THE CARPET AND RUG INSTITUTE

P.O. Box 2048 Dalton Georgia 30722-2048
706.278.3176
carpet-rug.org

Acoustical Characteristics Of Carpet
Technical Bulletin

Carpet is an outstanding sound absorptive material. When properly selected, carpet absorbs airborne noise as efficiently as many specialized acoustical materials. Impact sound transmission to rooms below is an acoustical advantage that becomes obvious as soon as carpet is installed over previously hard-surfaced floors. The pronounced "hush" is striking. No other acoustical material performs the dual role of a floor covering and a versatile acoustical aid.

Understanding Acoustical Measurement and Test Terminology

Sound Absorption

Sound absorption coefficients, the fraction of incident sound energy that is absorbed by a material, usually vary strongly with frequency. Noise Reduction Coefficient (NRC) is used to grade the effectiveness of a material employed for sound control.

Small samples can be measured by the impedance tube method while larger specimens can be measured by the reverberation room method. Reverberation room coefficients are usually provided as a single number, (NRC). This is the average of the coefficients at 250, 500, 1000, and 2000 Hz (from low to high pitched sounds.)

Sound Transmission

Transmission through walls, floors, and other barriers is much greater for low frequency sounds than for high frequency sounds.

Sound transmission is measured between two reverberation rooms for at least 16 standard frequency bands. For convenience in comparison of different constructions, the sound transmission class (STC) rating condenses sound transmission information into a single number according to ASTM E-413. STC is fairly accurate for human speech; however, for low frequency sound such as a motor, fan, or even music strong in bass, the perceived sound may be greater than that indicated by STC.

Impact Noise

To evaluate transmission of impact sound through a floor, a standard tapping machine is used in accordance with ASTM E-492. This test consists of five hammers striking the floor at a total rate of ten times a second. Sound pressure in 16 frequency bands (or levels) is measured in a reverberation room below the floor and used to calculate a single figure impact insulation class (IIC), ASTM standard E-989 (A deficiency of the tapping machine is that footfalls generate annoying, low frequency sounds that are difficult to measure because the wavelength of the sound is so long compared to the test room dimensions.)

Impact Noise Rating (INR) is a single figure rating of the sound insulation provided by a floor-ceiling assembly from an impact noise. Sound levels are measured in an isolated room beneath the ceiling with a standard tapping machine on the floor above, i.e., floor-ceiling assembly. The data is related to a minimum standard of “zero” INR. Assemblies rating less than zero (minus INR) are deemed unsatisfactory. Assemblies rating more than zero (plus INR) are deemed superior. The INR criterion was developed by HUD as a minimum standard for multifamily dwellings (FHA Guide #750 - “Impact Noise Control in Multifamily Dwellings”).

The IIC rating system differs from INR, not in the test procedure, but in the numerical scale applied. IIC rates floor-ceiling assemblies with positive numbers only in ascending degrees of efficiency - the higher the rating, the greater the sound insulation. As a rule of thumb, INR ratings can be converted to IIC ratings simply by adding 51 to the plus or minus INR number. However, the conversion is not accurate in every case and should serve only as an estimate.

Acoustical Test Programs

A comprehensive test program has established distinct acoustical characteristics of carpet. A summary of the laboratory test studies follows.

Test Program A (Airborne Sound Reduction)

The first program was conducted to determine whether carpet is capable of significant sound absorption of airborne sound. Various representative carpet and carpet systems were tested in accordance with ASTM C-423 “Sound Absorption of Acoustical materials in Reverberation Rooms.” Standard sound absorption measurements were made with and without various types of cushion underlay. The results showed that many of the carpets tested in combination with 40 oz/sy hair jute cushions had NRCs equal to many acceptable special absorption materials, i.e., NRCs from 0.50 - 0.60.

Individual test series, A-1, A-2, and A-3, resulted in data which supported the distinct advantage offered by carpet and carpet assemblies in the absorption of sounds.

Test Series A-1. Carpet was placed directly on the concrete floor of the test chamber.

