# Analysis of the Efficiency of Auditory Protectors used in the Civil Construction industry in the City of Manaus in Brazil

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**Abstract**—*The construction sector provides occupational risks to construction workers at the building site. Despite the obligation of the use Individual Protection Equipment (IPE), the noise is one of the occupational risks, which persist as one of the most injury to workers. The causes may be inherent in the control, but also the inappropriate choice of the methods of implantation of hearing protectors as an individual control measure. This paper aims to analyze the efficiency of hearing protectors, taking into account the octave band spectrum at the sound pressure levels of the main equipment used in the civil construction sector in the city of Manaus in Brazil, following the limits defined in the Brazilian standard.*
**Keywords—Construction, occupational hazards, noise, octave band, PPE.**

## I. INTRODUCTION

Civil Construction in a little more than 150 years, has achieved a growing evolution in the industrial area, through the modernization of processes that were previously done manually. From the mechanization and automation of the production processes and the use of machine tools, the types of occupational hazards were mainly ergonomic began to have the noise not as a new problem, but there was the intensification, due to the use of mechanized equipment.

Andrade (2004) says that since then, techniques aimed at reducing noise levels and vibrations typical of this industry have been disseminated, although levels of hearing damage have been raised by unprotected and continuous exposure to them at the construction site.

Technological advances bring undisputed benefits to the construction industry, so that the workers are benefited, the concern with the risks arising should be made according to specific technical standards.

Through this scenario, it became indispensable to demonstrate the types of noise, to discern it from a term almost always used as its synonym: the sound (DIAS, 2015). Sound is used for pleasurable sensations such as music or speech, while noise is used to describe an undesirable sound such as horn, blast, traffic noise and machines (SANTOS, 1996). This annoying aspect of noise is then treated as aggressive, as noise pollution, causing "hypo acoustics and deafness in adults" (AZEVEDO 1993).

In addition to the loss in the worker's working life, Medeiros (2011), endorse in his work, based on the data costs of Social Security and the relevance of occupational noise induced hearing loss - NIHL, the legal and ethical

necessity of the careful adoption of effective measures by companies that guarantee the health and integrity hearing. This work arises from the need to meet these criteria applied to workers in the Civil Construction industry.

## II.    LITERATURE REVISION

The construction industry presents particular characteristics that build a dynamic structure, complex and with a high degree of risk inherent in the activities developed(ANDRADE, 2004). Construction workers, in most activities, do not find adequate protection for their health and physical integrity. Dias (2015), JORGE highlights among the main problems reported in the sector are the effects caused by the excessive noise of equipment that is routinely used in the construction sites.

### 2.1 SOUND AND NOISE

The sound or noise is formed by the variation of the atmospheric pressure audible to the human ear. For Mateus (2008), the distinction between sound and noise is subjective, not only depends on frequency and amplitude, but the sound is associated with pleasant sensations (music and voice) and noise associated with unpleasant sensations.According to BISTAFA (2011), sound is a sensation produced in the auditory system, and noise is a sound without harmony, usually of negative connotation. For Iida (2005), physically, the noise is a mixture of vibrations, measured on a logarithmic scale, in a unit called decibel (dB). The human perception of sound occurs in the range of frequency and amplitude of fluctuation that characterize the threshold of hearing. Frequency is the full rate of change of pressure that generates sound, determined by cycles of a second and known worldwide by Hertz (Hz).According to Gerges (2000), the threshold of human hearing is between 20 Hz and 20 kHz. Above the threshold of painful perception can damage the hearing aid. The frequencies below the hearing threshold are called infrasound; the frequencies above the threshold of hearing are called as ultrasonic.

### 2.2 Sonorous spectrum

The sonorous spectrum is an approach little explored in general terms of the concern with the selection of hearing protectors, the characteristic that distinguishes between serious sounds and acute sounds is called height, which is a function of frequency. High frequencies generate high sounds, and low frequencies generate bass sound. For Bistafa (2011), sounds with a frequency of less than 200 Hz may be considered serious; average sounds between 200 and 2000 Hz; and treble ones above 2000 Hz.Generally noise sources generate sounds that are not considered pure.According toBistafa (2011), sounds at a single frequency are known as pure tones, but commonly heard sounds are almost never pure tones. For Medeiros

(2011), what you hear are usually combined sounds of pure tones at various frequencies.

The identification of the frequency of each tone that composes the sound applies to the direct Fourier transform to extract the sound spectra. The sonorous spectrum provides the effective value of the sound pressure for each frequency present in the sound.The pure tone is a single frequency sound. According to Mateus (2008), the human ear does not respond linearly to frequency variations, the difference between a sound of 250 Hz and a sound of 125 Hz is close to the difference between a sound of 2000 Hz and a d 1000 Hz. frequency representation, in the form of octaves. In the octave bands, the upper limit of each frequency band is approximately double the frequency of the respective lower limit, it is generally associated with the octave band at its central frequency, given by the square root of the final product.ForBistafa (2011), the total pressure level of a noise frequency spectrum can be obtained by a decibel meter with 1/1 octave band filter, equation 2.1 represents the log sum formula.

$$NPSt = 10log_{10}\big[10^{(NPS125Hz/10)} + 10^{(NPS250Hz/10)} + 10^{(NPS500Hz/10)} + 10^{(NPS1kHz/10)} + 10^{(NPS2kHz/10)} + 10^{(NPS4kHz/10)} + 10^{(NPS500Hz/10)} + 10^{(NPS1kHz/10)} + 10^{(NPS2kHz/10)} + 10^{(NPS31,5Hz/10)}\big]$$

$$(2.1)$$

The result is extracted directly from the decibel meter to a computer program via the USB cable, these results are used in the various analyzes.

Leq represents the continuous (stationary) level equivalent in dB (A), which has the same potential for hearing loss as the varied level considered.

