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Rating low levels of ambient noise in performing arts facilities

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ABSTRACT

Previous studies have indicated that common indoor noise rating metrics, such as Noise Criteria NC and Room Criteria RC, do not best correlate to human perceptions of annoyance and distraction in typical office environments. Based on investigations conducted at the University of Nebraska using noise levels between 30 – 60 dBA, the author has proposed that an effective indoor noise rating method should begin with a rating of level (either dBA or sones), then an assessment of spectral quality, tones, and fluctuations. How well would such a system work at very low levels of ambient noise, though, as found in performing arts facilities? This paper compares and discusses the performance of assorted indoor noise rating metrics, calculated from background noise level data measured in existing performing arts facilities.

1 INTRODUCTION

A number of indoor noise rating metrics have been proposed in the last sixty years to quantify the background noise in a built environment, including Noise Criteria (NC)[1], Balanced Noise Criteria (NCB)[2], Room Criteria (RC)[3], Room Criteria Mark II (RC Mark II)[4], A-weighted Equivalent Sound Pressure Level (LAeq)[5], and others. An on-going debate has existed among ASHRAE members in particular as to which rating system to use for the various types of background noise situations encountered. The 2011 ASHRAE HVAC Applications Handbook[6] lists NC, RC and RC Mark II, while ANSI S12.2-2008[7] recommends the use of Room Noise Criteria (RNC), and the ANSI S12.60-2010[8] standard on classroom acoustics sets background noise criteria in LAeq.

Studies conducted at the University of Nebraska sought to explore this issue by gathering human performance and perception data under a number of assorted background noise conditions commonly found in office environments, some which had discrete tonal components or time-fluctuating components.[9-11] The general range of noise levels extended from 30 to 60 dBA. The conclusion drawn from those studies is that an 'ideal' methodology for rating indoor noise should do well in assessing (1) loudness first and foremost, then secondarily (2) rumble, and the presence of (3) time-varying fluctuations and (4) tones. This research has found that, while all the indoor noise rating metrics tested differentiate well between obvious sound level differences, the most sensitive ratings of level are provided by the A-weighted equivalent sound level (LAeq) or a sones rating[12]. Consequently, an 'ideal' criteria should start with such a value.

Then spectral characteristics are next in importance, particularly that of excessive low frequency rumble when the level of the noise signal is greater than 50 dBA. As a 'survey' method of low frequency content, LCeq – LAeq would be suitable, as these values are easily gathered from sound level meters at the same time as an A-weighted equivalent sound pressure level. Signals whose measured LAeq is greater than 50 dBA and whose measured LCeq – LAeq value is greater than 20 dB are of great concern, but lower level signals with large low frequency fluctuation were not found to be as annoying. As for detection of tones, Annex A of ANSI S1.13[13] states that the prominence ratios for tones at lower frequency ranges (under 1000 Hz) are in the 9 to 18 dB range. However, further research is recommended towards defining more specific levels of tonalness metrics to ensure that they correlate with annoyance perception (rather than prominence alone).

How well would such a proposed noise rating system perform at lower noise levels, as commonly found in performing arts spaces? Annex E of ANSI S12.2-2008[7] presents suggested one-third octave band sound pressure levels for recording studios and other low-noise environments that are essentially derived from the human threshold of audibility, but many performing arts facilities may not achieve levels as low as audibility thresholds. Annex C of the same standard[7] suggests NC-15 to NC-25 or 30-35 dBA for larger performing arts spaces. In this paper, a comparison is first made of some of the more popular noise rating methods at low levels above the threshold of audibility. Then case studies are presented from existing low level spaces to gain further understanding as to how these noise rating metrics compare.

2 COMPARISON OF CRITERIA AT LOW LEVELS

In this section, values of the three most commonly used indoor noise rating metrics in the United States are compared at low levels: NC, RC, and dBA. The octave band values of the NC curves and the RC lines, both from NC/RC-15 to NC/RC-40, were converted to dBA values, as displayed in Figure 1.

