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Noise generated from large construction sites: Measurements and possible mitigations

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Abstract

In this study, the issue of noise arising from the activities of large construction sites is analysed. The problem is particularly significant when the sites are close to protected natural areas or to residential areas and also when the duration of the construction works is very large. The case of the construction of a mobile barrier system, known as the MoSE, for the safeguard of the city of Venice from intruding tidal waters, is here reported. Since the early beginning of the construction activities, in April 2005, noise emission monitoring was conducted in order to evaluate possible effects on the presence of bird communities in the surrounding areas and also to evaluate the noise disturbance in some of the residential buildings close to the sites. During the monitoring activity, it was possible to measure the noise levels, the noise spectra and spectrograms in real-time and occasionally even the audio signal for particular activities was recorded. The analysis of data collected in different periods defined the pile driving and some other activities as the most significant from the standpoint of noise emission, therefore the possibility to mitigate their emission was investigated.

Keywords: Measurements, Noise control, Construction sites
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1 Introduction

Noise generated from activities in construction sites is usually considered, within environmental noise legislation, as a specific case, together with other temporary activities. The possibility to perform activities also in densely populated urban areas requires a compromise between the noise generated and the safeguard of the population. The Italian legislation takes into account these activities, among other temporary activities, and allows for the possibility to have a waiver with respect to the standard noise limit values; the procedure generally requires a monitoring of the time table and number of hours of activities and maximum levels permitted in a restricted period of time. When the duration of the activities and the areas involved in the construction sites are very large and the type and localisation of the most noisy activities change in time, it is very difficult to find a simple procedure to apply the waiver. In those cases in which the sites are close to protected natural areas, with the possible impact on the presence of birds and other animals, it is necessary to perform other procedures to guarantee that the noise levels remain below the agreed threshold.

In the case of the construction of a mobile barrier system for the safeguard of the city of Venice from intruding tidal waters [1], a monitoring plan [2] was organised and performed. The monitoring plan regarded a number of different aspects related to the environmental impact of the works. CORILA (Consortium for the coordination of research activities concerning the Venice lagoon system), as an independent third party, was involved by the Water Authority in the programming and the execution of the monitoring plan. The aims of the monitoring plan are to give prompt feedback regarding the preservation of the foreseen level of environmental impact of the works, in order to allow the adoption of appropriate countermeasures and to provide objective information in order to acknowledge and demonstrate the effective incidences of the construction activities on the environment and to plan and manage related mitigation/compensation measures.

The noise problems related to the construction sites has been an important part of the monitoring plan, although smaller with respect to other potential impact. It is known that disturbance by anthropogenic noise can influence bird communication. In particular the installation of a construction site may modify the natural behaviour of birds living nearby. Bird communication is particularly important during the nesting period, thus through long term monitoring it is necessary to establish where the risk of masking bird song may compromise bird communication [3, 4]. A number of studies show evidence of a decline in both the number of species and number of individuals due to increased environmental noise levels caused by road traffic [5, 6]. Birds make use of a rich array of sounds to communicate, find mates, express territorial occupation and other social behaviours.

The monitoring plan was used also to verify the disturbance when the noisiest activities were performed in the proximity of populated areas. In these cases, the legislation refers to the A weighted sound pressure level (LAeq) as the only parameter to determine the disturbance.
However, when the noise is characterized by a low frequency contribution, the measurement of LAeq underestimates the real disturbance, and other procedures should be used to integrate the evaluation [7].

2 Italian Legislation for environmental noise

The current Italian legislation for environmental noise is defined under the framework law n° 447 from 10-26-95 and its implementation decrees. The main limiting values to be applied according to the territory usage destination class and to the day and night periods are:

- single emission limit value (referred to the single noise source alone);
- overall emission limit values (referred to all sound sources present);

The latter are divided into “absolute” overall limit value and “differential” overall limit value. The absolute limit values are reported in the following table, according to the destination classes.

Table 1: Limits defined by the Italian legislation for six different areas

<table>
<thead>
<tr>
<th>Destination class</th>
<th>Description</th>
<th>overall limit dB(A)</th>
<th>single emission limit dB(A)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Day</td>
<td>Night</td>
</tr>
<tr>
<td>I</td>
<td>Protected areas</td>
<td>50</td>
<td>40</td>
</tr>
<tr>
<td>II</td>
<td>Residential areas</td>
<td>55</td>
<td>45</td>
</tr>
<tr>
<td>III</td>
<td>Mixed areas</td>
<td>60</td>
<td>50</td>
</tr>
<tr>
<td>IV</td>
<td>Intensive human activities areas</td>
<td>65</td>
<td>55</td>
</tr>
<tr>
<td>V</td>
<td>Mainly industrial areas</td>
<td>70</td>
<td>60</td>
</tr>
<tr>
<td>VI</td>
<td>Industrial areas</td>
<td>70</td>
<td>70</td>
</tr>
</tbody>
</table>

The differential overall limit value is of 5 dB for the day period and of 3 dB for the night period, measured inside a home. The differential overall limit values cannot be applied to the noise produced by the transportation system (road, rail, aeronautical and naval). Usually, when the noise sources are displaced near the habitable places it is the differential limit values that are more likely to be exceeded.

