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NOISE AND VIBRATIONS IN THE URBAN CONTEXT OF ROME: A CASE STUDY

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ABSTRACT

Noise can be generated by different causes, and the great variation in noise levels is determined by the cumulative effect of 9 have reported associations between exposure to noise, vibration, and annoyance and show that the greatest effects in terms of population prevalence are due to sleep loss and severe annoyances. Moderate speed vehicles, quiet engines, special road surfaces, smooth flow, etc. may be important to achieve comfort improvement. These results motivate the need for noise assessments. The primary objective of this work was to study the effects of noise generated by vehicular traffic in the urban context of Rome and to identify a relationship with level vibrations generated by the same traffic. The data illustrate the measurement campaign carried out in different sites for the purpose of detecting noise levels within the structures. Subsequently, the data obtained compared with vibration levels, and the results confirm a strong relationship between the two physical agents.

Keywords: *noise exposure, threshold, urban context, vibrations, noise.*

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1. INTRODUCTION

Many researchers have conducted studies on the negative effects on population health and well-being generated by traffic noise and vibrations [1-3]. This problem affects residential areas and has mainly focused on urban populations living in buildings [4-6]. Studies point out that the main source of annoying noise and vibration in a city is road traffic [7-9]. In fact, different types of vehicles, such as cars, trucks, motorcycles, and buses, travel on city streets during the day and night, generating significant levels of noise and vibration [10]. It is also important to note that traffic disturbance in the residential setting, vehicular sounds and vibrations are negative physical agents that can fuel chronic stress and thus decrease quality of life and compromise people's health [11-13]. Noise is among the physical agents most unwanted by citizens, and, according to statistical data, petitions by residents to reduce noise pollution are more common than petitions for air pollution [14]. In addition, human senses react differently in relation to the experience of noise exposure [15]. The negative effects of exposure to this physical agent are also studied for workers in the context of the workplace; many studies confirm that prolonged exposure to high and continuous noise levels generates annoyance and risks to human health [16-17]. In addition, the higher rates of travel in urban settings can lead to higher noise levels than in flat agricultural areas. In these settings, in fact, the noise generated is approximately on minimum values compared to urban areas. Many parameters can influence people's noise exposure. Meteorological effects, such as refraction due to wind speed gradients, air temperature, humidity, and turbulent dispersion, can significantly affect noise levels, especially in shielded locations [18]. To cope with its negative effects, many cities around the world have developed noise maps for different modeling areas, different noise sources and with different results [19]. Some cities have developed noise maps for their urban areas, but most of them are diagnostic studies involving only noise level measurements. Environmental monitoring is recognized as a key tool for identifying areas where action is needed to reduce noise [20]. In other word the aspect of optimizing the location of noise monitoring stations is very important for urban noise monitoring and has attracted the attention of much researchers [21-22]. Data measured by noise monitoring systems are useful for noise analysis and reduction in order to identify specific technical interventions, such as the installation of noise barriers [23]. Generally a city noise map is calculated by considering sound propagation over a rigid ground [24-25]. Finally, it has been considered that noise, but also subjective annoyance and disturbance, can impair physical functioning, sleep quality, psychological well-being, self-perceived health, and health-related quality of life for years without inducing serious illness or death [26]. For this reason, many countries have mandated by law integrated environmental impact assessments that consider how environmental conditions affect not only physical health but also social, economic, cultural and psychological well-being. In recent years, the impact of noise pollution has changed due to many factors, such as new building materials, and to make roads, noise reduction and the construction of special noise barriers have improved [27-28]. In particular, during the exceptional Covid period, there was a significant reduction in private vehicle travel due to the Italian government's adoption of strong and strict measures to contain the spread of Coronavirus and thus a drastic reduction in noise emissions [29].

