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ASSESSMENT OF NOISE LEVELS GENERATED BY THE OPERATION OF A CONVEYOR BELT

Toma ZAPLAIC[1], Mihnea MAGHETI[2], Victor MINCHEVICI[3], Nicolae ENESCU[4]

The paper presents some elements regarding the assessment of noise levels in the vicinity of a limestone conveyor belt, used as a raw material in a cement plant. ***.*** *The conveyor belt passes through many inhabited area and the assessment of exposure to noise of the sensitive receptors (dwellings) using measurement is a laborious activity, affected by the existence of significant values of residual noise, which disturbs the measurement activity. The sources of residual noise are traffic in the area, domestic activities, domestic animals.*

One way to overcome these difficulties is the acoustic modeling along the area of the conveyor belt and the assessment of noise levels in the vicinity of sensitive receptors by computing. The quality of the results is clearly influenced by the quality of the modeling, and some elements that the authors of the paper have taken into account have contributed to the completion of this paper under acceptable conditions.

Keywords: conveyor belt, noise sources, noise maps.

1. Introduction

In order to verify the compliance of the transport of the raw material (limestone) for the cement plant by using the conveyor belt (Figure 1), it was necessary to assess the noise exposure of the sensitive receptors (dwellings) located along its path, about 8 km, which crosses four localities. The landscape in the area is varied and the conveyor tracks, generally land depressions. The height at which the belt housing is located is variable, adapting to the existing conditions during the construction of the belt. The measurement of noise levels can be done for dwellings located within 15 to 20 m of the belt, the area where the noise generated by its operation is predominant, compared to the random residual noise

[1] Eng., SC Cepstra Grup SRL, Bucharest, e-mail: toma.zaplaic@cepstra.ro
[2] Eng., University POLITEHNICA of Bucharest, Romania, *corresponding author, e-mail: mihnea.magheti@gmail.com
[3] Counselor, General Directorate for Impact Assessment and Pollution Control, Ministry of Environment, e-mail: victor.minchevici@gmail.com
[4] Prof., Department of Mechanics, POLITEHNICA University of Bucharest, e-mail::enescu.nae@gmail.com

having as sources activities specific to a locality, as road traffic and noise produced by domestic animals.

Fig.1: Series of "snapshots" on the analyzed area

According to the provisions of the standard SR ISO 1996-2:2018 [1], if between the levels of total noise L_t and residual noise L_r, the following relation is applied:

$$L_t - L_r > 10dB \tag{1}$$

no correction is required since the measurement uncertainties having residual noise as the source being small. Total noise is composed by the noise of the conveyor belt, to which is added the noise generated by all existing sources in the measurement area. Residual noise is the existing noise at the measuring point when the conveyor belt is not functioning.

The specific noise generated by the operation of the belt is approximately constant under the conditions of nominal conveyor belt operation. The residual noise is random. If:

$$3dB \le L_t - L_r \le 10dB \tag{2}$$

to obtain the level of noise generated by the conveyor belt, it is necessary to make a correction based on the relation (3):

$$L_s = 10 * \lg\left(10^{\frac{L_t}{10}} - 10^{\frac{L_r}{10}}\right) \tag{3}$$

If:

$$3dB > L_t - L_r \tag{4}$$

corrections are not allowed, the uncertainty of measurement being high in this case.

Therefore, it has been chosen as working procedure the accomplishment of noise measurements at points near the band, to characterize the emission where its noise is predominant over residual noise, combined with the acoustic modeling of the source and area of the band followed by the evaluation by calculation of the noise exposures of sensitive receptors in this area [2].

2. Specific elements on modeling

The conveyor belt is included in a 3m x 3m housing and represents a structure with a very long length compared to the dimensions of its transversal section so that, starting from a certain distance, it can be modeled by a linear source with incoherent emission, characterized by an acoustic emission level L_{p1} [dB(A) /m].

