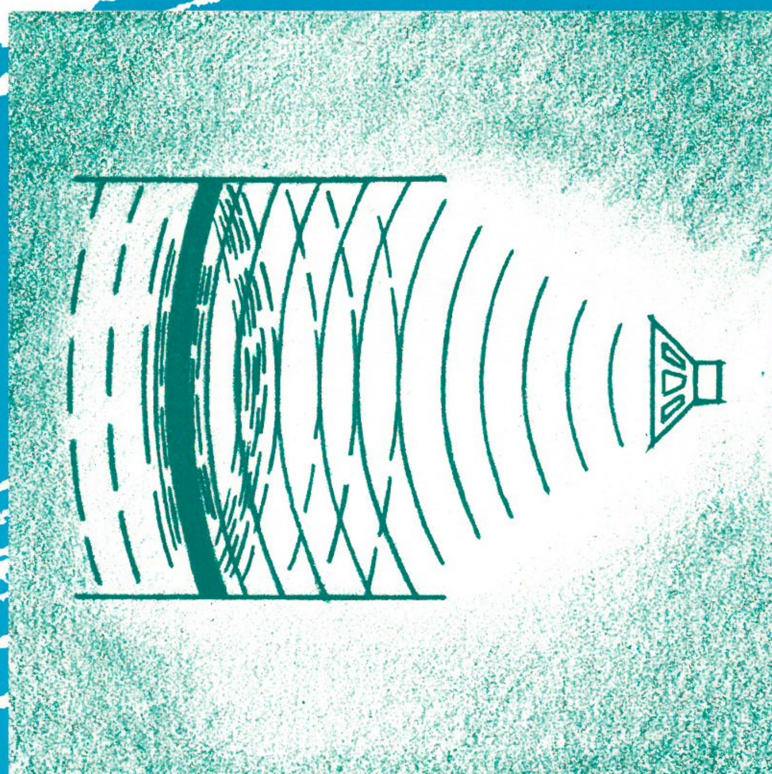
Noise Control With Concrete Masonry



Concrete Masonry Association of California and Nevada

Noise Control With Concrete Masonry

PUBLISHERS

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PREFACE

Isolating unwanted sound in multi-family dwellings is the subject we address in Noise Control. We begin by answering the question, "Why is concrete masonry an ideal material for party walls?" We review the principals of sound transmission and the relevant properties of masonry. You'll work through both exterior and interior wall problems. You'll also cover impact control in ceiling/floor assemblies. *Noise Control with Concrete Masonry* offers you all the information you need to meet the California Noise Insulation Standards. Written for the building designer, this booklet is one of a series describing the complete range of performance qualities of concrete masonry.

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TABLES

SECTION 1 GENERAL INFORMATION

Compliance with State Noise Insulation Standards is required for all new multi-family dwelling units constructed in California.* These Standards set minimum ratings for the sound transmission of party walls and floor/ceiling separations between dwelling units. In addition, a maximum allowable interior exposure is specified for intrusion from external noise sources, such as that produced by traffic on the arterials, rail system movements, aircraft operations and industrial activities. The selection of masonry party walls is described and step-by-step procedures for exterior wall selection are provided, leading to compliance with the State Standards. The various terms referred to in the Standards are defined in Section 11 Glossary, and a summary of the Standards is provided below. The full text of the pertinent section of the Administrative Code is included in Section 12, page 18.

California Noise Insulation Standards

Purpose: Establishes uniform minimum noise insulation performance standards.

Scope: Applies to new hotels, motels, apartment houses and dwellings other than detached, single-family dwellings.

Sound Transmission Control

a. Wall and Floor/Ceiling Assemblies separating dwelling units shall meet a Sound Transmission Class (STC) of 50 (45 if field tested), and an Impact Insulation Class (IIC) of 50 (45 if field tested).

b. Entrance Doors from interior corridors shall have an STC rating of not less than 30.

c. Laboratory Tests of walls and floor/ceiling systems having an STC and/or IIC of 50, may be used to establish an acceptable design.

d. Field Testing of proposed walls and floor/ceiling systems to obtain STC and/or IIC ratings, if required to prove compliance with the code shall include all sound flanking paths.

Noise Insulation from Exterior Sources

a. Interior Community Noise Equivalent Levels (CNEL) shall not exceed 45 dB in any habitable room with all doors and windows closed.

b. Residential Locations having a CNEL value greater than 60 dB require an acoustical analysis showing that the structure has been designed to meet the interior CNEL value of 45 dB.

c. CNELs shall be determined by local jurisdictions in accordance with their General Plan (Noise Element).

d. Exception: Railroads with only four daytime and no nighttime operations.

Evidence of Compliance

Compliance with the code is shown by submittal of an acoustical analysis. Field testing is required if inspection indicates the construction is not in accordance with the approved design or if there is a complaint to warrant testing.

*California Administrative Code: Title 24, Part 2, Chapter 2-35.

SECTION 2 WHY MASONRY?

Masonry structures are particularly well suited to the requirements of noise control in multi-family structures. Concrete block masonry wall assemblies provide a density of material with the noise reduction values needed to minimize tenant annoyance and comply with recognized standards. Sound transmission ratings are achieved with masonry construction for the reduction of the noise from freeways, rail movements, aircraft operations or near-by industrial activity. Sound rated masonry wall systems tested by application of standardized laboratory procedures are available to the architect for combating these exterior noise sources, as well as the undesirable sounds which may be experienced between dwelling units in multi-family construction.

To exemplify the advantage of masonry construction, Figure 2 shows the variation of sound rating to wall weight. It is noted that increasing the weight of the wall generally improves the STC value in accordance with the accepted "Mass Law" sound transmission characteristics.

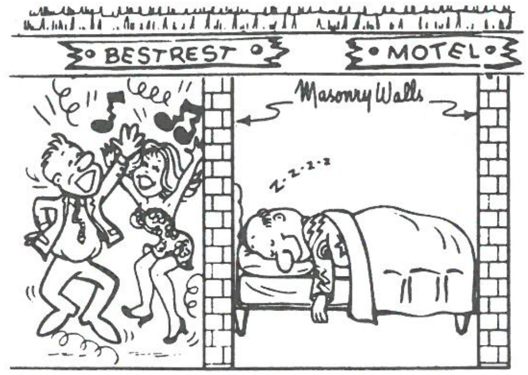


FIGURE 1. MASONRY WALLS INSULATE AGAINST NOISE TRANSMISSION.

This guide specifically addresses the question of masonry wall design as needed to provide the isolation from exterior noise and the insulation of sound between living units to meet the requirements of the State Standards.

SECTION 3 ISOLATION VS. INSULATION

The distinction between isolation and insulation as they relate to the Standards must be emphasized. This important distinction is described as follows:

Isolation of interior spaces from exterior sources is measured by positioning one sound level meter in the room of concern and another directly outside. The difference in the A-weighted sound level* measured by each instrument is a direct measure of the isolation provided by the building. The difference depends on that portion of the sound energy which entered the room and was not absorbed by the interior furnishings, carpeting, drapes and walls, as well as the sound transmission loss through the exterior walls, roof, windows, doors and vents. Note, it should be emphasized, when considering the isolation portion of the Standards, the sound absorption provided

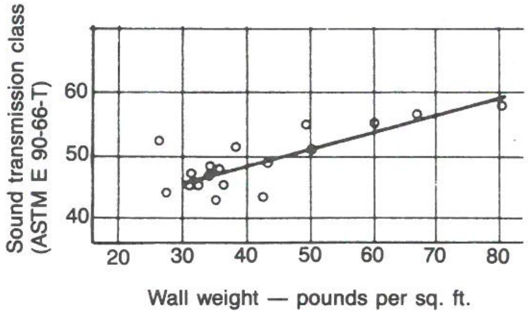


FIGURE 2. STC VS. WALL WEIGHT FOR SINGLE WYTHE PAINTED OR PLASTERED BLOCK WALLS.

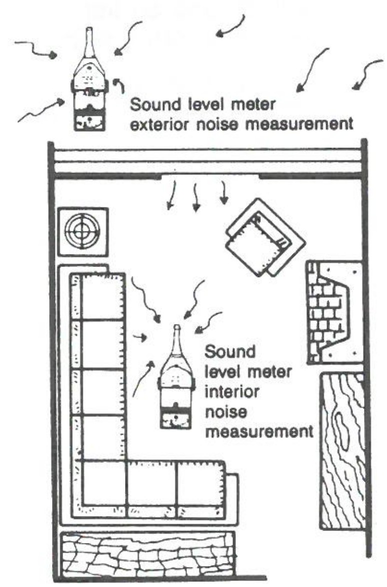


FIGURE 3. ISOLATION: DIFFERENCE BETWEEN THE EXTERIOR AND INTERIOR NOISE LEVEL MEASUREMENT.

*Refer to Glossary of Terms, Section 11.

by the interior space is an important part of the reduction between interior and exterior noise levels.

The Standards specify a minimum amount of insulation for party wall and floor/ceiling separations between the dwelling units by application of the Sound Transmission Class (STC). This one-numbered rating of the sound transmission characteristics of building assemblies is accepted by the architects, building officials, building tradesmen and the various suppliers of components which make up a wall or floor/ceiling separation. The scheme assigns a one-number rating to the 16 values of Sound Transmission Loss (TL), data obtained by application of the appropriate American Society for Testing and Materials (ASTM) standards.

