# Acoustic Analysis of the Framework and Walls Stage in the Construction of a Housing Block

Maria Jesus Ballesteros, Samuel Quintana, Marcos Fernandez, Jose Ballesteros and Laura Rodriguez

Universidad de Castilla-La Mancha, Campus Universitario, 16071 Cuenca, Spain
josea.ballesteros@uclm.es

The noise in the construction process is one of the main environmental and industrial noise sources. There are no specific regulations in several European countries for assessing such kind of noise, neither reference indexes for its evaluation. Therefore, the limits adopted are those for environmental and industrial noise, despite that they do not take into account the intrinsic characteristics of this noise.

A measurement procedure has been stated for assessing the noise in building sites in which, the most appropriate indexes for this noise have been analyzed and used for deriving the acoustic characteristics of the framework and walls stage. This stage is considered as one of the most annoying in the construction process of a housing block.

# 1   Introduction

The noise emitted by the construction process is one of the main acoustics contaminants in our society. This noise source not only affect to the workers that suffer its effects personally, but also to the neighbourhood where the construction site is.

To evaluate the neighbours annoyance and to propouse correction actions, we must understand that the noise emissions have a temporary character and depend on the stage of the construction process, because the machinery used and the propagation conditions are differents. Because of this, it is important to characterize the noise emissions in different stages of the construction process.

There are no specific regulation in several European countries for assessing and mitigating this noise source, although it causes annoyance and risk for health in a lot of persons. In Spain this activity is regulated by the actual noise law, that is stated in the Royal Decree 1513/2005 [1, 3] and later enlarged in the Royal Decree 1367/2007 [2, 3]. Nevertheless, the construction activity is a noise source that is very different from another activities, and it cannot be regulated with the same criteria established in this law, due for example to their temporal emision sources and to a noise generation non constant with the time.

The purpose of this research is to establish an appropiate measurement procedure for this kind of sound sources, and to carry out an analysis of the noise emitted by the same, that allow to characterize the sound emissions in the construction process to, in base of this, be possible to state the appropriate noise control criteria for this activity [8, 9].

# 2   Measurement design

This research is carried out in the construction process of a housing block representative of the construction sector in Spain. The construction process in this stage starts with the construction of the load wall, later the load pillars are built, above which the slabs that finish this stage will lay. The construction process is the same in their three steps, as a reinforced concrete framework has been chose; therefore, the process used is: first, the casing is done, that consists in the layout of some metal sheets where the reinforcement is put and then, the concrete is poured. Once the concrete have forged, the uncasing jobs are developed, that consist in putting out the metal sheets that holded down the concrete.

The housing block location makes possible to do the measurements around it, as it is shown in the Fig.1. where the scratched zone shows the housing block used for this research.



Figure 1: Housing block location.

Because of this, four measurement points are placed, one in each side of the plot, as they are showed in the Fig.1. The first measurement point is located in a street with little traffic, the second one is located in a road with little traffic too, and the third and fourth are located in a waste ground zone.

The measurement protocol is based on simultaneous measurements in the four points with a duration of twenty minutes. The measurement is taken with four integrator sound level meters, one day every week all along the duration of the framework and walls stage.

We chose to do a spatial sampling with four points distributed along the perimeter of the construction site, because the dimensions of it are not big enough so as to need more points. On the other hand, a 20 minutes duration was chosen because this is a duration long enough to take the measurement without distortions from external events as traffic. Moreover, we have taken periodical measurements every week to guarantee that the sampling is representative, because the duration of the framework and walls stage last some months and this

guarantee than the main events have been measured.

# 3 Election of the parameters to study

As there is no specific regulation for this kind of sound sources, we look for the more appropriate parameters to study the sound emissions of a typical construction process.

To characterize the noise emissions in the construction process we start with a spectral analysis [6], to compare the spectrum obtained in the different measurement days to see if the spectral behaviour is the same along the stage, and therefore if it can determinate the characteristic spectrum of the the process and possible tonalities.

On the other hand, we do a percentile sound level study to specify the statistics and temporal character of the noise, the impulsivity and randomly. Furthermore, we establishe the sound climate L10 - L90 , and look for the more similar percentile to the LAeq, that also will give information about the statistic character of this kind of noise.