### 2.3 Total Sound Pressure Level

Corresponds to a simple global measure, disregarding the frequency bands, the equipment that helps to obtain this measure is the simple decibel meter. There are two variables that determine the potential for harm to human hearing. The relationship of different NPS with varying exposure times is given by Equivalent Noise Level - Leq.The Equivalent Level represents the integration of sound over a period of time, is defined by the equation2.2

$$Leq = 10 \log (1/T) \int_0^T [P^2(t)/P_0^2]dt \quad (2.2)$$

where:

T is the time of integration;

P(t) is the instantaneous acoustic pressure;

P0 is the reference acoustic pressure $(2x10^{-5}$ N/m$^2)$;

Leqrepresents the continuous (stationary) level equivalent in dB(A), which has the same potential for hearing loss as the varied level considered.

### 2.4 Noise dose

The Annex n° 1 of Regulatory Norm NR-15 of Portaria 3214/78 of Brazil that defines unhealthy activities and

operations, shows the tolerance limits table for continuous or intermittent noise.

The noise dose represents the percentage of noise to which the worker was exposed during the period of his working day. The dose is obtained through the dosimeter, an equipment composed of a microphone to be installed near the worker's hearing zone, and that integrate the noise levels on the journey, offering the noise dose, which should not exceed 100%.

According to item "b" paragraph 9.3.6.2 of regulatory standard9 of Brazilian legislation, which deals with the Environmental Risk Prevention Program (PPRA), for a dose above 50% equivalent to 80dB (A) for 8h, minimizes the probability, that the exposure will exceed the exposure limits.

If no dosimeter is available, the calculation of the dose can be carried out by means of the instantaneous readings of a common decibel meter using the following equation:

$$D= C_1/T_1 + C_2/T_2 + C_3/T_3 + ... C_n/T_{nvvvv} \quad (2.3)$$

where:

$C_n$ is the actual time of exposure to a specific NPS;

$T_n$ is the total time allowed for that NPS.

## 2.5 Occupational Noise-Induced Hearing Loss

According to MEIRA et al 2013, PAIRO is a gradual decrease in auditory acuity due to prolonged occupational exposure to high sound pressure levels (> 85 dB (A) for 8 hours / day). For Maia (2001a perdaauditivainduzidapeloruído de origemocupacional, conhecidacomo noise-induced pernianent threshold shift (NIPTS), can be defined as a cumulative, bilateral, sensorineural loss that manifests over the years. It results from chronic exposure to noise from sound pressure levels of 80 to 120 dB(A) in the workplace. It is possible to prevent PAIRO and for this, preventive programs should include actions to eliminate noise, effective actions are shown by (TAK; DAVIS; CALVERT, 2009). In their impossibility, the exposures can be controlled initially from collective and / or individual measures that help to reduce the levels of noise that reach the worker (EL-DIB, 2007; MEIRA, 2012; NELSON et al., 2005; CONCHA-BARRIENTOS et al., 2004). The protection measures should have, as a matter of priority, a collective nature, based on the control of the emission at the main source of exposure, the propagation of the agent in the work environment and actions at the administrative level. However, the most common measure has been that of an individual character, which refers to the use of hearing protection equipment (KIM et al, 2010; EL-DIB, 2007).

## 2.6 Personal Protective Equipment (PPE)

It is considered as the last option in the actions taken to reduce occupational noise to levels acceptable according to the regulatory standard 6 (NR-6), PPEis any device or product, of individual use used by the worker, intended to protect against risks that may threaten safety and health at work. The NR-6 also has a list of PPE; among them is the PPE for hearing protection, which can be of three types: circum-auricular hearing protector; ear protector; semi-auricular ear protector(BRASIL, 2010).

## 2.7 Noise Reduction Rating (NRR)

Obtained for the PPE are provided by the manufacturers in accordance with the regulations of the standards bodies. However, the actual value of noise attenuation resulting from the use of the PPE depends on the interaction of three elements: user, types of protector and working environment (CIOTE; CIOTE; HABER, 2005). Currently, the NRR is obtained through laboratory studies based on the ANSI standard (American National Standards Institute) S12.6-1997 (SAMELLI; FIORINI, 2011; CIOTE; CIOTE; HABER, 2005). This norm has brought advances in relation to the previous ones, however, it still distances itself from the reality, once the average of the values obtained with a group of individuals in the laboratory does not always correspond to the performance of the user in professional environment. The ideal condition would be the individual assessment from the placement of the PPE by the users in their work environment (SAMELLI; FIORINI, 2011).

## 2.8 Hearing Protectors

Various types, brands and models of hearing protectors are available in the market. According to Gerges (2000), the selection of a particular type of hearing protector should consider the type of noisy environment, comfort, user acceptance, cost, durability, possible communication problems, safety and hygiene.

The selection of Hearing Protectors should take into consideration the following requirements: the environment and work activity, the necessary noise attenuation, the Certificate of Approval - CA of the Ministry of Labor and Employment, comfort of protector for the user, medical disorders, and compatibility with other PPE's, such as helmets, glasses, etc.

Each type of hearing protector has a characteristic noise attenuation. This attenuation is generally associated with reduced data such as mean attenuation and standard deviation in dB per 1/1 octave band and a simple number on global attenuation, such asNoise Reduction Raiting - NRR, o Noise Reduction Raitingsf – NRRsfou o Single Number Rating – SNR supplied by manufacturers and importers of equipment.

O NRR, o NRRsf e o SNR are based on exposure to a pink noise spectrum in a standard environment that does not cover all users. According to BISTAFA 2011, he pink noise is characterized by presenting the drop of 3dB to each octave. An example of pink noise is the noise emitted by TVs out of tune. According to GERGES 2000, these

reduced values should not be used to accurately calculate attenuator attenuation in other environments. The same author recommends for the evaluation of the efficiency of the hearing protectors the use of the long method.

