MEASUREMENTS OF THE SOUND TRANSMISSION LOSS OF WINDOWS

by J. D. Ouirt

Institute for Research in Construction, National Research Council Canada

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Résumé

Il est utile de connaître les caractéristiques des fenêtres au point de vue transmission sonore tant pour pour les cas particuliers comme les régies, dans les studios de télévision ou de radio, que pour l'enveloppe des habitations ou des immeubles à bureaux, qui doivent être protégés du bruit extérieur. Il existe des données concernant la perte de transmission sonore de bien des types de fenêtres, mais les résultats des différentes études menées à ce sujet ne concordent pas exactement. Afin de clarifier la situation, le CNRC a réalisé dans son installation d'essais toute une série de mesures de perte de transmission sonore des fenêtres en faisant intervenir une foule de variables comme les dimensions, le type de montage des vitres ou d'autres aspects ayant trait aux modes opératoires utilisés en laboratoire.

Cette Note présente les résultats des mesures effectuées par la DRB/CNRC. Les données qu'elle renferme ont une certaine utilité immédiate, car elles concernent un large éventail de fenêtres courantes. On espère qu'elles constitueront aussi une base d'information permettant de tirer des conclusions générales applicables à d'autres types de fenêtres.

Introduction

The sound transmission characteristics of windows are of interest not only for specialized applications such as the control rooms of recording studios but also for the exterior shell of buildings where the intrusion of outdoor noise into homes and offices is of concern.

Although transmission loss data for many types of windows are available, the results of different studies are not in close agreement. Figure 1, which is based on data taken from a recent review paper.[1] illustrates the typical variation in published results. Although the windows involved had essentially equivalent glazing and interpane separation, the results obtained in the three sets of measurements differ appreciably.

There are several reasons for discrepancies:

1. At low frequencies sound transmission is considerably affected by panel resonances whose frequencies depend on the dimensions of the panes of glass.

2. The damping and edge constraint provided by putty or other material used to seal glass in window frames can significantly alter the sound transmission over the entire frequency range.

3. Most data in the literature are for openable windows and such transmission loss results are often dominated by the sound transmission characteristics of the cracks around the openable sections.

4. Results vary somewhat from one laboratory to another. Different room geometries cause differences in the coupling from the reverberant sound field in the source room to the sample and from the sample to the reverberant field in the receiving room. These differences can be further affected by the size and position of diffusing panels in the test chambers, by the location of noise sources and microphones, and by specific details of the measurement procedure.[1]

Such problems are probably only a partial listing of the systematic discrepancies that confound efforts to evaluate trends in the sound transmission of windows from published data. Unfortunately, none of the major studies covers the entire range of glass thickness, interpane spacing, and other features of interest. In an effort to clarify the situation an extensive series of window transmission loss measurements was made in the NRC test facility, holding as many of the variables like window dimensions, glass-mounting, and other laboratory-related details as constant as seemed practicable.

This Note is designed to present the results of the DBR/NRC measurements. The data are of some immediate use because they provide information on a wide range of practical windows. It is hoped that the data will also serve a broader purpose by providing a data base from which general conclusions applicable to other windows may be derived. This Note is a complete record of the test results; a subsequent paper will analyse the general features of the data from empirical and theoretical viewpoints.

EXPERIMENTAL DETAILS

All sound transmission measurements were made in accordance with ASTM E90-75[7], "Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions." Test specimens were mounted in an opening 2.44 m (8 ft) high by 3.05 m (10 ft) wide separating the two reverberation rooms. The source room has a volume of 62 m^3 (2100 cu ft) and the receiving room a volume of 255 m^3 (9000 cu ft). Following ASTM E90, each room is equipped with fixed and moving diffusing panels adjusted to provide as good an approximation as possible of the diffuse sound field that is assumed in transmission loss theory. The sound pressure level in each room is sampled by a set of nine GenRad 1961 electret condenser microphones with associated pre-amplifiers whose outputs may be observed individually. The signals from the microphones are selected via a GenRad 1566 32-channel multiplexer/amplifier and measured with a GenRad 1921 1/3-octave real-time analyzer. These instruments and the noise sources are all interfaced to a minicomputer that controls the measurements and performs all necessary calculations. Measurements were made for the standard 1/3-octave bands with centres from 125 to 5000 Hz. Data were also obtained for the 80 and 100 Hz bands, but because the test facility does not satisfy the room dimension requirements for these bands the data should be treated with caution.

