DOI: 10.61782/fa.2023.0755

forumacusticum 2023

MEASUREMENT AND EVALUATION OF NOISE CONTRIBUTION OF A MAJOR INFRASTRUCTURE YARD ACCORDING TO UNI 10855:1999 STANDARD

E. Boria[1*] **E. Tesser**[1] **M. Fiore**[1]
[1] Direzione Progettazione – S.O. Ambiente & Energy Saving, Italferr,
Gruppo delle Ferrovie dello Stato Italiane, Via Galati 71, Rome, Italy

ABSTRACT

Railway construction yards are often located in heterogeneous contexts, where different acoustical sources overlap. As a result, it is difficult to compare the construction activity emissions to local acoustic limits.
The site of the new Belfiore Florence railway junction is characterized by multiple noise sources, e.g. intense car traffic, railway traffic and various anthropic activities, which contribute in creating the local acoustic environment together with works acoustic emissions.
The Italian technical standard UNI 10855:1999 [4] suggests various methods to find the acoustic impact of a specific source and, among these, three has been used: an equivalent ambient and residual noise level assessment (Method A), a temporal analysis evaluation (Method B) and a frequency-based analysis (Method C).
The present paper reports about an acoustic monitoring campaign carried out by Italferr technicians in the second quarter of 2021 with all the three methods cited above.

Keywords: *ambient noise, residual noise, noise pollution, temporal analysis, frequency-based analysis.*

1. INTRODUCTION

The project of urban penetration of High-Speed/High-Capacity (HS/HC) railway line in the Florence node consists essentially of two new train tracks connecting the Florence-Bologna HS line to the Florence-Rome HS line without passing through the central station of Florence to save several minutes of travel time.
Within the aforementioned project, the main works are the mechanized digging of two 6 km long single-track tunnels at a depth of approximately 20 meters between Firenze Castello and Firenze Campo di Marte stations and the construction of new underground Belfiore station in a densely populated neighborhood (Figure 1).

Figure 1. Belfiore station construction site (image Google Earth).

The construction yard is subjected to periodic monitoring of noise as well as vibrations, air pollution and others environmental components to identify potential impacts caused by works and prevent damages to local environment and disturbance to the people living in the surroundings.
During monitoring activities of noise pollution performed by Italferr acoustic technicians in accordance with regulations in place and to evaluate the applicability of methods foreseen by UNI 10855:1999 standard, the construction site activities consisted mostly of earthmoving

[*]*E. Boria: e.boria@italferr.it*

and loading of railway wagons for transportation of excavated materials to external storage sites (Figure 2)

Figure 2. Cranes during earthmoving activity.

2. MATERIALS AND METHODS

2.1 Materials and installations

The monitoring campaign has been performed by using three Sound Level Meters (SLM) at the same time.
All acoustic measurement chains were composed of a windscreen, a 1/2" free-field pre-polarized omnidirectional microphone with nominal sensitivity of 50 mV/Pa, providing performance conforming to Class 1 sound level meter standards, a 1/2" microphone preamplifier (PRM831), a microphone extension shielded cable, a SLM Larson&Davis 831 analyzer and a tripod stand.
All SLMs were calibrated before the start of measurements as required by current legislation.
In this case study, the entire construction site was considered as sound source and its layout and the distance from the receptor allows to consider the whole site as a punctiform source.
One analyzer (SLM 2) was positioned in proximity of the crane in operation (source), another (SLM 1) on the balcony at the third floor of an apartment building near the construction site (receptor), as shown in Figure 3.

Figure 3. Construction site layout, sound source and SLM locations (image Google Earth).

A third analyzer (SLM 3) was positioned on the street edge (Figure 4), which is considered the major interfering source, at 15 meters from the receptor with the microphone at 1,5 meters from the roadplan in vertical position.

Figure 4. SLM 3 located next to interfering source.

SLM 2 installation was far about 35 meters from the main sound source (crane) and the microphone was at 1,5 meters from the floor in vertical position (Figure 5). It is specified that sound diffraction caused by obstacles between source and SLM has not been considered, since SLM 2 has been used only to evaluate the time evolution of sound pressure.

Figure 5. Auxiliary sound level meter (SLM 2) located close to investigated source.

Figure 6. Sound level meter located on the receptor balcony.

SLM 1 installation was at about 180 meters from the crane in operation and the microphone was oriented at 45 degrees, facing the construction yard (Figure 6).

2.2 Methods

The Italian technical standard UNI 10855:1999 "Measurement and evaluation of the noise contribution of single sound sources" describes eight methods (from A to H) to detect a specific source especially when investigated sound source is in complex and heterogenous acoustic habitat, such as the urban one hereby considered.
On the basis of Italferr acoustic technicians experience, it is reasonable to think that the three A, B, C methods are enough to calculate the emission of a specific source. Therefore, acoustic measurements have been conducted with the due precautions explained in next paragraphs and according to these three methods to compare the results.