Finally, to characterize the noise emitted during the framework and walls stage we choose the mathematical model that is more aproximated to the spectral behaviour of this stage, and with this we establishe a prediction equation.

To assess the emitted noise we observe parameters as LAeq that allow to compare the annoyance and to relate this with the sound energy emitted, because they have a proportional relation. Moreover, we calculate the low frequency content with the LCeq and LAeq difference [6, 7], and finally we measure the peak level in C weighting to evaluate the impulsive characteristics of the noise.

# 4 Results

With the spectral analysis we have obtained the average spectrum for each one of the measurement points. Almost all of days have the same spectral trace and consequently, we can state that the average is representative of the emission of the building site in this point. In this analysis we observe that the point number three has very high spectral variations due to the concrete unload, given that in this cases the tanker are near this measurement point.

Also we can observe that, as with other jobs, the concrete unloads have a special spectral emission and it is different from the previous jobs, as it is showed in the Fig.2.

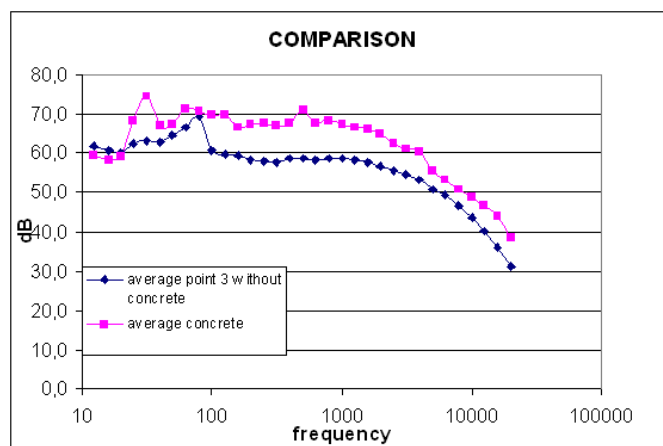We observe that the concrete unloads are characterized by a more flat emission spectrum, with a higher



Figure 2: Comparison of the average spectrum of the point number 3 including the concrete unloads and the rest of the jobs of this stage.

level and content at medium and low frequencies.

In the Fig3 we observe the average spectrum for each one of the measurement points. As we can observe, all of the points have a similar spectral trace, and due to this, we can calculate the global emission spectrum of this stage as the energy sum of the four measurement points, being the global spectrum representative of the emission of the construction site in this stage because, as we have stated, the spectral variations between differents days and points are very little.
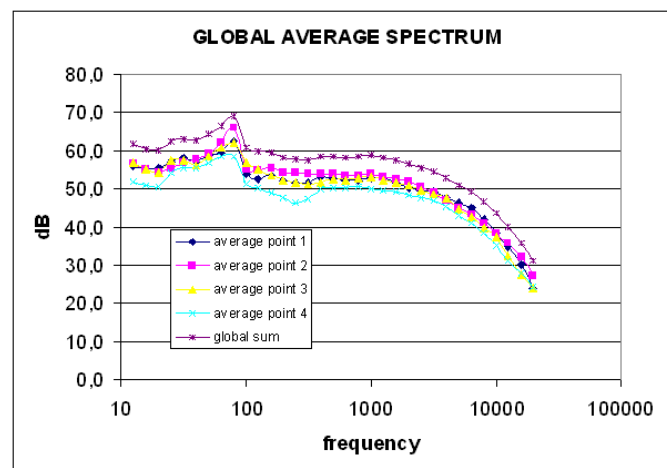


Figure 3: Average spectrum of each measurement point and the global average spectrum of the emission of the construction site.

With the global emission spectrum of this stage, we look for the mathematical model that is more aproximated to the spectral behaviour of this stage. To do this we consider different mathematicals models of study.

As we can observe in the Table 1 the best aproximation is obtained with the exponential model, with which we obtain the higher R squared value. Replacing the constants obtained for this case into the exponential model equation, we derive the prediction equation 1.