Figure 2 shows the relevant dimensions of the window units and the associated filler wall in which they were mounted. The frame had three openings for the window units and was sufficiently deep to permit interpane spacings up to 200 mm (8 in.). The filler wall was of double wood stud construction with multiple layers of gypsum board on each face. Tests were made with heavy panels inserted in the window openings to make sure that flanking transmission, including sound transmitted through the filler wall and frame, was insignificant relative to sound transmission through the windows.

The window mounting details are shown schematically in Figure 3. All windows were mounted in wooden sashes of the same size: 620 mm (24.5 in.) wide, 1750 mm (68.75 in.) high, and 41 mm (1.625 in.) thick. The glass panes (560 x 1680 mm) were held in place by wooden strips nailed to the sash; and a thin bead of caulking sealant ensured a good seal between glass and wood. Double glazing was tested both with two panes mounted in a single sash (interpane spacings up to 19 mm) and with each pane mounted in a separate sash (spacings of 19 am or greater). The triple glazing tests included windows with three panes mounted in each sash and some with two panes in one sash and the third pane in a separate sash. The window sashes were equipped with spring metal weatherstripping at the perimeter and fitted snugly in the frame openings. Each sash was butted against a wooden positioning strip and held firmly in position by a second wood strip fastened to the frame. All cracks were sealed at the sash perimeters using an adhesive fabric-backed tape that provides a seal essentially equivalent to caulking for narrow cracks.

The windows tested had single, double, or triple glazing, with nominal glass thicknesses of 3, 4, or 6 mm. Their actual mass/unit areas were 8.1 kg/m^2 (26 oz/sq ft), 10.4 kg/m^2 (34 oz/sq ft) and 14.4 kg/m^2 (47 oz/sq ft), respectively.

DESCRIPTIVE CODE FOR WINDOWS

For ease of presentation the data in Tables I to III are identified by means of a simple descriptive code based on the nominal glass thickness in millimetres, and the interpane spacing, also in millimetres, for double or triple glazing. In this Code, single glazing with 3 mm glass is simply denoted by “3” and double glazing with two panes of 4 mm glass separated by a 50 mm airspace by “4(50)4” and so on. Special details related to the interpane cavity are indicated by minor variations, as discussed below.

The main series of tests was intended to determine the changes in sound transmission as a function of glass thickness and interpane spacing. Additional tests were performed to assess how some treatments of the interpane cavity affected transmission loss. These included the following:

1. Non-parallel double-glazing with interpane spacing at the top of the window different from that at the bottom, indicated in the descriptive code by specifying the maximum and minimum distances, e.g. “4(6 to 19)4.”

2. Absorptive treatment at the perimeter of the window cavity between the sashes, using 25 mm (I in.) thick glass fibre ceiling tile material, denoted by the addition of the letter A to the interpane spacing, e.g. “3(100 A)3.”

3. Addition of a diagonal divider across the cavity as illustrated schematically in Figure 4. These dividers touched both sashes, but did not completely bridge the interpane space. They are indicated in the descriptive code by addition of the letter D to the interpane spacing, e.g. “6(150 D)6”.

Some tests were performed with commercially produced hermetically-sealed double glazing with a 6 mm metal spacer between the two layers of glass. This is indicated by the addition of the letter M to the descriptive code, e.g. “3(6 M)3.” The pane and sash dimensions of these windows were the same as those listed previously.