2. MATERIALS AND METHODS

In order to investigate the above issues, an experimental campaign was carried out in the urban center of Rome. The purpose of the work is to analyze the relationship between the speed of vehicles and the noise they generate. The first step of the work was to identify a site where there was relevant vehicle traffic and suitable points to carry out the measurement campaign. A hotel near the famous Italian monument Bocca della Verità was chosen because its location is on a road with heavy traffic, both at night and during the day. The following image shows the exact location of the building where the measurements were taken (red squares highlight specific points). As can be seen, the main road where the signal was acquired is located in front of the building where vehicles pass through. The

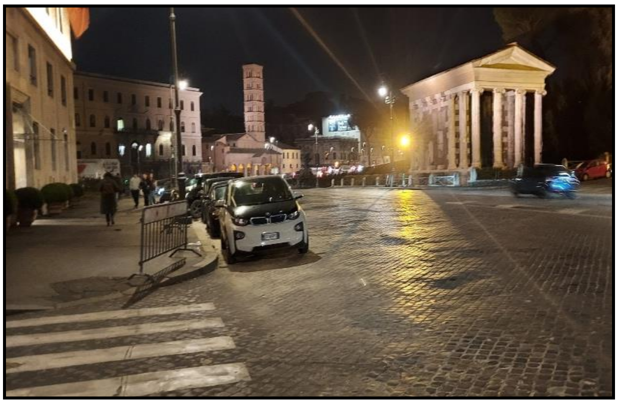

Figure 1: overview of the street during the night

The street is made up of three elements: sidewalk made of basalt and a central part made of cobblestones where the vehicles transit in either direction.

Figure 2: overview of the street during the day

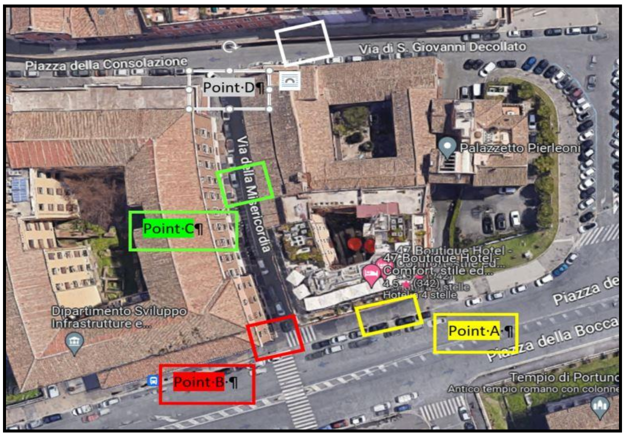

Figure 3: map of the measurement points

Four measurement points were chosen in in close proximity of the building: points A and B were set in front of the hotel for the purpose of characterizing the signal source; points B and C (near and behind the structure, respectively) were defined for the purpose of analyzing how the noise is absorbed by the building walls.

Figure 4: specific points near the structure

The measurements were taken on different days, and it was necessary to establish a specific procedure for each theme. The experimental work was carried out on four points:

1) Fixing the instruments on the road;
2) Acquisition of the noise signal;
3) Characterization of vehicular traffic;
4) Post-processing of the acquired data;

The experimental data were acquired through an averaging and integration sound level meter with included spectrum analyzer and a sound calibrator, model Larson Davis 824. The instrument was fixed on a metal stand 1.5 meters above the ground. The distance to the signal noise source for points A and B was about 5 meters, while points C and D were 20 m and 80 m from the road, respectively.

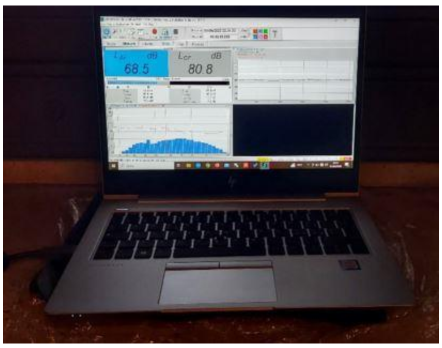

Figure 5: instrument for signal acquisition

Calibration is realized before and after measurements with an instrument that applies only a reference sound (94 dB at 1 kHz) and accepts a small error of less than 0.5 dB to validate the measurement. Data processing was carried out using Noise Vibration Work software to extract, process and plot the measured parameters, particularly the signal time history and frequency spectrum. The methodology adopted in this work is based on the fact that the actual input signal is generated by different vehicles. Each of them has different characteristics in terms of weight, transit speed and specific engine. This fact implies that the noise signal is composed of different elements and therefore it is very complex to define a single noise source signal.

