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PERCEPTION OF LOW-FREQUENCY NOISE ON INHABITANTS OF BUILDINGS LOCATED NEAR ARTERY LINES WITH HEAVY TRAFFIC

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ABSTRACT
Heavy road traffic on the main street in a cities generate noise and vibrations. It is very important to inhabitants of buildings, placed near the streets, railways, underground lines. Simultaneously appearance vibrations and noise decrease acoustic climate in these dwellings. For recognize this complicate problem the measurement parameters which describe these phenomenon's (vibrations and noise) have been evaluated. Measurements were made in ground floor of dwellings which placed near the roads. The paper presents a proposition for a criterion for evaluating man's perception of a vibro-acoustic phenomenon of this type. The results of measurements conducted in buildings particularly exposed to simultaneous occurrence of noise and vibrations caused by heavy traffic were presented as well.

1 - INTRODUCTION
The phenomenon of the occurrence of noise in residential premises caused by vibration on the surfaces of building partitions confining the premises (walls, ceiling, floor) is very complex (Fig. 1) [4].

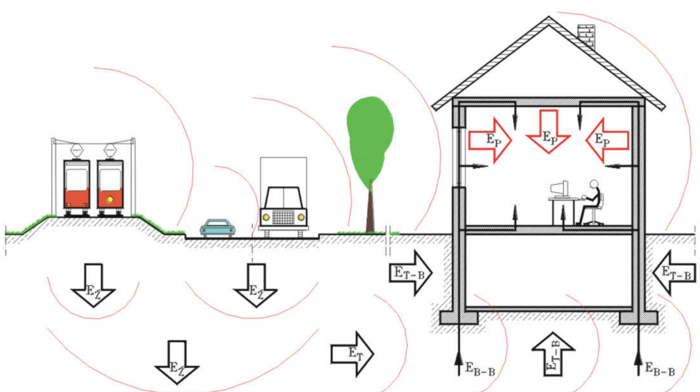

Figure 1: Diagram of the propagation of traffic-induced vibrations to a residential building [4].

The final stage of the phenomenon of transmitting the vibrations energy to the building, that is:

- emission of acoustic energy by induced to vibrations building partitions confining the residential premises - E_p

This emission depends on many factors. The final effect of the occurrence of vibrations on the partitions in premises given above depends on four acoustic phenomena, namely:

- the dispersion of vibrations on the building's structure, **-E**$_{\mathrm{B-B}}$
- inducing the building's structure to vibrations through the interaction of the base and the building's foundation, **-E** $_{\mathrm{T-B}}$
- propagation of waves in the base on the source ⇒ building path, **-E**$_{\mathrm{T}}$
- inducing the base to vibrations by a passing heavy vehicle (tram, train, bus, truck tractor with semi-trailer, truck), that is generation of a vibration wave, **-E**$_{\mathrm{Z}}$

2 - PROPOSITION FOR A CRITERION ON THE BASIS OF OWN STUDIES

Analyzing the contemporary trends in evaluating noise in the low frequency range it was proposed to adopt the frequency spectrum (75-k_G)+(10-k_A), [1] and calculations were carried out of the levels of sound pressure adjusted by this curve for the frequency range 1−160 Hz.

The total real level of sound pressure $L_{p\ (1-160)\ (75-k_G)+(10-k_A)}$

$$L_{p(1-160)(75-k_G)+(10-k_A)} = 10\log\left[\sum_{k=1}^{l} 10^{0.1\cdot\left(L_{p_{k1/3oct}}-k_n\right)}\right] \text{ dB, for } L_{p_{k1/3oct}} > k_n \qquad (1)$$

where:

- $L_{p(1-160)(75-k_G)+(10-k_A)}$ − the total real level of sound pressure from the frequency range 1−160 Hz, dB
- $L_{p_{k1/3oct}}$ − the real level of sound pressure in k 1/3 octave frequency band, dB
- k − next 1/3 octave frequency band in frequency range 1−160 Hz
- k_n − correction curve (75-k_G)+(10-k_A)
- l − number of 1/3 octave bands for which the condition $L_{p_{k1/3oct}} > k_n$ is fulfilled

