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Influence of low frequency bands on airborne and impact sound insulation single numbers for typical Portuguese buildings

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ABSTRACT

This paper presents an analysis of in situ measurements for airborne and impact sound insulation performed in typical buildings in Portugal. The direct partition element separating rooms consists of different types of walls or floors. The buildings have concrete frame structures and the partitions are, in the main, heavy walls or floors. A number of group of lightweight walls were studied.

The next revision of ISO 717 provides for the inclusion of low frequency bands in the calculation of the sound insulation descriptors and so the aim of this work is to ascertain the influence of the low frequency band measurements on the descriptor results for typical buildings in Portugal. The descriptors (single numbers) for airborne sound insulation $D_{nT,w}$, $D_{nT,w} + C$, $D_{nT,w} + C_{50-5000}$, $D_{nT,w} + C_{tr}$ and $D_{nT,w} + C_{tr,50-5000}$ were calculated and analysed. The impact sound insulation descriptors calculated and studied are $L'_{nT,w}$, $L'_{nT,w} + C_I$ and $L'_{nT,w} + C_{I,50-2500}$. Additional calculations were performed to determine the uncertainty of the descriptors analysed.

The airborne sound insulation tests were performed according to NP EN ISO 140-4 in one-third octave bands from 50 Hz to 5000 Hz. The impact sound insulation tests followed the procedure set out in NP EN ISO 140-7 with measurements in one-third octave bands from 50 Hz to 5000 Hz.

1. Introduction

Comfort in buildings is related to parameters such as lighting, thermal conditions, air quality, ergonomics, and acoustics. The adverse effects of noise on people, whether neighbourhood noise or environmental noise, are well known [1,2]. Requirements for the acoustic performance of buildings increased gradually during the last century and at the beginning of this one. Current national building codes state requirements for environmental noise, impact and airborne noise, reverberation time for some uses of the interior space, and noise from technical equipment in buildings. In 2010, Rasmussen published a study [3] where the main requirements for airborne and impact sound insulation in 24 countries in Europe were described and discussed. It was found that in several countries the legal sound insulation requirements for new buildings do not seem to provide satisfactory privacy and protection against neighbour noise.

Compliance with the minimum legal requirements is not synonymous with acoustic comfort to the satisfaction of occupants.

In [3] the author found that, in addition to the differences observed in the levels of legal requirements, the descriptors used and the frequency range applied differ from country to country. Rasmussen and Rindel [4] discussed the suitability of various descriptors and suggested harmonizing the airborne and impact sound insulation descriptors in building regulations. COST Action TU0901 "Integrating and Harmonizing Sound Insulation Aspects in Sustainable Urban Housing Constructions" contained a proposal for harmonizing sound descriptors in Europe [5].

The variety of descriptors and spectrum adaptation terms with different frequency ranges are allowed by the current version of ISO 717 [6]. The frequency range for requirements in building acoustics in Europe has traditionally been 100–3150 Hz in 1/3 octave bands. However, some countries with a tradition in lightweight buildings recognized that low frequencies have to be taken into account to characterize acoustic performance. Several studies [7–10] have set out to understand the effect of the low frequency content on neighbour noise and to assess the correlation between subjective and objective evaluation of sound insulation. Rasmussen [3] and Rasmussen and co-author [4] suggested that the descriptors should especially take low frequencies into account for impact sound insulation.

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Scholl et al. [11,12] presented a proposal for the revision of ISO 717 whereby the frequency range for the calculation of single number ratings would be changed. New single-number quantities called $R_{traffic}$, R_{living}, R_{speech} and R_{impact} are proposed. The calculations use four reference spectra that describe traffic, living, speech and impact sounds. The single values are obtained using a unique equation for each single quantity. This is a similar procedure to that used in standard EN 1793-2 [13] and does not involve the reference curve fitting technique to obtain the weighted sound indexes.

R_{living} and $R_{traffic}$ are obtained using the sound reduction index measured in the 1/3 octave bands from 50 Hz to 5000 Hz while R_{speech} only includes the 1/3 octave bands from 200 Hz to 5000 Hz as proposed by Park et al. [14]. $R_{traffic}$ and R_{living} would be equivalent to the $R_w + C_{tr,50\text{–}5000}$ and $R_w + C_{50\text{–}5000}$, while R_{speech} has no actual corresponding expression. The sound reduction indexes in situ, normalized to standard absorption areas or reverberation times in the receiving room, would be $D_{n,living}$ or $D_{T,living}$, and so forth. R_{impact} has a different meaning from the current $L_{n,w}$ since it is proposed to move from the impact sound pressure level to an impact sound reduction index. R_{impact} can be related to the former single number by $R_{impact} = 104 - L_{n,w} + C_{I,50\text{–}2500}$.

This method makes the calculation of single number quantities simpler and separate spectrum adaptation terms are no longer needed. Nevertheless, most countries do not use adaptation terms in their acoustic requirements so the building regulations will need to be revised to adapt the requirements to the performance yielded by the new quantities.