TEST A-1 Commercial Carpet Laid Directly on Concrete				
Test Variables	Pile Weight oz/sy	Pile Height inches	Surface	NRC
identical construction, different manufacturers	44	.25	loop	.30
	44	.25	loop	.30
	44	.25	loop	.30
identical construction, different pile surfaces	35	.175	loop	.30
	35	.175	cut	.35
pile weight/height relationships in cut pile carpet	32	.562	cut-nylon	.50
	36	.43	cut-acrylic	.50
	43	.50	cut-wool	.55
increasing pile weight/height relationships in woven wool loop pile carpet	44	.25	loop	.30
	66	.375	loop	.40
	88	.50	loop	.40
increasing pile weight (pile height constant) in tufted loop pile carpet	15	.25	loop-nylon	.25
	40	.25	loop-wool	.35
	60	.25	loop-wool	.30
varying pile height (pile weight constant) loop pile with regular back		.125	loop	.15
		.187	loop	.20
		.250	loop	.25
		.437	loop	.35
varying pile height (pile weight constant) loop pile with foam back		.187	loop	.25
		.250	loop	.30
		.312	loop	.35
		.437	loop	.40

Observations: A-1

1. Carpet tested in this program, which were laid directly on concrete, had NRCs ranging between .15 and .55.
2. It was found that when manufacturers met identical specifications, their fabrics have the same NRCs. However, the sound absorption coefficients at individual frequencies varied somewhat.
3. Cut pile carpet, because it provides more “fuzz,” provides a greater NRC than loop pile construction in otherwise identical specifications.
4. As pile weight and/or pile height increases in cut pile construction, the NRC may not change substantially.
5. Increasing pile weight while increasing or holding pile height constant in a loop pile construction resulted in sound absorption “topping out” because the surface does not change in absorptivity at higher frequencies.
6. Increasing pile height while holding pile weight constant in loop pile fabrics results in improvements in absorption. Loop pile carpets average NRC values of .20 to .35.
7. Foam-backed loop construction resulted in an increased NRC value compared to conventional secondary backed carpet.

Test Series A-2. Carpet was placed over a 40 ounce per square yard hair cushion on the concrete floor to determine the sound absorption benefits of cushion under carpet.

TEST A-2 Carpet over 40 oz/sy Hair Cushion				
Pile Weight oz/sy	Pile Height inches	Surface	NRC Without Cushion	NRC With Cushion
44	.25	loop[1]	.30	.40
32	.56	cut[2]	.50	.70
43	.50	cut[3]	.55	.70
Note: 40 oz/sy hair cushion, NRC 0.25 - [1]woven wool - [2]tufted nylon - [3]tufted wool				

Observations: A-2

1. As a general rule, the more permeable the carpet backing, the more sound energy can penetrate into the cushion and the higher the resulting NRC.
2. In this test, installing carpet over a 40 ounce per square yard hair cushion can increase the NRC by .10 to .20.

Test Series A-3. The purpose of this series of tests was to discover to what effect various weights and types of cushions have on NRC when tested with a control carpet. The test carpet was a 40 ounce per square yard pile weight, a .390 inch pile height with a loop pile construction typical of many commercial carpets.

TEST A-3 40 oz/sy Carpet with Various Cushion Types		
Cushion Weight oz/sy	Cushion Material	NRC
32	hair	.50
40	hair	.55
54	hair	.55
86	hair	.60
32	hair jute	.55
40	hair jute	.60
86	hair jute	.65
31	3/8 inch foam rubber	.60
44	sponge rubber	.45
86	3/8 inch sponge rubber	.50
Note: 40 oz/sy tufted wool, 0.39 inch pile height, loop pile control carpet on bare floor. NRC = .35		

Observations: A-3

1. For acoustical purposes, permeability was the most critical construction factor. The more permeable hair, hair-jute, and foam rubber cushions tend to produce higher NRCs than the less permeable, rubber-coated, hair-jute and sponger rubber cushions, weight for weight.
2. A sponger rubber cushion bonded to carpet was tested and produced an NRC of only .30. This indicated that some permeability caused by air spaces between layers of carpet and cushion would cause a variance in the NRC factor.
3. Carpet over cushion gives better NRC values than carpet over concrete. Cushion with higher weight and thickness improves NRC.

