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Influence of sample size on impact noise test results

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ABSTRACT

In order to determine the impact sound insulation of floors by the normalized method is required to carry out laboratory tests with samples of at least 10 m^2 since the impact sound is defined from the entire response composition of the vibration sampling system. However, the use of small size samples is permitted for comparative purposes and it offers operational advantages in relation to reducing sample handling time, latency time of test chambers and consumption of materials for sampling manufacture. The aim of this work was to evaluate the influence of sample reduction on impact noise in laboratory tests, with reduced dimensions of 16, 8, 4, 2 and 1 m^2, in the UNISINOS' (Brazil) standardized chambers. The results indicate that the use of small sized samples may present significant distortions in the results.

Keywords: Impact noise, Small sample, Laboratory test.
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1. INTRODUCTION

The analyses to assess the acoustic behavior to impact noise on floor systems are made on the basis of the normative methods of ISO 10140-3:2010 (1), which determines the necessary parameters to perform the acoustic tests, in normalized reverberation chambers and with samples with a minimum area of 10 m².

The fact that samples must have rather large area directly influences in the test costs and its execution time. The ideal would be having the samples with the same dimensions of the assessed, elements which wouldn't be feasible for the laboratory (2). It is commented that constructive elements with an area below 1 m² will have representative results using this test method (2).

The sound originated from impact noise derives from the sound energy transmission due to shock actions, such as objects falling and furniture being dragged to a certain point at a partitioning element in a building (3). Differently from airborne sounds, which are direct actions exciting the air, the impact noise is defined as the excitation that propagates through elastic waves in the whole element, converting it in a radiation source of sound energy in structural and non-structural elements which are linked to one another.

One of the relevant questions that are tied to the samples is its vibrational configuration which determines its impact noise behavior, being extremely important for the analysis of wave propagation in floor systems. Patrício (4) also comments that when the thickness of an element is small, compared to the wave length provoked by vibration, it is observed that the resulting movement is deflection, which is similar to the waves propagated in airborne sound. Hence, when the propagation is located at the limits of the elements, where there is deflection, it is verified that, depending on the reflection degree of the joints of the element to the structural system which is adjacent to it, the waves propagate directly in the partitioning element, generating, in this way, the resonance phenomenon.

Punctual sources at the corners are responsible for the majority of potential sound radiation (2). However, it is necessary to pay attention to the fact that this will be affected by any interaction among the corner sources when the samples are smaller than a certain wave length.

On the other hand, through the analysis of reduced samples, it was verified that the floating concrete floor propagates vibrations in all its surface, but the energy dissipation changes accordingly to the dimensions and may affect the value of the impact noise insulation (5). It is observed that the oscillations found in samples of smaller dimension are consequence of the vibration modulus of the samples directly, meaning that at smaller slabs more significant oscillations occur in higher frequencies (6).

Researches have been made in order to compare the acoustic performance to impact noise in constructive systems in samples of reduced size (7) (8). All the papers used the standard impact sound transmission results comparatively, in 1 m² samples. At Dikavičius et al (9) work it was also analyzed the influence of utilization of smaller samples, having different dimensions, although all of them presented superficial area below 1 m², which enabled the direct analysis of results found regarding its vibrational aspects and resonance of the elements evaluated.

The necessity to classify different constructive systems demands several tests of the civil construction productive chain to assess and classify its systems. However, it is observed, in several cases, that the standard sample to perform this test is excessively large, involving the use of many resources, being them financial and/or materialistic, besides the generation of a considerable amount of residues after the conclusion of the tests. This way, analyzing reduced size samples and observing its coherence is extremely relevant, in a way where it would enable companies with lower financial resources to assess their systems and adequate them to reach the performance required in standards, to improve the dweller's comfort.

Therefore, this study aims to evaluate the results obtained through laboratory tests regarding impact noise and verify the influence of area reduction in the samples, in order to determine the possibility of utilization of samples in reduced sizes.

2. METHODOLOGY

The performed study analyzed the influence of sample size to the weighed normalized impact sound pressure level ($L_{n,w}$) and the impact sound pressure level reduction (ΔL_w). The sample varied the superficial dimension of its cementitious flooring, being just one in accord to what proposes the ISO 10140-3:2010 (1), while the other samples possessed an area below 10 m^2, minimal normalized parameter.