## 2.9 Long method

The Long Method tests the average attenuation levels of sound pressure in dB by frequency bands of 1/1 octave, from 125Hz to 8kHz, provided by the hearing aid manufacturer with the frequency band spectra obtained in the working environment, through a decibel meter with 1/1 octave band filter. According to Gerges (2000), this method provides the total ear level protected by a particular ear protector and the total attenuation provided by this equipment in a particular working environment. To obtain the total noise to which the workers are exposed one must realize the logarithmic sum of the NPS. In order to obtain the total attenuation of a given ear protector, with 98% confidence, the total noise subtracted by the logarithmic sum of the mean attenuation of NPS in the frequencies of 125Hz, 250Hz, 500Hz, 1kHz, 2kHz, 4kHz, 8kHz, discarded from two standard deviations, obtained in the EPP Certificate of Approval.

## III. MATERIALS AND METHODS

### 3.1 TypeandNatureofResearch

This work has a descriptive, exploratory and comparative nature, since it was done a survey of the legislation and techniques of risk recognition related to occupational noise, then collected the data in the field through equipment and standardized techniques and after comparing the data collected with the specifications.

### 3.2 Data collect

The data collection was performed through a direct application to the construction site by the author himself with the aid of a decibel meter with octave band filter, and dosimetry with dosimeter equipment, all equipment owned by the company JFR Engenharia de Segurança do Trabalho.

### 3.3 Collection point

Data collection was carried out at the construction site of the company Construtora ETAM Ltda, construction is the construction of the level crossing of the Avenue Governador José Lindoso (Av. das Torres) with AvenueTimbiras, no bairro da Cidade Nova I, Manaus-Am-Brazil.

### 3.4 Collection period

Data collection was carried out between May 15 and 18, 2017, the collection was performed during the work 8:00hs e 17:00hs.

### 3.5 Noise sources

The selected noise sources were the ones that generated the most noise in the work, the activity was the completion of a retaining wall which received projected concrete blasting, for that activity was used a breaker hammer Wacker Neuson EH9, a compressor XAS 420 Atlas Copco, a designed concrete pump CP6 and a concrete mixer truck and concrete projection nozzle, these items will be illustrated below.

In figure 3.1 shows the complete system of the concrete projection set in the work studied, the application as explained above was performed in a retaining wall on the sideof the work.



*Fig.3.1: Concrete projection system.*
*Source: Author.*

In this system the designed concrete pump is fed concrete by the truck mixer and fed air by the compressor, the pump projects the concrete that passes through the

mangrove and exits through the concrete projection nozzle.

The air compressor, whose basic feature is to convert mechanical movements generated by electric energy, or

possibly some other form of energy such as diesel and gasoline engines in compressed air.

The projected concrete consists of a continuous process of projecting concrete or mortar under pressure (compressed air) which, through a hose, is led from a mixing equipment to a projector nozzle, and launched with great speed on the base.

In the study the pump used is dry. In the nozzle projector there is a water inlet that is controlled by the operator. The dry concrete is brought under pressure to the nozzle where it receives the water and the additives.

The truck mixer is responsible for receiving the machined concrete from the metering plant and transporting it to the application site at the works. However, the function of the concrete mixer truck is not unique and exclusive to transport the concrete. In addition, the concrete mixer trucks are also responsible for mixing the materials (water, stone, sand, cement, sand and additives) to transform them into concrete. In the study system as a whole the concrete mixer truck feeds the concrete projection pump.

The standard specifying the projected concrete is DNIT 087/2006 – ES, that deals with the Execution and finishing of the projected concrete - Specification of service.

### 3.6 Processing of collected data

The results of the data collected through the equipment described in item 3.2, were downloaded to a portable computer used to perform the experiments has the following configurations: processor Intel i7 Core™ i7-3632QM, 2.20 GHz, 4 Gb de RAM e 1 Tb de HD. The operating system was the Windows 10 64-bit in Portuguese language, through the SmartdB Software analysis of Chrompack.

### 3.7 Data Analysis Factors

In order to perform the interpretation and evaluation of the results, the Occupational Hygiene Standard – (NHO 01 In Brazil)more conservative tolerance limits, which guarantee a higher level of protection, since it is in line with the technical principles of ACGIH.

The factors used in this study are: Lavg, leq, twa and nen. The NHO 01 defines the abbreviations and main test items relationships.

LEQ - means Equivalent Level, is defined by the expression:

$$LEQ = 80 + 10 * \log (0,16 * Dose\% / T \, horas) \quad (3.1)$$

It represents the average level of noise during a certain period of time, using the increment of dose doubling "3".The rule of equivalence principle for noise assessment considers that whenever the acoustic energy in a given environment doubles, there is three decibels increase in noise level.

The equivalent continuous audio pressure level is widely used around the world as an index for noise. It is defined as "The weighted level of audio pressure of a noise fluctuating within a period of time, expressed as the average amount of energy."The result is expressed in db (A), which represents a reasonable approximation of the human perception of sonority.

LAVG - The term means Average Level, is defined by the expression:

$$LAVG = 80 + 16,61 * \log (0,16 * Dose\% / T \, horas) \quad (3.2)$$

It represents the mean of the noise level during a certain period of time, using any increase in dose doubling, except for the "3". Annex 1 of NR - 15 does not specify the increase in dose doubling used for the calculation of established tolerance limits, but after analyzing the table, it is verified that whenever there is an increase of 5 decibels

TWA - Time Weighted Average, represents the weighted average of the sound pressure level for a day of 08 hours. It is important to note that the TWA can only be used if the measurement time is exactly 08 hours, and always using the dose doubling increment "5". If the measurement time is higher or lower than 08 hours, there will be an overestimated or underestimated result, respectively. When we find the acronym TWA (08h), it means that the original TWA formula has been changed to the same as the LAVG, and the results are both identical.

NEN - The term stands for Normalized Exposure Level and represents the Mean Level (LAVG, TWA, LEQ) converted to a standard 8-hour journey for purposes of comparison to the 85 dBA tolerance limit.The calculation of the NEN is requested by the INSS in its Normative Instructions only for purposes of launching in the PPP. If the average level of noise exposure refers to an eight-hour day, the resulting value, after applying the NEN formula, will be identical to the average level, and there is no change. If the working day is different from eight hours (six, twelve, twenty-four hours, etc.), the NEN should be calculated and the result compared to the tolerance limit of 85 dBA. An important reminder is that the calculation of NEN in Fundacentro's NHO-01 is presented for the increment of dose doubling "3". To use the NHO-01 formula it is necessary to correct it for the dose doubling increment "5".