Test Program B (Impact Sound Insulation)

Two series of impact noise transmission tests were made to determine the Impact Noise Rating (INR) of carpet and cushion combinations.

In order to measure the ability of a floor covering to insulate a floor-ceiling assembly from transmitting impact noise, a standard means of generating measured impacts is used. The method employs an ISO R-140 Tapping Machine on the test floor of the floor-ceiling assembly. See Figure 1. The resulting sound levels are measured by means of a microphone located in an isolated room below. The results are reported as an Impact Noise Rating (INR) or as an Impact Insulation Class (IIC).

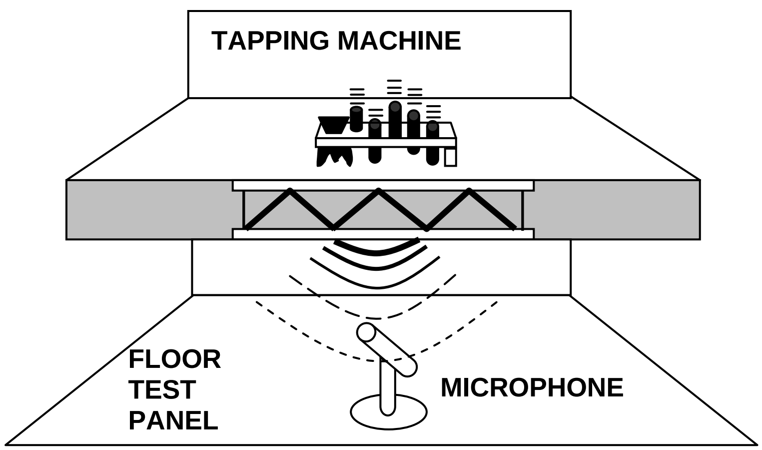

Figure 1. IMPACT NOISE TESTING FACILITY

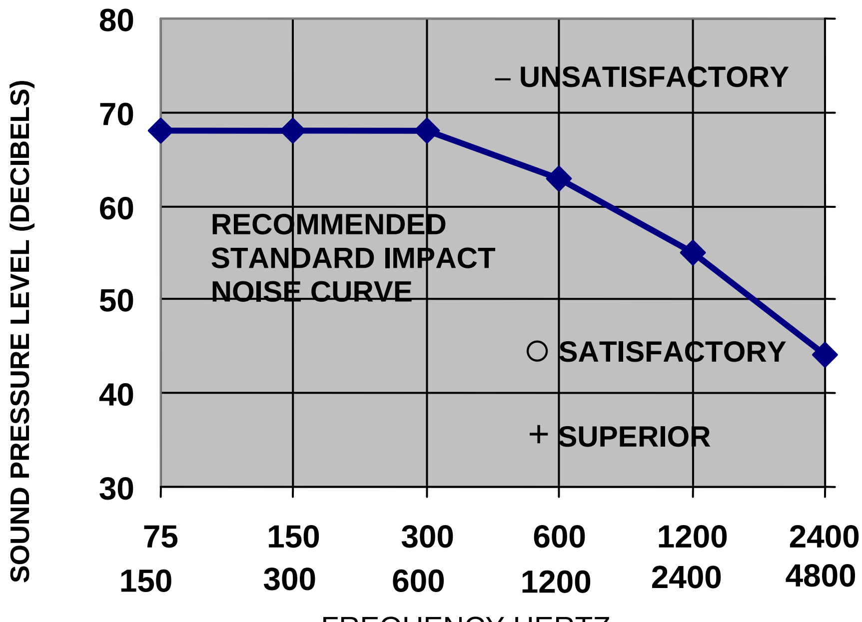

Figure 2. STANDARD IMPACT NOISE CURVE - INR

Impact Sound Transmission data is measured in a series of continuous 1/3 octave frequency bands over a range of 100 to 3,150 hertz. FHA's Guide #750 recommends a minimum standard noise curve. Any flooring achieving this standard curve isolation has a minimum "zero" Impact Noise Rating (INR). If the measured impact noise value falls above the standard noise curve, the construction has a minus (or less satisfactory) INR number. If below the curve, the construction has a plus (or superior) INR number. See Figure 2.