In Figure 1 it is possible to identify the positioning of the samples during the tests execution inside the test chamber and consequently the area comprehended in each study element, being them 16, 8, 4, 2 and 1 m^2. These consisted of a leveling cementitious flooring composed by cement and sand coarse aggregate with nominal thickness of 5 cm.

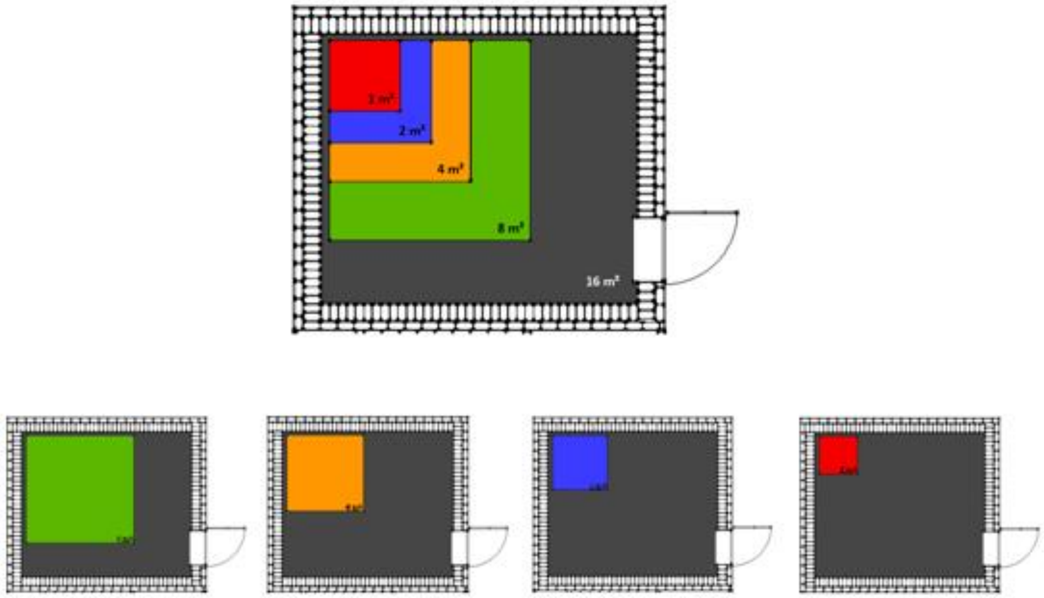


Figure 1: Positioning of the samples in the chamber.

The other elements that composed the test system were a 12 cm thick reinforced concrete and a 0,5 cm thick resilient elastic basis whose function was to damp shocks. As it is possible to verify in Figure 2, the samples previous the tests.

(a) 8 m^2 sample

(b) 4 m^2 sample

(c) 2 m² sample (d) 1 m² sample

Figure 2 – Reduced samples; (a) 8 m² surface; (b) 4 m² surface; (c) 2 m² surface; (d) 1 m² surface.

The impact noise tests were executed in laboratory through superposed chambers, following the standards of ISO 10140-5:2010 (10), being performed one test for each sample size. The test preparation for one of the analyzed samples is demonstrated in Figure 3.

Figure 3 – Preparation to perform the test in the 1 m² sample.

The necessary equipment to determine the sound pressure level, including cables and microphones is indicated in ISO 10140-4:2010 (11), having to comply the Class 1 exigencies according to IEC 61672-1 and the filters Class 0 or 1 according to IEC 61260. The calibration device must comply the Class 1 exigencies according to IEC 60942. The equipment used were from B&K brand and are indicated in Table 1.

Table 1 – Equipment used for the measurement

Equipment	Model
Sound & Vibration analyzer	2270
Microphone	4189
Calibrator	4231
Tapping Machine	3207
Sound Source	4292-L
Hygrothermograph	ITMP-600

3. RESULTS

With the values obtained for each one of the frequency bands analyzed, the comparison of the generated curve with the standard curve is made, resulting in the weighed normalized impact sound pressure level ($L_{n,w}$), where these levels represent a unique value that characterizes the sample system as a whole. The ΔL_w is the weighed normalized impact sound level for the leveled slab and the flooring system, which is used to characterized to evaluate improvements regarding the construction of the layer above the concrete slab regarding impact sound insulation.

At the present paper it was possible to identify that the sample with a smaller dimension obtained a close performance when compared to the largest sample, diverging only for the average samples of 8 and 4 m², as it can be analyzed in Figure 4.