The total rise in the level of sound pressure $L_{p\ (1-160)\ (75-k_G)+(10-k_A)}$ (for sound transmission by material path)

$$\Delta L_{p(1-160)(75-k_G)+(10-k_A)} = 10\log\left[\sum_{k=1}^{l} 10^{0.1\cdot\left(L_{p_{k1/3oct}}-k_n\right)}\right] - 10\log\left[\sum_{k=1}^{m} 10^{0.1\cdot\left(L_{air_{k1/3oct}}-k_n\right)}\right] \text{ dB}$$
$$\text{for } L_{p_{k1/3oct}} > k_n \text{ and } L_{air_{k1/3oct}} > k_n \qquad (2)$$

where:

- $\Delta L_{p(1-160)(75-k_G)+(10-k_A)}$ − the total increase in the level of sound pressure (for sound transmission by material path) from the frequency range 1−160 Hz, dB
- $L_{p_{k1/3oct}}$ − the real level of sound pressure in k 1/3 octave frequency band, dB
- $L_{air_{k1/3oct}}$ − the level of sound pressure for airborne sound transmission in k 1/3 octave frequency band, dB
- m − number of 1/3 octave bands for which the condition $L_{air_{k1/3oct}} > k_n$ is fulfilled
- k, k_n − as above

The total real level of sound pressure $L_{p\ (1-160)\ (75-k_G)+(10-\ k_A)}$ and *the total increase in the level of sound pressure* $\Delta L_{p\ (1-160)\ (75-\ k_G)+(10-k_A)}$ in 1/3 octave bands adjusted by the frequency spectrum (75-k_G)+(10-k_A) may be used as the single-figure index being a proposition of criterion of the simultaneous occurrence of traffic noise and vibrations on the acoustic conditions in residential buildings. The first factor determines man's perception of noise in the range of low frequencies and the second one the input to this perception of vibrations occurring on the partitions confining the studied premises in the total

Figure 2: Perception of noise in the range of low frequencies at Solidarnosci Ave. (passing tram) [2], [3], [4].

level of sound pressure in these premises. Below are presented the graphic results of calculations for the studied premises depending on the analyzed sources of traffic noise and vibrations. These are single cases for various types of vehicles.

Some of the results of $L_{p\ (1-160)\ (75-\ k_G)+(10-k_A)}$ and $\Delta L_{p\ (1-160)\ (75-\ k_G)+(10-k_A)}$ are presented in table 1. The results considering causes which has been described in this paper.

Localization of building (source)	$L_{p\ (1-160)\ (75-k_G)+(10-k_A)}$ dB	$\Delta L_{(1-160)\ (75-k_G)+(10-k_A)}$ dB
Solidarnosci Ave. (tram)	37.9	9.3
Grochowska St. (truck tractor with semi-trailer)	24.8	8.2
Niepodleglosci Ave. (bus)	16.2	3.1

Table 1: Total real level of sound pressure $L_{p\ (1-160)\ (75-\ k_G)+(10-k_A)}$ and the total rise in the level of sound pressure $\Delta L_{p\ (1-160)\ (75-\ k_G)+(10-k_A)}$ in 1/3 octave bands adjusted by the frequency spectrum (75-k_G)+(10-k_A) [4].

We see from the dependencies for the values of results obtained from the tests presented below that:

- when analyzing noise annoyance from the total increase in sound pressure $\Delta L_{p\ (1-160)\ (75-\ k_G)+(10-k_A)}$, there is a higher correlation coefficient than in the case of analyzing noise annoyance from the total real level of sound pressure $L_{p\ (1-160)\ (75-\ k_G)+(10-k_A)}$,
- there exists a strong linear dependence − correlation coefficient r=0.87 between the total increase in the level of sound pressure $\Delta L_{p\ (1-160)\ (75-\ k_G)+(10-k_A)}$ and the total real level of sound pressure $L_{p\ (1-160)\ (75-\ k_G)+(10-k_A)}$.

3 - SUMMARY AND CONCLUSIONS

The aim of the work was to demonstrate the possibility of developing a method and evaluation criterion for of traffic noise and vibrations occurring simultaneously on the acoustic conditions in residential buildings located near communication routes.

