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FREQUENCY CONSIDERATIONS IN THE SUBJECTIVE ASSESSMENT OF SOUND INSULATION

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ABSTRACT

Sound insulation problems involve two aspects: the physical process of sound transmission through some barrier between source to listener, and the listener's reaction to the sounds that reach him. This paper describes a laboratory study of the subjective aspect of the process. The observer, placed in a controlled ambient sound field, hears a signal typical of what the occupant of an office or dwelling might hear from an adjacent space. The signal reaches him alternately through each of two electrical networks that simulate the transmission loss characteristics of two walls, and he adjusts the overall attenuation of one network until the two transmitted signals are judged to be equally annoying. The objective of the study is to determine the relative importance of various frequency bands in assessing the performance of a partition. In particular, the results are compared to the objective rating system known as the ASTM Sound Transmission Class (STC).

RAPPORT ENTRE L'INDICE D'AFFAIBLISSEMENT ACOUSTIQUE EN FONCTION DE LA FREQUENCE ET L'IMPRESSION SUBJECTIVE DE L'ISOLATION

SOMMAIRE

Les problèmes de l'isolation acoustique comprennent deux parties: le procédé physique de la transmission du son et la réaction d'un occupant d'un bâtiment aux bruits qui arrivent jusqu'à lui. Cet article s'intéresse uniquement à la deuxième partie, c'est-à-dire aux réactions subjectives des individus. En laboratoire, l'observateur écoute un bruit transmis à travers un réseau électrique destiné à simuler l'affaiblissement acoustique d'une cloison. En effet, il compare, tour à tour, deux réseaux qui ont des variations différentes en fonction de la fréquence, en ajustant l'atténuation générale d'un réseau pour rendre les deux signaux également "ennuyeux". Le but de l'expérience est de déterminer la contribution de chaque bande de fréquences à la réaction subjective. En particulier les résultats sont comparés aux systèmes adoptés par l'ISO et par l'ASTM, c'est-à-dire le Sound Transmission Class (STC).

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Frequency Considerations in the Subjective Assessment of Sound Insulation

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Introduction

Modern building technology, turning increasingly to the use of light materials and prefabricated elements, has solved many of the attendant problems such as strength, durability and fire resistance, but there remains the major problem of adequate sound insulation. It is therefore becoming increasingly important to establish a reliable way of rating the sound insulation value of a wall or floor construction.

There are, of course, many regulations governing sound insulation, but an examination of their origins reveals that they are not based on much concrete acoustical evidence. The most realistic approach was to identify by social surveys certain constructions where the sound insulation was deemed adequate by the majority of the occupants. Then recommendations were devised that reflected the characteristics of those particular constructions. Several parallel developments of this sort, in Europe and in North America, culminated in a proposal for an international standard for the rating of sound insulation between dwelling units. Essentially the same scheme is already in use in several European countries and in North America, where it bears the designation "Sound Transmission Class" (STC).

This rating system tries to compress into a single number all the characteristics that may affect the ability of a wall to provide acoustical separation between two occupancies in a building. The process by which the present requirements have developed was a rough, empirical one, but the method that finally evolved is itself very precise. It begins with measurements of the sound transmission loss of the wall or floor, for a series of octave or third-octave frequency bands. The results are plotted as a graph of transmission loss (TL) against frequency, and compared to a standard contour (the STC contour) which may be thought of as an ideal TL curve that gives appropriate weight to the TL at each frequency. The comparison is made by adjusting the vertical position of the reference contour on the graph so that a limited portion of the TL curve falls below the contour. The permissible extent of this "deficiency" of the TL curve is carefully specified, as will be noted later.

It would be fortunate if this precise determination were backed by an equally precise understanding of the acoustics and psycho-acoustics involved, but this is not so. A number of people, including ourselves, have looked at the problem, but all have invoked serious assumptions, especially about the subjective side of the process. The present paper reports some systematic experimental studies of these subjective aspects.

Procedure

In any sound insulation problem there are three primary factors:- (1) the character of the intruding noise; (2) the character of the "ambient" noise (i.e., the noise that the occupants find an acceptable part of their environment); and (3) the occupant's assessment of the annoyance caused by the noise. It is the third of these factors that is the principal object of this study.