The framework law established that for noisy temporary activities, such as construction yards, a waiver of the overall limit values, as stated by the DPCM 14-11-97, may be provided. The regions have the duty to determine the procedures and the municipalities have the duty to issue the exemption authorizations.

The request for the waiver authorization is not compulsory but becomes absolutely necessary when it is predictable that the construction activity will overcome the limit values. The request should be done beforehand to the opening of the work yard.

The municipality can authorize temporary exemptions of the single emission limit values, any time there is a particular local need or for a public utility reason. The respective authorization though has to prescribe the necessary measures to reduce to a minimum the effects of the noise on a third party, and has to give the time limits for the validity of the waiver.
3 The MoSE system and the construction sites

MOSE (Experimental Electromechanical Module) is an integrated system with the aim to protect the Venice lagoon, its cities and its historic, artistic and environmental heritage from flooding. The system, which construction is under completion, consists of mobile barriers at the lagoon inlets (two at the Lido inlet, one at Malamocco and one at Chioggia) designed to temporarily isolate the Venetian Lagoon from the high tides of the Adriatic sea. In fact, particular meteorological factors such as low pressure and strong winds (north-easterly bora and south-easterly scirocco), may determine a significant phenomenon of rising sea level in the gulf of Venice. These phenomena can occur up to 20 times per year, with a duration of 5-6 hours. More significant events, with higher and dangerous level of the sea, as occurred in 1966, when the city of Venice reported extensive damages, are possible, too.

The four barriers, for a total length of 1.6 kilometres, are made of 78 mobile gates. One lock for large ships at the Malamocco inlet enables port activities to continue when the gates are in operation. Three small locks (two at Chioggia and one at Lido-Treporti) allow the transit of fishing boats and other smaller vessels when the gates are in operation.

MoSE is flexible and can be operated in different ways according to the characteristics and height of the tide. Given that the gates are independent and can be operated separately, all three inlets can be closed in the case of an exceptional event; the inlets can be closed one at a time according to the winds, atmospheric pressure and height of tide forecast; or again, each inlet can be partially closed.

The construction of the system, which started at the end of 2004, has seen 18 kilometres of linear worksites on land and at sea, involving directly or indirectly almost 4000 employees. During all these years, the construction sites utilizes a huge number of machines, equipment and construction materials.

4 Noise monitoring procedures

Noise monitoring was carried out during the construction activities considered to be the noisiest and most disturbing. Long term (minimum one week) noise monitoring was undertaken on the most sensitive positions. The measurement stations were equipped with a GSM modem for remote connection, with a data transmission system in order to provide real time visualization of the monitoring. The data analysers were inserted into apposite weather resistant cases with power-batteries able to supply energy for 2 weeks approximately.

In addition to the long period surveys scheduled by the agreements, additional measurements have been occasionally made at various distances from noise sources, in order to evaluate the noise propagation of the activity and the noise levels induced on the surrounding areas in order to have a better understanding of the sources responsible for exceeding the noise threshold and the dimension of the affected areas.

The results of the long term noise monitoring permits 3 types of verifications. The first was related to the reference period levels which were compared with the allowed limits; daily reports were given and in occurrence of levels above the limit, formal advisory warnings were issued. The second was related to the verification of the noisy activity in the time intervals agreed for the protection of the nesting period of the birds. The third verification was introduced to improve the process of identifying critical situations that could create disturbance or impact on birds. The
procedure consists of two phases; a first checking phase of the noise levels due to the construction site on intervals of 30 minutes, by calculating the corresponding level in dB (A) and comparing the obtained value with the limit value adopted of 60 dB (A). In case this value was exceeded, in the second phase the sound spectrum of construction activities and the sound spectrum of the singing of birds were compared in order to verify possible masking effects on intelligibility of birdsong.

5 Possibility of noise abatement of pile driving and other significant activities

Many different activities have been monitored during more than ten years of construction. The pile driving and the horizontal drilling of cable ducts were arguably among the noisiest, the first for the intensity and duration, the second for the duration and the proximity to the natural protected areas. In the next paragraphs the solutions adopted to mitigated the noise produced by these two construction activities are presented and discussed; the measurements of the pile driving activity were made at the Cà Roman protected area and the horizontal drilling at Alberoni protected area (Figure 1).

