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Publisher's version / Version de l'éditeur:

Journal of the Acoustical Society of America, 53, 4, pp. 1025-1027, 1973

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INSULATING HOUSES AGAINST AIRCRAFT NOISE

ANALYZED

BY

R. J. DONATO

REPRINTED FROM
THE JOURNAL OF THE ACOUSTICAL SOCIETY OF AMERICA
VOL. 53, NO. 4, 1973
P. 1025 - 1027

51462

TECHNICAL PAPER NO. 391
OF THE
DIVISION OF BUILDING RESEARCH

OTTAWA

PRICE 10 CENTS

NRCC 13335

3746386

L'ISOLATION DES MAISONS
DU BRUIT DES AVIONS

SOMMAIRE

L'auteur présente une série de règles permettant de choisir les éléments constitutants de l'enveloppe d'une maison ou d'un appartement en fonction de leurs propriétés acoustiques, de leurs aires relatives, du niveau de bruit qui peut être toléré et des contours prévus d'exposition au bruit.

CISTI / ICIST

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Insulating houses against aircraft noise

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(Received 10 July 1972)

A set of rules is devised whereby the component types of the envelope of a house or an apartment may be chosen from a knowledge of their acoustical properties, their relative areas, the degree of intrusive sound that may be tolerated, and the noise exposure forecast contours.

Subject Classification: 2.10; 7.1.

INTRODUCTION

With the increase in air travel and the use of higher-powered jet aircraft, it has become almost trite to say that noise is an increasing problem. Ideally, the solution would be to separate the people from the noise by building or shifting airports to well beyond the conurbations. Given that this extreme solution is economically unsound, we must then design shells to surround people to reduce the indoor noise to levels that are acceptable. Past history has shown what these values are, at least for the noise perceived in the buildings, and our goal then must be to design structures so that outside noise is reduced to these recommended internal levels.

The following discussion is based on a series of calculations made to establish construction guidelines for the financing of housing near airports. The aim was to produce tables of various types of building components that could be used to produce the kind of insulation required. Simplicity was stressed throughout, which means that individual buildings were not, as they ideally should have been, treated as individual cases. Thus typical rooms furnished in the normal manner were used so that noise reduction could be readily calculated knowing the number and proportion of the various components. Further, although there are many possible combinations of components, viz., walls, ceilings, windows, and doors, the design procedures were based on the assumption that equal sound energy is transmitted by each path. Then if any individual component is better than this minimum requirement the overall performance may be slightly better than predicted, although the process is such that the excess performance will never be large. The result is a kind of optimum design that keeps the relative importance of the major construction elements in perspective. The one parameter allowed to be altered over wide limits, and which is dealt with explicitly, is the ratio of window to wall area.

It is important to stress the kinds of persons who will be using this method. Typically they will be architects, planners or builders. While they may be acquainted with decibels they will not be at ease in combining levels, i.e., converting decibel values to energy, summing

and then converting back again into decibels. With the method outlined they will only need to know the number of components contributing to the overall internal sound field. Thus, if there are two components, they will be told to make the components 3 dB better in performance than if there were only one. For three components the figure is 5 dB and for four components 6 dB. Thus, while some flexibility in the design is lost, the gain in simplicity is great.

I. THE PROCEDURE

The problem reduces to this: Given the outdoor noise contour around an airport, an enclosure to be used as a family dwelling that will reduce the inside noise to certain levels must be designed. Noise predictions for Canadian airports are now being expressed in terms of the Noise Exposure Forecast (NEF), so designs in terms of this particular rating will be discussed. All we need to remember for our purposes is that the NEF value is really the noise level in PNdB plus a correction for number of flights, duration of events, time of day and spectral irregularities.

The next step in the procedure is to relate the sound insulation provided by a particular component having a certain sound transmission class (STC) to the reduction in PNdB levels. The sound transmission class is a single number derived from a transmission loss curve which is normally given in $\frac{1}{3}$ -oct increments. Details of the STC rating procedure are given in ASTM standard E413-70T. Several calculations made with the transmission loss of practical walls and windows and practical aircraft spectra yielded the following rule, which seems to hold fairly generally:

$$\text{PNdB (inside)} = \text{PNdB (outside)} - (\text{STC} + 2) + (\text{room corrections}). \quad (1)$$

The room corrections are really a property of each situation and are essentially given by $10 \log S/A$, where S is the area of the exposed component and A is the total absorption of the receiving environment.

