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Acoustic Comfort in Libraries

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Abstract [144] There is a wide range of acoustical quality among library spaces. The general public may assume that a good library is a "quiet" library, when in fact objectively low background sound levels in open library spaces often lead to subjectively uncomfortable acoustics. To better define the issues, it is useful to identify objective acoustic measures that correlate with students' and administrators' subjective responses to libraries. Based on the results of surveys conducted by consultants at Acentech Incorporated, the author proposes that a "comfortable acoustic environment" in a library is an environment that provides freedom from distraction; that is, casual conversation and other noises in the library do not distract users reading or studying in the library. "Freedom from distraction" can be quantified and measured in terms of Articulation Index (AI) or other metrics based on signal-to-noise ratio. In highly reverberant library spaces, Speech Transmission Index (STI) may be more correlative to subjective impression of acoustic comfort. In order to provide a comfortable environment acoustically, a library must have 1) appropriate levels of background sound, 2) a physical barrier between noise-producing and noise-sensitive sections, and 3) sufficient sound absorbing material in the space. Measured quantitative metrics support these conclusions. A preliminary version of this paper was presented at the 146th meeting of the Acoustical Society of America in Austin, Texas.

1 INTRODUCTION: THE IMPORTANCE OF GOOD LIBRARY ACOUSTICS

More than mere collections of books and scholarly periodicals, libraries play an important role in cities and towns, colleges and universities, grade schools and large corporations. The author Shelby Foote wrote that a "university is nothing but a group of buildings around a library." Libraries function as work spaces, study spaces, and meeting spaces. With a rising demand for inexpensive and public access to Internet and multimedia services, libraries are as popular now as they ever were. With so many varied services in the modern library, the need for acoustic comfort is paramount, even as libraries become populated not just with people but with noisy machinery (printers, copiers, and beeping bar-code scanners to name a few).

Library designers and architects have long recognized the need for large open spaces where patrons can spread out, read, study, or simply relax. Sometimes these open spaces are integrated into the library book stacks, other times the stacks are separate. Often, libraries also feature closed rooms for private study or group meetings, or classrooms with multimedia presentation capabilities. Specialized rooms for viewing films or listening to audio recordings are also sometimes part of a library master plan. Each of these spaces has unique requirements necessary to promote acoustic

comfort. Classroom acoustics and associated topics have played a major part in acoustics-related literature recently; this paper concentrates on the acoustics of open study areas in libraries.

In addition to the library user spaces that are noted above, libraries usually have areas designated for administrative uses and for user support (e.g. reference desks, circulation desks, copy rooms, computer clusters, and other similar areas). These areas are easily identifiable as noise-producing sections of the library, and can have a detrimental effect on general acoustic comfort, particularly when located in or near open study areas in libraries.

Acoustic comfort is necessary for a library to succeed. What makes a library acoustically comfortable? How can a subjective impression such as "acoustic comfort" be properly quantified? What features are necessary in library building design to promote acoustic comfort?

2 SUBJECTIVE IMPRESSIONS OF LIBRARY ACOUSTICS

In connection with a library design project at Princeton University, consultants at Acentech Incorporated informally surveyed 35 students, professors, and librarians at the University [1]. Each individual was asked to list his or her "most preferred" library area on campus in which to work or study. When asked to list a reason for their preference, the most common answer among those surveyed was that the library space was "quiet".

Following this survey, Acentech consultants took background noise measurements in each of the "most preferred" libraries on campus, and found that the subjectively "quiet" libraries tended to have objectively high background noise levels when compared with other libraries on campus. Figure one compares the average background noise levels of "favored" libraries to the average background noise levels of more objectively quiet libraries on campus. Seventeen library spaces were measured in all. For reference, a common sound masking spectrum for open-plan office space acoustics is also plotted.

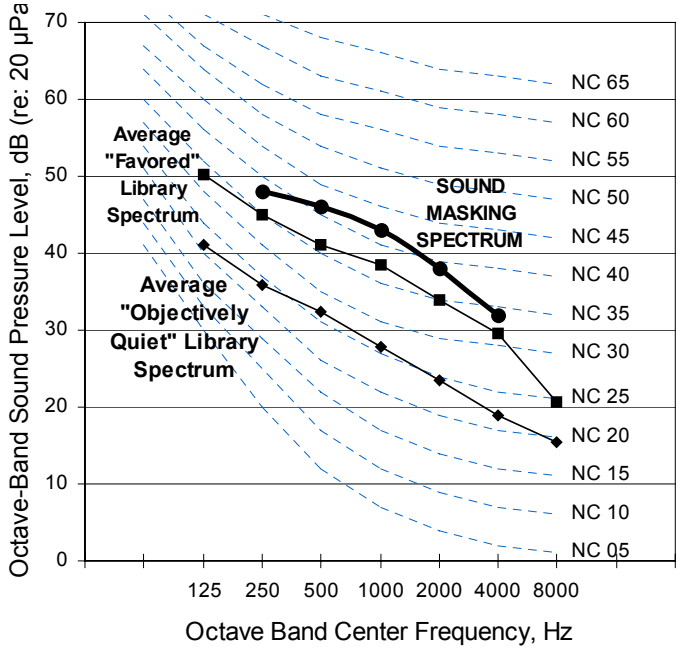

Figure 1. *Average background noise levels of libraries at Princeton University, measured in March 2003.*

Clearly, the subjective impression of acoustic comfort that library users at Princeton described as "quiet" does not correlate to objective measures of background noise levels [1]. Based on the aforementioned survey at Princeton and other similar project experience, the author proposes that a "comfortable acoustic environment" in libraries is an environment that provides freedom from distraction.