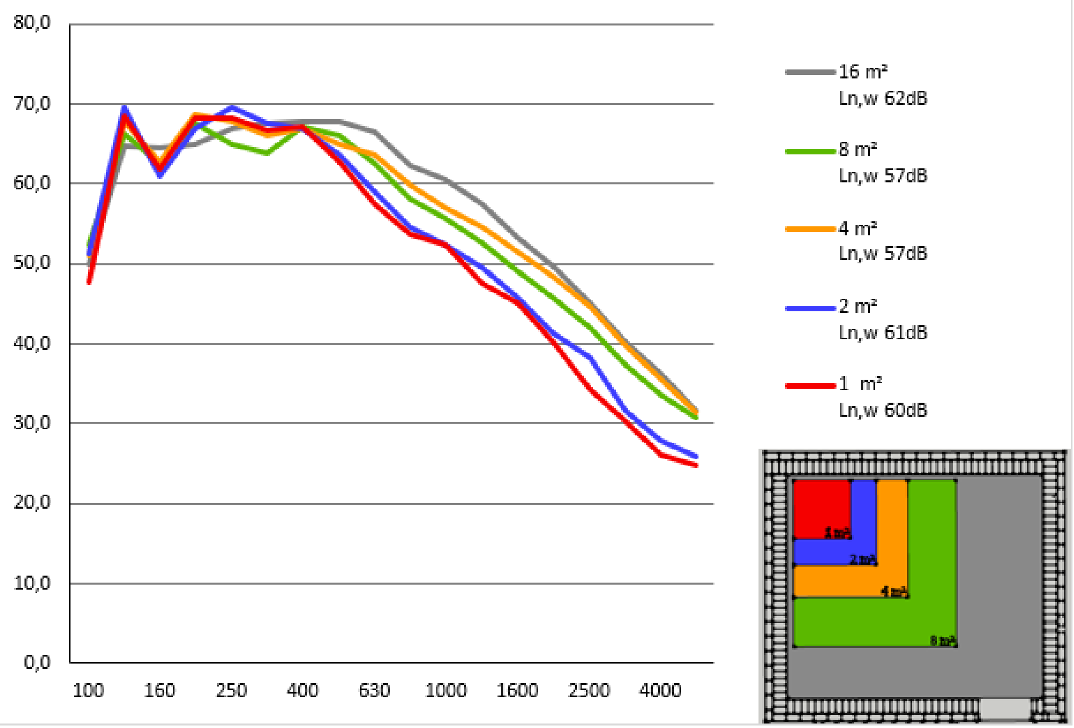


Figure 4 – Obtained results.

The results of impact sound pressure level (*ΔL_w*) are in Figure 5.

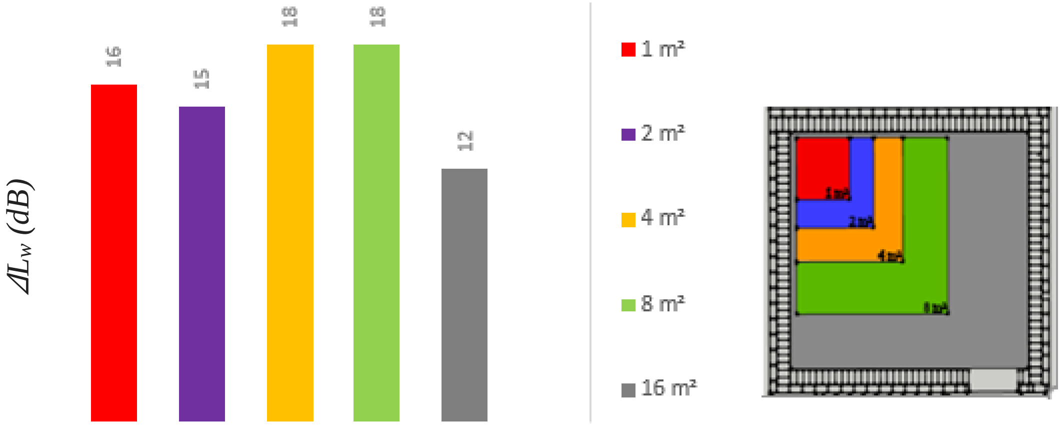


Figure 5 – Analysis of the reduction of the impact sound pressure level (ΔL_w).