The calculation of the noise level generated by a source at a certain distance [3] is made with the following relation:

$$L_{Aeq} = L_E - \Delta_{geo} - \Delta_{air} - \Delta_{gr} - \Delta_{scr} + \Delta_{refl} \tag{5}$$

where: L_{Aeq} is the noise level at the receiver;

L_E is the emission value per source type and octave band;

Δ_{geo} is the attenuation due to geometric spreading;

Δ_{air} is the attenuation due air propagation;

Δ_{gr} is the ground absorption correction;

Δ_{scr} is the screening effect;

Δ_{refl} is the reflection correction, including the effect of the facade.

The conveyor belt is generally located at around 5 to 7 meters height and for receptors close to it (up to 35 meters), without shielding, the only attenuation remains Δ_{geo}.

The most used sources for modeling real-world situations are [4], [5], [6]: point source, linear source, planar source having a uniform emission or characterized by directivities. Another category is the finite linear sources.

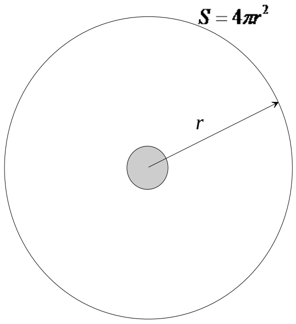

Fig. 2: Spherical spreading for a point source

The most common is the omnidirectional point source, characterized by the acoustic power $\Pi[W]$. The acoustic intensity I [W/m^2] represents the energy flow passing through the surface unit surrounding the source, in a unit of time and defined by the relation:

$$I = \frac{\Pi}{4\pi r^2} \tag{6}$$

The intensity could also be defined by the relation:

$$I = 10\log\left(\frac{p^2}{\rho c}\right) \tag{7}$$

where *p* is the effective pressure, *c* is the sound speed and the product ρc is the specific impedance of the environment at a certain temperature.

Taking into account that the reference pressure is $p_0 = 2 * 10^{-5}$ N/m^2

and the reference power is $\Pi_0 = 10^{-12}$ W, respectively $I_0 = 10^{-12}$ W/m^2, by applying the "$10\log$"transformation, it is obtained [6]:

$$L_I = 10\log\left(\frac{p^2}{\rho c I_0}\right) = 10\log\left(\frac{p^2}{p_0^2}\frac{p_0^2}{\rho c I_0}\right) = 20\log\left(\frac{p}{p_0}\right) + 10\log\left(\frac{p_0}{\rho c I_0}\right)$$

$$L_I = L_p + 10\log\frac{(2*10^{-5})}{414*10^{-12}} = L_p - 0{,}15 \qquad (8)$$

where $L_I = 10*\log\left(\frac{\Pi}{\Pi_0}\right)$ and $L_p = 20*\log\left(\frac{p}{p_0}\right)$

Approximately it is considered:

$$L_I = L_p \qquad (9)$$

So, starting from the relation (6), it is obtained:

$$L_p = L_P - 20\log(r) - 11 \qquad (10)$$

Per distance doubling results 6 dB reduction in all directions.

Often, the finite linear sources model real-world situations, including aspects of this paper, such as assigning acoustic emissions to conveyor belt segments.

Different sections of the conveyor belt have different emissions due to the rehabilitation work previously applied to sectors, so for the band modeling, the problem of determining the acoustic emissions characteristic of these sectors, especially for situations in the sensitive receptor area, has been raised. The starting point represents the calculation relations existing in the work [5] and presented in the following paragraphs.

The acoustic intensity pertained to the elementary segment *dx* (fig. 3) has the expression:

$$dI = \left(\frac{\Pi}{l}dx\right)*\frac{1}{4\pi r^2} \qquad (11)$$

where:

$\frac{\Pi}{l}$ is the linear density of acoustic power corresponding to the linear source of length *l*.