It is important to recognize that these transmission loss values for wall or floor/ceiling assemblies are independent of the sound absorption in either the source or receiver room. It is the noise insulation characteristics of the separation between dwelling units that has been specified in the Standards, and not the noise reduction between units.

SECTION 4 INSULATION BY SOUND TRANSMISSION CONTROL

To cover the insulation requirements, the State essentially adopted the 1979 Uniform Building Code** requirements for sound transmission control. Party walls and floor/ceiling assemblies tested by application of American Society for Testing and Materials (ASTM) standards are considered acceptable designs under this code.

The Standards state, "...separating walls or floor/ceiling assemblies shall provide an airborne sound insulation equal to that required to meet a Sound Transmission Class (STC) of 50..." That is, the design is to achieve an STC of 50. However, in the event that the completed structure were to be tested, the Standards indicate that an STC of 45 need only be demonstrated. In effect, recognizing the potential deficiencies between a laboratory tested assembly and the assembly as constructed, within a multifamily dwelling, the State has allowed five decibels.

SECTION 5 STC VALUES OF MASONRY WALLS

Masonry wall systems which meet or exceed the design requirement of an STC of at least 50 are listed in Table A. In addition to the rated wall assemblies which are suitable for compliance with the State Standard, wall assemblies with lower ratings which may be used to control the noise from exterior sources have been included in Table A. The application of these assemblies for noise control is discussed in a later section.

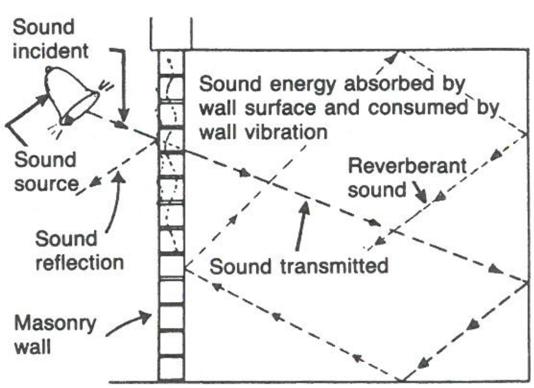


FIGURE 4: INSULATION BY SOUND TRANSMISSION CONTROL.

**International Conference of Building Officials, Uniform Building Code, 1979, Appendix Chapter 35, Sound Transmission Control.

STC VALUES OF MASONRY WALLS

TABLE A

Wall Thickness (Inches)	STC	Wall Description	Weight Of Weight lbs./sq. ft.	Test No.
4		Hollow Concrete Block, Unplastered, Ungrouted		
	40	Lightweight Units, Unpainted	18.0	KAL 359-1-66
	41	Normal Weight Units, Painted Both Sides (2 Coats)	26.5	TL 67-99
4		Hollow Concrete Block, Painted Both Sides (2 Coats)		
	43	Lightweight Units, Ungrouted	22.0	KAL 1379-5-72
	44	Normal Weight Units, Ungrouted	29.0	KAL 1379-3-72
4		Hollow Concrete Block, Plastered Both Sides, Ungrouted		
	44	Normal Weight Units	34.8	TL 67-102
4		Hollow Concrete Block, ½"Gypsum Board on Resilient Channels each side		
	47	Lightweight Blocks, Ungrouted	26.0	KAL 1379-4-72
	48	Normal Weight Blocks, Ungrouted	32.0	KAL 1379-2-72
4	48	Hollow Concrete Block, Plastered Both Sides, Ungrouted	30.0	KAL 359-7-66
6	44	Hollow Concrete Block, Unpainted, Unplastered, Ungrouted	21.0	KAL 359-4-66
6		Hollow Concrete Block, Painted Both Sides (2 Coats)		
	46	Lightweight Blocks, Ungrouted	28.0	KAL 933-2-70
	48	Normal Weight Blocks, Ungrouted	39.0	KAL 1379-1-72
6	53	Hollow Concrete Block, 2 Coats Paint One Side ½" Gypsum Board on Resilient Channel Other Side	27.0	KAL 359-6-66
8	45	Hollow Concrete Block, Unpainted, Unplastered Ungrouted	36.0	KAL 359-3-66
8	48	Hollow Concrete Block, Painted Both Sides, 2 Coats, Ungrouted	33.5	TL 67-61
8	49	Hollow Concrete Block, Unpainted, Unplastered, Ungrouted	42.8	KAL 1144-2-71
8	50	Hollow Concrete Block, Exterior Wall Painted Outside (2 Coats) Gypsum Board on Furring Strips Inside, Ungrouted	45.6	TL 67-93
8	51	Hollow Concrete Block, Cells filled with Zonolite, Unpainted	39.6	KAL 1144-4-71
8	52	Hollow Concrete Block, Normal Weight Block, Ungrouted, Unpainted	53.0	KAL 1144-3-71
8	55	Hollow Concrete Block, Lightweight Block, Solid Grouted, Painted Both Sides (2 Coats), Reinforced	73.0	KAL 1023-3-71
8	56	Hollow Concrete Lightweight, Ungrouted ⅝" Gypsum Board on Resilient Channels One Side Lightweight Block	40.4	KAL 933-1-70
8		Hollow Concrete Lightweight Block, Solid Grouted, Reinforced		
	56	½" Gypsym Plaster Both Sides	79.0	KAL 1023-9-71
	60	½" Gypsum Board on Resilient Channels, Both Sides	77.0	KAL 1023-3-71
12	55	Solid Concrete Block, Unpainted, Unplastered	121.0	NGC 3002
12	58	Solid Concrete Block, 5/8" Gypsum Board on Resilient Channels, One Side	124.0	NGC 3003

SOURCES OF DATA:
KAL: Kodaras Acoustical Lab., Elmhurst, New York
TL: Riverbank Acoustical Lab., Geneva, Illinois
NGC: National Gypsum Company, Buffalo, New York

SECTION 6 SOUND ABSORPTION AND NOISE REDUCTION

Sound is absorbed by any surface that dissipates sound energy by converting it to heat. If the surfaces of a room were capable of absorbing all of the sound generated within the room they would have a sound absorption coefficient of 1. If only 50 percent of it were absorbed, the coefficient would be 0.50. A commonly used measure of sound absorption is the Noise Reduction Coefficient (NRC).

NOISE REDUCTION COEFFICIENT (NRC)

	Sound absorption coefficient						
Frequency (cps)	125	250	500	1000	2000	4000	NRC
COEFFICIENT	22	62	85	70	65	58	70

Numerical average

Typical coefficents of a ceiling system

FIGURE 5: EXAMPLE OF NOISE REDUCTION COEFFICIENT (NRC).

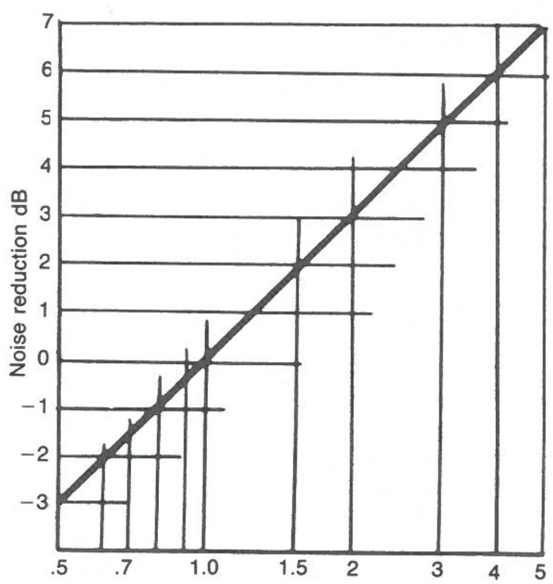
It is determined by measuring the sound absorption coefficient at the frequencies of 250,500,1,000 and 2,000 cycles per second (cps). The NRC is the average of these four measured coefficients. The noise reduction coefficients for concrete block and other materials are given in Table B.

An estimate of the average sound absorption (average NRC) in a room may be obtained by multiplying the NRC value of each material in the room by its surface area, summing these (NRC x surface area) values and dividing this sum by the total surface area of the room.

The noise reduction provided by the sound absorption of furnishings within a room can be estimated by evaluating the average NRC of the unfurnished room and that of the carpeted and furnished room. The ratio of the two average NRC values is then obtained and Figure 6 is used to determine the noise reduction.