## IV. RESULT AND DISCUSSIONS

### 4.1 Evaluation of the noise of the martelete

### 4.1.1 Dosimeter configuration (Martelete)

| Dosimeter configuration 01 | | Dosimeter configuration 02 | |
|---|---|---|---|
| Criterion Level: | 85 dB | Criterion Level: | 85 dB |
| Threshold level: | 85 dB | Threshold level: | 85 dB |
| Exchange rate: | 3 dB | Exchange rate: | 5 dB |
| Frequency weighting: | A | Frequency weighting: | A |
| Time weighting: | Slow | Time weighting: | Slow |

*Fig.4.1 – Noise meter settings for the marteleteprocess.*
*Source: Author.*

The Figure 4.1 shows dosimeter configurations according to Regulatory Standard 15 (NR-15) and Occupational Hygiene Standard 01 (NHO-01). For dosimeter 01 (NR-15) the Criterion Level is set to 85dB, Threshold Level is 80dB, doubling rate is 3dB with frequency weighting A and time weighting Slow. For Dosimeter 02 (NHO-01), the Criterion Level with 85dB, Threshold Level of 80dB, doubling rate is 5dB with frequency weighting A and Slow time weighting, default is set for performing the noise evaluation.

### 4.1.2 Doimeterresults (Martelete)

| Resultados Dosímetro 01 | | | | Resultados Dosímetro 02 | | | |
|---|---|---|---|---|---|---|---|
| LAVG: | 108,3 dB(A) | LMAX: | 120,1 dB(A) | LAVG: | 105,4 dB(A) | LMAX: | 120,1 dB(A) |
| LEQ: | 108,3 dB(A) | $LMAX_{Time}$: | 14:52 | LEQ: | 108,3 dB(A) | $LMAX_{Time}$: | 14:52 |
| TWA: | 98,0 dB(A) | $Lpico_{>115dB}$: | 133,1 dB(A) | TWA: | 88,0 dB(A) | $Lpico_{>115dB}$: | 133,1 dB(A) |
| NEN: | 108,3 dB(A) | $Lpico_{Time}$: | 14:59 | NEN: | 105,4 dB(A) | $Lpico_{Time}$: | 14:59 |
| DOSE: | 2083,20% | Lmin: | 70,9 dB(A) | DOSE: | 159,70% | Lmin: | 70,9 dB(A) |
| $DOSE_{8horas}$: | 21777,10% | $DOSE_{p8hs}$: | 21777,10% | $DOSE_{8horas}$: | 1691,20% | $DOSE_{p8hs}$: | 1691,20% |

*Fig.4.2 – Noise measurements according to NR-15 and NHO01 for the martelete process.*
*Source: Author.*

In figure 4.2, the results of the noise measurement are presented. Of these results, what is most important in the evaluation is the NEN (Normalized Exposure Level) to compare with the tolerance limit of NR-15 and NHO-01. NEN with the NR-15 parameters presented a result of 108.3dB(A) that is above the tolerance limit of 85dB(A). The NEN with the NHO-01 parameters presented a result of 105.4dB(A) that is above the tolerance limit of 85dB(A). The exposure dose for 8 hours is 1691.2% of the acceptable, more than 16 times the maximum dose.

All indices are above the limit specified by the NR-15, which limits the worker's exposure to noise by 85dB.
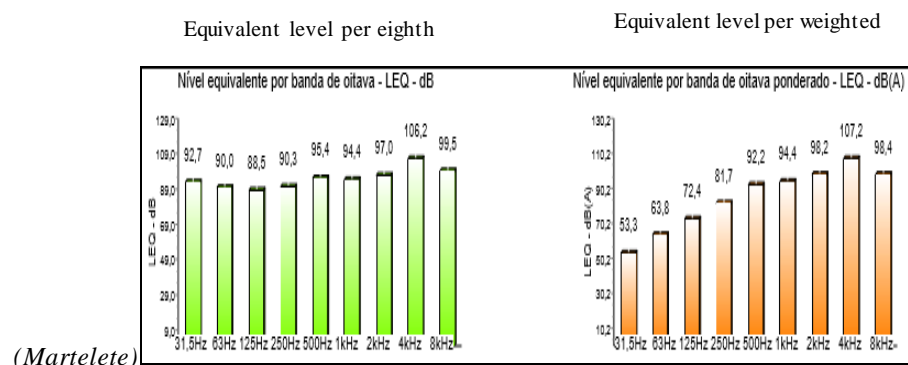
*4.1.3 Level ofequivalence per octaveband*

Equivalent level per eighth        Equivalent level per weighted



*(Martelete)*

*Fig.4.3 – Equivalent noise level per octave band without weight and with weighting curve A for the martelete process.*
*Source: Author.*

In figure 4.3 the equivalent level is presented by weighted octave band the noise that the worker was exposed (31.5Hz, 63Hz, 125Hz, 250Hz, 500Hz, 1kHz, 2kHz, 4kHz, 8kHz). The equivalent level per octave band - LEQ-dB, in the illustration the green bar histogram, shows the actual noise the equipment collects. The equivalent level by weighted octave band - LEQ-dB(A), the histogram with orange bars, which gives a reasonable approximation of the human perception of sonority, that is, represents the perception of the human ear to the noise.

All noise values for the LEQ-dB frequency bands are above the 85 dB (A) threshold specified by the NR-15.

It is possible to note that the weighted octave band equivalent values LEQ-dB(A), corresponding to the frequencies of 500Hz, 1kHz, 2kHz, 4kHz and 8kHz, even with weighting, exceed the specified 85 dB (A) by NR-15. One mistake would be to calculate the noise output through a simple average, which would return a value of 84.62dB (A), which results in false compliance with the maximum exposure limits.