Figure 6: instrument fixed on the support

Before measurements began, the weather conditions were checked, particularly for wind.

3. RESULTS

The graphs reported in this section of the paper show the signal acquired during the experimental campaign by the sound level meter, as described above. The first graph in the picture number 7 point outs the Time History of the first measurement; in the x-axis time is reported in terms of seconds (s) while in the y-axis the Sound Pressure Levels expressed in terms of Decibel (dB)is indicated. The graphs are referred to measurement number one and number two. The following graphs number 8 reports the frequency spectrum of the signal expressed in terms of decibel (dB) and frequency (HZ). Each column reports the specific SPL value for each frequency within of human audible field

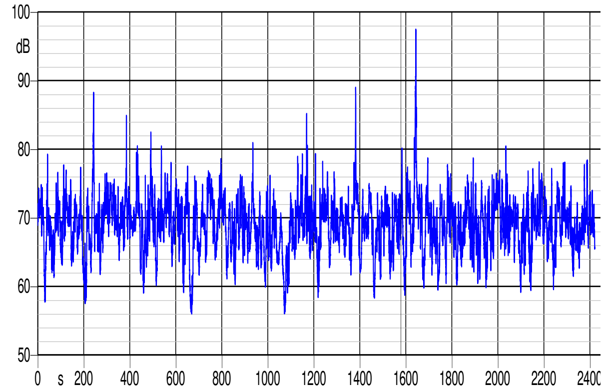

Figure 7: time history of the daily first measurement

The experimental campaign, as indicated in the previous section, was carried out at different times, daily and nightly, at different locations near the facility. In order to compare the results obtained from the measurements, the data were reported in Table 1 below. The columns, respectively from left to right, indicate the number of measurements, data, period and duration. The columns, respectively from left to right, indicate the number of measurements, data, measurement period, and sound pressure level result expressed as Leq. The latter parameter should be considered as a numerical value representing the mean square root of the measurement referring to the measurement time.