TABLE B
NOISE REDUCTION COEFFICIENT (NRC) OF BUILDING MATERIALS AND FURNISHINGS

MATERIAL	NRC
Brick, Unglazed	.04
Unglazed painted	.02
Carpet, Heavy or Concrete	.30
on 40 oz. pad or foam rubber	.55
Concrete Block, coarse	.40
medium	.35
fine	.30
painted	.10
Concrete Floor	.01
Asphalt Tile Floor on Concrete	.03
Wood Floor	.08
Marble or Glazed Tile	.01
Glass, Single strength window	.12
Heavy plate, large panes	.04
Gypsum Wall Board on 2″ × 4″ Studs	.07
Gypsum Wall Board on Concrete	.03
Plaster on Brick or Concrete Blocks	.03
Plywood Paneling on Furring Strips	.13
Drapes, Light Fabric, 10 oz./sq. yd.	.14
Medium Fabric, 14 oz./sq. yd.	.40
Heavy Fabric, 18 oz./sq. yd.	.55
FURNISHINGS (values in absorption per square foot of floor area)	
Bed	.80
Sofa	.85
Wood Table, Chairs, etc.	.20
Leather Covered Upholstered Chair	.50
Cloth Covered Upholstered Chair	.70



Ratio: (Average NRC) Furnished Room / (Average NRC) Unfurnished Room

FIGURE 6: NOISE REDUCTION

EXAMPLE
NOISE REDUCTION PROVIDED BY SOUND ABSORPTION

To establish the decibel noise reduction provided by furnishings, consider the sound absorption in a hotel room 15′ × 20′ in plan, proceed as follows:

UNFURNISHED ROOM

SURFACE	MATERIAL	AREA SQ. FT.	NRC*	AREA x NRC
Walls	Concrete Block Unpainted	340 sq. ft.	.35	119 sq. ft.
	Glass (8′0″ × 6′9″)	54 sq. ft.	.04	2 sq. ft.
	Wall Board on Studs	120 sq. ft.	.07	8 sq. ft.
Floor	Concrete	300 sq. ft.	.01	3 sq. ft.
Ceiling	Wall Board on Concrete	300 sq. ft.	.03	9 sq. ft.
	TOTAL UNFURNISHED ROOM =	1,114 sq. ft.	TOTAL =	141 sq. ft.

$$\text{Average NRC, unfurnished room} = \frac{141}{1114} = 0.13$$

FURNISHED ROOM

SURFACE	MATERIAL	AREA SQ. FT.	NRC*	AREA x NRC
Walls	Concrete Block	320 sq. ft.	.35	112 sq. ft
	Medium Drapes Over Window	54 sq. ft.	.40	22 sq. ft.
	Wall Board on Studs	120 sq. ft.	.07	8 sq. ft.
Floor	Heavy w/Pad on Concrete	225 sq. ft.	.55	124 sq. ft.
Ceiling	Wall Board on Concrete	300 sq. ft.	.03	9 sq. ft.
Sofa		25 sq. ft.	.85	21 sq. ft.
Bed		40 sq. ft.	.80	32 sq. ft.
Chairs and Tables		10 sq. ft.	.20	2 sq. ft.
	TOTAL FURNISHED ROOM =	1,094 sq. ft.	TOTAL =	330 sq. ft.

$$\text{Average NRC, furnished room} = \frac{330}{1094} = 0.30$$

$$\frac{\text{(NRC) FURNISHED} \quad 0.30}{\text{(NRC) UNFURNISHED} \quad 0.13} = 2.31^{**}$$

The Noise Reduction provided by the 2.31 ratio of the furnished room absorption when compared to the unfurnished room absorption is found from Figure 6 to be about four decibels.

*Refer to Table B.
**Refer to Figure 6.

SECTION 7 FLANKING PATH CONTROL

The transmission of sound from one room to another may occur not only through the separating partition, but also through windows, doors, convenience outlets, common ventilation or plumbing systems. These additional "sound leaks" are commonly called flanking paths. When required to demonstrate compliance with the Standards, "all sound transmission from the source room to the receiver room shall be considered to be transmitted through the test partition." The implication is clear; a sound-rated party wall could be selected which meets the requirements of the Standards, however, flanking paths could reduce its effectiveness and the completed building placed in a category of non-compliance.

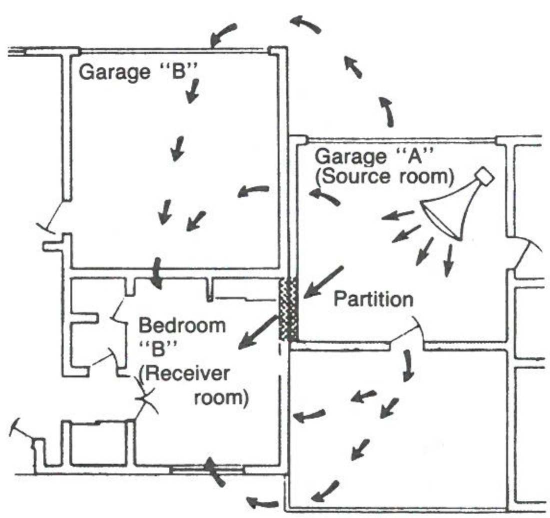


FIGURE 7: FLANKING PATHS BETWEEN SOURCE ROOM AND RECEIVER ROOM OF FIELD-TESTED BUILDING PARTITION.

For example, the partition separating the bedrooms of a condominium, Figure 7, was tested and found to yield an STC which was less than 45. Since the laboratory tests of the partition provided an STC significantly greater than that required by the State, it was apparent that the flanking paths, identified in the Figure, were responsible for the poor performance of the field tested assemblies.

Masonry provides a uniform wall assembly from floor to ceiling, which avoids the potential sound leaks of other types of construction. The designer is assured that all joints and intersections from floor to ceiling are well sealed, without the need for acoustic sealants or excessive on-site inspection. However, the potential flanking paths around the wall assembly, through windows and doors must be considered in the design.

SECTION 8 IMPACT NOISE CONTROL

In addition to specifying a minimum STC of separating walls and floors, the Standards specify a minimum Impact Insulation Class (IIC) for floor/ceiling assemblies. This characteristic of the building's sound control capability is a mixture of insulation and isolation. A standardized tapping maching is placed on the floor of the floor/ceiling separation to be evaluated, and the noise produced by the machine is then measured in the room below. Sound pressure level measurements are obtained at sixteen one-third octave bands from 100 Hz to 3,150 Hz. The measured sound pressure levels are corrected to account for the absorption within the room being tested relative to that of a "reference" absorption of 108 square feet. From the data obtained, a one-number rating, Impact Insulation Class (IIC), is determined. Compliance with this portion of the Standard is generally assured if the floor separation units are carpeted or covered with a cushion-backed material.

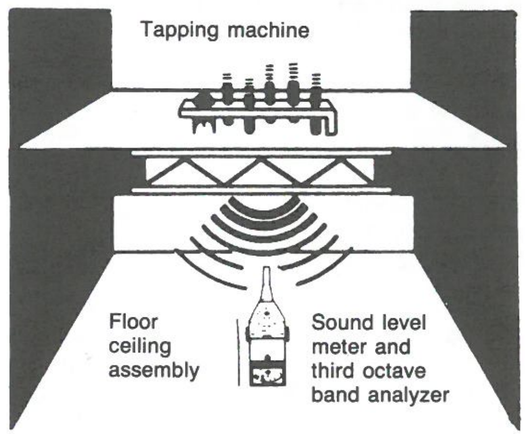


FIGURE 8: IMPACT SOUND TRANSMISSION MEASUREMENT.

SECTION 9 ISOLATION OF INTERIOR SPACES FROM EXTERNAL NOISE

The Standards specify that the interior Community Noise Equivalent Level (CNEL) attributable to exterior sources shall not exceed 45 dB in any habitable room. In addition, it states, "Residential structures to be located within an annual CNEL contour of 60 dB require an acoustical analysis showing that the structure has been designed to limit intruding noise to the prescribed allowable (interior) levels."

CNEL Contours are identified by local jurisdictions during the preparation of their General Plan, as required by California Government Code.* Under this section of the Code, each jurisdiction is required to prepare noise contours, identify noise producing activities within the Community and adopt a Noise Element consistent with these findings.

Proposed multi-family residential locations in proximity to major airports, primary highways and freeways and main-line railways may be exposed to excessive noise and, therefore, will require analysis and acoustical design consideration. The factors affecting noise exposures produced by traffic on the arterials and rail movements are provided in the step-by-step procedure which follows:

*California Government Code: Chapter 775, Section 6530(g)

SECTION 10 IDENTIFYING NOISE PROBLEMS AND ESTIMATING SOLUTIONS

The information obtained by following the procedure below will be useful in assessing the extent of a potential noise problem. In addition, the procedure will yield an estimate of the required Sound Transmission Class of exterior masonry walls and windows.

Exterior Noise Exposures

Determine the Exterior Community Noise Equivalent Level (CNEL) for:

a. Vehicle Movements on the arterials by use of Figures 10 and 11.

b. Train Movements on railroads in proximity to the project from Figure 12.

c. Aircraft Flight operations (provided by local airport authorities).

Calculation of Noise Reduction

For each dwelling unit within the project exposed to noise, determine the difference between the CNEL and 45 dB.