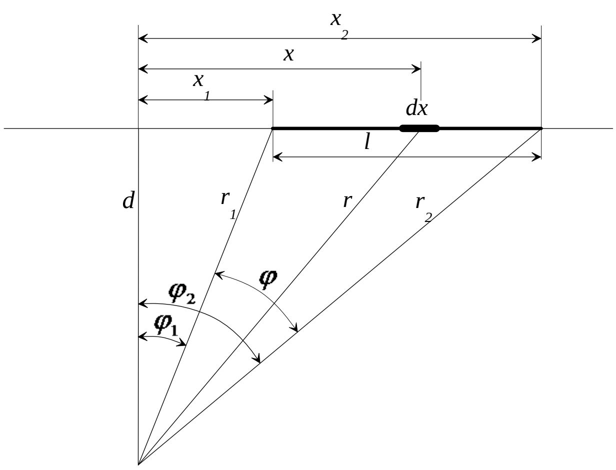

Fig. 3: The finite linear source, represented by the segment l = x_2 - x_1

$$I = \int_{x_1}^{x_2} dI = \frac{\Pi}{4\pi l} \int_{x_1}^{x_2} \frac{dx}{x^2 + d^2} = \frac{\Pi}{4\pi l d}\left(arctg\frac{x_2}{d} - arctg\frac{x_1}{d} \right) = \frac{\Pi}{4\pi l d}\left(\varphi_2 - \varphi_1\right) \qquad (12)$$

where:
d is the perpendicular distance between the receiver point and the finite linear source; l is the length of the linear source.
It is noticeable that the intensity at a receiver point is proportional to the angle under which the linear source is seen.
Relation (12) is useful in determining the acoustic power level of a coveyor belt segment that can be assimilated to a finite linear source. It is advantageous for the measuring point to be in a position where the following conditions are met:
- an unhindered view of the analysed sector or a part of the sector;
- the measurement point should be on the segment midperpendicular;
- the distance from the segment must be such that other attenuations can be neglected except the geometric one, but also the free field condition for measurement should be fulfilled.
Taking into account the second condition above, the equation (12) can be written as:

$$I = \frac{\Pi}{4\pi l d}\left(2 * arctg\frac{l}{2d} \right) \qquad (13)$$

By applying the transformation "$10\log$", after dividing at $I_0 = 10^{-12}$ W/m^2, and taking into account that $L_I \cong L_p$, it is obtained:

$$L_p = L_{p1} - 8 - 10\log d + 10\log\left(arctg\frac{l}{2d} \right) \qquad (14)$$

where:
L_p [dB] is the measured acoustic pressure level at distance d;
L_{p1} [dB/m] is the acoustic power level per meter for the analyzed linear source.

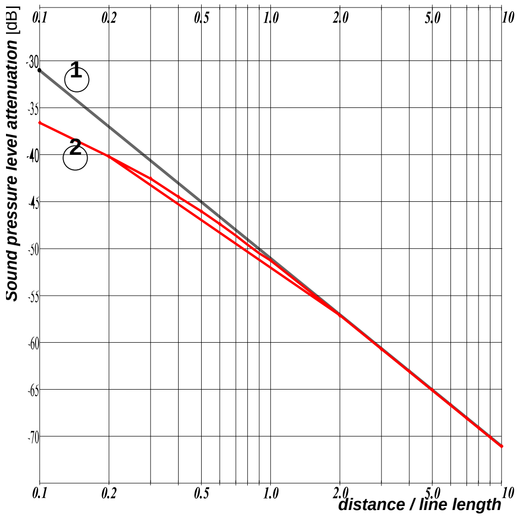

Fig. 4: Sound pressure level attenuation for two different tipes of sources versus relative distance beetween source and receiver. The sources have the same acoustic power
1 - point source - reduction 6 dB per distance doubling;
2 - finite line source.

For comparison, in fig. 4, the attenuation of the sound pressure level for a point source and for a finite linear source, depending on the relative distance from the source, has been drawn.

The point source has a reduction of 6 dB per distance doubling.

The finite line source has variable behaviour in the first part and a similar source point behaviour in the second part.

Table 1 presents an exemple of use of the relation (14).

The example corresponds to a point located at about 30 m from the conveyor belt, the segment of the belt is visible on a length l = 68 m, where the measured noise level at 1.5 m was 56.5 dB(A) with the spectral distribution shown on the second line of the table.