2.2.1 METHOD A: evaluation based on the measurement of equivalent ambient and residual noise levels

This is the basic method to evaluate the sound level of a specific source (L_s) even if the background noise level (L_{BG}) is variable.

$$L_s = 10\log\left[10^{L_E/10} - 10^{L_{BG}/10}\right] \qquad (1)$$

Environmental noise level (L_E), with the investigated source active as well the other sources in the area, and L_{BG} (source turned off) must be measured in the same position but clearly at different times. Usually, L_{BG} is measured during lunch time or before/after work shifts to discard the source sound contribution.
In consequence of this and considering the possible variability of L_{BG} throughout the daytime, an assumption must be respected to use equation (1): the difference between L_E and L_{BG} must be greater than 3 decibels.
Anyway, as reported by Curcuruto et Al. [1], a noticeable improvement in the accuracy of the result can be reached if an auxiliary SLM analyzer (SLM 3) is used to check emissions of interfering sources (e.g. roads) and to evaluate their variations (Δ). This Δ can be transposed with equation (2) to the receptor, also considering the attenuation of sound during outdoor propagation (described in ISO 9613-2:1996, Figure 7), and added to L_{BG} to correct the value of the background noise level.

$$L_{s,r} = L_{*,road} - 20\log\left[d_1/d_2\right] \qquad (2)$$

where:
- $L_{s,r}$ is estimated sound level of interfering source at receptor (dBA);
- $L_{*,road}$ is environmental sound level of interfering source ($L_{E,road}$);
- d_1 is distance of measuring point from sound source;
- d_2 is distance of receptor from SLM 3.

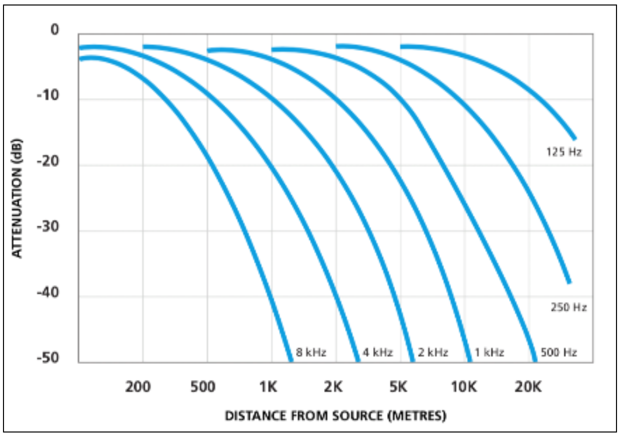

Figure 7. Sound attenuation in air as a function of distance and frequency, 2000 Brüel&Kjær Sound & Vibration Measurement A/S [2].

As shown in Figure 7, below 200 Hz and for small distances (about 30 meters in this case) air attenuation is negligible.
However, if the difference between L_E and L_{BG} is lower than 3 dB(A) it is necessary to proceed with method B, as provided by the technical standard.

2.2.2 METHOD B: evaluation based on temporal analysis

This method is applicable when investigated source can be deactivated, its sound level is stationary and residual noise fluctuates.
After assessing whether the specific source is stationary with a SLM onsite (SLM 2), it's necessary to identify time intervals with active source when the sound level fluctuates between ±5 decibels around the stationary value (Figure 8) and time intervals when the source is off.
Potential sound diffraction caused by obstacles between source and SLM has not been considered because its effect is negligible for the calculation method used.

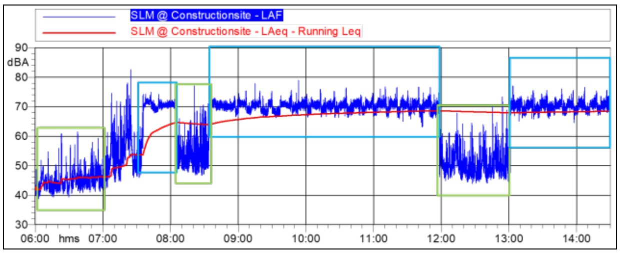

Figure 8. Time history recorded onsite (SLM 2): stationary source noise (squared in blue) and residual noise (source off, squared in green).

The same time intervals must be used to identify environmental noise level (source on) and background noise level (source off) on time history recorded by the SLM at the receptor (SLM 1, Figure 9).

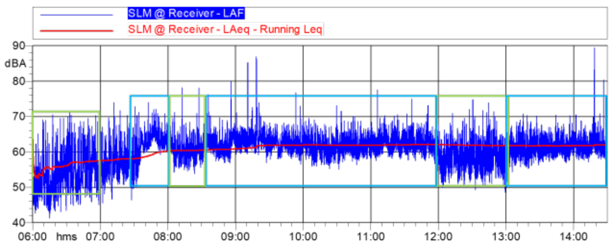

Figure 9. Time history recorded at the receptor (SLM 1): active source (environmental noise, squared in blue) and residual noise (source off, squared in green).

