ACTA TECHNICA CORVINIENSIS
BULLETIN OF ENGINEERING

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ACOUSTICAL ARRANGEMENT OF THE URBAN ROADS

Abstract:
The phonic pollution on the urban roads is mainly generated by the transportation means. This affects the human being's live and activity. In this paper we presented the results obtained in the investigation and mitigation of the phonic pollution generated by the transportation means in the urban area through acoustical arrangement of the roads. Specific noise sources, characteristic levels, noxious effects, admissible limits and propagation way are identified. Description of measurements and analysis of the results are presented along with some methods concerning the decrease of the phonic pollution. The efficiency of the implementation of these methods is also discussed.

Keywords:
phonic pollution, decrease, urban roads, acoustic arrangement

INTRODUCTION

Noises and vibrations are generated on the urban roads by road transportation means such as trams, buses, trolleybuses, microbuses, cars, trucks, tractors or motorcycles. Sometimes, these noises and vibrations are generated also by the rail and air transportation means. This is possible when the urban roads are near the railway or the airport.

The noises and vibrations generated by transportation means have characteristic spectra and levels of intensity. In this way it is possible to identify the main noise sources from the road transportation means, specifying the noxious effects, admissible limits and propagation way.

Starting from the results of the measurements, we establish some methods concerning the phonic pollution reduction in the urban area through the acoustical arrangement of the roads. The efficiency of the implementation of these methods was evaluated by new measurements. The acoustical arrangement can be applied in every practical situation concerning the urban roads.

NOISE SOURCES ON THE URBAN ROADS

The noise is generated on the urban roads by transportation means. This is characterized by specific frequency spectra, acoustic pressures and their variations in time. This noise depends on the intensity and composition of traffic, as well as on the speed of movement and it is generated by three basic sources: the engine, the exhaust system and the tire/road contact. The trams generate noise and vibrations due to the variation of speeds, the clearance of the rail extremity (joints), the elasticity of the rails, the conicalness, the eccentricity and the deformations of the bandages, the wheel guide on the rails and the brakes and accelerations.

NOXIOUS EFFECTS OF THE PHONIC POLLUTION

The phonic pollution generated by the road transportation means on the urban roads is extremely injurious for the human beings' life and activity. Thus, for the 70 dB(A) equivalent noise level during the daytime, 60% of the population on the urban roads is disturbed [8].

The phonic pollution affects human beings nervous system generating psycho-psychological and blood circulation modifications, as well as sleeps disturbances. Also the visual function and endocrine gland are adversely affected. At the same time the phonic pollution generates auditory tiredness and sonorous trauma.

In order to reduce the effects of the phonic pollution on the urban roads, limit values which cannot be exceeded are established. These limits are characterized by the equivalent noise level, by the noise curves (C_z) and by percentual noise level (L_{10}). The equivalent noise level corresponds to an equivalent intensity which could be constant during the whole considered period of time and it is defined by relation

$$L_{ech} = 10 \lg \left[\frac{1}{T} \int_0^T 10^{0,1L(t)} dt \right] \qquad (1)$$

where L(t) is the instant acoustic level.

The noise curves (C_z) define the relation between the characteristic frequency of a sound and the proper acoustic pressure level in the conditions of a subjective equivalent intensity.

In this way, Romanian standard STAS 10009-88 "Urban acoustics" established the admissible limits of the noise level in urban environment, differentiated on zones and functional endorsements. For the noise level on the urban roads these values are presented in table 1.

Table 1. The noise level on the urban roads

Street type (according to STAS 10144-80)	L_{eq} [dB]	C_z [dB]	L_{10} [dB]
I-main	75-85	70-80	85-95
II-linking	70	65	75
III-collecting	65	60	75
IV-local serving	60	55	70

In the same time the location of residential buildings on streets having different technical categories or at the limit of some functional areas as well as the road traffic organizing must be made so that to be assured the admissible limits for the exterior noise level (which is 50 dB or C_z45 curve). This noise level is measured in a point located at 2m distance from the building's wall, according to STAS 6161/1-79.

In order to limit the effects generated by rail traffic noise upon the urban environment, it is stipulated that this one cannot exceed 70 dB(A) at the limit of the rail area (or C_z65 curve).

For the limitation of the noise generated by the air traffic, it is recommended that this noise arising from airplanes displacement do not exceed 90 dB(A) during the daytime between 7.00-19.00 hours, 85 dB(A) during the evening between 19.00-22.00 hours and 80 dB(A) during the night between 22.00-7.00 hours.

PROPAGATION WAY OF THE NOISE

During the activity of different noise sources from the urban roads, rail or air transportation ways, their vibrations propagate in the surrounding environment as spherical and cylindrical waves and, at long distance, as plane waves.

The equation of spherical waves, in an elastic, homogeneous and isotropic medium with the speed potential Φ as a parameter is

$$\phi = \frac{A_c}{r} e^{j(\omega t - kr)} \qquad (2)$$

where r is the radial coordinate, A_c is the complex amplitude of the spherical wave at the frequency $f = \frac{\varpi}{2\pi}$ that travels from the source with the speed c and $k = \frac{\varpi}{c}$ is the wave number.