The results seen in Figure 4 may be explained by the characteristics of the samples and its positioning, once the impact noise is the transmission of sound energy due to shock actions in a certain point of a partition element (4). In this manner, the concentration of the samples on the sides of the chamber made that the dissipation of sound energy decreased significantly in the smaller samples, focusing all the energy in the spot and consequently reducing its performance. Differently, the samples with an average area, from 4 to 8 m^2, displayed a better performance, once there is a significant area to dissipate the sound energy, before reaching the solid media and the linking elements which transmit the noise to the lower room, as identified by Miškinis *et al* (5) in their study.

The results found in this study go towards Miškinis et al (5), which found better weighed normalized impact sound pressure level ($L_{nt,w}$) for the reduced samples, obtaining a difference of 43 dB in relation to bigger samples of 13,4 m^2 and its smaller sample of 0,5 m^2. Miškinis *et al* (5) also made the analysis of the reduction of the impact sound pressure level (ΔL_w), which presented a variation of 11 dB when comparing the biggest and the smallest sample. This may be explained due to the phenomenon of resonance found in sample plates of smaller dimensions, once the vibration fields generated in small samples, lower than 2 m^2, presumably are different from those with larger dimensions, in this case, larger than 10 m^2. Miškinis *et al* (5) elaborated an equation to perform the correction among the results of the reduction of the impact sound pressure level (ΔL_w) found in reduced samples, enabling values closer to the values of samples with larger dimensions, where this equation takes into consideration aspects as sample area and pre-defined coefficients to correct the impact sound pressure level. On the studies of Dikavičius et al (9) it is possible to identify that the use of this equation enables to eliminate the resonance found in smaller samples, reaching closely the real value of the reduction of the impact sound pressure level (ΔL_w) found in samples with an area superior to 10 m^2.

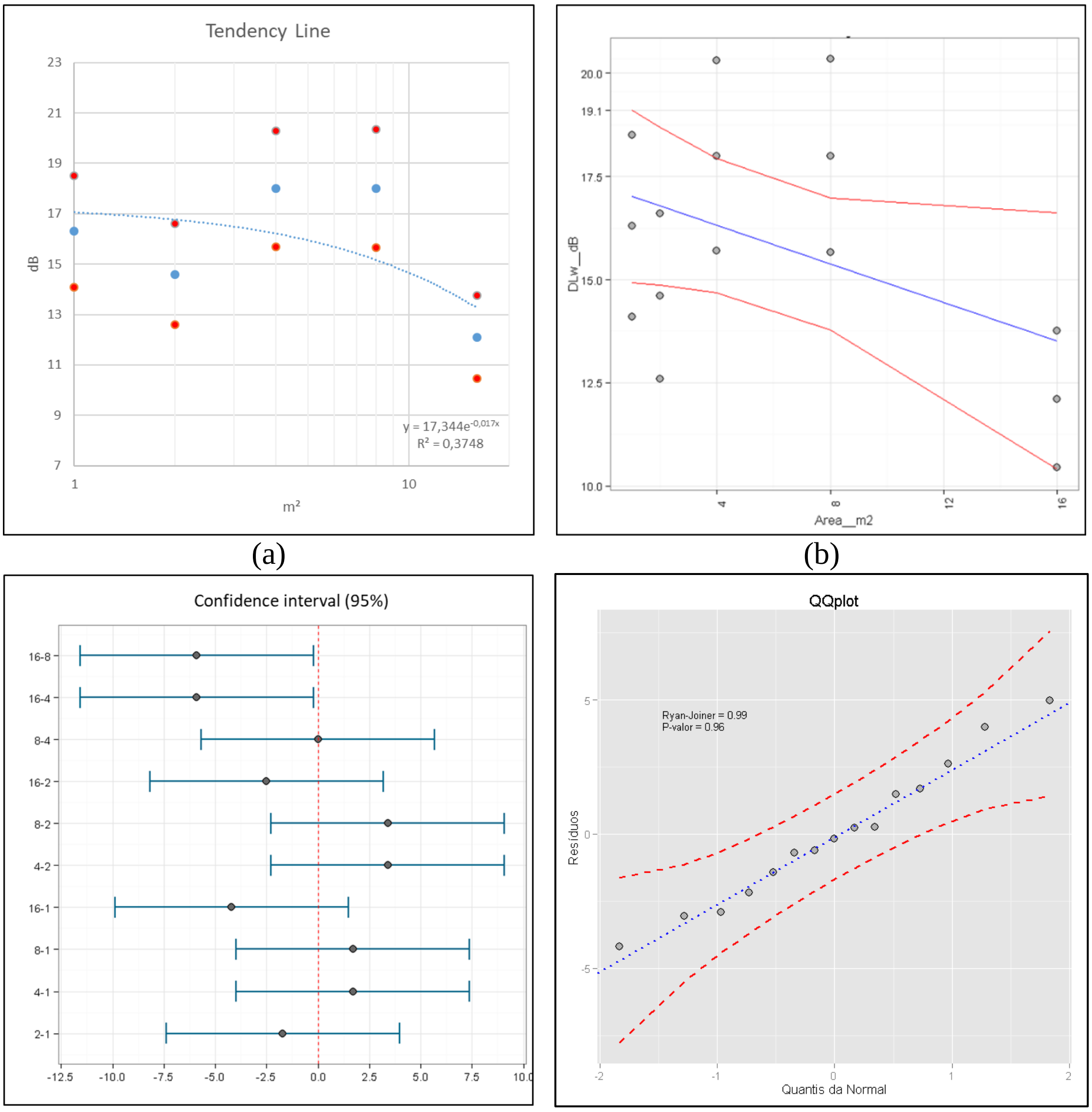
Dikavičius et al (9) verified the influence of 5 samples with very similar areas, approximately 0,5 m^2, however, geometrical typologies of the analyzed plates were different and the results obtained showed a variation of 3 dB to the weighed normalized impact sound pressure level ($L_{n,w}$). Another relevant aspect corresponds to the different sample dimensions which presented an enormous performance variation in different frequency bands, where much of it is due to the resonance phenomenon of each sample, which has a direct influence on the vibrational transmission of the plate.