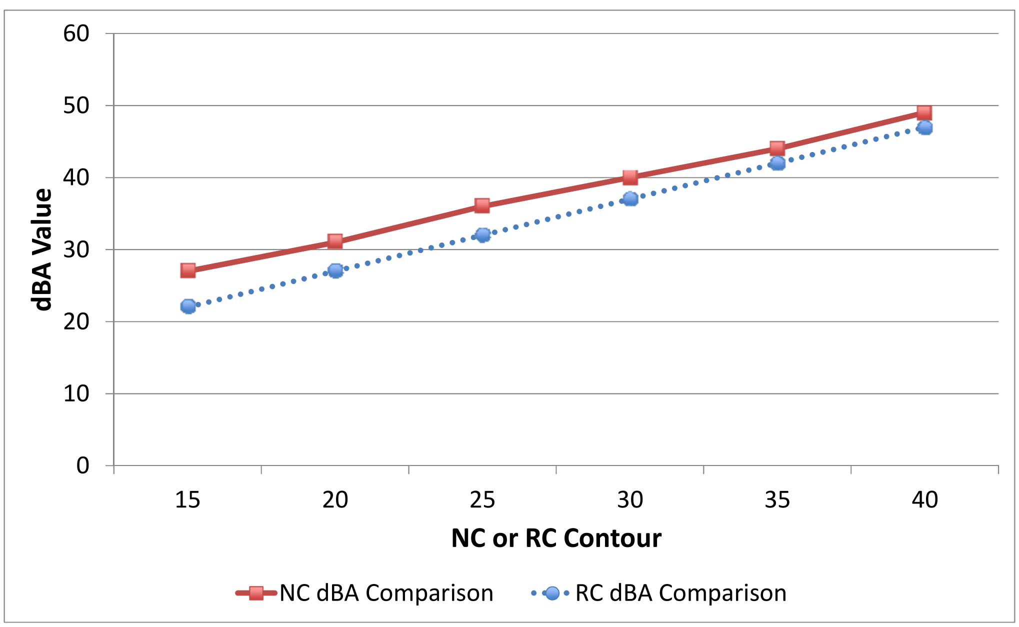

Figure 1: Comparison of NC and RC contours to equivalent dBA values

The NC contours generally produce an overall dBA value that is 9-12 points greater. Because the NC curves do not uniformly vary in shape as they increase in value, the A-weighted values also deviate slightly from having a perfect linear relationship with NC ratings. The RC contours (taken as neutral in this analysis) are straight lines with a -5 dB slope across octave bands, though, so that the dBA value is found to always be 7 dB above the corresponding RC line.

From this comparison, it appears that NC 15-25 generally corresponds to 27-36 dBA, while RC 15-25 corresponds to 22-32 dBA. At these low noise levels, then, NC and RC guidelines should not be used interchangably or equivalently, as they can relate to significantly different dBA values.

3 CASE STUDIES

While the previous section comparing NC and RC contours to corresponding dBA values is helpful in understanding how these metrics relate to each other, more insight may be gathered from comparing these metrics from actual background noise level data measured in existing performing arts spaces. The authors are still in the process of collecting and analyzing data from existing spaces. An example is presented below, using background noise level data gathered from Strauss Performing Arts Center on the University of Nebraska at Omaha campus.

Figure 2 plots the measured background noise levels in octave bands. The associated NC, RC, and dBA ratings are listed in Table 1.

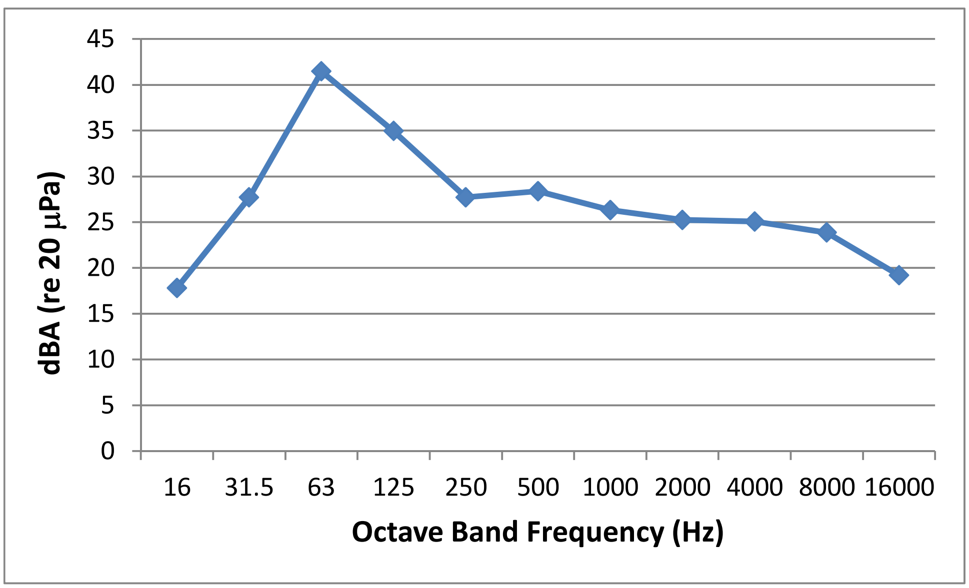

Figure 2: Background noise level spectrum for Strauss Performing Arts Center

Table 1: Associated indoor noise ratings for Strauss Performing Arts Center

NC	RC	dBA
41	27(RH)	43

For this space, all three rating methods do indicate an issue with the acceptability of the background noise. The spectrum shows the background noise level at 63 Hz as being particularly high, which pushes the NC and dBA value to be in the 40s. The relatively low sound levels from 500 Hz to 2 kHz octave bands produce the lower RC rating of 27, but the spectral quality indicators in RC highlight that there are spectral issues, at both the low and high frequencies. In this case study, then, all three metrics do clearly indicate an unacceptable noise condition; however, for diagnosis purposes, the RC rating does give a clearer indication that the problem generally exists due to spectral imbalance, rather than an overall level problem.

Similar comparisons for a number of other existing performing arts spaces will be presented at ISRA 2013, and further summaries and conclusions drawn.

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