If we consider $A_c = Ae^{j\alpha}$, then the acoustical pressure can be determined with relation [3]

$$p = \rho_0 \omega \frac{A}{r} \sin(\omega t - kr + \alpha) \qquad (3)$$

In the same time, taking into account that some parts of the sources from the transportation means have cylindrical shape, because of their vibrations, there are produced cylindrical waves.

The equation of cylindrical waves is

$$\phi = \left[AJ_m(kr) + jBY_m(kr) \right] e^{-jm\varphi} e^{-j\omega t} \qquad (4)$$

where ϕ has the known signification, r and φ are the cylindrical coordinates, A and B are constants, J_m is the Bessel function of the first degree and m range and Y_m is the Bessel-Neumann function of the second degree and m range.
In case of the waves that travel uniformly, then $m = 0$ and the acoustical pressure can be written

$$p = A[J_0(z) + jY_0(z)]e^{-j\omega t} \quad (5)$$

Propagation of spherical, cylindrical and plane waves is causing the variation of the pressure in a point of the acoustical field. If we consider that a pressure at a specific moment is p, then the level of the acoustical pressure is

$$L = 20 \lg \frac{p}{p_0} \quad (8)$$

where $p_0 = 2 \cdot 10^{-5} [N/m^2]$ is the reference acoustical pressure.

MEASUREMENTS ACCOMPLISHMENT

Taking into consideration the huge number and variety of sources that have a part to play in generating the noise on the urban roads, as well as the nature of the acoustic produced by these ones, the acoustic field is extremely complex and its study is indicated to be of an experimental nature.
Noise level measurements were carried out in 119 measurements points which were located near some of the most noisy roads crossings from Timişoara city [1], [5]. The measurements were performed using the Brüel & Kjaer 2237 Controller Integrating Sound Level Meter and the Hand-held Analyser Brüel & Kjaer 2250. These ones allowed measuring and automatic recording of the most important parameters of the noise such as: L_{eq} (equivalent noise level), L_{AE} (exposure level), L_{max} (maximum noise level), L_{min} (minimum noise level), $L_{0,1}$, L_5, L_{10}, L_{50}, L_{90}, L_{95} (percentage noise levels). These parameters were obtained during a continuous 8 hours period of time (7.30-15.30), divided into 1 hour time intervals.
By means of these measured parameters, it was possible to compute other physical indicators which characterize the effect of phonic pollution, such as:
- the noise climate

$$N.C. = L_{10} - L_{90} \quad (7)$$

- the traffic noise index

$$T.N.I. = 4(L_{10} - L_{90}) + L_{90} - 30 \quad (8)$$

- the level of phonic pollution

$$L.N.P. = L_{ech} + L_{10} - L_{90} \quad (9)$$

In order to perform the measurements, the microphone was placed next to the urban roads border at 7,5 m distance from the axis of the first runway, at 1,30 m high from the ground.
Simultaneously with the noise data recording, the traffic composition and intensity as well as the speed of the vehicles were determined.
The results of the measurements, the intensity and composition of the traffic were centralized in a data base designed for the study of phonic pollution in Timişoara City.

ANALYSIS OF THE MEASUREMENTS RESULTS

From the obtained data it results that the equivalent noise level exceeds the maximum admissible value (defined by Romanian standard STAS 10009-88 concerning "Urban acoustics") in 95 points from the total of 119 measured points, which means 79,85% of the total points.
The overtaking was included into the interval 0,5-15,5 dB. Table 2 presents the statistical distribution of the equivalent noise level (L_{eq}) in the measured points, as well as the percentage of disturbed people [8].

Table 2. Statistical distribution of the equivalent noise level (L_{eq}) in the measured points, as well as the percentage of disturbed people

L_{eq}	No. of points	%	Percentage of disturbed people
54,3	1	0,85	8
55÷60	0	0	0
60,3÷63,5	9	7,6	25÷40
65,1÷70	37	31,1	42÷60
70,1÷74,9	51	42,8	60,1÷79,9
75,1÷79,6	18	15,1	80,1÷98
81,8	1	0,85	100
85,5÷85,9	2	1,7	100

In the majority of the measurement points, the peak noise level was exceeded with 1-9,5 dB while the admissible noise level established to 50 dB measured at 2 meters distance from the buildings was generally exceeded with 1,3-32,9 dB(A).

The average equivalent noise level for the 119 measured points was 71,03 dB(A) and the average traffic intensity was 1202,3 aut./h. The traffic intensity ranged between 9 and 2681 aut./h while the speed of vehicles ranged between 40 and 60 km/h.

The percentage of different transportation means is presented in table 3. The noise level generated by trains measured at the limit of the rail area exceeded the admissible value with 2,2-12,7 dB(A).

Table 3. The percentage of different transportation means

Transportation means	Minimum percentage	Maximum percentage
Trams	0,4	18
Buses	0,01	7,5
Trolleybuses	0,04	7,8
Microbuses	1,1	15,9
Cars	34,2	95,27
Trucks	0,3	18,1
Tractors	0,01	2,9
Motorcycles	0,01	4,1
Trains	0,08	54,7

Because in the majority of the measured points the admissible limits were exceeded, it was found to be necessary to apply some measures for acoustic arrangement of the urban roads.