### 4.1.4 Result with use of EPP (Martelete)

| Result with the use of EPP - Calculation by the long method ABNT NBR 16077 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Assumed protection | | | | |
| Type of hearing protector | Nº | CA | Validity | LEQ | 125 Hz | 250 Hz | 500 Hz | 1 kHz | 2 kHz | 4 kHz | 8 kHz |
| Shell type | 29176 | | 28/03/2021 | 87,9 | 68,4 | 71,7 | 78,2 | 70,4 | 69,2 | 86,2 | 79,4 |

*Fig.4.4 – Calculation of the efficiency of the ear protector for the martelete process.*
*Source: Author.*

In Figure 4.4, the efficiency of the ear protector is presented according to the long method of ABNT-NBR 16077 that used the octave band frequencies for the calculation.

In this case it is possible to note that the CA 29176 ear protector is not sufficient to let the noise below the 85dB(A) threshold as soon as the LEQ is 87.9dB, so the

worker is exposed to noise that is harmful to the both regarding NR-15 and NHO-01.

In this case the actions suggested according to NR-15 is the application of the rest interval for the worker.

### 4.2 Evaluation of compressor noise

### 4.2.1 Dosimeter Configuration (Compressor)

| Dosimeter configuration 01 | | Dosimeter configuration 02 | |
|---|---|---|---|
| Criterion Level: | 85dB | Criterion Level: | 85 dB |
| Threshold level: | 85dB | Threshold level: | 85 dB |
| Exchange rate: | 3dB | Exchange rate: | 5 dB |
| Frequency weighting: | A | Frequency weighting: | A |
| Time weighting: | Slow | Time weighting: | Slow |

*Fig.4.5 – Noise meter settings for the compressor process.*
*Source: Author.*

In the figure 4.5 shows dosimeter configurations according to Regulatory Standard 15 (NR-15) and Occupational Hygiene Standard 01 (NHO-01). For dosimeter 01 (NR-15) the Criterion Level is set to 85dB, Threshold Level is 80dB, 3dB doubling rate with frequency weighting A and time weighting Slow. For

Dosimeter 02 (NHO-01), the Criterion Level with 85dB, Threshold Level of 80dB, 5dB doubling rate with frequency weighting A and Slow time weighting, default is set for performing the noise evaluation.

### 4.2.2 Dosimeter Results (Compressor)

| Result dosimeter 01 | | Result dosimeter 02 | | Resultados Dosímetro 02 | |
|---|---|---|---|---|---|
| LAVG: | 89,1 dB(A) | LMAX: | 114,5 dB(A) | LAVG: | 87,2 dB(A) | LMAX: | 114,5 dB(A) |
| LEQ: | 89,2 dB(A) | $LMAX_{Time}$: | 10:40 | LEQ: | 88,9 dB(A) | $LMAX_{Time}$: | 10:40 |
| TWA: | 84,7 dB(A) | $Lpico_{>115dB}$: | 127,8 dB(A) | TWA: | 79,7 dB(A) | $Lpico_{>115dB}$: | 127,8 dB(A) |
| NEN: | 89,1 dB(A) | $Lpico_{Time}$: | 10:40 | NEN: | 87,2 dB(A) | $Lpico_{Time}$: | 10:40 |
| DOSE: | 92,40% | Lmin: | 59,4 dB(A) | DOSE: | 48,30% | Lmin: | 59,4 dB(A) |
| $DOSE_{8horas}$: | 259,30% | $DOSE_{p8hs}$: | 259,30% | $DOSE_{8horas}$: | 135,50% | $DOSE_{p8hs}$: | 135,50% |

*Fig.4.6 – Noise measurements according to NR-15 and NHO01 for the compressor process.*
*Source: Author.*

The noise measurement results are shown in Figure 4.6. In these results, what is most important in the evaluation is the NEN (Normalized Exposure Level) to compare with the tolerance limit of NR-15 and NHO-01. The NEN

with the NR-15 parameters presented a result of 89.1 dB(A) that is above the tolerance limit of 85dB(A). The NEN with the NHO-01 parameters presented a result of 87.2 dB (A) that is above the tolerance limit of 85db (A).

The exposure dose for 8 hours is 135.5% of the acceptable dose.

The indices are above the limit specified by the NR-15, which limits the worker's exposure to noise by 85dB.

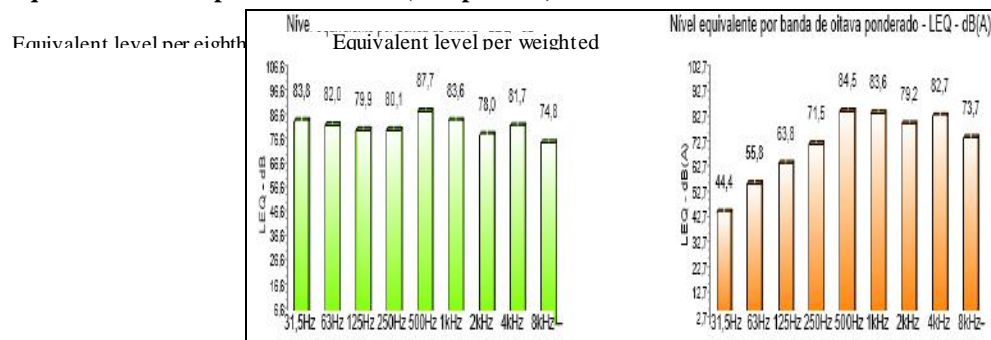### 4.2.3 Equivalence level per octave band (Compressor)



*Fig.4.7 – Equivalent noise level per octave band without weight and with weighting curve A. for the Compressor process. Source: Author.*

In figure 4.7 is presented the equivalent level by weighted octave band the noise that the worker was exposed (31.5Hz, 63Hz, 125Hz, 250Hz, 500Hz, 1kHz, 2kHz, 4kHz, 8kHz). The equivalent level per octave band - LEQ-dB, in the illustration the green bar histogram, shows the actual noise the equipment collects. The equivalent level by weighted octave band - LEQ-dB(A), the histogram with orange bars, which gives a reasonable approximation of the human perception of sonority, that is, represents the perception of the human ear to the noise. For the equivalent level values per octave band - LEQ-dB. Only the respective noise values of the 500Hz

frequency bands are above the 85 dB (A) threshold specified by the NR-15.