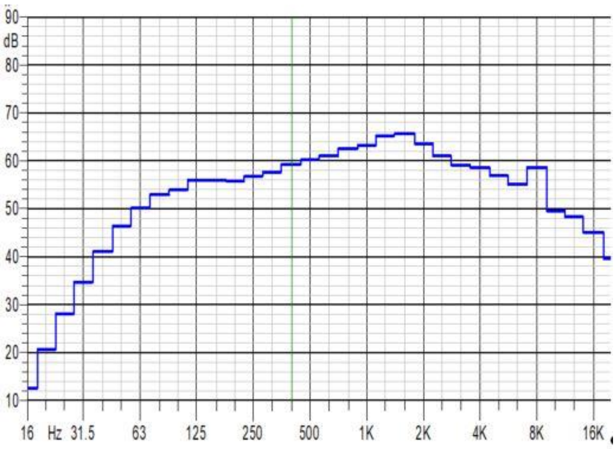

Figure 8: frequency spectrum of the first daily measurement

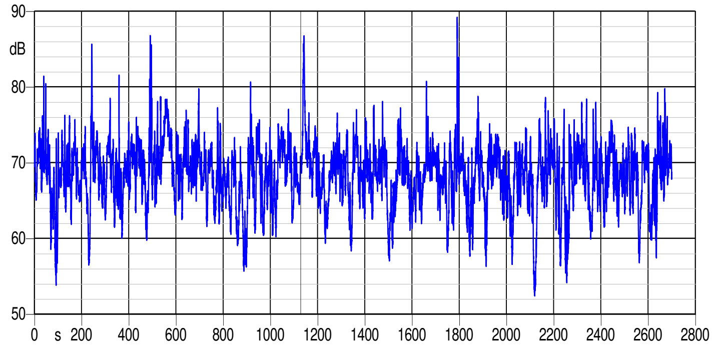

Figure 9: time history of the nightly first measurement

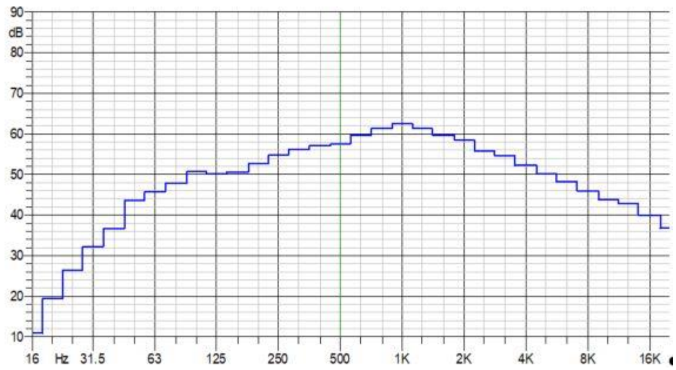

Figure 10: time history of the nightly first measurement

The following graphs report the measurements of the second night (Time history and frequency soectrum)

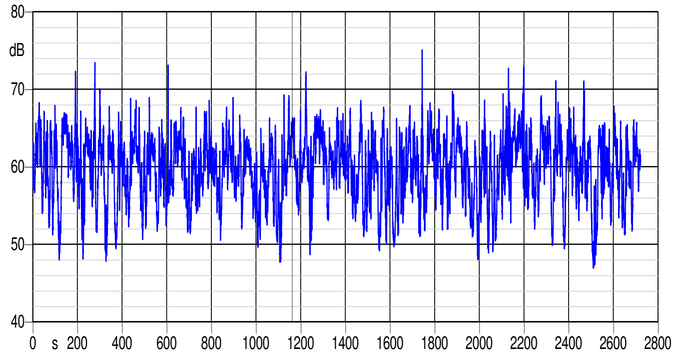

Figure 11: time history of the nightly second measurement

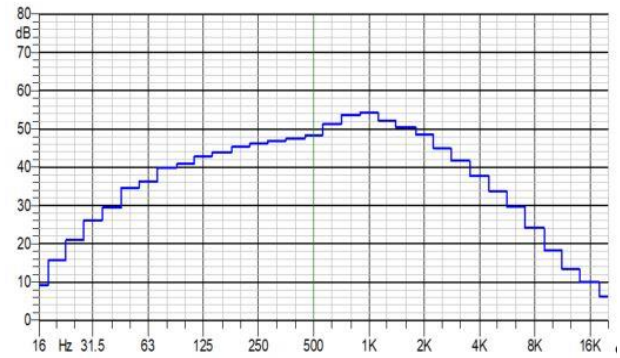

Figure 12: frequency spectrum of the nightly second measurement

The measurement carried out behind the structure is shown in images number 13 and 14. The peaks in the history were generated by anomalous events, such as transits of people talking. Therefore, during post-processing, they were removed by special tools in the software.

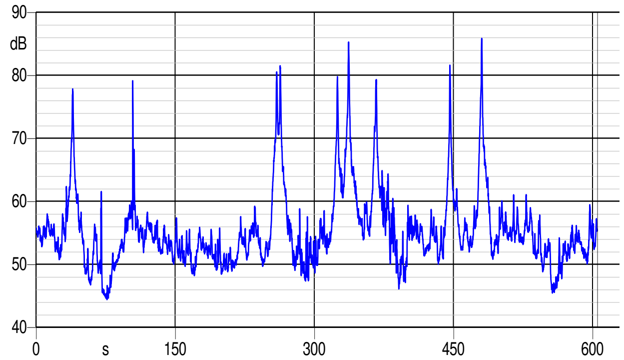

Figure 13: time history of the measurement realized behind the structure

The following table 2 indicates the position of the measurement and the exactly point (as reported in picture number 3). Each point defined by a specific letter, from A to C