Analyzing the results of objective measurements and additional subjective tests conducted in buildings exposed to the simultaneous occurrence of noise and vibrations generated by heavy road traffic, we can formulate the following specific conclusions, as these results may not be the basis for setting out general conclusions owing to their low number:

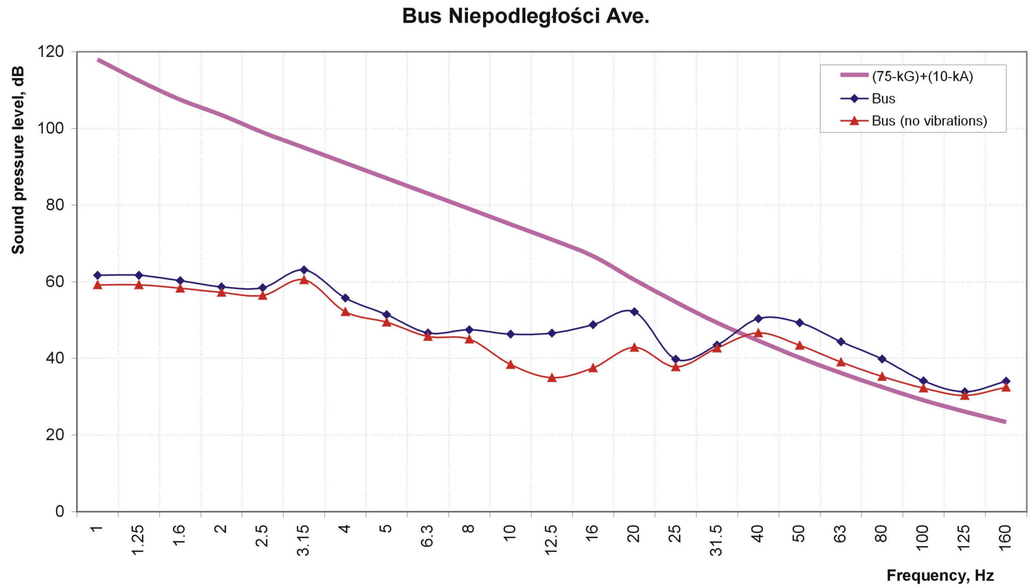

Figure 3: Perception of noise in the range of low frequencies at Niepodlegosci Ave. in Warsaw (passing MZK bus) [2], [3], [4].

- the calculated increases in the levels of sound pressure caused by vibrations on building partitions in the studied premises were restricted by values of the measured acoustic background. The "acoustic background" was taken to include values of sound pressure, at which only noise reaches the premises (airborne sound transmission) generated by light vehicles. This means that in building situated directly on the road these values are lower that in the case of buildings found at a distance from traffic arteries (this results from the adopted principle of analyzing the "net" influence of the passing of a heavy vehicle).
- the total increases in the level of sound pressure $\Delta L_{p(1 \div 160)}$ (for sound transmission by material path) from the frequency range 1−160 Hz calculated using the coherence function taking into consideration the existing acoustic background, depending on the analyzed vehicle and location of the flat, adopt values from 1.7−10.3 dB

The work does not exhaust the entire subject of the simultaneous occurrence of noise and vibrations in residential buildings located in the close proximity of communication routes, particularly taking into consideration heavy traffic. It demonstrated a method (proposition) for a complex evaluation of the vibro-acoustic phenomenon appearing in flats generated by passing heavy vehicles. It is clear that on the basis of the obtained results, due to their low number, as well as the high variability of conditions in the environment of the tested building, they may not be used as a basis for drawing general conclusions regarding the analyzed phenomenon. But they should form the basis for further measurements and analyses in order to explain all the aspects connected with the above phenomenon.