...Add 2 dB to the Noise Reduction found in Step 2 if the room is lightly carpeted and has no drapes and consists of primarily hard surfaced furniture.**

STC of the Wall

The required Sound Transmission Class (STC) of the walls exposed to noise is determined by applying corrections of the Noise Reduction, as follows:

...Little or no truck traffic on the highway (less than 1% of the ADT consists of trucks) STC = NR + 5

...Heavy truck traffic on the highways (about 3% to 7% of the ADT consists of trucks) .... STC = NR + 7

...Train Movements, diesel locomotive ..... STC = NR + 6

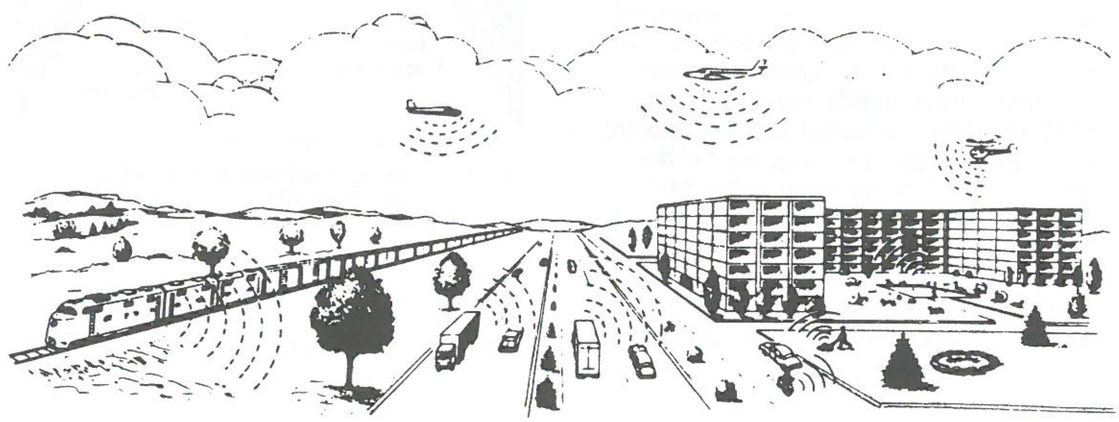


FIGURE 9: COMMON OUTDOOR NOISE SOURCES

This difference is the Noise Reduction (NR) required for the combination of exterior walls and windows to assure compliance with the Noise Insulation Standards. That is,

NR = CNEL − 45 = __________ dB

Room Sound Absorption

An additional factor which must be considered involves the sound absorption within the room which is exposed to exterior noise. Corrections for room absorption are considered as follows:

...No correction to the Noise Reduction obtained in Step 2 if the room has a carpet with heavy felt or foam pad, heavy drapes and upholstered furniture.

...Aircraft Operations
- Predominately Side Line .... STC = NR + 7
- Predominately Approach .... STC = NR + 7
- Predominately Take-Off .... STC = NR + 9

The STC obtained in Step d is the required value for the wall assembly exposed to the exterior noise. In the event the exterior wall(s) contain windows, it is necessary to apply an additional correction, Step e.

**Most living rooms and bedrooms will fall into the first category. Kitchens, sun rooms, game rooms, etc., are in the second category.

STC of Wall and Window

Windows will degrade the sound reduction performance of the wall. The composite STC of the exterior wall. The composite STC of the exterior wall and window(s) is estimated as follows:

a. Determine the ratio of window area to wall area.*

$$\frac{\text{Window Area}}{\text{Wall Area}} = \_\_\_\_\_\_\_\_$$

b. Select a wall configuration from Table A and a desired window installation from Table C. Determine the difference between the STC of the wall and window. A conventional window will have an STC of about 22 dB.

$$STC_{wall} - STC_{window} = \_\_\_\_\_\_\_\_$$

c. Determine from Figure 13 the amount to subtract from the wall STC to establish the composite STC of the window and wall.

$$STC_{wall} - \Delta dB = \_\_\_\_\_\_\_\_$$

This is the composite STC of the wall and window and must be equal to or greater than the required STC found in Step 4. If the composite rating is less than that required, it will be necessary to select a window and/or wall system with higher STC ratings.

Additional Design Details

In addition to the proper selection of sound rated walls and windows, a number of design details should be considered. These details depend on the amount of Noise Reduction needed as follows:

Noise Level Reduction, 25 to 30 Decibels. For a building located where a noise level reduction of from 25 to 30 decibels is required, the building design should include the following:

a. Arrangements for any habitable room should be such that any exterior door or window may be kept closed when the room is in use. A forced air circulation system should be provided that will give a minimum of two complete air changes per hour, of which at least one-fifth is fresh air (per requirements of the Mechanical Code).

b. Air ducts or connections to out-of-doors must contain an interior sound absorbing lining acoustically equivalent at least to glass-fiber duct liner one-inch thick. The duct length should be at least five times the diameter of the duct.

c. There should be no direct openings, such as mail slots, from the interior to the exterior of the building. All chimneys should be provided with well-fitted dampers.

d. Entry doors should be solid-core construction close fitting units with weather stripping seals incorporated on all edges to eliminate gaps. Air gaps and rattling should not be permitted.

Noise Level Reduction 30 Decibels or Greater. For a building located where a noise reduction of 30 decibels is needed, the building should be constructed to incorporate the features described in the preceeding section (NR 25 to 30 dB). In addition, a ceiling or exhaust duct for the forced air ventilation system should be provided with a bench in the duct such that there is no direct line of sight through the duct from outside to inside. The bend should be lined with the equivalent of glass-fiber duct liner one-inch thick. Ducting having a length of at least five diameters of the duct should be placed on each side of the bend.

The step-by-step procedure greatly simplifies the wall selection process. However, it should be applied with caution. The more detailed analysis considers the one-third octave band sound levels of the course. In addition, the transmission loss characteristic of the wall, windows and room sound absorption are analyzed on a one-third octave band basis. Calculations are performed for at least 16-bands, from 125 Hz to 4000 Hz, and then A-weighted to determine the exterior and interior A-weighted sound levels. The difference between these calculated A-weighted sound levels is the Noise Reduction which is estimated by the simplified procedure described above.

In general, residential units should not be located where the CNEL is greater than 65 dB. If possible, barriers should be located between the noise source and the residential property to reduce the exposure to at least the 65 dB level.

*The areas of concern are those of surfaces exposed to the exterior noise.

In general, residential units should not be located where the CNEL is greater than 65 dB. If possible, barriers should be located between the noise source and the residential property to reduce the exposure to at least the 65 dB level.

Masonry walls with conventional windows will provide the isolation required to meet the State requirements at CNELs to 65 dB. Well weather-stripped and tight fitting double glazed or even stationary windows are required at CNELs approaching 70 dB and greater. However, with properly sound-rated windows, conventional, well-sealed masonry walls will provide the noise reduction needed even at CNELs approaching 75 to 80 dB.

TABLE C
SOUND TRANSMISSION (STC)
OF WINDOW ASSEMBLIES*

DESCRIPTION			STC
Stationary (Well stopped and sealed at the perimeter)			
Glass 1/8″ thick (SS)			23
1/4″ thick (Plate)			28
Laminated with .030″ Plastic Film			
1/4″ and 1/8″ thick			32
3/8″ and 1/8″ thick			36
Openable (Window size: 6′0″ × 4′0″).*			
	Nominal Glass Thickness		
	Exterior	**Interior**	
Single Slider	1/16″ (SS)	None	22
Single Slider	1/8″ (DS)	None	23
Single Slider	3/16″ (CRY)	None	24
Double Sliders**	1/8″ (DS)	1/16″ (SS)	32
Double Sliders	3/16″ (CRY)	1/16″ (SS)	34
Double Sliders	3/16″ (CRY)	1/8″ (DS)	36
Double Sliders**	1/8″ (DS)	1/8″ (DSB)	34
Double Sliders	3/16″ (CRY)	3/16″ (CRY)	36
Glass Sliding Door			
Tempered Glass, 3/16″ thick pane			25
Insulated, 1/4″ air space, between two 3/16″ thick panes			28
Laminated, 1/4″ thick			32

SS: single strength; DS: double strength; CRY: crystal

EXAMPLE

Noise Reduction Provided by an Exterior Wall

Consider the hotel room, Figure 7 on page 8, which has a masonry exterior wall (15′0″ × 8′0″) with a glass sliding door (8′0″ × 6′9″). This wall is 100 feet from the near lane centreline of a four-lane highway with heavy truck traffic and an Average Daily Traffic (ADT) of 40,000. We wish to select wall and window STCs which comply with the State Noise Insulation Standards.

Referring to the step-by-step procedure, we proceed as follows:

a. Exterior CNEL for an ADT of 40,000 and distance of 100 feet:

1. CNEL at 50 feet is 73 dB (Fig.10).
2. CNEL Reduction to 100 feet is 3 dB (Fig. 11).
3. Hence the CNEL at 100 feet is $73 - 3 = 70$ dB.

b. The Noise Reduction needed is:
$NR = CNEL - 45 = 70 - 45 = 25$ dB

c. Since the room is carpeted, furnished and the windows draped, no correction for room sound absorption is applied to the Noise Reduction. Hence the Noise Reduction required is 25 dB as found in Step 2.

d. Exterior wall and window.
$STC = NR + 7 = 25 + 7 = 32$

e. The required composite STC of the wall with window was found in Step d, we now need to determine the STCs of the wall and the window, as follows:

1. $\frac{\text{Window Area}}{\text{Wall Area}} = \frac{54}{120} = 0.45$
2. From Table A we select an 8″ thick exterior wall with an STC of 50 and a glass slider (Table 3) which has an STC of 28 hence:

$$STC_{wall} - STC_{window} = 50 - 28 = 22$$

3. Referring to Figure 6, the intersection of the Ratio, 0.45, and the STC Difference, 22 dB, is located and the amount, in dB, to subtract from the wall STC to find the composite STC of the wall and window is determined. This amount is found to be 17 dB, hence:

$$STC = STC_{wall} - \Delta = 50 - 17 = 33$$

Hence, the composite STC of the wall and window combination selected is one decibel greater than that required in Step d. Therefore, the combination selected is considered satisfactory.