In brief, each of some 30 subjects was installed in a controlled environment, with a certain level of ambient sound, and presented alternately with two intruding noises (actually, the same noise transmitted through two frequency-weighting networks). He was instructed to make an adjustment in the level of one intruding noise until he considered the two sounds to be equally annoying. The level adjustments then provided a basis for comparing the effects of the two different networks.

An anechoic room was selected as the test environment. The ambient and intrusive noises reached the subject by way of two loudspeakers, placed one over the other and about 3 metres in front of him.

The ambient noise was random noise modified to have a spectrum corresponding in frequency and level to an NC-25 curve. The intruding noise began with a tape loop of a typical signal such as speech, and passed through either of the two frequency-weighting networks, which could be set to simulate, for example, the transmission loss of a wall. The level of intruding noise was set so that it was slightly perceptible over the ambient noise. Thus for speech a level appropriate for a 5 percent articulation index was aimed at. The subject could switch manually from one network to the other, or it could be done automatically at intervals of 2 or 3 seconds, as he made the necessary level adjustment in one channel.

To deal with the semantic problem posed by the word "annoyance," the observer was asked to imagine himself, for example, sitting in his living room reading a book or playing chess, and to gauge the annoyance of the intruding noise in such a situation.

Results

The exact form of the results depends on the spectra of intruding and ambient noise as well as on the subjective reactions. Their general form will be illustrated by the results for one particular set of conditions: intruding male speech against an ambient noise spectrum corresponding to NC-25.

All subjective assessments in this group were made with one weighting network adjusted to simulate the STC reference contour. The second channel varied in shape with the particular experimental objective.

(a) Variation of annoyance with frequency - A question of major interest is the relative importance of various frequency bands of the intruding noise. Accordingly, the observers were asked to compare octave and third-octave bands of the speech signal with the reference signal transmitted through the STC network. The results for one of these cases (third-octave bands) are shown in Fig. 1, where relative levels giving equal annoyance are plotted against frequency. The vertical range shown for each point corresponds to the standard deviation of the mean.

For comparison an STC contour is superimposed at approximately the position of best fit. The shape of the STC contour constitutes, in the normal rating process, an assumed variation of annoyance with frequency; it is therefore of interest to compare the STC assumption with actual subjective judgments.

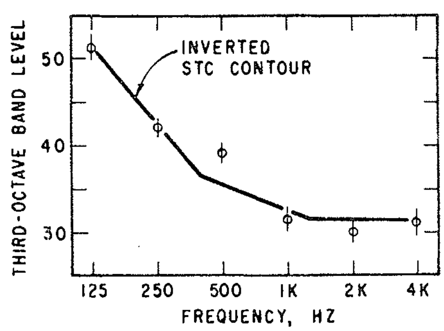

FIGURE 1
THIRD-OCTAVE BAND LEVELS GIVING EQUAL ANNOYANCE

The agreement is astonishingly close, and it seems necessary to emphasize that these are the results for only one kind of noise (male speech) and for one spectrum of ambient noise. At least, however, it may be concluded that the shape of the STC contour is reasonably correct.

(b) Variation of annoyance with narrow-band signal level - The second element in the normal rating process is the method of comparing the shapes of an actual TL curve and the STC contour. The basic procedure simply is to allow an average deficiency of 2 dB regardless of how it is distributed with frequency; but there is an overriding limit of 8 dB for any one frequency band. The latter requirement usually comes into play only when there are narrow dips (e.g., coincidence dips) in the TL curve. An experiment was set up to simulate this situation.

A smooth TL curve, closely resembling the STC contour, was set up in the second channel, together with an auxiliary network that permitted the introduction of a dip either an octave or third-octave wide and variable in depth from 0 to 20 dB relative to the smooth curve. These simulated TL curves were then compared with the STC contour in the reference channel.

The results indicate that the change in subjective rating as a dip increases in depth is rather small. This is consistent with the average-deficiency part of the STC rating procedure, but not with the 8 dB maximum-deficiency limit. It appears that, for intruding speech, even a deep dip in a TL curve should be assessed approximately in terms of the total area of the deficiency, and the 8 dB limit for an individual band is inappropriate.