Selected time intervals are used to construct environmental noise ($L_{a'}$) and background noise ($L_{r'}$) time histories of stationary levels only (±5 decibels around the stationary value of levels measured at the receptor) by using minimums of A-weighted levels with fast time constants [3] to ensure greater stability of pressure levels (Figure 10, Figure 11).

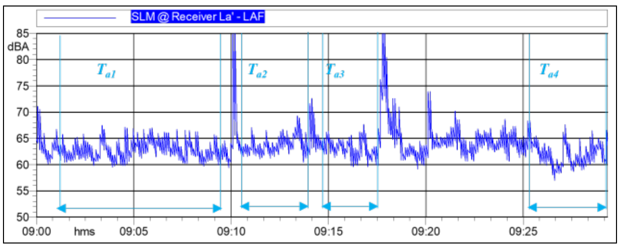

Figure 10. Time history recorded at the receptor (SLM 1): stationary levels with source on selected to calculate La'.

With equation (3) is possible to calculate ambient noise level from selected time intervals ($L_{a',T}$):

$$L_{a',T} = L_{a'}(T_{a1} + T_{a2} + T_{a3} + T_{a4}) \tag{3}$$

The same procedure shall be performed to quantify background noise level ($L_{r',T}$).

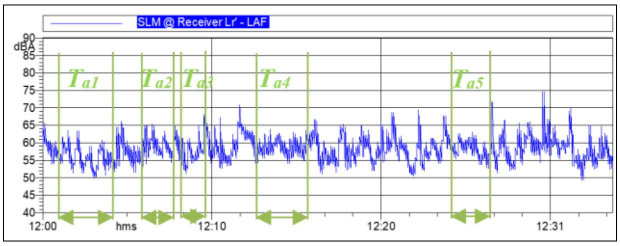

Figure 11. Time history recorded at the receptor (SLM 1): stationary levels with source off selected to calculate Lr'.

Method B can be applied when the difference between $L_{a',T}$ and $L_{r',T}$ is greater than 6 dB(A) and equation (1) can be used to calculate the specific noise contribution (L_s) of investigated source, otherwise it is necessary to proceed with the method C.

2.2.3 METHOD C: evaluation based on frequencies analysis

Last method requires a good knowledge about 1/3 octave band analysis, in fact it's necessary to extract background (L_{fr}) and environmental noise (L_{fa}) spectrum, identify bands where ambient noise (L_{fa}) is greater than at least 3 dB respect to residual noise (L_{fr}) and for each of these bands use equation (1) to define the specific source emission spectrum (L_{fs}).

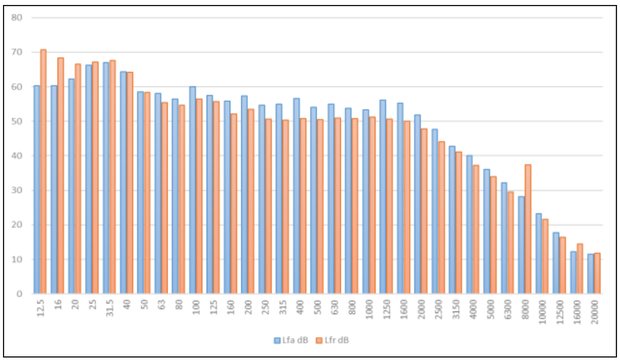

Figure 12. Comparison between environmental noise in blue (Lfa) and background noise in orange (Lfr).

For remaining frequency bands, L_{fs} level is estimated to be between L_{fs} Max = L_{fa} - 3dB (when $L_{fs} = L_{fr}$) and L_{fs} Min = Negligible.
This allows to identify the maximums and minimums level spectrums and define the interval of specific source equivalent level depending on the spectral features of environmental and residual acoustic signals.
Specific equivalent level of investigated source is included between L_s Min < L_s < L_s Max, but, as a more precautionary scenario for receptors, is always considered the maximum emission value.

3. RESULTS

The purpose of measurements is to identify the specific construction site acoustic source among a heterogeneous and complex acoustic scenario as the urban one.
In Table 1 are presented data/parameters, measured levels and calculations to assess the construction site specific acoustic level by using method A.

Table 1. Calculation table of specific sound source level at the receptor according to method A of UNI 10855:1999 and Curcuruto et Al [1].