Table 1: Different mathematical models to aproximate the average emission spectrum of the framework and walls stage.

| Equation | $R^2$ |
|---|---|
| Linear | 0.918 |
| Logarithmic | 0.693 |
| Inverse | 0.172 |
| Quadratic | 0.931 |
| Cubic | 0.934 |
| Power | 0.639 |
| S | 0.149 |
| Exponential | 0.958 |

$$L_{eq} = 61.211 \cdot (e^{-3.39 \cdot 10^{-5} \cdot f}) \qquad (1)$$

With this equation we can get the spectral behaviour of the framework and walls stage depending on the frequency. We can see in the Fig.4 that the aproximation is very good, mainly at high frequencies.
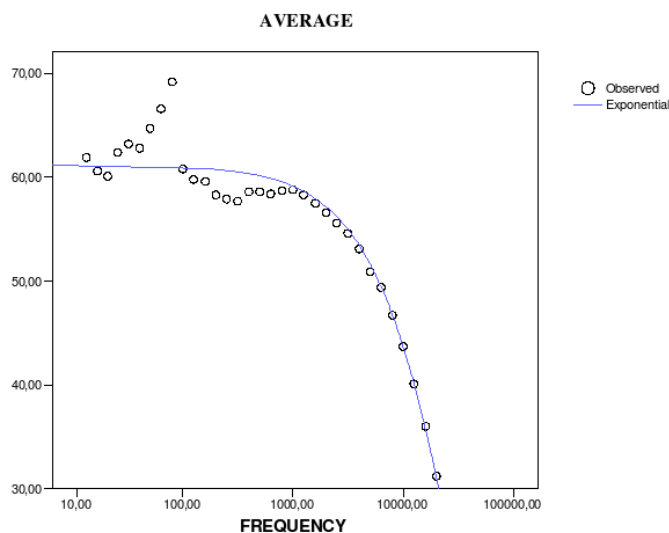


Figure 4: Aproximation of the exponential model to the average spectrum of the construction site

On the other hand, we carry out a percentile analysis, with which we obtain the values that we can observe in the Table 2.

We can state that the noise is mainly impulsive, because we obtain very high values in the lower percentiles (L1 and L10) and a high difference among the different percentiles, as we can observe in the sound climate (L10

- L90), which has an average value of 16 dB, showing then a bigger noise variability. We must emphasize the importance of this impulsive character due to the stress and the annoyance this kind of noise can cause in the people.

To finish with the research of the percentiles, we look for the percentile that is closer to LAeq, with the purpose of associating the numeric value of the energy with the statistic numeric value [10]. For this, we make a comparison among the different percentiles and we observe that the closer percentiles are L10 and L20. This is due to the fact that the noise is impulsive and produced at randomly intervals of time. This is showed in the Fig.5 for the third point.
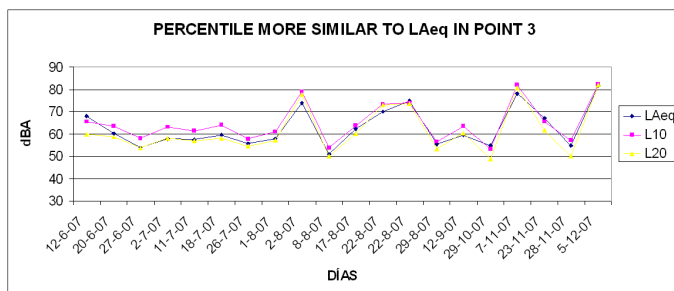


Figure 5: Percentile similar to LAeq for the third point.

The same happens for the others points, except for the concrete unload case, where the noise is more constant and the percentile that is closer is the L50; nevertheless, as it is a more constant noise, the difference between percentiles is very little, and because of this the L10 and L20 difference is very little.

The Table 3 shows the average and the standard deviation for the rest of the analyzed parameters.

If we observe the LCeq and LAeq difference, that is about 7 dB for the average, we can observe the big low frequency content. This stress the annoyance grade that is produced in the neighbours because the isolation of the building is worse at low frequencies. Due to that, the received level into the buildings nearby is higher. Moreover the low frequencies are propagated for a higher distance because the attenuation is less due to the air effect.

About the peak level in C weighting, it is about 100 dBC and then, it is whithin the limits allowed to the workers according to the Royal Decree 286/2006 [4, 5]; nevertheless, as the measurements have been done out of the construction site perimeter, about 3 meters away of it, we can state that the C peak levels could be very high for the workers and very high to the neighbours that live in the nearby places, although the Royal Decree 1513/2005 [1, 3] and its ampliation into the Royal Decree 1367/2007 [2, 3] do no establish limits in this aspect.