Table 1

Data corresponding to an analyzed situation

f[Hz]	63	125	250	500	1000	2000	4000	8000	
L_p[dB(A)]	29.0	39.0	42.0	51.5	52.5	46.5	39.0	27.0	
$L_{p,tot}$dB(A)]									56.5
$L_{\Pi 1}$ [dB(A)/m]	53.3	62.3	65.3	74.8	75.8	69.3	62.3	50.3	
$L_{\Pi 1 tot}$ [dB(A)/m]									79.3

Note:
- line 1: frequencies corresponding to octave-bands spectral analysis;
- line 2: the A-weighted measured values at the indicated point, on octave-bands;
- line 3: the resultant from the logarithmic summation of line 2 values using the relation:

$$L_{p,tot} = 10 * \log\left(\sum_{1}^{8} 10^{\frac{L}{10}}\right) \tag{15}$$

- line 4: the calculated values of the band segment emission, per octave-bands, using the relation (14);
- line 5: the resultant from the logarithmic summation of line 4, using the relation (15).

Fourth line values were used as emission data for the finite linear source represented by the specified conveyor belt segment

3. Results and conclusions

Fig. 5 and fig. 6 presents the results of the noise mapping of the mentioned area in order to assess the noise levels at which sensitive receptors in the area are exposed.

The realization of the digital acoustic model of the analyzed area was made by first introducing the data on the relief, which in this case significantly influences the propagation of the noise and consequently the distribution of its levels. Also, all important obstacles to noise propagation have been introduced, including façade absorption coefficients. By specific indexes, the necessary information on the acoustic properties of the soil was introduced. Acoustic modeling and calculation were performed using a SoundPlan 7.1 software. The noise source, represented by the limestone conveyor belt, was modeled as a combination of finite linear sources using the theoretical and practical elements presented above.

The use of the method of obtaining acoustic emission by using the theoretical elements described in the work [5], combined with their adaptation to the concrete situations by the authors of this paper, represents an example of a situation where the above method can be used to model finite linear sources.

The presented mode of operation has assessed the noise levels at which the sensitive receptors in the analyzed area are exposed. This avoided the difficulties created by the existence of high residual noise.

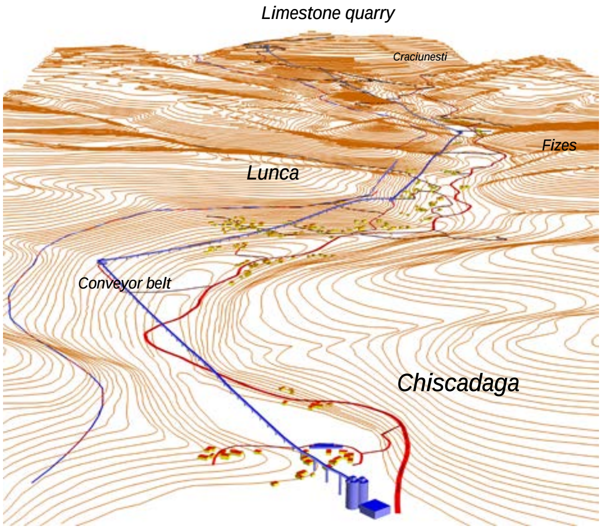

Fig.5: Geographical elements from digital noise model

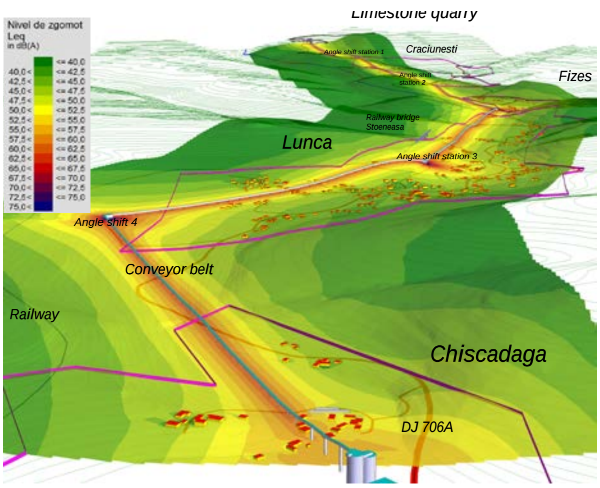

Fig.6*:* Noise map of the area in order to assess the noise levels at which sensitive receptors in the area are exposed