As mentioned earlier, it would seem preferable *prima facie* to present the architect/developer of a proposed

TABLE I. Acoustic insulation factor for windows. Window area as percentage of floor area. WS—single window; WD—double window 2-in. spacing; WTh—thermal glazing $\frac{3}{8}$ -in. spacing. Glazing: 1—24 oz; 2—32 oz; 3— $\frac{3}{16}$ in.; 4— $\frac{1}{4}$ in.

Window type	AIF for various window/floor percentages						
	10	15	20	30	40	60	80
WS1	34	32	31	29	28	26	25
WS2	36	34	33	31	30	28	27
WS3	37	35	34	32	31	29	28
WTh1	38	36	35	33	32	30	29
WS4	39	37	36	34	33	31	30
WTh2	39	37	36	34	33	31	30
WD1	41	39	38	36	35	33	32
WD2	43	41	40	38	37	35	34
WD3	44	42	41	39	38	36	35
WD4	47	45	44	42	41	39	38

dwelling with formulae to enable him to calculate the interior PNdB level for each situation. This was deemed impractical almost at the outset and the compromise was made that only *average* situations would be evaluated. One may see that this probably leads to a more sensible situation, anyway, if one considers that most of the ratings will be extrapolated from laboratory measurements, and a certain latitude will always be present in converting to the field situation.

II. CALCULATION OF ROOM CORRECTION

Some simple correction factor is needed to enable us to calculate the sound level in a typical room once the STC rating of the wall is known and the external level in PNdB is given. If we take the room dimensions to be B , L , and H , where H is the height, $10 \log S/A$ may be expressed in terms of these dimensions. For the normal case of two exterior walls, S may be written as $(B+L)H$. To account for A , the total absorption in the room, we assume the floor and ceiling combined to have an absorption coefficient of 0.3 and the walls to have an absorption of 0.05. Included in with an assumed carpet, allowance has been made for the upholstered furniture which indicates 0.3 as a reasonable estimate. To be strictly accurate, one should use the absorption figures for different frequencies to correct the STC curves, but this again would be instilling a disproportionate rigidity and accuracy into the system.

If we take the window area to be a fraction β of the total exterior wall area, then the room correction factor to be applied to transmission through the windows will be

$$\beta \left/ \left[\frac{BL(0.6)}{(B+L)H} + 0.10 \right] \right.$$

The corresponding factor for transmission through the exterior walls excluding the windows will be:

$$(1-\beta) \left/ \left[\frac{BL(0.6)}{(B+L)H} + 0.10 \right] \right.$$

In living rooms, an average figure for $(B+L)H/BL$ would appear to be 1.2 and for bedrooms the average is 1.4 giving a mean of 1.3. Thus, for a window occupying 15% of the exterior wall, we use a correction figure of +8 dB, for 20% a correction of 7 dB, and for one taking up 30% the figure of 5 dB. The exterior wall corrections in the three cases are +1 dB. These correction figures are algebraically added to the STC values. In the case of ceilings, the correction figure is again +1 dB.

The next element is the door. For a direct access door (i.e., a door opening directly from a room to the exterior) and for a door adjacent to or immediately opposite to a room we use the data in the table without modification. When the door is coupled, via a foyer, with an internal door, we allow a further 10 insulation points for the effect of the foyer space and the inner door.

III. TRANSMISSION LOSS FOR CEILING ROOF SPACE

The effective STC value for the ceilings must be evaluated using a somewhat different procedure than that used for walls and windows. With normal construction, the chief factor determining the sound transmission in the roof space will be the amount of ventilation opening to the exterior. If we take the ventilation opening to be 1/100 of the roof area and assume the sound absorption for the roof space (with thermal insulation on one surface) to be 0.5, then the STC value for the ceiling will be effectively increased by 17 dB.

IV. THE CALCULATION

Tables were initially prepared on the previous basis. However, it was found that some difficulty was en-

TABLE II. Acoustic insulation factor for exterior walls. EW1— $\frac{1}{2}$ -in. gypsum board, 2- by 4-in. studs, 2-in. mineral wool, sheathing, $\frac{3}{4}$ -in. siding. EW2—EW1 but $\frac{1}{2}$ -in. stucco in place of siding. EW3—EW1 but after sheathing 1-in. air space and 4-in. brick veneer. EW4— $\frac{1}{2}$ -in. gypsum board, $1\frac{1}{2}$ -in. rigid insulation, 4-in. back-up block, 4-in. face brick. EW5—as EW4 but with 6-in. back-up block. EW6— $\frac{1}{2}$ -in. gypsum board, $1\frac{1}{2}$ -in. rigid insulation, 8-in. concrete.