GENERAL NOTES

Although most details of glass mounting and the test procedures were consistent throughout the series of measurements, there were some changes. The tests were conducted in three series of measurements, with intervals of approximately one year between successive series. During these intervals alterations were made in the diffusing panels in the receiving room, in the position of the noise sources, and in the number and position of microphones used for measurements. Although the test procedures nominally conform in all cases to the ASIM E90-751 standard, it must be recognized that such alterations could (and apparently did) introduce systematic changes in the transmission loss results.

To assess the extent of the changes, the second and third series of measurements each included a number of window types that had been tested in the previous series. The data indicate that there were small but quite consistent differences between the transmission loss results for nominally identical windows in different series. Although they were not very large, it is strongly recommended that detailed comparison of transmission loss results to assess trends associated with glass thickness (or other variables) be restricted to comparisons within a given series. The cases that were retested were largely chosen to facilitate such comparisons.

As discussed, all the data presented in Tables I to III are for windows sealed to the frame. As a general rule of thumb the Sound Transmission Class (STC) [8] of an openable window with good weather-stripping is 3 to 5 decibels lower than that for the corresponding sealed window. In most cases the leakage reduces the sound transmission loss more at high frequencies than at low frequencies; detailed discussion, however, of sound transmission by the leaks is beyond the scope of this Note.

Probably the most common use of sound transmission data for windows is in the design of the exterior envelope of buildings to limit intrusion of outdoor noise. It should be recognized that differences between the source sound field at an exterior facade and in a reverberant source room may cause the sound attenuation obtained in such applications to differ appreciably from the laboratory results presented here. In addition, the reduction in the A-weighted sound level (or other similar measure of loudness) for common noise sources such as road or railway traffic is appreciably different from the field STC derived according to ASTM E336[9] and E413[8]. These features have been discussed in some detail in a previous Note.[10]

The basic results of the main series of tests for double glazing are presented in Figure 5 in terms of the STC. The most obvious feature is the steady increase in STC with increasing interpane spacing. It exhibits a quite consistent trend of 3 dB increase/doubling of separation. The second obvious trend is the consistent improvement in STC with thicker (or heavier) glass. This too is maintained for all data, giving reason to believe that considerable success was achieved in minimizing variations associated with damping, edge constraints, and other such confounding variables.

Simply increasing the thickness of both panes is not the only way to improve STC for a given interpane spacing. Figure 6 compares the STC results for the thickest glazing tested (two layers of 6 mm glass) with the corresponding data obtained when one of the layers of 6 mm glass is replaced by 3 mm glass. It was found that substituting the lighter glass gave the same STC, or higher, in most cases. This is a well established technique in designing windows for noise control.

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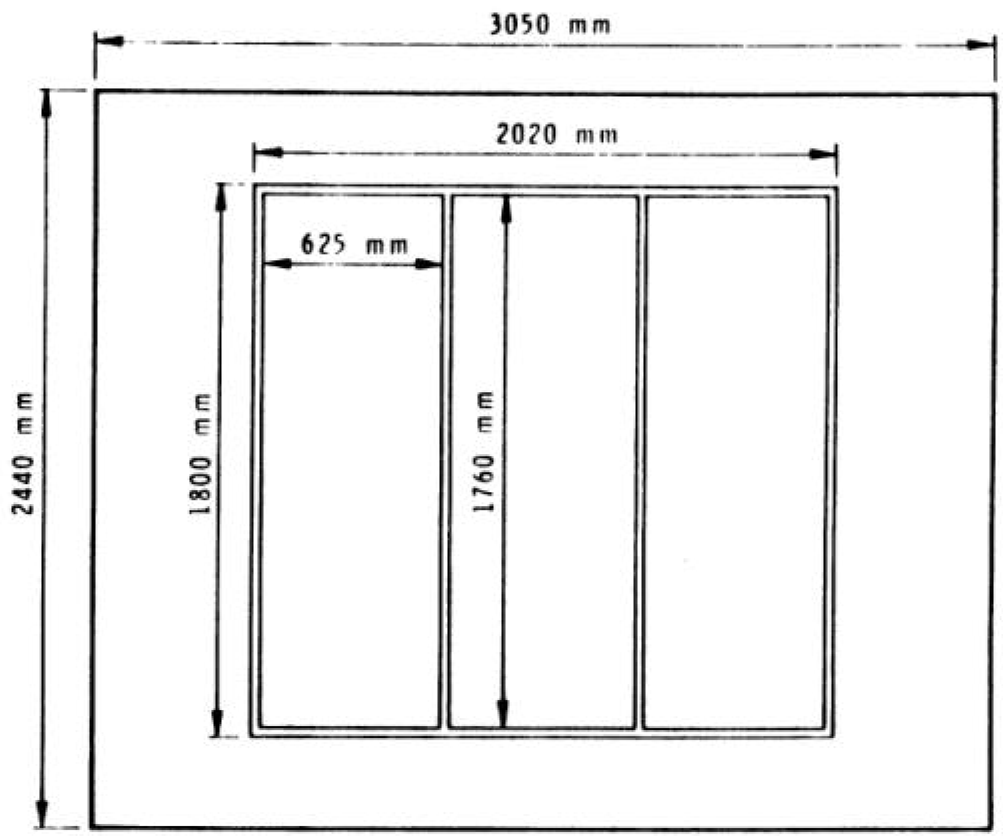