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A N N E X

Defining the acoustic power level per unit of length and deducting the relation (14)

The following preliminary definitions are presented:

- the reference value of acoustic power:

$$\Pi_0 = 10^{-12}[W]$$

- the reference value of the acoustic intensity:

$$I_0 = \frac{\Pi_0}{S_0} = 10^{-12}\left[\frac{W}{m^2}\right]$$

where $S_0 = 1m^2$ is the surface unit;

- definition of acoustic power level:

$$L_\Pi = 10 * \log\left(\frac{\Pi}{\Pi_0}\right) \quad \text{[dB]}$$

- definition of the acoustic intensity level:

$$L_I = 10 * \log\left(\frac{I}{I_0}\right) \quad \text{[dB]}$$

Defining the acoustic power per unit of length for a linear length source "*l*"

If the total acoustic power of a linear source is $\Pi[W]$, assuming it is evenly distributed, the following can be written as:

$$\Pi[W] = \Pi_l\left[\frac{W}{m}\right] * l[m]$$

Π_l is the acoustic power measured in $\left[\frac{W}{m}\right]$, by rewriting the relation and taking into account that the unit of length is dividing both members into the reference acoustic power, the form is obtained:

$$\frac{\Pi}{\Pi_0} = \frac{\Pi_l}{\Pi_0} * \frac{l}{l_0}$$

By applying the transformation "$10 * \log$", it results the following:

$$10 * \log\left(\frac{\Pi}{\Pi_0}\right) = 10 * \log\left(\frac{\Pi_l}{\Pi_0}\right) + 10 * \log\left(\frac{l}{l_0}\right)$$

which is equivalent to

$$L_\Pi = L_{\Pi l} + 10 * \log(l),$$

because $\log(l_0) = 0$, where:

L_Π is the total acoustic power level of the linear source [dB];

$L_{\Pi l}$ is the acoustic power level per linear meter $\left[\frac{dB}{m}\right]$;

l is the length of the linear source.

<u>Deducting relation (14), starting from relation (13)</u>

$$I = \frac{\Pi}{4\pi l d}\left(2 * arctg\,\frac{l}{2d}\right)$$

By dividing both members to I_0 and highlighting the units of measurement, we get the following relation is obtained:

$$\frac{I\left[\frac{W}{m^2}\right]}{I_0\left[\frac{W}{m^2}\right]} = \frac{\Pi[W]}{4 * \pi * l[m] * d[m] * I_0\left[\frac{W}{m^2}\right]} * \left(2 * arctg\,\frac{l[m]}{2d[m]}\right)$$

It can be noticed that the units of measurement are simplified by obtaining a relation between abstract and non-dimensional numbers, some of these numbers remaining in the form of initial literal symbols. Therefore, the homogeneity of the relation resulting from logarithm is not affected, being a relation between abstract numbers.

By applying the "$10*\log$", the following relations are obtained:

$$10*\log\left(\frac{I}{I_0}\right)=10*\log\left[\left(\frac{\Pi}{\frac{\Pi_0}{S_0}}\right)*\left(\frac{1}{2\pi}\right)*\left(\frac{1}{d}\right)*\left(\frac{1}{l}\right)*\left(arctg\,\frac{l}{2d}\right)\right],\text{ where } S_0=1m^2$$

$$L_I=L_\Pi-8-10*\log(d)-10*\log(l)+10*\log\left(arctg\,\frac{l}{2d}\right)$$

Because $L_I \cong L_p$ and $L_{\Pi l}=L_\Pi-10*\log(l)$, the relation becomes:

$$L_p=L_{\Pi l}-8-10*\log(d)+10*\log\left(arctg\,\frac{l}{2d}\right) \quad (14)$$