One issue that Scholl et al. [11] discussed is related to uncertainty. Although the large uncertainty at frequency bands from 50 to 80 Hz that may will propagate into the single number quantity they may be reduced by the application of special sampling techniques [15]. Mahn and Pearse [16] subsequently studied the effect on uncertainty of expanding the frequency range included in the calculation of the single number ratings, using laboratory measurements of 200 lightweight walls as data. The calculations were performed for R_{living}, $R_{traffic}$ and R_{speech}. They found that the uncertainty of the single number ratings is highly dependent on the shape of the sound reduction index curve. The uncertainty obtained for the new single number rating R_{living} was greater than that of the traditional weighted sound reduction index for 98% of the 200 lightweight building elements included in the evaluation.

Hongisto et al. [17] investigated the reproducibility value of the proposed single number quantities $R_{traffic}$ and R_{living} to see if it is larger than the reproducibility value of the present single number quantities, based on a round robin test carried out with a window specimen using the sound pressure method. They further examined the difference in reproducibility when measuring the sound reduction index with the sound intensity method below 200 Hz. The authors demonstrated that the reproducibility values of the proposed single number quantities (50–5000 Hz; R_{living}, $R_{traffic}$) are larger than those of the present single number quantities for measurements using the pressure method. The reproducibility increased very little when the sound intensity method was used.

Similar conclusions have been drawn by Scrosati et al. [18] based on an on-site round robin test on a lightweight wall and a heavy floor for measuring airborne sound insulation. The authors are of the opinion that the calculation of single number quantities for low frequencies includes a measurement uncertainty that is too high to justify the decision to perform field measurements down to low frequencies. Additionally, they observe that the scientific evidence for including the low frequencies should be significantly improved.

Concerns about the practical application of the new single number quantities are aired in [16] and [17]. One concern is that changing the legal requirements for sound insulation in national building codes can be a lengthy process and it will take time for manufacturers to retest their products, therefore ISO 717-1 and the new standard may in fact co-exist for many years [16]. Thus, they recommend that the proposed new standard should include an additional single number rating calculated over the traditional frequency range of 100 Hz to 3150 Hz so that countries worried about the increased uncertainty of the single number ratings can adopt the new standard.

Hongisto et al. [17] note that if the reproducibility value of the single number quantities grows, the manufacturers have to increase the tolerance declared for the single number quantities of their products, which will result in an increase in the cost of building components in the long term since their performance must be improved in line with the increase in the safety margin. Although the anticipated benefit of adding the 50–80 Hz bands to the calculation of the proposed single number quantities is a better correlation between the subjective rating of sound insulation and those quantities, Hongisto et al. [17] note that the reason for the airborne sounds below 100 Hz being the main cause for neighbour noise complaints has not been adequately shown scientifically. They also referenced the work of Mortensen [7] to point out that despite experiments indicating that noise from neighbours transmitted through light constructions is rated more annoying than noise transmitted through heavy constructions (because there is more low frequency content transmitted through light constructions) the negative ratings were unacceptably high for both lightweight and heavy structures, so it was not proved that there is a significant perceived difference between light and heavy structures. It is also reported that the standardized living noise spectrum does not properly represent living sounds inside dwellings since these are mostly dominated by middle and high frequencies and the low frequency content is less than the standardized living noise spectrum [19,20].

In Portugal, as in other European countries, the acoustic requirements set out in the Building Acoustics Code [21] are expressed by $D_{nT,w}$ for airborne sound insulation between rooms and $L'_{nT,w}$ for impact sound pressure level. The inclusion of spectrum adaptation terms to calculate single number quantities and also the extended frequency range (from 50 to 5000 Hz) will imply the change of the legal limits of the regulations. Buildings and walls are mainly heavy structures and various authors say that the low frequency adaptation terms are more important in lightweight constructions than in heavy ones. In this work we assess the influence of including low frequency bands on the sound insulation single number quantities based on an extensive set of in situ measurements. The calculated descriptors (single number quantities) for airborne sound insulation are $D_{nT,w}$, $D_{nT,w} + C$, $D_{nT,w} + C_{50\text{–}5000}$, $D_{nT,w} + C_{tr}$ and $D_{nT,w} + C_{tr,50\text{–}5000}$. The descriptors calculated for impact sound insulation are $L'_{nT,w}$, $L'_{nT,w} + C_I$ and $L'_{nT,w} + C_{I,50\text{–}2500}$. The uncertainty associated with the descriptors that include the adaptation terms ($D_{nT,w} + C$, $D_{nT,w} + C_{50\text{–}5000}$, $D_{nT,w} + C_{tr}$, $L'_{nT,w} + C_I$ and $L'_{nT,w} + C_{I,50\text{–}2500}$) is also calculated. Uncertainty was calculated using the standard deviation of spatial measurements.

We next describe the method used for the sound insulation measurements and the calculation of uncertainty. The results are presented and discussed in Section 3.

2. Methodology

2.1. Measurement data

This study uses measurements recorded in the last two years in sound insulation tests performed in situ to ascertain acoustic requirements in Portugal. Although most of the tests were performed in dwellings some results are from service buildings. The data comprise results from airborne sound insulation (where the