Regarding the LAeq and LCeq level, which are about 62 dB and 70 dB respectively, we can observe that the

LAeq is within the established limits by the Royal Decree 286/2006 [4, 5] for the workers case too. Nevertheless, the environmental contamination according to the Royal Decree [1, 2, 3] is stablished between 60 and 65 dB for the LAeq, in function of the zone where we are and, due to this, in this case, we would be at the top limit of the fulfilment of this regulation, though this standard is not aimed at this kind of activities.

# 5    Conclusion

In the framework and walls stage, having into account its behaviour as sound source, we can distinguish only the concrete unloads from the rest of the other jobs in this stage. The difference of the concrete unload is characterized by a constant emmission of noise with a flatter spectrum.

The rest of the jobs are characterized by impulsive noises at random, as show the percentile study and the fact of obtaining a percentile so low as the more similar to the equivalent level. In the study of the spectrum, we can emphasize that there exists a peak about 80 Hz and after it the spectrum decreases as the frequency increases.

On the other hand, the framework and walls stage is characterized by a high content at low frequencies and, because of this, the attenuation of the measurement level regarding the level the neighbours receive is very little because usually, the isolation in the buildings is lower at low frequencies. Moreover, this stage has a high sound climate that shows the variability of it

Taking into account that the emmited levels in this construction site are within the legal limits for the workers, and that in the case of the environmental pollution there is no specific regulation for this kind of activities, the annoyance associated to this kind of noise is very high due to its impulsive character.

Finally, we can state that the result obtained with the prediction equation is very good, as it is showed by the R squared value. Moreover, we can consider it as a representative mean spectrum of the stage because, practically all of days, we have very similar spectrums; and the same happens when we compare different measurement points.

Regarding the measurement procedure and the noise control during the construction process, we can state that every characteristic that define this kind of noise must be taken into account, as for instance its randomly character, the high low-frequency content. All of this depends on the stage of the construction process; and specifically in the case of the framework and walls stage there is a big penalty with the high impulsivity that the noise of this stage has.

# Acknowledgments

# References

[1] Real Decreto 1513/2005 de 16 de diciembre, por el que se desarrolla la Ley 37/2003, de 17 de noviembre, del Ruido, en lo referente a la evaluacion y gestion del ruido ambiental.

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Table 2: Average level and standard deviation of the sound climate and the percentile L1, L10, L90 for each one of the measurement points.

| | POINT 1 | | POINT 2 | | POINT 3 | | POINT 4 | |
|---|---|---|---|---|---|---|---|---|
| | AVERAGE | STANDARD DESVIATION | AVERAGE | STANDARD DESVIATION | AVERAGE | STANDARD DESVIATION | AVERAGE | STANDARD DESVIATION |
| L10-L90 (dBA) | 16,3 | 5,3 | 14,9 | 4,7 | 16,0 | 6,6 | 16,6 | 5,2 |
| L1 (dBA) | 73,6 | 3,4 | 75,5 | 3,2 | 73,1 | 7,2 | 70,7 | 5,8 |
| L10 (dBA) | 65,0 | 4,1 | 63,0 | 3,0 | 64,9 | 8,8 | 63,1 | 6,2 |
| L90 (dBA) | 48,7 | 3,7 | 48,2 | 4,9 | 49,0 | 11,9 | 46,5 | 6,6 |

Table 3: Average and standard deviation to the LAeq, LCeq, LpC and low frequency content to every measured days for each one of the four measurement points.

| | POINT 1 | | POINT 2 | | POINT 3 | | POINT 4 | |
|---|---|---|---|---|---|---|---|---|
| | AVERAGE | STANDARD DESVIATION | AVERAGE | STANDARD DESVIATION | AVERAGE | STANDARD DESVIATION | AVERAGE | STANDARD DESVIATION |
| LAeq (dBA) | 62,7 | 3,0 | 63,4 | 3,3 | 62,7 | 8,9 | 60,3 | 6,0 |
| LCeq (dBC) | 69,3 | 1,8 | 71,1 | 2,6 | 70,2 | 7,5 | 67,1 | 5,8 |
| LpC (dBC) | 99,9 | 4,0 | 100,6 | 7,6 | 99,8 | 7,0 | 98,4 | 7,4 |
| LCeq - LAeq (dB) | 6,6 | 2,4 | 7,7 | 1,9 | 7,5 | 2,8 | 6,8 | 3,4 |