*Refer to manufacturer's Data for STC of specific window sizes and configurations. Tests of windows per ASTM E90-70 or E336-71 and E413-70 (refer to13 for explanation of the tests).
**At least a 3½″ air space between the sliders.

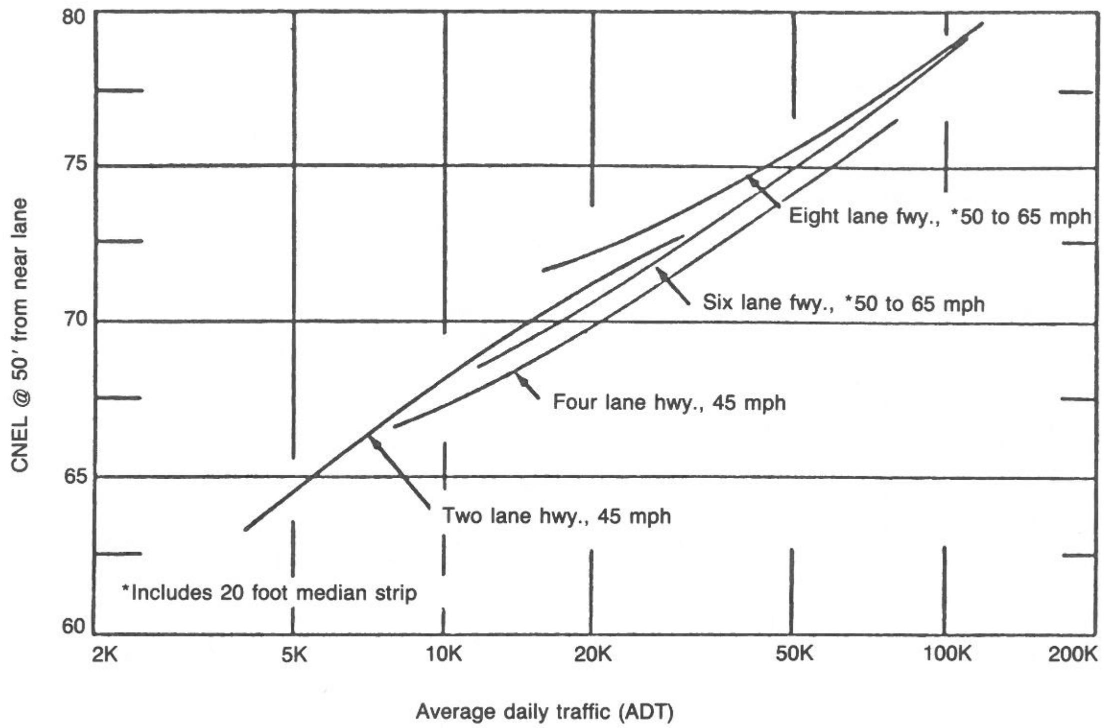


FIGURE 10: COMMUNITY NOISE EQUIVALENT LEVEL (CNEL) FOR TRAFFIC NOISE (50 FEET FROM NEAR LANE CENTERLINE, HEAVY TRUCK TO AUTO MIX OF 4%)

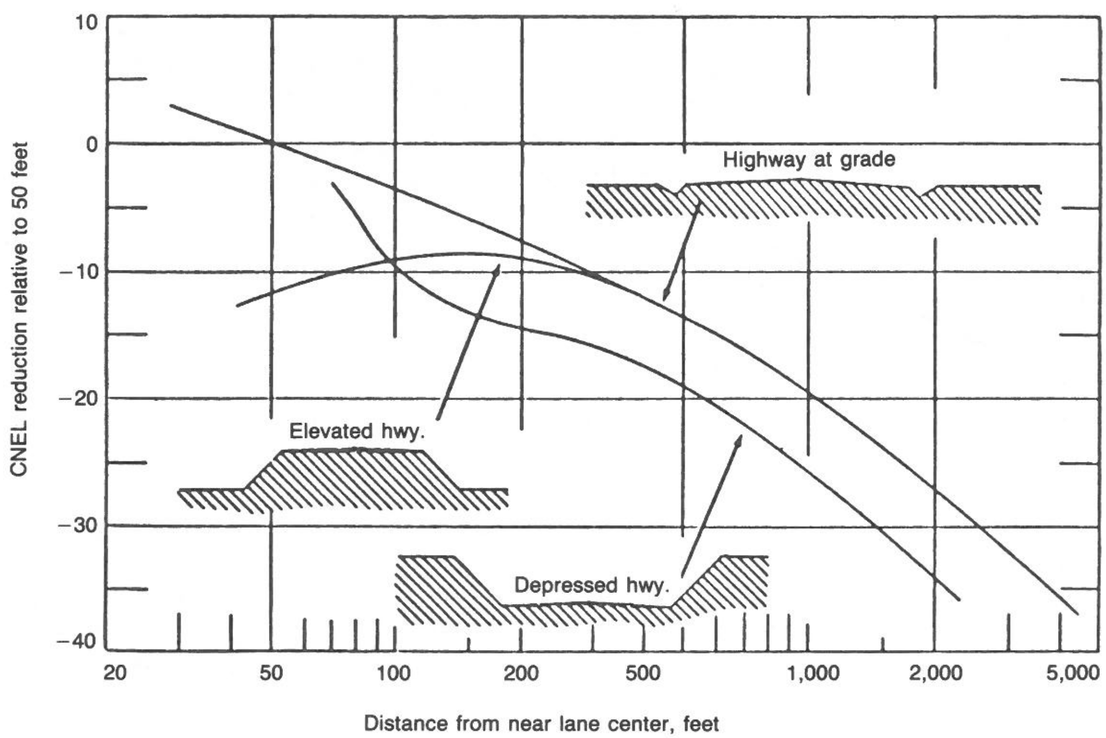


FIGURE 11: CNEL REDUCTION FOR VARIOUS HIGHWAY CONFIGURATIONS.

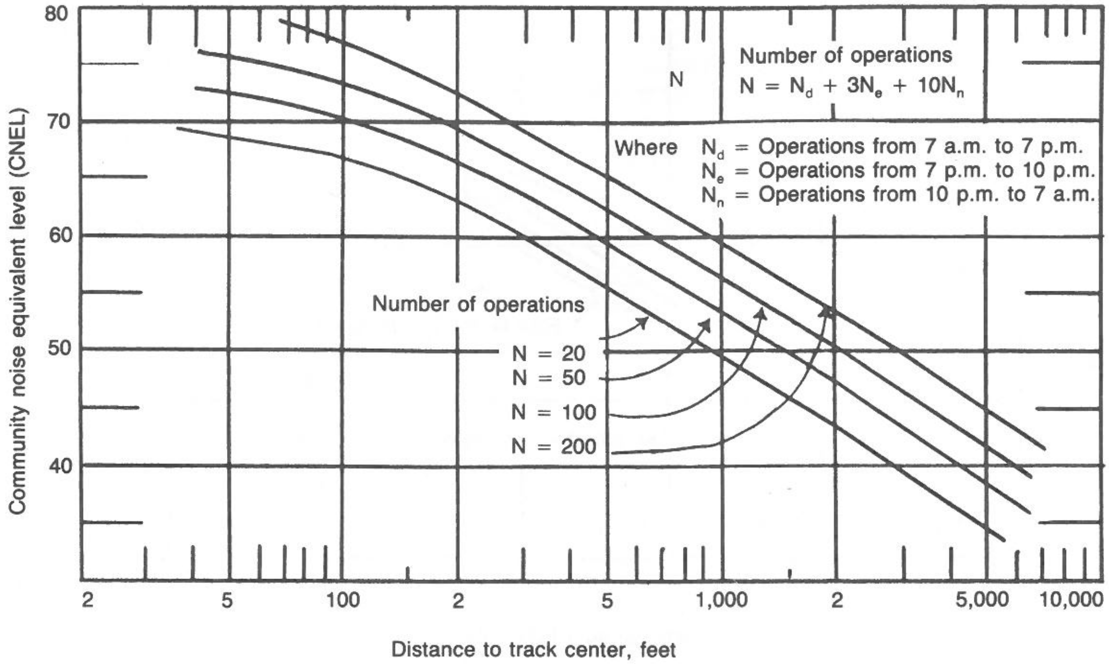


FIGURE 12: COMMUNITY NOISE EQUIVALENT LEVEL (CNEL) OF RAIL SYSTEM NOISE (WITH LINE-OF-SIGHT TO THE RAILWAY).