5.1 Pile driving activity

The data measured during these years of acoustic monitoring defined the pile driving as the most significant construction activity from the standpoint of noise emission. The pile driving activity showed an increase in the sound pressure level of the construction site of 15 – 20 dB. Moreover, the generated noise is characterized by a wide spectrum, from the very low frequencies up to 10 kHz, Figures 2, 3. The pile driver is a mechanical device that drives piles
into the soil to provide foundation support for civil structures. The mitigation system was designed to enclose the noise source. The driving hammer was encapsulated in a complex metal box lined with sound absorbing materials. Due to safety and maintenance reasons it was not possible to completely enclose the driving hammer. Nevertheless the acoustic shield provided a noise reduction of approximately 10 dB(A), Figure 3.

Figure 2: Time History and Spectrogram referred to ten minutes of pile driving activity, without (left) and with (right) the acoustic shield. The noise is characterized by frequency components between 16 and 8000 Hz, with particularly high levels between 160 and 1600 Hz

Figure 3: Frequency comparison of the levels measured at a distance of 110 m from the driving hammer, before and after the coverage.
5.2 Horizontal drilling activity before and after the realisation of the barrier

In 2007 the horizontal drilling of a cable duct started near the naturalistic area Alberoni. The broadband noise, from 20 Hz to 3000 Hz, Figure 4, produced by this activity was mainly due to the engine noise: the hydraulic system, the compressor and the pump system for bentonite mud. In order to mitigate the noise emission and protect the bird communities in the Alberoni area a noise barrier between the drilling site and the naturalistic area was installed.

The effectiveness of this measure was evaluated comparing the data measured before and after the barrier installation. For each period, ten days in which the drilling activity was performed have been considered. In each of these days, the sound pressure level was averaged for each third-octave bands over a period of 5 minutes, with no meteorological events or other activities that could influence the experimental data, in order to acoustically characterize the drilling of the cable duct. The comparison between the sound pressure levels measured before and after the noise barrier installation are reported in Figure 6. The barrier allowed to reduce the sound pressure level measured at the monitoring point from 40 Hz to 1250 Hz and a sound pressure level difference a weighted of 10 dB(A), Table 2. Due to the high pitched singing, the dawn chorus, performed by birds during the breeding season, it was not possible to extend this comparison up to higher frequencies. The birdsong is characterized by tonal components from 2000 Hz to 4000 Hz, Figure 5, hence it was no possible to correctly evaluate the noise reduction above 1250 Hz.

Table 1: Sound pressure levels before and after the noise barrier installation

<table>
<thead>
<tr>
<th>Medium levels before the barrier installation [dB]</th>
<th>Medium levels after the barrier installation [dB]</th>
<th>Difference [dB]</th>
</tr>
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<tbody>
<tr>
<td>[lin] 73.9</td>
<td>66.9</td>
<td>7.0</td>
</tr>
<tr>
<td>[dB(A)] 57.0</td>
<td>47.00</td>
<td>10.0</td>
</tr>
</tbody>
</table>

Figure 4: Time History and Spectrogram referred to the horizontal drilling activity, without the noise barrier.
Figure 5: Time History and Spectrogram referred to the horizontal drilling activity, with the noise barrier. The contemporary presence of bird song masks the high frequency of the activity.

Figure 6: Comparison between the average sound pressure levels, in one-third octave bands, before and after the noise barrier installation.
6 Conclusions

The probability of masking effects for birds depends directly on the overlapping of characteristic frequencies of birdsong and construction site noise. Birdsong with high characteristic frequency bands has less probability of being masked by construction site noise, because most construction site noises are characterized by low frequency. Birdsong at 6300-10000 Hz has a low probability of being masked, so birds can hear each other and their natural behaviour is not compromised. However noisy construction activities with a wide frequency range, like pile driving, could be potentially annoying for birds, depending on the duration of the activity.

Having defined the pile driving activity as the most significant from the standpoint of noise emission and considering the number of piles to be inserted (approximately 1500 for every inlet), an attempt to reduce noise emission was made by the construction company. The dimension of the machinery was very large and the starting height of the hammering did not permit any possibility to reduce the noise on the propagation. The only possibility was to intervene directly on the structure of the machinery, very close to the driving hammer, using an enclosure to encapsulate the main impact noise source. The first results, as shown in paragraph 5, was quite satisfying considering almost 10 dB(A) of noise mitigation. After the first application, for safety reasons, part of the enclosure needed to be opened, to permit visibility and avoid fire. Therefore, the following experimental measurements show a reduction of only 5-6 dB(A).

Regarding the horizontal drilling activity, the realization of a noise barrier gave a noise mitigation of approximately 10 dB(A). This result was considered positive, taking into account that the noise was mainly at the low-medium frequency bands and that the activity was performed using different machineries distributed in quite a large area.

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