It is possible to note that all values of the equivalent level per weighted octave band - LEQ-dB(A), corresponding to the frequencies are below the limit of 85 dB(A) specified by the NR-15. For the analyzed process, it is not necessary to use the ear protector, but the one on the construction site is exposed to indirect noises from noise sources that normally exceed the limit, and it is always mandatory to use the ear protector in the premises of the site. work.

### 4.2.4 Result with use of EPP's (Compressor)

| Result with the use of EPP - Calculation by the long method ABNT NBR 16077 | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Assumed protection | | | | | | |
| Type of hearing protector | Nº CA | Validity | LEQ | 125 Hz | 250 Hz | 500 Hz | 1 kHz | 2 kHz | 4 kHz | 8 kHz |
| Shell type | 15624 | 07/05/2020 | 65,8 | 55,8 | 58,5 | 61,5 | 59,6 | 52,2 | 52,7 | 41,7 |
| Shell type | 27971 | 05/11/2018 | 69,9 | 60,8 | 60,5 | 65,5 | 64,6 | 57,2 | 56,7 | 46,7 |
| Preformed type | 13027 | 28/02/2018 | 76,6 | 56,8 | 61,5 | 73,5 | 71,6 | 61,2 | 67,7 | 50,7 |

*Fig.4.8 – Calculation of the efficiency of the ear protector for the compressor process. Source: Author.*

In figure 4.8, it is presented to the efficiency of the ear protector according to the long method of ABNT-NBR 16077 that used the frequencies of octave band for the calculation. In this case it is possible to notice that all ear protectors analyzed are efficient, since the noise was

already below the tolerance limit with regard to NR-15 as with respect to NHO-01.

### 4.3 Evaluation of concrete mixer truck

### 4.3.1 Dosimeter configuration (truck mixer)



*Fig.4.9 – Noise gauge settings for truck mixer process. Source: Author.*

The figure 4.9 shows dosimeter configurations according to Regulatory Standard 15 (NR-15) and Occupational Hygiene Standard 01 (NHO-01). For dosimeter 01 (NR-15) the Criterion Level is set to 85dB, Threshold Level is 80dB, 3dB doubling rate with frequency weighting A and time weighting Slow. For Dosimeter 02 (NHO-01), the

Criterion Level with 85dB, Threshold Level of 80dB, 5dB doubling rate with frequency weighting A and Slow time weighting, default is set for performing the noise evaluation.

**4.3.2 Dosimeterresults (Concrete mixertruck)**

Result dosimeter 01

| Resultad Result dosimeter 02 | | | | Resultados Dosímetro 02 | | | |
|---|---|---|---|---|---|---|---|
| LAVG: | 100,1 dB(A) | LMAX: | 117,6 dB(A) | LAVG: | 95,6 dB(A) | LMAX: | 117,6 dB(A) |
| LEQ: | 100,1 dB(A) | LMAX$_{Time}$: | 09:57 | LEQ: | 100,1 dB(A) | LMAX$_{Time}$: | 09:57 |
| TWA: | 92,4 dB(A) | Lpico$_{>115dB}$: | 134,1 dB(A) | TWA: | 82,8 dB(A) | Lpico$_{>115dB}$: | 134,1 dB(A) |
| NEN: | 1⌃⌃6 dB(A) | Lpico$_{Time}$: | 10:11 | NEN: | 96,4 dB(A) | Lpico$_{Time}$: | 10:11 |
| DOSE: | 569,20% | Lmin: | 70,4 dB(A) | DOSE: | 74,80% | Lmin: | 70,4 dB(A) |
| DOSE$_{8horas}$: | 3274,70% | DOSE$_{p8hs}$: | 3684,10% | DOSE$_{8horas}$: | 434,60% | DOSE$_{p8hs}$: | 489,00% |

*Fig.4.10 – Noise measurements according to NR-15 and NHO01 for the truck mixer process.*
*Source: Author.*

In figure 4.10, the results of the noise measurement for the truck mixer process are presented. Of these results, what is most important in the evaluation is the NEN (Normalized Exposure Level) to compare with the tolerance limit of NR-15 and NHO-01. The NEN with the NR-15 parameters presented a result of 100.6 dB (A) that

is above the tolerance limit of 85dB (A). The NEN with the NHO-01 parameters presented a result of 96.4 dB (A) that is above the tolerance limit of 85db (A). The exposure dose for 8 hours is 434.6%, well above acceptable.

**4.3.3 Level of equivalence per octave band (Mixer truck)**
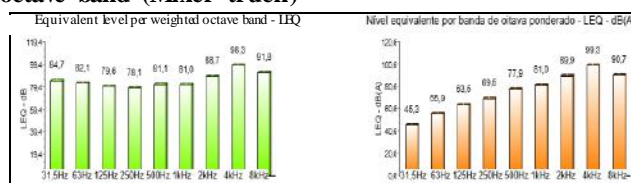
Equivalent level per eighth band - LEQ dB



*Fig.4.11 – Equivalent noise level per octave and without weight and with A. Weighting curve for thetruckmixerprocess.*
*Source: Author.*

The figure 4.11 shows the equivalent level by weighted octave band the noise the worker was exposed (31.5Hz, 63Hz, 125Hz, 250Hz, 500Hz, 1kHz, 2kHz, 4kHz, 8kHz). The equivalent level per octave band - LEQ-dB, in the illustration the green bar histogram, shows the actual noise the equipment collects. The equivalent level by weighted octave band - LEQ-dB(A), the histogram with orange bars, which gives a reasonable approximation of the human perception of sonority, that is, represents the perception of the human ear to the noise. For values of the equivalent level per octave band - LEQ-dB(A), the noise

values of the respective 2 kHz, 4 kHz, 8 kHz frequency bands are above the 85 dB(A) threshold specified by the NR-15.