Description	Value
L_{E} measured at the receptor	67,6 dB(A)
L_{BG} measured at the receptor	60,7 dB(A)
d1 eq. (2)	3 m
d2 eq. (2)	15 m
$L_{E, road}$ environmental noise transposed with eq. (2)	47,0 dB(A)
$L_{BG, road}$ background noise transposed with eq. (2)	43,0 dB(A)
$L_{BG*} = L_{BG} + (L_{:SE,road} - L_{SBG,road})$	60,8 dB(A)
$\Delta = L_E - L_{BG*}$	6,8 dB(A)
L_S eq. (1)	66,6 dB(A)

As shown the difference between L_E and L_{BG} is greater than 3 dB(A), so the method is applicable. Anyway, for greater precisions, it has been investigated the noise variability of road (interfering source) next to the receptor. As a result, L_S was equal to 66,6 dB(A).
Method B allowed to analyse and identify stationary contributes of environmental and residual noise and calculate $L_{a',T}$ and $L_{r',T}$ by using equation (3).
Environmental noise ($L_{a',T}$) resulted equal to 61,4 dB(A) while background noise level was about 58,9 dB(A), so the difference between them is lower than 6 dB(A) and investigated source level (L_s) cannot be calculated with eq. (1) accordingly to UNI standard.

Results of frequency-based analysis performed accordingly to method C are presented in Table 2.

Table 2. Environmental (L_{fa}) and background (L_{fr}) noise spectrum with calculated specific source spectrum A-weighted (L_{fs} min and max).

f [Hz]	**Lfa [dB]**	**Lfr [dB]**	**LFs**	
			Max [dB(A]	**Min [dB(A]**
12.5	60,3	70,7	57,3	Negligible
16	60,3	68,4	57,3	Negligible
20	62,3	66,6	59,3	Negligible
25	66,2	67,2	63,2	Negligible
31.5	67	67,6	64,0	Negligible
40	64,3	64,1	61,3	Negligible
50	58,5	58,4	55,5	Negligible
63	58,1	55,4	55,1	Negligible
80	56,4	54,6	53,4	Negligible
100	60	56,5	57,4	57,4
125	57,5	55,7	54,5	Negligible
160	55,9	52,1	53,6	53,6
200	57,3	53,4	55,0	55,0
250	54,6	50,7	52,3	52,3
315	54,9	50,4	53,0	53,0
400	56,6	50,8	55,3	55,3
500	54	50,5	51,4	51,4
630	55	50,9	52,9	52,9
800	53,7	50,8	50,7	Negligible
1000	53,3	51,2	50,3	Negligible
1250	56,2	50,6	54,8	54,8
1600	55,3	50	53,8	53,8
2000	51,8	47,8	49,6	49,6
2500	47,6	44,1	45,0	45,0
3150	42,7	41,1	39,7	Negligible
4000	40	37,2	37,0	Negligible
5000	36	33,9	33,0	Negligible
6300	32,2	29,5	29,2	Negligible
8000	28,1	37,4	25,1	Negligible
10000	23,3	21,6	20,3	Negligible
12500	17,8	16,4	14,8	Negligible
16000	12,2	14,4	9,2	Negligible
20000	11,5	11,8	8,5	Negligible

As a result, the sound contribution of construction yard (L_s) was between 61,0 and 61,6 dB(A). This value is reasonably valid, since the range is not so extended to make the relative uncertainty unacceptable.

4. CONCLUSIONS

Results presented above confirm that the methods foreseen by the UNI 10855:1999 standard to investigate a specific sound source in a complex habitat are not always applicable. In the case study it was possible to apply methods A and C.

Method A, enriched with the analysis of variable contribution of interfering source (road), estimated a value of 66.6 dB(A) for emission level of construction site, while method C reported an emissive level of investigated source included in a range between 61 and 61.6 dB(A), with a difference between the two estimations of about 8÷9%.

The narrow range defined with method C allows to hypothesize that the specific source level is probably closer to these values respect to estimation made with method A. So, it possible to assess that method C could be more precise to quantify the source contribution. However, at same time, it must be considered that method A requires less processing to obtain a comparable result.

5. ACKNOWLEDGMENTS

The authors thank Francesco Nigro and all the Italferr environmental monitoring team for its participation to the development of this work.

6. REFERENCES

[1] S. Curcuruto, D. Atzori, E. Lanciotti, A. Poggi, M. Cavicchi, V. Cipriani, A. Merlino, L. Piani, S. Ortica, A. Sansone Santamaria: “Linee Guida per il monitoraggio del rumore derivante dai cantieri di grandi opere” *Delibera del consiglio Federale Seduta del 20 ottobre 2012 Doc. n. 216/12*, pp 13-14, 2013.

[2] Brüel&Kjær Sound & Vibration Measurement A/S, Nærum, Denmark. *“Environmental noise”*, pp. 3, 2013.

[3] A. Armani: “Riconoscimento delle component tonali in conformità al DM 16-03-98” *Nota tecnica Spectra*, pp. 03, 2013.

[4] UNI 10855:1999 *“Measurements and evaluation of the noise contribution of single sound sources”* Commissione “Acustica”.