Table 1: position of the each measurement

Measurement	Position
1	A
2	B
3	A
4	A
5	C
6	D

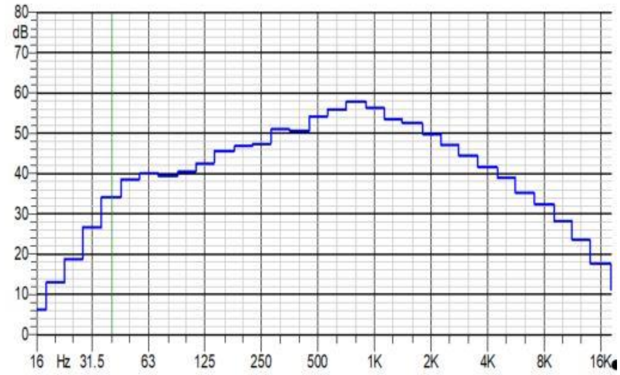

Figure 14: frequency spectrum of the measurement realized behind the structure

Measurement data are summarized in the following tables. In Table 1, the first column shows the measurement number, the second column points out the date, after the start time, and the last column on the right shows the weather conditions of the day.

Table 2: date/time/weather

Measurement	Date	Time	Weather
1	01.04.2023	14:00	sun – no wind
2	01.04.2023	23:00	sun – no wind
3	03.04.2023	08:00	sun – no wind
4	03.04.2023	22:10	sun – no wind
5	03.04.2023	23:00	sun – no wind
6	03.04.2023	23:30	sun – no wind

The following table 3 is similar to the previous one. The data reported from left to the right are respectively: number of the measurement, period (day or night), number of the vehicles transit and level noise. This last is defined such as an average valued (Level equivalent) computed by R.M.S (Root Mean Square) during the measurement time.

Table 3: period/traffic/level noise

Measurement	Period	Traffic	Level noise
1	day	1417	71.6
2	night	1008	70.3
3	day	626	73.8
4	night	950	61.3
5	night	-	55.8
6	night	253	64.4

The graph shown in Figure 15 compares the different frequency spectra of each measurement, while the last graphs (Figures 16 and 17) show data from the measurement taken near the hotel, in Circo Massimo Square. The latter measurement was made on a different type of road, not cobblestones but compact asphalt and , furthermore, near the traffic lights during the night.