Figure 2: Location and size of window openings in the filler wall.

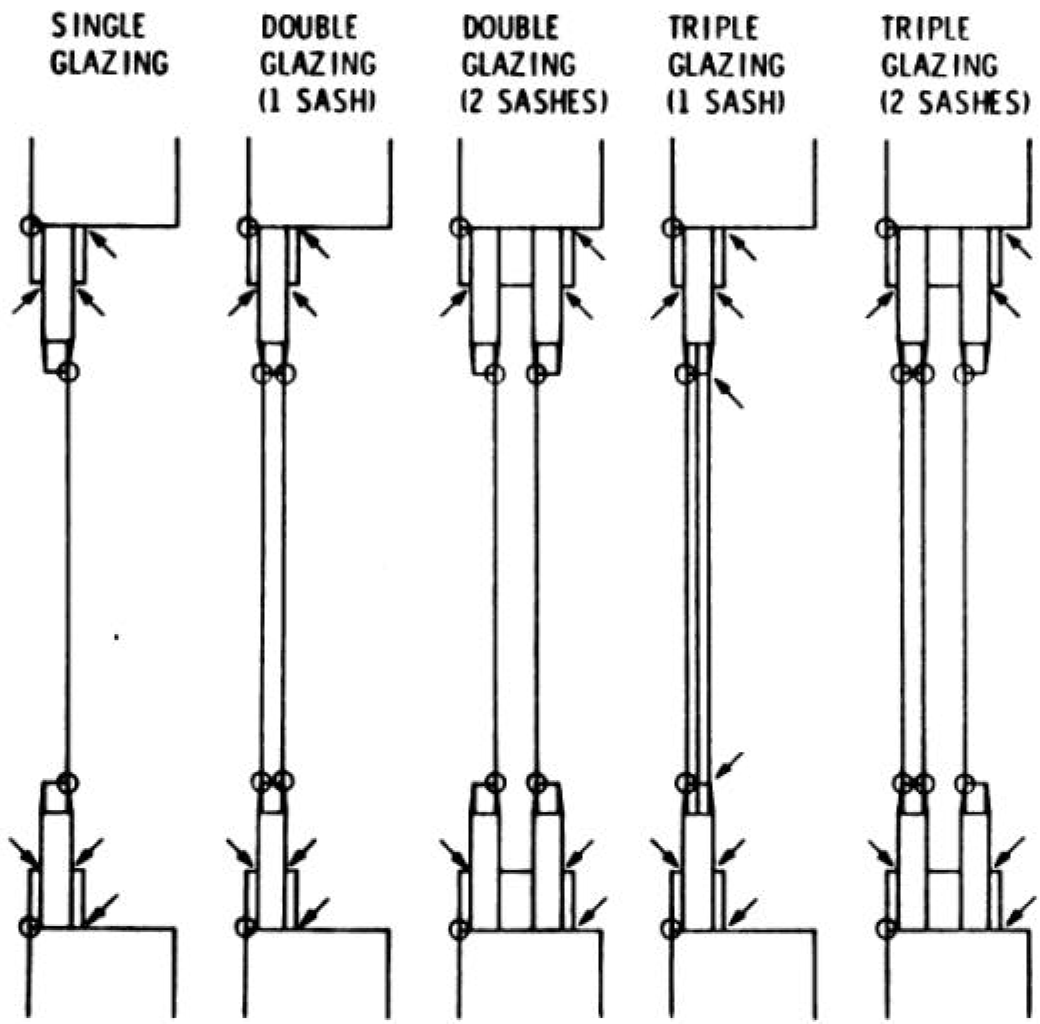

Figure 3: Schematic representation of window mounting details. caulked seals are indicated by