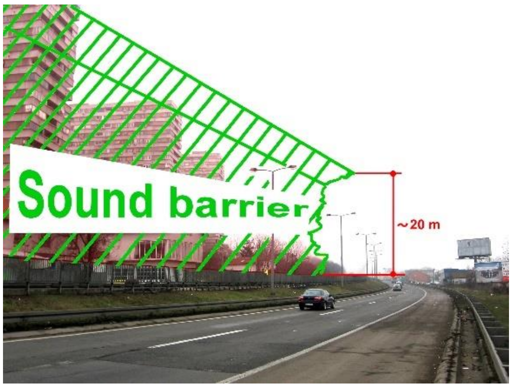
During that, it should be borne in mind that the construction of common sound barriers (4 to 5) m high, and even broken (5 to 7) m high, would not be of importance, because the protection of the higher floors would require a much higher construction (at least 20 m of height) which is impractical for static reasons.



a) An example of a common sound barrier



b) An example of a broken sound barrier



c) An example of a high sound barrier to protect higher floors

Fig. 7 Sketches of some examples of sound barriers

In the picture Fig. 7 illustratively, under a) and b) are presented barrier constructions that contribute to noise protection only on the lower floors, while under c) the possible appearance and height of the sound barrier so that the higher floors are also protected from noise is presented.

An eventual possible solution for protecting the higher floors from noise coming directly from the busy traffic road would be the construction of a tunnel, which increases the protection of the target objects, but then it should be borne in mind that in that case the acoustic energy would be amplified at the exit opening of the tunnel, which would certainly require carefully selected position of the same.

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