The equivalent level values per weighted octave band - LEQ-dB(A), corresponding to the frequencies 2kHz, 4kHz, 8kHz are above the 85 dB(A) threshold specified by the NR-15. If the sound pressure result was calculated arbitrarily, the value would be 74.77 dB(A), which would generate a false result and would harm the worker.

**4.4.4 Result with use of EPI's (Concrete Mixer Truck)**

| Result with the use of EPP - Calculation by the long method ABNT NBR 16077 | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Assumed protection | | | | | | | |
| Type of hearing protector | Nº CA | Validity | LEQ | 125 Hz | 250 Hz | 500 Hz | 1 kHz | 2 kHz | 4 kHz | 8 kHz |
| Preformed type | 5745 | 31/01/2019 | 84,6 | 54,5 | 56,5 | 63,9 | 65,0 | 68,9 | 84,3 | 68,7 |
| Preformed type | 19578 | 07/02/2018 | 89,9 | 59,5 | 65,5 | 70,9 | 72,0 | 76,9 | 89,3 | 76,7 |

*Fig.4.12 – Calculation of the efficiency of the ear protector for the truck mixer process.*
*Source: Author.*

The figure 4.12 shows the results of the efficiency of the ear protectors according to the long method of ABNT-NBR 16077 that used the octave band frequencies for the

calculation. In this case it is possible to note that the CA 19578 Pre-Insertion Insert Earphone, the LEQ shows 89.9 dB(A), and the 4 kHz frequency has 89.3 dB(A), both are

above the limit of tolerance with respect to NR-15 as with respect to NHO01.

In this analysis it is important to verify that for two protectors of the same type of pre-insertion, different results were obtained, one of the practices used in the companies is to standardize the use of auricular protector

by separate function by color, or a specific color for visitors, which often ends up exposing the worker or visitor to noise above the tolerance limit.

**4.4 Evaluation of the noise of the concrete projector nozzle**

**4.4.1Dosimeterconfiguration (concrete projection)**

| Dosimeter configuration 01 | | Dosimeter configuration 02 | |
|---|---|---|---|
| Criterion Level: | 85 dB | Criterion Level: | 85 dB |
| Threshold level: | 85 dB | Threshold level: | 85 dB |
| Exchange rate: | 3 dB | Exchange rate: | 5 dB |
| Frequency weighting: | A | Frequency weighting: | A |
| Time weighting: | Slow | Time weighting: | Slow |

*Fig.4.13 – Noise meter settings for concrete projection.*
*Source: Author.*

In the figure 4.13 shows dosimeter configurations according to Regulatory Standard 15 (NR-15) and Occupational Hygiene Standard 01 (NHO-01). For dosimeter 01 (NR-15) the Criterion Level is set to 85dB, Threshold Level is 80dB, 3dB doubling rate with frequency weighting A and time weighting Slow. For

Dosimeter 02 (NHO-01), the Criterion Level with 85dB, Threshold Level of 80dB, 5dB doubling rate with frequency weighting A and Slow time weighting, default is set for performing the noise evaluation.

**4.4.2 Dosimeterresults (concrete projection)**

Result dosimeter 01

| Result dosimeter 02 | | | | Resultados Dosímetro 02 | | | |
|---|---|---|---|---|---|---|---|
| LAVG: | 103,8 dB(A) | LMAX: | 117,4 dB(A) | LAVG: | 100,9 dB(A) | LMAX: | 117,4 dB(A) |
| LEQ: | 103,8 dB(A) | LMAX$_{Time}$: | 15:00 | LEQ: | 103,8 dB(A) | LMAX$_{Time}$: | 15:00 |
| TWA: | 97,8 dB(A) | Lpico$_{>115dB}$: | 130,8 dB(A) | TWA: | 90,9 dB(A) | Lpico$_{>115dB}$: | 130,8 dB(A) |
| NEN: | 103,5 dB(A) | Lpico$_{Time}$: | 15:00 | NEN: | 100,4 dB(A) | Lpico$_{Time}$: | 15:00 |
| DOSE: | 1959,40% | Lmin: | 59,4 dB(A) | DOSE: | 228,40% | Lmin: | 59,4 dB(A) |
| D$_{8horas}$: | 7699,30% | DOSE$_{p8hs}$: | 7218,10% | DOSE$_{8horas}$: | 906,30% | DOSE$_{p8hs}$: | 849,60% |

*Fig.4.14 – Noise measurements according to NR-15 and NHO01 for the concrete projection process.*
*Source: Author.*

In Figure 4.14, the results of the noise measurement for the truck mixer process are presented. Of these results, what is most important in the evaluation is the NEN (Normalized Exposure Level) to compare with the tolerance limit of NR-15 and NHO-01. The NEN with the parameters of the NR-15 presented a result of 103.5 dB (A) that is above the tolerance limit of 85dB (A). The

NEN with the NHO-01 parameters presented a result of 100.4 dB (A) that is above the tolerance limit of 85db (A). The exposure dose for 8 hours is 906.3%, well above acceptable.

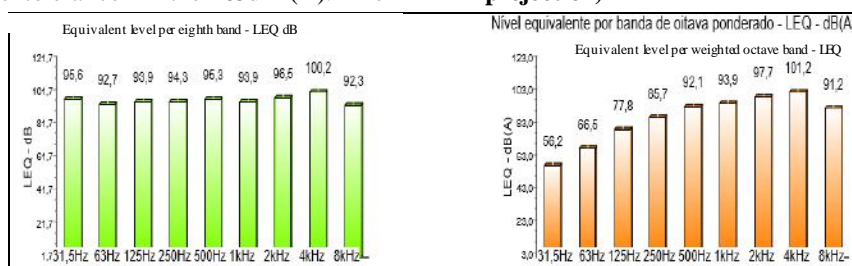**4.4.3 Level of equivalence per octave band (concrete projection)**



*Fig.4.15 – Equivalent noise level per octave band without weight and with A-weighting curve for the concrete projection process.*
*Source: Author.*

In the figure 4.15 shows the equivalent level by weighted octave band the noise the worker was exposed (31.5Hz, 63Hz, 125Hz, 250Hz, 500Hz, 1kHz, 2kHz, 4kHz, 8kHz). The equivalent level per octave band - LEQ-dB, in the illustration the green bar histogram, shows the actual noise the equipment collects. The equivalent level by

weighted octave band - LEQ-dB (A), the histogram with orange bars, which gives a reasonable approximation of the human perception of sonority, that is, represents the perception of the human ear to the noise.