This way, it is possible to identify that the best performances are found in samples with average dimensions (4 and 8 m^2), following the pattern seen in the weighed normalized impact sound pressure level.

The fold factor of the sample area was used, taking advantage of the acoustic chamber geometry, where the largest area used (16 m^2) corresponds to the total partition area of the chamber. This sample yielded the lowest value of ΔL_w, being far from the sample with half of that area. However, considering the uncertainty in measurement of around 2 dB, its performance is closer to the samples with area values of 2 m^2.

When verifying the values considering the uncertainty in measurements, it is noticed that there is a dim relation between them, when verified with a tendency line (Figure 6a). The exponential tendency returned a residue of 0.37. Considering that the closer to one is the residue, the closer the tendency will be to the actual values.

By verifying the interpolation of the values through the analysis of variance (ANOVA), all values are within a confidence interval (Figure 6b). In this situation, the sample value of 8 m^2 presents the shortest interval, being the absolute value outside the confidence interval with a residue of 2.62, a very high value to this situation when compared to the other values, which means that this value is outside the linear regression presented by the ANOVA.



(a) (b)

(c) (d)

Figure 6 – Statistical analysis of values considering the uncertainty in measurement (a) tendency line, (b) linear regression (c) sample families from Tukey test, and (d) quartile-quartile plot.

The Tukey test is used to verify if the groups of values of the same sample make up the same sample family, using the confidence interval for a 5% error. When is verified the graphical presentation of this test, shown in Figure 6c, the samples belong to two different families. The test in the sample of 4 and 8 m² belongs to family "*a*", and the test of the sample of 16 m² belongs to family "*b*". That is, these values are not related to each other, being out of reach of uncertainty, when relating.

On the other hand, the tests with samples of 1 and 2 m² belong to the "*ab*" family, being considered statistically related to others for a probability of 95%.

Finally, considering the quartile-quartile plot (Figure 6d), two probability distributions are compared, where quartiles are superimposed over each other in relation to a distribution. The closer to the tendency line (dashed in blue) are the values, the greater the ratio they have to each other. In this case the distribution was very close to the tendency, which is mainly due to the fact that the results have very similar measurement uncertainty (around 2 dB), leaving quartile values very close.

4. CONCLUSION

Taking into consideration the presented aspects, it is possible to analyze and identify discrepancies on the results obtained when comparing the samples in reduced scale to the standard sample, once the difference among them was relevant when analyzed the weighed sound pressure level, being this 5 dB. For the difference of weighed normalized impact sound pressure level, the difference was more relevant, reaching 6 dB.

Thus, it is perceived that the usage of samples in a reduced scale, while not normalized, is valid to identify possible solutions in a smaller time and cost, being of great value to improve the development of the acoustic performance of the buildings.

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