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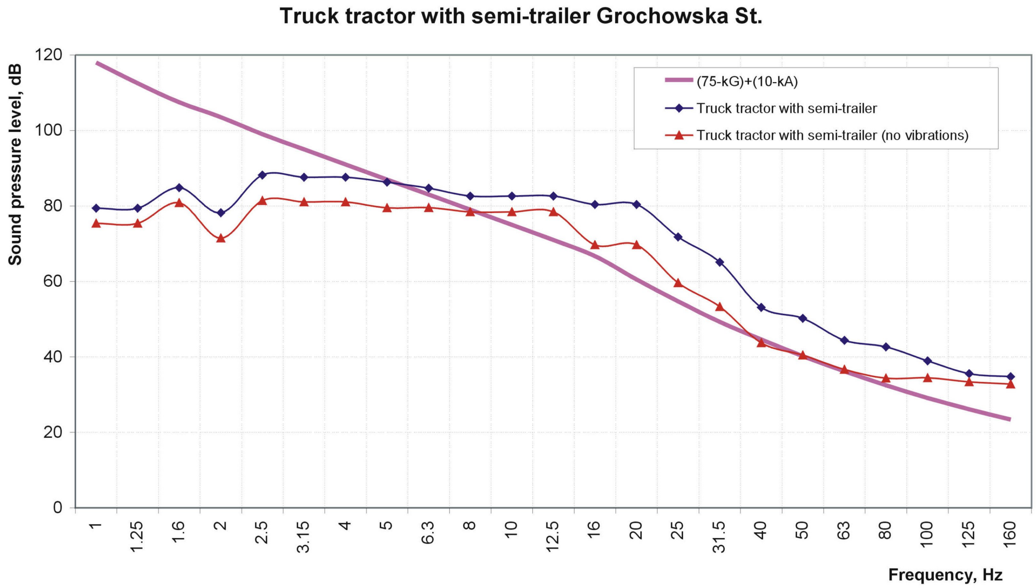

Figure 4: Perception of noise in the range of low frequencies at Grochowska St. in Warsaw (passing truck tractor with semi-trailer) [2], [3], [4].

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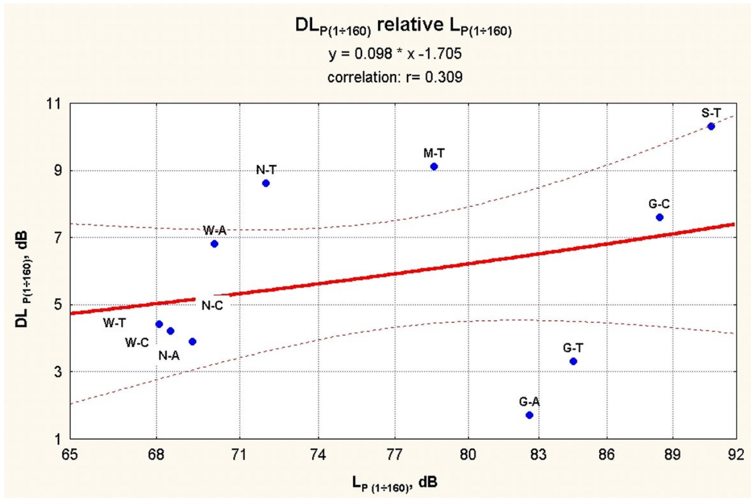

Figure 5: Dependence $\Delta L_{(1-160)}$ of the total rise in the level of sound pressure from $L_{p\ (1-160)}$, the total real level of sound pressure [4].

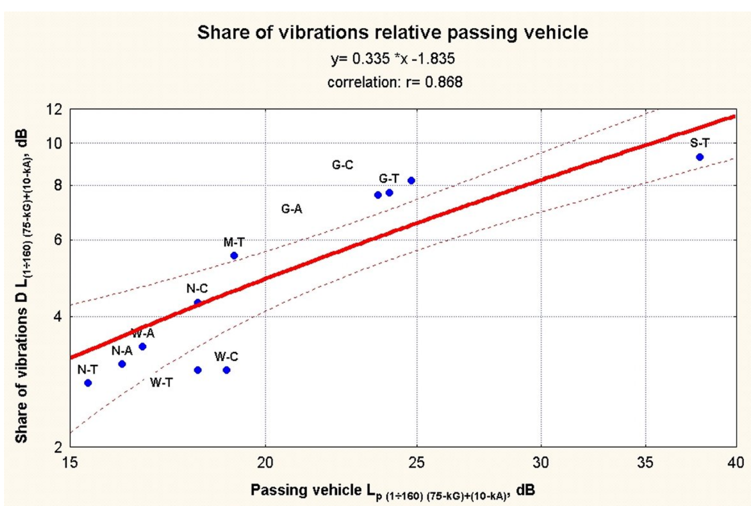

Figure 6: *Dependence* $\Delta L_{p\ (1-160)\ (75-\ k_G)+(10-k_A)}$ of the total rise in the level of sound pressure from $L_{p\ (1-160)\ (75-\ k_G)+(10-k_A)}$ of the total real level of sound pressure [4].