circles, and taped seals are indicated by arrows

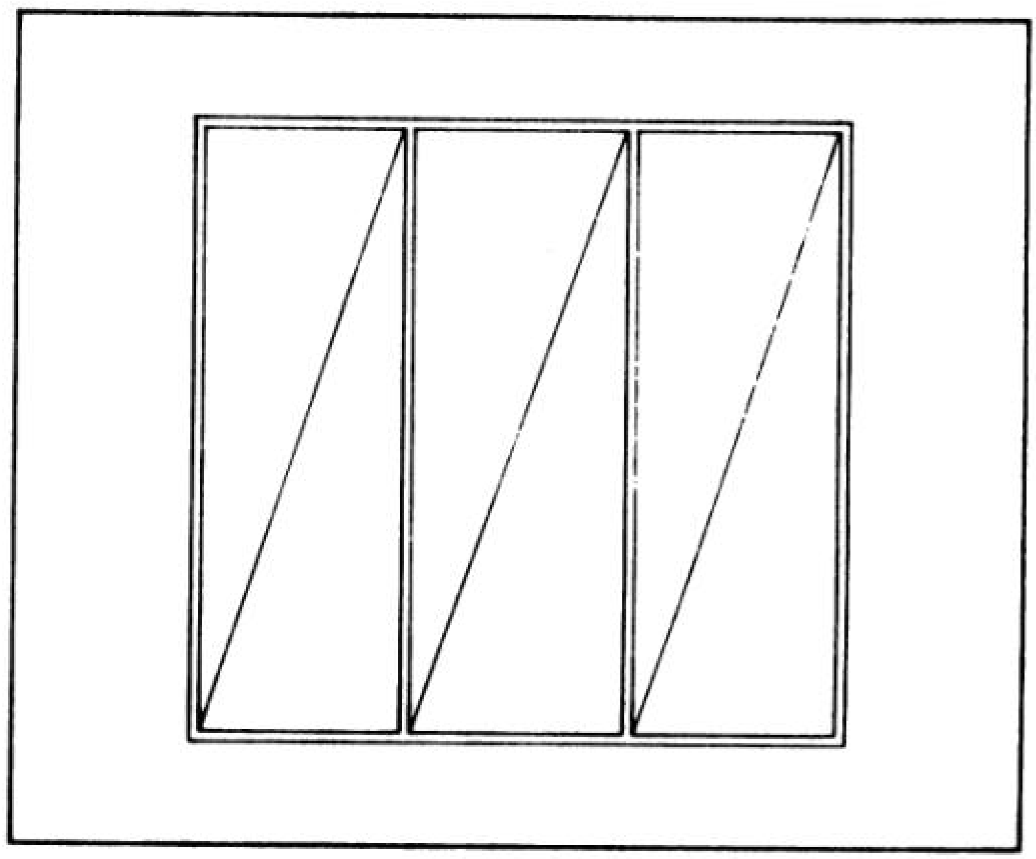

Figure 4: View of test wall from either reverberation room to indicate location of diagonal dividers in interpane cavities