ACOUSTICAL ARRANGEMENT OF THE URBAN ROADS

In order to reduce the noise on the roads in Timişoara City, some measures for acoustic arrangement were established and implemented. In this way, the old rail system was completely changed and replaced with a modern one, more silent, with better insulating properties. All the old noisy trams were replaced with a newer generation, but unfortunately not the newest one.

On many streets it was improved or replaced the superstructure of the runway. Many crossings were modernized and semaphores were installed. One-way traffic was imposed for some streets and the speed of vehicles was limited. It was eliminated the presence in traffic of heavy trucks in the central area of the City. On some roads it was allowed the access only for certain categories of vehicles. On the other side, in order to avoid the presence of heavy trucks on the urban roads, it was started the construction of a ring-road for Timişoara. Protective green zones were implanted between the runways and the residential areas.

The effect of the implementation of these measures on the noise abatement were evaluated through new measurements performed in 46 measurement points, selected near some of the most important crossings of the urban roads from Timişoara City.

From the obtained data it results that in the 46 measured points, the equivalent noise level was reduced with 0,1-12,4 dB and in 32 points (69,56%) the noise level does not exceed any more the admissible value defined by STAS 10009-88.

In the following section, we present a comparison between the situation existing in these 46 measurement points before and after the implementation of noise abatement measures.

In table 4 and table 5 we present the statistical distribution of the equivalent noise level and the percentage of disturbed people in those 46 measurement points before (table 4) and after (table 5) the implementation of noise abatement measures.

Table 4. The statistical distribution of the equivalent noise level and the percentage of disturbed people in those 46 measurement points before the implementation of noise abatement measures

L_{eq} [dB]	No. of points	%	Percentage of disturbed people
63,5	1	2,2	37
66,2÷69,7	10	21,7	47÷59
70,1÷74,9	28	60,9	60÷79
75,1÷78,6	7	15,2	80,1÷97

Table 5. The statistical distribution of the equivalent noise level and the percentage of disturbed people in those 46 measurement points after the implementation of noise abatement measures

L_{eq} [dB]	No. of points	%	Percentage of disturbed people
60,1÷65	16	38,4	25÷44
66,1÷69,9	18	39,1	47÷60
70,4÷74,2	11	23,9	61÷78
75,1	1	2,2	80,1

The average equivalent noise level in these 46 measurement points was 71,8 dB(A) for an average traffic intensity of 1260,7 aut./h before the application of noise abatement measures and 67,3 dB(A) for an average traffic intensity of 1429 aut./h after the implementation.

Regarding the average equivalent noise level existent at 2 meters distance from buildings, this one was 67,3 dB before the application of noise abatement measures and 62,7 dB after that.

Table 6. The transportation means before application of noise abatement measures

Transportation means	Minimum percentage	Maximum percentage
Trams	0,4	15,1
Buses	0,01	2,7
Trolleybuses	0,04	3,0
Microbuses	2,9	10,9
Cars	68,7	95,27
Trucks	0,4	16,4
Tractors	0,03	1,4
Motorcycles	0,01	1,7
Trains	0,1	1,7

Table 7. Transportation means after application of noise abatement measures

Transportation means	Minimum percentage	Maximum percentage
Trams	0,4	47,9
Buses	0,1	8,6
Trolleybuses	0,1	1,9
Microbuses	2,1	16,8
Cars	39,6	93,6
Trucks	0,1	15,3
Tractors	0,1	1,4
Motorcycles	0,3	10,4
Trains	0,1	1,5

The percentage of transportation means in these 46 measurement points is presented in table 6 (before application of noise abatement measures) and in table 7 (after application of noise abatement measures).

In the same time it was proved that an important contribution to the noise generated by the road transportation means on the urban roads has the tire/road contact, which can be reduced by covering the road superstructure with rubberized asphalt or with rubber pavement. Using these measures it is expected to obtain a noise level reduction with approximate 4 dB. These methods will be also useful for an increased traffic security realized through the elimination of the vehicle skidding.

CONCLUSIONS

After performing the investigations described in the paper, it was possible to evaluate the degree of phonic pollution for Timişoara City. The acoustical arrangement of the urban roads leads to a diminution of the pollution degree also a diminution of the percentage of disturbed people.

The measurements performed after the acoustical arrangement of the urban roads proved its efficiency. This can be underlined by comparing the results of the measurements performed before and after the acoustical arrangement of the urban roads.

Once the acoustical arrangement of the urban roads proved its efficiency, these methods can be easily applied in every practical situation concerning traffic or industrial noise.

Finally one can conclude that the acoustical arrangement of the roads implemented in Timişoara City proved its efficiency.

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ACTA TECHNICA CORVINIENSIS – BULLETIN of ENGINEERING

Scientific supplement of
ANNALS of FACULTY ENGINEERING HUNEDOARA – INTERNATIONAL JOURNAL of ENGINEERING
ISSN: 1584-2665 [print]
ISSN: 1584-2673 [CD-Rom]