Wall type	AIF for various wall/floor area percentages										
	5	7.5	10	15	20	30	40	60	80	100	150
EW1	51	49	48	46	45	43	42	40	39	38	36
EW2	54	52	51	49	48	46	45	43	42	41	39
EW3	61	59	58	56	55	53	52	50	49	48	46
EW4	64	62	61	59	58	56	55	53	52	51	49
EW5	65	63	62	60	59	57	56	54	54	52	50
EW6	69	67	66	64	63	61	60	58	57	56	54
Interior gypsum wall on resilient clips											
EW1R	60	58	57	55	54	52	51	49	48	47	45
EW2R	62	60	59	57	56	54	53	51	50	49	47
EW3R	66	64	63	61	60	58	57	55	54	53	51
EW4R	68	66	65	63	62	60	59	57	56	55	53
EW5R	69	67	66	64	63	61	60	58	57	56	54
EW6R	73	71	70	68	67	65	64	62	61	60	58

countered when part of an exterior wall was screened as, for example, by a stairwell. After considering several such cases and experiencing considerable trouble in formulating a simple rule for such screening, the calculation was slightly modified. Instead of using the exterior wall area as the normalizing area, we changed to using the floor area. This had the further advantage in that apartments, which had previously required separate tables of component values, could now be included in the same table as houses.

Table I gives the comparison between various window types and different area ratios for houses. The unit AIF is what we have termed the Acoustical Insulation Factor and the figures represent the value one should subtract from the exterior PNdB level to obtain the interior PNdB level. Table II shows the AIF values for exterior walls and Table III the values for ceilings.

The AIF factor has been introduced into the overcrowded lexicon of acoustical terminology not by choice but of necessity. This unit really gives the PNdB loss of a component which is not covered by any other unit. Further, experimentation with it showed it to be readily understood and accepted by the prospective user.

The basic step in the calculation is the combination of the different insulation factors. Let us say we require an overall reduction of 25 PNdB. If we design so that the contributions of all elements to the overall sound field are equal, then we may use the following rule: If there are only two elements (doors and windows), we add 3 dB to 25 dB to get 28 dB (since the energy carried by two equal parts is 3 dB higher than either) and look for the figure nearest to 28 in the Tables. If there are three components (doors, windows, and walls), the corresponding figure would be 5 and for four elements the figure 6 would be added.

In terms of the old Composite Noise Rating, 75 CNR has been fixed to describe the internal level for a normal living room; 70 CNR has been chosen for a bedroom. These are based on our interpretation of numerous surveys of people's reaction to noise. In current nomenclature the corresponding figures would be +2 NEF and -3 NEF.

Perhaps a detail from a worked example will clarify the procedure. In Fig. 1 consider bedroom 1, which has

FIG. 1. Example for calculation.

15% window area. If the outdoor level is 30 NEF and the indoor level designed for is -3, we must look for a reduction in PNdB of 33. There are three components (ceiling, windows, and exterior walls), so 5 is added to 33, giving 38. Reference to the Tables shows that a single window with glass at least $\frac{1}{4}$ in. thick is needed. An exterior wall composed of $\frac{1}{2}$ -in. gypsum board, 2- by 4-in. studs, 2-in. mineral wool batts, sheathing, and $\frac{3}{4}$ -in. siding would be sufficient. Any one of the ceilings shown in Table III would be adequate.

V. FUTURE WORK

It must be stressed that to meet immediate requirements this study has been based on estimates of performance of particular components. These, in the main, have been obtained from laboratory tests and data for exterior walls with some extrapolation of the results for internal partitions. A real need exists to put these ideas to the test. The next stage is to build experimental houses, subject them to aircraft flyovers, and measure the indoor level produced by various combinations and types of components. Special attention will be given to types and relative areas of windows and walls, room size and properties, the effects of different roof types, attic spaces, and ceiling constructions. The distribution of doors and foyers will be considered as well as secondary transmission paths like air vent openings and chimneys.

ACKNOWLEDGMENT

This paper is a contribution from the Division of Building Research, National Research Council of Canada, and is published with the approval of the Director of the Division.

TABLE III. Acoustic insulation factor for ceilings. C1— $\frac{1}{2}$ -in. gypsum board, 3-in. mineral wool, typical wood roof truss with ventilated attic. C2—As C1 but double $\frac{1}{2}$ -in. gypsum board. C3—Paint finish, 6-in. concrete slab, 2-in. rigid insulation, tar and gravel roofing. C4—As C1 but extra gypsum layer via resilient clips. C5— $\frac{1}{2}$ -in. gypsum board, 2-in. mineral wool, tar and gravel roofing with joist and beam roof construction.

Ceiling type	AIF
C1	46
C2	49
C3	51
C4	52
C5	50