3 QUANTIFYING LIBRARY ACOUSTICS

Measurement of background noise level alone is insufficient to characterize the acoustic comfort of a library space properly. In order to understand library acoustics fully, there must be a measurable objective metric that corresponds to subjective impression of acoustic comfort.

3.1 Articulation Index and Freedom from Distraction

A half-century of research related to open plan office acoustics suggests that Articulation Index (AI) and other similar metrics that are based on a signal-to-noise ratio effectively quantify distraction from speech. A variety of specific frequency-based weighting functions have been debated, but each of these metrics give an indication of distraction from speech signals. Articulation Index is a function of the signal-to-noise ratio, the geometric relationship between the source sound and the receiver, and room finishes.

In libraries, speech is only one of a number of potential distracters, which also include machinery noise (e.g. from copy machines, printers, and other equipment), noise generated from circulation through the library, and other noise. Empirical evidence from a variety of projects at Acentech suggests that an Articulation Index rating of 0.20 or less corresponds to relative "freedom from distraction".

3.2 Modeled Results of Library Articulation Index

Each of the seventeen libraries that Acentech consultants evaluated as part of the aforementioned survey were modeled using proprietary software called *OPLAN,* developed by Acentech staff. Originally designed to evaluate open-plan office acoustics, *OPLAN* is a type of Articulation Index calculator that uses user-defined room geometry, room finishes, and a variety of measured data (source level, received level, and ambient levels) to predict the Articulation Index of a given location.

Each of the libraries listed as "most preferred" in the survey of library users at Princeton has an average Articulation Index of less than 0.20. Some isolated cases had extremely low AIs, as low as 0.03. By contrast, the relatively quiet (and generally disliked) libraries at Princeton that contributed to the Average "Objectively Quiet" Spectrum shown in Figure one have consistently higher Articulation Index values – as high as 0.84.

Empirical user-response on a variety of library projects confirms these initial findings: Articulation Index values of 0.20 or less tend to correspond to subjective acoustic comfort in libraries, while library spaces with Articulation Index values greater than 0.20 may be problematic acoustically.

Project experience suggest that in highly reverberant library spaces, a metric that accounts for reverberation time in addition to signal-to-noise ratio such as the Speech Transmission Index [2]

may correlate to subjective impression better than Articulation Index does. Further research is required to validate this hypothesis.

4 DESIGN SOLUTIONS

In order to provide a comfortable environment acoustically, a library must have 1) an appropriate background noise level, 2) a physical barrier between noise-producing and noise-sensitive sections, and 3) sufficient sound absorbing material distributed in the space. These design solutions follow directly from the Articulation Index measurement results: by adhering to these three design solutions, a library space will have an acceptably low Articulation Index.

4.1 Background Noise Level in Libraries

Background sound is necessary to mask unwanted and potentially distracting speech and other noises in an open-plan environment. The background noise should have level and spectral characteristics that are sympathetic to its sound masking function: the background noise itself should not be a distraction. If the background sound has too much low-frequency energy ("rumble"), too much high-frequency energy ("hiss"), or is too loud overall, the background sound itself could be a source of distraction.

Similarly, the background sound can become the source of distraction if it is dominated by an irregular or cyclical HVAC system that abruptly alters the noise level. HVAC systems can also be distracting if they are spatially non-uniform, since users will be able to easily localize on the sound source.

The background noise level in open study spaces of libraries is ideally strong in the speech frequencies and relatively weak in frequencies above and below the most common speech frequencies. The "Sound Masking Spectrum" plotted on Figure one was developed by staff at BBN Technologies as an appropriate background noise level for sound masking in open-plan office environments. A similar spectrum might be appropriate in open study areas of libraries. An ideal background sound is also uniform in level and spectrum, both spatially and temporally.

4.2 Geometric Arrangement and Space Planning in Libraries

The introduction to this paper identifies several known noise-producing elements in libraries. Among these are circulation and reference desks, noisy copiers or printers, corridors and other circulation paths. A physical barrier between these known noise-producing areas and known noise-sensitive areas such as open study areas can be effective in decreasing the Articulation Index and thereby increasing acoustic comfort. The most common barrier in library settings comes naturally, with the judicial use of backed library book stacks or shelving.

4.3 Room Finishes and Materials in Libraries

An acoustically comfortable library has absorptive finishes distributed evenly throughout open study areas. In addition to improving the Articulation Index, absorptive finishes decrease the

reverberation time and noise build-up in library spaces. If reverberation time is extremely long, activity noise can build up in a library and create an uncomfortably elevated ambient noise level during regular use.

5 SUMMARY

Three design features are necessary to provide acoustic comfort in open study areas of libraries: appropriate background noise levels, physical barriers between noise-producing and noise-sensitive sections, and sufficient sound-absorbing material in the space. Each of these three design elements works to decrease the Articulation Index, a metric that correlates to the subjective impression of "freedom from distraction" in library spaces. Freedom from distraction is necessary in order for libraries to be comfortable acoustically. While the success of a library depends on many factors, acoustic comfort is fundamental to the usability and desirability of libraries as a place to work and study.

REFERENCES

[1] B. Markham, "A survey of the acoustical quality of seventeen libraries at Princeton University", in *Journal of the Acoustical Society of America* **114**, No 4, Pt 2 of 2, paper n. 2aAA11 (2003).

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