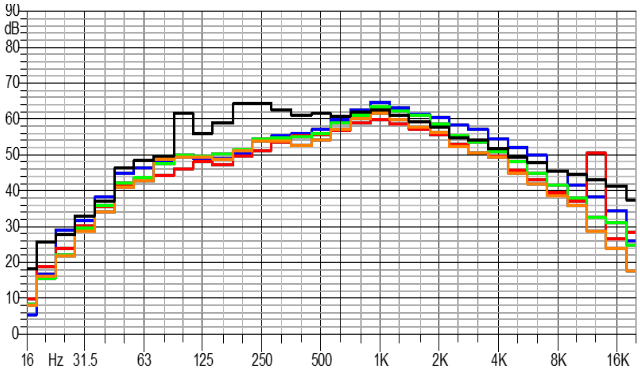

Figure 15: comparison of frequency spectrum

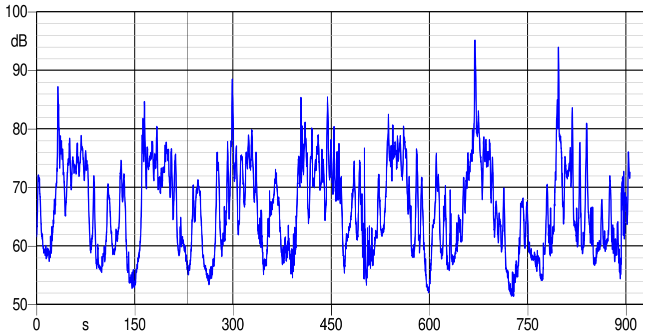

Figure 16: Time History of the measurement

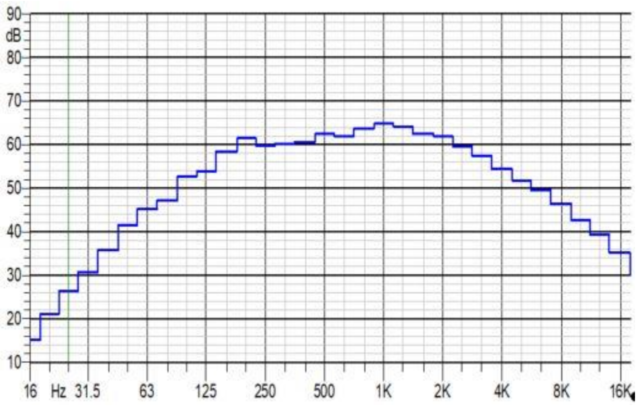

Figure 17: frequency spectrum of the measurement Circo Massimo during the night

4. DISCUSSIONS

The above data show that the noise generated by vehicular traffic is defined in a range from 56 db to 74 db. The noise levels recorded at night are lower than the values acquired during the day, with a difference of about 10 dB. Measurements taken in front of the building recorded the highest values near the street. This is because the sound pressure wave does not hit obstacles during its path from the signal source (vehicles) to the instrument. The second reason is due to the small distance between the road and the measurement point. So the sound pressure level does not decrease enough in terms of decibels. Another important consideration is the difference between noise levels at night and during the day. The difference in noise levels can be explained by the different traffic characteristics between day and night. In fact, vehicular traffic during the daytime generally consists of a large number of motorcycles, buses and cars, with different transit speeds depending on traffic conditions. Vehicle transits were calculated during the day and night; the observation time was defined as every 10 minutes; about 350 daily and 240 overnight transits were counted. The traffic data were analyzed and the results show that heavy vehicles (buses, trucks) are about 8 percent compared to ordinary cars. In addition, these different characteristics of the noise sources are highlighted in the frequency spectra obtained in post-processing. It should be emphasized that the acquired signal does not allow the identification of specific individual transits due to the excess of transits in both directions. In many cases, the transits were interrupted due to the passage of pedestrians and thus the vehicles remained stationary on the road for a long time. Daily measurements show high components, approximately at 8kHz, probably generated by motorcycles, which have a different engine than buses and cars. Another key aspect is the transit speed of the vehicles; it was estimated to be about 80km/h for nighttime transits and about 60-70km/h for daily transits. the results obtained in the last measurement made in Circus Maximus Square show that different road conditions generate a different level noise in terms of frequency spectrum, but still a relevant level noise. This aspect can be explained by the fact that the measurement point was set close to the traffic light and therefore the noise of accelerating vehicles is measured. Additional computations were performed with combinations of the different graphs of the different measurement points and the noise levels results comparable, with similar values.

5. CONCLUSIONS

Noise and vibration in the urban context are among the main environmental problems. In this paper we present the results of an experimental campaign carried out in the historic center of Rome to study the parameters that influence the noise generated by passing traffic. The main conclusions are described below. Two essential issues were addressed: the difference in traffic-generated noise between night and day and the influence of vehicle transit speed. The results show that the proposed data estimate acoustic noise levels comparable with normal traffic values, as observed by the graphs and tables, with a relevant difference between day and night. Higher values of noise levels are related to higher values of transit speed. In addition, it was confirmed that increasing the distance from the signal source reduces the noise impact on the building, and the structure can absorb relevant sound pressure. Another important aspect concerns the type of road; the compact surface can be a relevant element in reducing the impact of vehicle noise, but this alone does not seem to be sufficient. The speed parameter turns out to be the element that most influences the noise impact and thus. The proposed result can be implemented by other road noise tests at different locations than the site for comprehensive environmental monitoring. This study has some limitations in the experimental phase. In almost all measurements in the present study, only the cobblestone road was considered, while only one measurement was made with the asphalt road. In addition, the accuracy of the results is also limited by the uncertainty of the number and type of vehicle passages. This limitation affects the characterization of the source of the noise signal. The preliminary experimental experience is very encouraging, can be a starting point for a noise model with correction factors for the noise mapping results, and can be realized. Another aspect that can be analyzed is the correlation between sound and vibration on the buildings.

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