For the equivalent level values per octave band - LEQ-dB, all noise values in respective frequency bands are above the limit of 85 dB(A) specified by the NR-15.

The LEQ-dB (A) weighted octave band equivalent values at the frequencies 250Hz, 500Hz, 1kHz, 2kHz, 4kHz, 8kHz are above the 85 dB (A) threshold specified by the

NR-15. If the sound pressure result was calculated arbitrarily, the value would be 84.77 dB (A), which would generate a false result and would harm the worker.

### 4.4.4 Result using PPE's (concrete projection)

| Result with the use of EPP - Calculation by the long method ABNT NBR 16077 | | | Assumed protection | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Type of hearing protector | Nº   CA | Validity | LEQ | 125 Hz | 250 Hz | 500 Hz | 1 kHz | 2 kHz | 4 kHz | 8 kHz |
| Shell type | 27971 | 05/11/2018 | 82,6 | 74,8 | 74,7 | 73,1 | 74,9 | 75,7 | 75,2 | 64,2 |
| Preformed type | 13027 | 28/02/2018 | 89,3 | 70,8 | 75,7 | 81,1 | 81,9 | 79,7 | 86,2 | 68,2 |
| Tipo concha | 15624 | 07/05/2020 | 78,6 | 69,8 | 72,7 | 69,1 | 69,9 | 70,7 | 71,2 | 59,2 |
| Shell type | 5745 | 31/01/2019 | 88,0 | 68,8 | 72,7 | 78,1 | 77,9 | 76,7 | 86,2 | 69,2 |

*Fig.4.16 – Calculation of the efficiency of the ear protector for the concrete projection process.*
*Source: Author.*

In figure 4.16 shows the results of the efficiency of the ear protectors according to the long method of ABNT-NBR 16077 that used the octave band frequencies for the calculation.

In this case it is possible to note that the CA 13027 pre-inserted insert earphone, the LEQ has 89.3 dB (A), and the 4 kHz frequency has 86.2 dB (A), the ear preformed insert No. CA 5745, the LEQ shows 88.0 dB (A), and the 4 kHz frequency shows 86.2 dB (A), both protectors present results above the tolerance limit with respect to NR -15 as with respect to NHO01.

Shell protectors are indicated in this process as they meet all criteria and frequency bands.

### V.    CONCLUSION

In this work, four of the main noise sources of a construction site were presented, the selected processes were the operations with the Wacker Neuson EH9 breaker, the XAS 420 Atlas Copco compressor noise source, the CP6 designed concrete pump noise, the truck concrete mixer and the concrete projection nozzle, these processes are commonly used in medium and large construction works.

Measurements of noise at source were made using the octave band filter decibelimeter, sound pressure level and octave band spectrum of noise sources, which provided sufficient information to perform the study.

The hearing protectors adopted at the studied construction site were mainly the shell type ear protector N ° CA 15624 and N ° CA 29176, which were efficient for most of the results analyzed, all the operators in the areas of the construction site are instructed to wear the shell-type earpiece, visitors are offered the CA 5745 Pre-Inserted Insert Ear Protector, and all persons are required to wear protective helmet and goggles. The work has a work safety technician and a work safety engineer.

Regarding the evaluation of the efficiency of hearing protector models by the long method, used in the processes of the analyzed construction site.

For the hammer process, the attenuation found with the shell type ear protector No. CA 29176, was above the tolerance limits of both standards, which is unhealthy. Risks have been presented and, according to item 6.6.1.1 Daily dose of NHO-01, where the daily dose of exposure to noise determined is greater than 100%, the exposure limit will be exceeded and will require the immediate adoption of measures, the process presented 159.7%. Also observing item 6.6.1.2 Normalized exposure level, based on the criterion presented in item 5.1.2, when the normalized exposure level (NEN) is greater than 85 dB (A), the exposure limit is exceeded and will require immediate adoption of control measures, the NEM exposure level for the martelete process was 105.4dB (A). In case the action taken is the use of ear protection that meets the level of attenuation and still not meeting, will be applied to the operator rotation according to NR-15.

According to the studies, the noise of the compressor did not exist the characterization of the insalubrity by noise and also met the NHO-01. The daily dose is below 100% for item 6.6.1.2 Normalized exposure level, based on the criterion presented in item 5.1.2, when the normalized exposure level (NEN) is greater than 85 dB (A), the exposure limit will be exceeded and will require the immediate adoption of control measures, the NEM exposure level for the compressor process was at 87.2dB (A), the immediate action is the use of the efficient ear protector. An observation in this process regarding the insalubrity criterion is that the operator who works close to the compressor is exposed to the noise coming from the cement mixer truck and the projection by blasting the concrete, is still exposed to dust and heat, items that were not analyzed in this study.

With the same analysis of the concrete mixer truck and concrete blasting operations, items 6.6.1.1 Daily dose of

NHO-01, whenever the daily dose of determined exposure to noise exceeds 100%, the limit of exposure will be exceeded and will require the immediate adoption of control measures, both processes presented above 100%, and also observing the item 6.6.1.2 Normalized exposure level, based on the criterion presented in item 5.1.2, whenever the level NEN - is greater than 85 dB (A), the exposure limit is exceeded and will require the immediate adoption of control measures, both processes also show higher than acceptable results.

Even if some protectors show results with attenuation levels within the limit specified in regulatory standards NR-15 and NHO-01 and other specific standards, it is important to note the set of action of the construction site as the sources of environmental risks in a process dynamic and complex and can not be worked in isolation.

## ACKNOWLEDGEMENTS

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