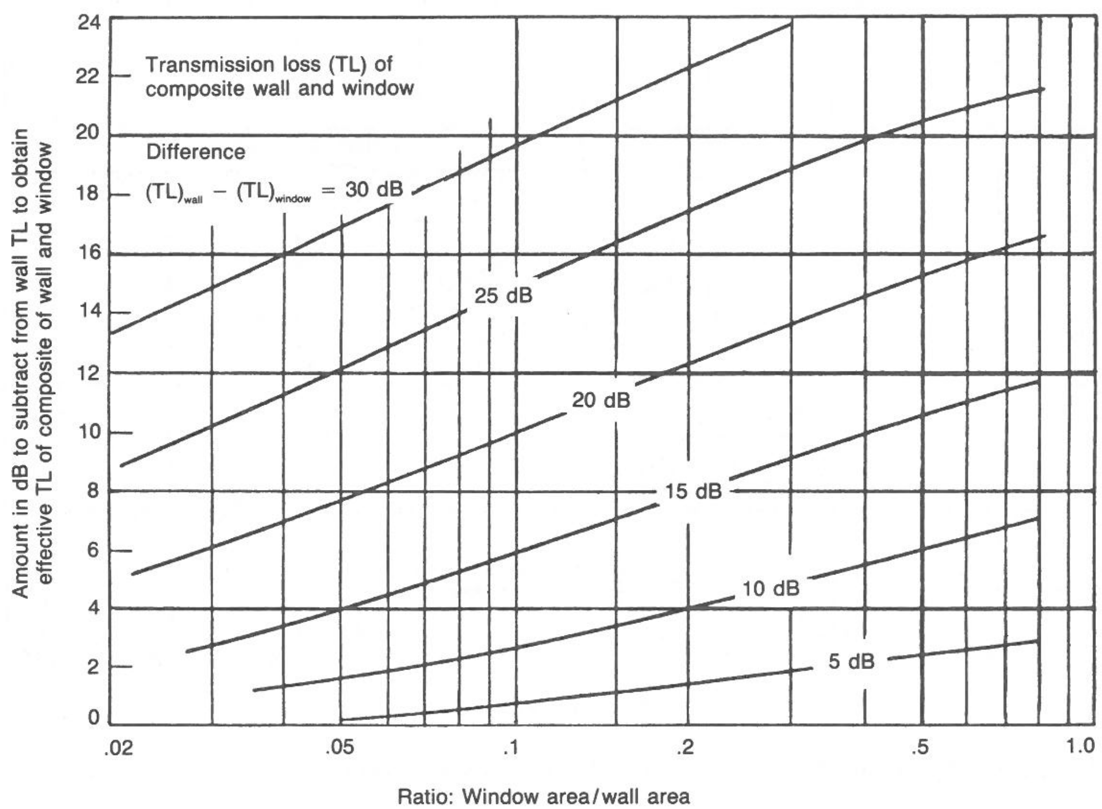
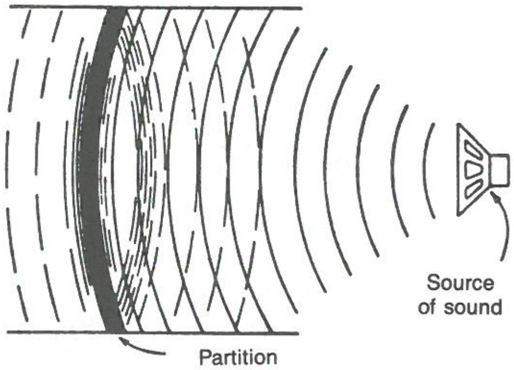


FIGURE 13: TRANSMISSION LOSS OF COMPOSITE WALL & WINDOW

SECTION 11 GLOSSARY OF NOISE CONTROL TERMS

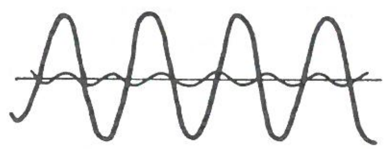
Airborne Sound Transmission

A sound source in a room sets the air into vibration. The vibrating air causes the partition it touches to vibrate; the vibrating partition, in turn, sets into vibration the air on the opposite side of the partition.



A-Weighted Sound Level (dB(A))

The A-weighted sound level is a quantity, in decibels, read from a standard sound-level meter that is switched to the weighting scale labeled "A." The A-scale discriminates against the lower frequencies according to a relationship approximating the auditory sensitivity of the human ear at moderate sound levels. The A-scale sound level measures approximately the relative "noisiness" or "annoyance" of sound.



Background Noise

The constant noise level in a room resulting from outside sources. It may be caused by outside traffic, ventilating equipment, industrial activity, etc.

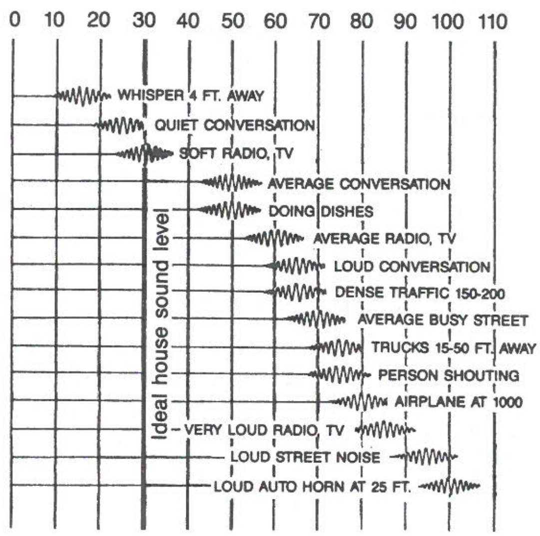
Community Noise Equivalent Level (CNEL)

CNEL is the energy averaged A-weighted sound level for a 24-hour period. To establish the CNEL, the sound levels for evening hours (7 to 10 p.m.) are increased 5 dB and those for the late evening and early morning hours (10 p.m. to 7 a.m.) are increased 10 dB. The daytime sound levels are combined with these penalized levels, and averaged, to obtain a CNEL value. Annual CNEL is the average of the daily CNEL over a 12-month period.

Decibel

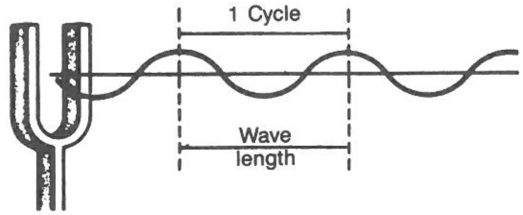
The decibel is a logarithmic unit of measure of sound pressure (or power) calculated according to a formula. Zero on the decibel scale corresponds to a standardized reference pressure (0.0002 microbar) or sound power (10^{-12} watt). Decibel is abbreviated dB.

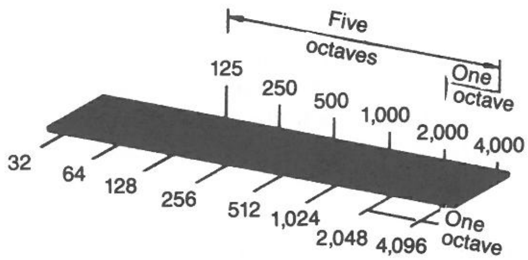
SOUND LEVELS IN DECIBELS



Frequency

The frequency of a sine wave of sound is the number of times it repeats itself in each second. In acoustics, the unit of frequency is the cycle per second or Hertz, abbreviated Hz.



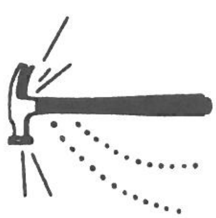


Frequency in cycles per second

The pitch of an audible sound depends mostly on its frequency and pitch (and vice versa). The human ear usually responds to frequencies from 20 to 15.000 pulsations or cycles per second.

Impact and Structure Borne Sound

Impact and structure borne sound is produced by the direct excitation of part of the building. This excitation may be caused by footsteps, a dropped object, moving furniture or a vibrating machine or other mechanical equipment.



Impact Insulation Class (IIC)

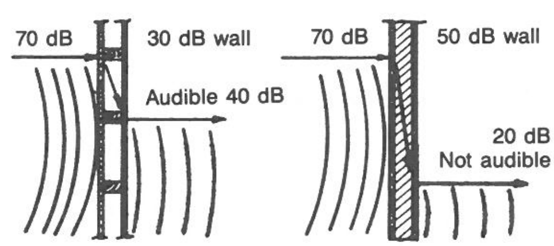
A single number rating for ceiling/floor construction that represents the ability of the construction to isolate impact noise.

Loudness

Loudness is related to the amount of change in air pressure that is produced by the vibrating source. Loudness varies directly as sound pressure increases or decreases. But the human ear is much more sensitive to middle and high frequencies than it is to low frequencies. Thus, the human ear does not respond uniformly, over its frequency range.

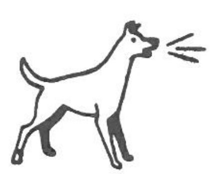
Masking

The presence of a background noise increases the level to which a sound signal must be raised in order to be heard or distinguished. If the level of background noise is significantly higher than that of a sound signal, it cannot be heard. Experiments have shown that for one sound to mask another, there must be about a 10 dB difference between the two sounds. This effect is known as masking.



Noise

Noise is any undesirable sound.



Noise reduction

Noise reduction is the difference in sound level from one room to another or from an exterior to an interior space. The difference is specified in decibels (dB).

Octave Band Sound Level

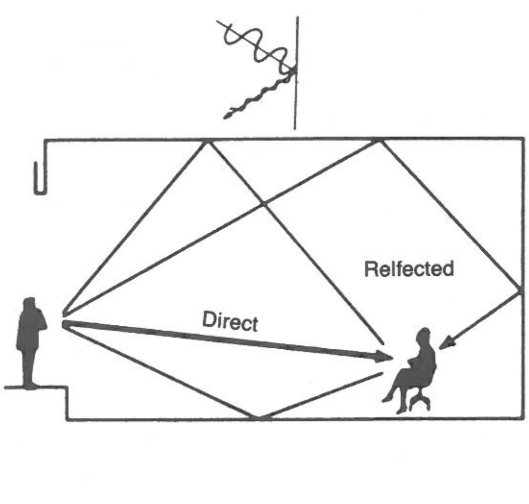
The sound level of a frequency band of noise measured by use of a filter having a specified upper and lower band edge. For example, the octave band filter centered at 125 Hz has a lower edge of 71 Hz and an upper edge of 141 Hz. Other standard octave band frequencies are centered at 250 Hz, 500 Hz, and 1,000 Hz, etc.

One-Third Octave Band Sound Level

The sound level measured by use of a filter having a specified upper and lower band edge. For example, the one-third octave band centered at 100 Hz has a lower edge of 89 Hz and an upper edge of 119 Hz. Other standard one-third octave band frequencies are centered at 125 Hz, 160 Hz, 200 Hz, 250 Hz, etc.

Reflected Sound

Hard, non-porous surfaces such as plaster, glass and smooth concrete are highly reflective, therefore, absorb very little sound. Hard surfaces may be useful in reflecting sound and directing it to distant parts of a room where it reinforces the sound coming directly from the source. In general, it is well to keep the surfaces near the speaker or sound source reflective, while the surfaces at the rear of the room should be non-reflective, particularly those which the speaker faces directly.

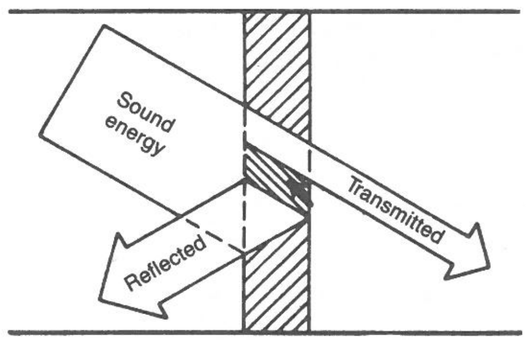


Sound

A pressure wave travelling outward in all directions from its source at about 1,120 ft. per second. The experience of hearing is caused by the variable pressure wave striking the eardrum.

Sound Absorption

The sound energy absorbed by materials in a room such as carpeting, drapes, upholstered furniture, etc., is classified as sound absorption. The difference between the amount of energy transmitted and the energy reflected is the amount absorbed.

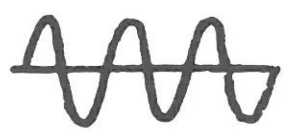


Sound Leak

A hole, crack or opening which permits the passage of sound.

Sound Level

The intensity of sound measured in decibels (dB). The louder the sound, the higher the decibel rating.

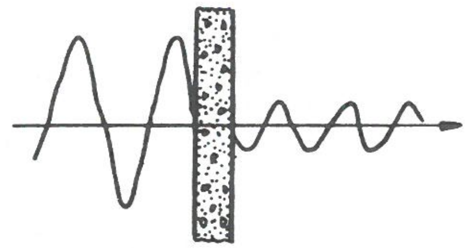


Sound Transmission Class (STC)

A single figure rating for floor/ceiling and interior wall partition construction that represents the ability of the construction to insulate from airborne noise. It is derived from measurements of the transmission loss (TL) of a partition in the laboratory or within the completed building.

Transmission Loss

Reduction in sound level which takes place when a sound passes through a structure. The amount of sound reduction is a fixed property of the structure but is variable with the frequency of the sound. Some frequencies pass through easier than others.



SECTION 12 MODEL STANDARD FOR SOUND CONTROL

Excerpts from Chapter 2-35 Title 24 Part 2, California Administrative Code

T25-1092. **Noise Insulation Standards (a) Purpose.** The purpose of this article is to establish uniform minimum noise insulation performance standards to protect persons within new hotels, motels, apartment houses, and dwellings other than detached single-family dwellings from the effects of excessive noise, including but not limited to hearing loss or impairment and persistent interference with speech and sleep.

(b) **Application and Scope.** The provisions of this article relating to noise insulation performance standards apply to new hotels, motels, apartment houses and dwellings other than detached single-family dwellings.

(c) **Definitions.** The following special definitions shall apply to this article as applicable:

(1) **Impact Insulation Class (IIC)** — A single number rating for ceiling-floor construction that represents the ability of the construction to isolate impact noise, where measurement procedure is based on ASTM E492-73T and as defined in UBC Standard No. 35-2.

(2) **Sound Transmission Class (STC)** — A single figure rating for floor-ceiling and interior wall partition construction that represents the ability of the construction to isolate airborne noise, where measurement procedure is based on ASTM E90-70 or ASTM E366-71 and as defined in UBC Standard No. 35-1.

(3) **Detached Single-Family Dwelling** — Any single-family dwelling which is separated from adjacent property lines by 3 feet or more or is separated from adjacent buildings by 6 feet or more.

(d) **Sound Transmission Control Between Dwelling Units.**

(1) **Wall and Floor-Ceiling Assemblies.** Wall and floor-ceiling assemblies separating dwelling units or guest rooms from each other and from public space such as interior corridors and service areas shall provide airborne sound insulation for floor-ceiling assemblies.

(2) **Airborne Sound Insulation.** All such separating walls and floor-ceiling assemblies shall provide an airborne sound insulation equal to that required to meet a Sound Transmission Class (STC) of 50 (45 is field tested) as defined in UBC Standard No. 35-1.

Penetrations or openings in construction assemblies for piping, electrical devices, recessed cabinets, bathtubs, soffits, or heating, ventilating or exhaust ducts shall be sealed, lined, insulated or otherwise treated to maintain the required ratings.

Dwelling unit entrance doors from interior corridors together with their perimeter seals shall have a Sound Transmission Class (STC) rating of not less than 30 and such perimeter seals shall be maintained in good operating condition.

(3) **Impact Sound Insulation.** All separating floor-ceiling assemblies between separate units or guest rooms shall provide impact sound insulation equal to that required to meet an Impact Insulation Class (IIC) of 50 (45 if field tested) as defined in UBC Standard No. 35-2. Floor coverings may be included in the assembly to obtain the required rating, and must be retained as a permanent part of the assembly and may only be replaced by other floor covering that provides the same sound insulation required above.

(4) **Tested Assemblies.** Field or laboratory tested wall or floor-ceiling designs having an STC or IIC of 50 or more as determined by UBC Standard 35-1, 35-2, or 35-3 may be used without any additional field testing when in the opinion of the Building Officials the laboratory tested design has not been compromised by flanking paths. Tests may be required by the Building Official when evidence of compromised separations is noted.

(5) **Field Testing.** Field testing, when required, shall be done under the supervision of a person experienced in the field of acoustical testing and engineering, who shall forward test results to the Building Official showing that the minimum sound insulation requirements stated above have been met.

(6) **Airborne Sound Insulation Field Tests.** When required, airborne sound insulation shall be determined according to the applicable Field Airborne Sound Transmission Loss Test procedures of UBC Standard No. 35-3. All sound transmitted from the source room to the receiving room shall be considered to be transmitted through the test partition.

(7) **Impact Sound Insulation Field Test.** When required, impact sound insulation shall be determined in accordance with UBC Standard No. 35-2.

(e) **Noise Insulation from Exterior Sources**

(1) **Location and Orientation.** Consistent with land use standards, residential structures located in noise critical areas, such as proximity to select system of county roads and city streets (as specified in 186.4 of the State of California Streets and Highways Code), railroads, rapid transit lines, airports, or industrial areas shall be designed to prevent the intrusion of exterior noises beyond prescribed levels with all exterior doors and windows in the closed position. Proper design shall include, but shall not be limited to, orientation of the residential structure, set-backs, shielding, and sound insulation of the building itself.

(2) **Interior Noise Levels.** Interior community noise equivalent levels (CNEL) with windows closed, attributable to exterior sources shall not exceed an annual CNEL of 43 dB in any habitable room.

(3) **Airport Noise Source.** Residential structures to be located within an annual CNEL contour (as defined in Title 4, Subchapter 6, California Administrative Code) of 60 require an acoustical analysis showing that the structure has been designed to limit intruding noise to the prescribed allowable levels. CNELs shall be as determined by the local jurisdiction in accordance with its local general plan.

NOTE: Excerpts from the 1973 UBC, Appendix Chapter 33, reproduced with permission of International Conference of Building Officials 5360 S. Workman Mill Road, Whittier, California.

(4) **Vehicular and Industrial Noise Sources.** Residential buildings or structures to be located within annual exterior community noise equivalent level contours of 60 dB adjacent to the select system of county roads and city streets (as specified in Section 186.4 of the State of California Streets and Highways Code), freeways, state highways, railroads, rapid-transit lines and industrial noise sources shall require an acoustical analysis showing that the proposed

building has been designed to limit intruding noise to the allowable interior noise levels prescribed in Section T25-1092(e)(2).

Exception: Railroads, where there are no nighttime (10:00 p.m. to 7:00 a.m.) railway operations and where daytime (7:00 a.m. to 10:00 p.m.) railway operations do not exceed four (4) per day.

(f) **Compliance.**

(1) Evidence of compliance shall consist of submittal of an acoustical analysis report, prepared under the supervision of a person experienced in the field of acoustical engineering, with the application for building permit. The report shall show topographical relationship of noise sources and dwelling site, identification of noise sources and their characteristics, predicted noise spectra at the exterior of the proposed dwelling structure considering present and future land usage, basis for the prediction (measured present and future land published data), noise attenuation measures to be applied, and an analysis of the noise insulation effectiveness of the proposed construction showing that the prescribed interior noise level requirements are met. If interior allowable noise levels are met by requiring that windows be unopenable or closed, the design for the structure must also specify the means that will be employed to provide ventilation, and cooling if necessary, to provide a habitable interior environment.

(2) **Field Testing.** Only when inspection indicates that the construction is not in accordance with the approved design, field testing may be required. Interior noise measurements shall be taken under conditions of typical maximum exterior noise levels within legal limits. A test report showing compliance or noncompliance with prescribed interior allowable levels shall be submitted to the Building Official.

SECTION 13 ASTM METHODS FOR THE MEASUREMENT OF SOUND TRANSMISSION

13.1 Laboratory Measurement of Sound Transmission

ASTM E 90-70 Laboratory Measurement of Airbone Sound Transmission Loss of Building Partitions:

Recommends the method for establishing the sound transmission loss of walls, floor/ceiling assemblies, windows, doors, etc. Laboratory conditions are specified which use two reverberant rooms in an arrangement such as that indicated in Figure 14. The one-third octave band sound level difference between the source room and receiver room is recorded at each of the 16 bands from 125 Hz to 4,000 Hz. These differences are considered along with the sound absorption of the receiver room to obtain the Sound Transmission Loss (TL) of the test partition.

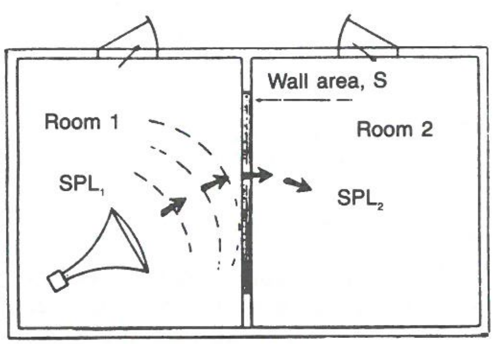


FIGURE 14: SOUND TRANSMISSION LOSS MEASUREMENT

$$NR = TL - 10 \log_{10} S + 10 \log_{10} A_2$$

TL = Transmission loss of the partition wall having S A_2 = Sound absorption in square feet in Room 2, where
$NR = SLP_1 - SLP_2$ = Sound pressure level in Room 1 minus the sound pressure level in Room 2.

13.2 Measurement In Buildings

ASTM E 336-71 Measurement or Airborne Sound Insulation in Buildings:

Specifies the method of measurement of sound transmission loss of partition elements (walls, floors, doors, etc.) which are part of or are installed in a building. Measurements of the difference in sound level across the partition are obtained at the 16 one-third octave bands from 125 Hz to 4,000 Hz and are applied to the same formula as is used in the laboratory measurements. The value derived from the test is identified as the Field Transmission Loss (FTL). A number of tests are described for the measurement across interior or exterior partitions. Table 4 summarizes the appropriate formulations. The Outdoor-to-Room test is best suited to the measurement of the FTL of windows.

13.3 STC Rating Procedure

ASTM E 413-70 Determination of Sound Transmission Class:

Specifies a method for establishing a single-figure rating of the 16 one-third octave band TL or FTL data acquired from the laboratory or field transmission loss tests. The single-rating, Sound Transmission Class (STC), is determined by fitting a standardized STC contour to the transmission loss data. Figure 15 indicates the Contour and its "best fit" to a set of TL values. The fitting procedure specifies that the STC contour is shifted vertically relative to the test data curve to as high a position as possible while fulfilling the following conditions:

a. The maximum deviation of the test curve below the contour at any single test frequency shall not exceed 8 dB.

TABLE D
MEASUREMENT OF AIRBORNE SOUND INSULATION IN BUILDINGS*

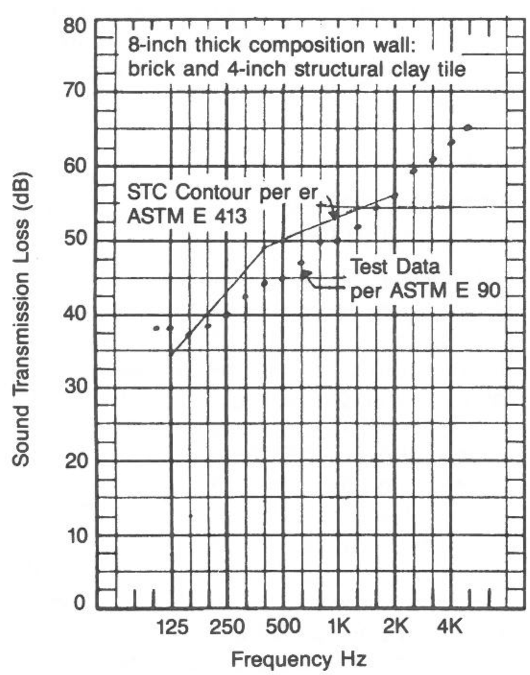
Procedure	Source Side Condition	Receiver Side Condition	Formula	ASTM Paragraph
Room-to-Room	Reverberant Room	Reverberant Room	$FTL = NR - 10 \log (A_2 / _s)$	6
Outdoor-to-Room	Outdoor Space	Reverberant Room	$FTL = NR - 6 + 10 \log \frac{1}{4} + \frac{S \cos \Phi}{A_2}$	A2.2
Room-to-Outdoors	Reverberant Room	Outdoor Space	$FTL = NR^1 - 6$	A2.3
Outdoors-to-Outdoors	Outdoor Space	Outdoor Space	$FTL = NR^1 - 6$	A2.4

*American Society for Testing and Materials (ASTM), Designation: E336-71.

FTL = Field Transmission Loss of the Partition.
NR = Noise Reduction, differences in sound pressure level between the source room and receiver rooms.
NR^1 = Noise Reduction, but with the microphone on the source side positioned directly next to the wall.
S = Area of the Partition being tested.
A_2 = Total sound absorptive area of the receiving room.
Φ = Angle of incidence of the source noise relative to a normal to the wall being tested.

b. The sum of the deficiencies at all 16 frequencies of the test curve below the contour shall not exceed 32 dB. This is an average deficiency of 2 dB.

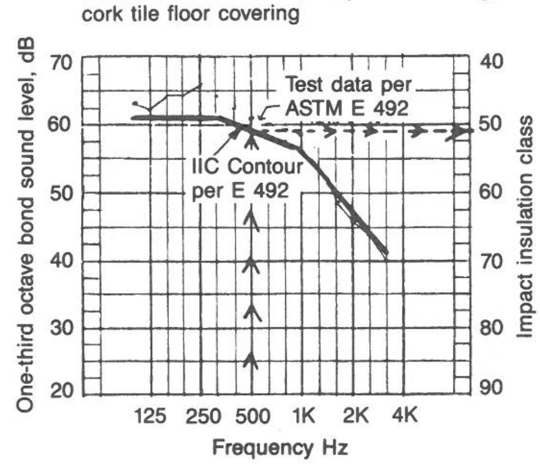
When the STC contour is thus adjusted, the STC value is read from the vertical scale of the test curve as the TL or FTL value corresponding to the intersection of the STC contour and the 500 Hz frequency line.



Sound transmission class: 50

FIGURE 15: EXAMPLE SOUND TRANSMISSION CLASS (STC) FROM TRANSMISSION LOSS (TL) TEST DATA

Hollow concrete beam, suspended ceiling, 3/16" cork tile floor covering



Impact insulation class: 51

FIGURE 16: EXAMPLE, IMPACT INSULATION CLASS (IIC) FROM TEST DATA.

13.4 Impact Sound Transmission

ASTM E 492 73 Laboratory Measurement of Impact Sound Transmission Through Floor/Ceiling Assemblies Using the Tapping Machine:

Floor/Ceiling assemblies are tested by measuring the sound pressure level in decibels in successive one-third octave frequency band of the noise generated in the room below by a standard tapping machine. To correct for receiving rooms having differing amounts of sound absorption with corresponding differences in measured sound pressure level, the measured levels are adjusted to a constant absorption value of 108 sabins (square foot units of sound absorption).

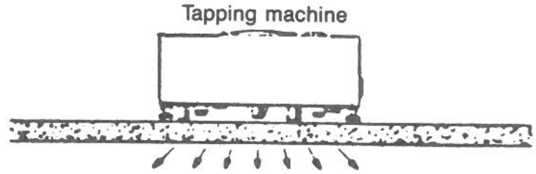
The Impact Insulation Class (IIC) is a method of rating the impact sound transmission performance of a floor/ceiling structure by means of a single number.

The IIC of the test specimen is determined by comparing the test curve with a reference frequency curve paring the test curve with a reference frequency curve (IIC Contour) as shown in the example, Figure 16.

The IIC number may then be determined by means of a transparent overlay on which the IIC contour is drawn. Applyling the overlay, the IIC contour is shifted vertically relative to the test data curve to as low a position as possible while fulfilling the following conditions:

a. The maximum deviation of the test curve above the contour at any single test frequency shall not exceed 8 dB.

b. The sum of the deviations at all 16 frequencies of the test curve above the contour shall not exceed 32 dB. This is an average deviation of 2 dB.



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