In Test B-1 the impact noise transmission of several carpet cushion and cushion types was conducted on a concrete slab floor-ceiling assembly. Following are the carpet construction details used in this series of tests.

CARPET KEY					
Carpet	Type	Surface	Pile Wt. oz/sq yd	Pile Ht. inches	Fiber Content
1	tufted	H-L loop	20	.15-.35	wool
2	tufted	loop	27	.20	olefin
3	tufted	cut	32	.56	nylon
4	tufted	cut	36	.44	acrylic
5	tufted	loop	40	.25	wool
6	woven	loop	44	.25	wool
7	tufted	loop	60	.25	wool
8*	woven	loop	44	.25	wool
*with attached 3/16 inch sponge rubber cushion					

Following are the test results of the above carpets on a concrete slab floor-ceiling assembly.

TEST B-1 Concrete Slab Floor-Ceiling Assembly			
Carpet	Cushion	INR Impact Noise Rating	IIC Impact Insulation Class
Bare Floor	---	-17	34
1	none	+2	53
2	none	+4	55
3	none	+6	57
4	none	+8	59
5	none	+9	65
6	none	+14	68
7	none	+18	70
8	attached 3/16 inch sponge rubber	+17	69
6	40 oz/sy yd hair-jute	+22	73
6	polyurethane foam	+24	76
6	44 oz/sy yd sponge rubber	+25	79
6	31 oz/sy yd 3/8 inch foam rubber	+28	79
6	80 oz/sy yd sponge rubber	+29	80

Observations: B-1

1. In the carpet test without cushion, carpet with the greater pile weights scored the highest INR.
2. In the carpet test with cushion, the order of efficiency shifted. Sponge rubber cushion, which had the lowest NRC characteristic, scored the highest INR.
3. In these tests, weight for weight, foam rubber cushion delivered the larger INR number.
4. Cushion materials, in general, add significantly to increased INR values.

Test Series B-2. Carpet samples 6 and 8 were selected and tested on a standard wood joist floor-ceiling assembly with a 5/8 inch tongue and groove plywood subfloor.

TEST B-2 Wood Joist Floor-Ceiling Assembly			
Carpet	Cushion	INR Impact Noise Rating	IIC Impact Insulation Class
Bare Floor	--	-19	32
8	attached 3/16 inch sponge rubber	+3	54
6	40 oz/sy yd hair-jute	+10	61
6	polyurethane foam	+12	63
6	44 oz/sy yd sponge rubber	+14	65
6	31 oz/sy yd 3/8 inch foam rubber	+16	67
6	80 oz/sy yd sponge rubber	+17	68

Observations: B-2

1. Impact Noise Ratings were all lower than that found in Test Series B-1. Various cushion/carpet combinations yielded substantially lower INR values for wood joist floors than for concrete floors.
2. Test Series B-1 has already shown that as pile weight increases, the INR increases. The assumption is also true with wood joist construction, but probably with lower relative ratings.

Testing for Sound Transmission Class (STC) of a residential carpet installed with cushion over a joist and plywood sub-floor

Tested Materials: Carpet and cushion – 25 ounces per square yard 100% nylon cut pile residential carpet installed over bonded polyurethane bonded cushion ½ inch thickness with 6.0 lb/ft^3 density.
Test Floor: Open Joist 2000 system, 13 inches deep installed 24 inches on center. Sub-floor 5/8 inch thick T&G plywood. Bridging of continuous 2X4 inch wood nailed to bottom chord and the sides of the diagonals with 2 inch long nails. Cellulose insulation with density of 1.6 pcf, 51/2 inches thick was used. Resilient channels of 24 gauge galvanized steel placed 16 inches on center and attached to bottom chords with screws. Ceiling of gypsum board of 5/8 inches thick. Sheets fastened to resilient channels by means of 1 ½ inch screws, spaced 6 inches on center. Joints taped and finished with two layers of compound.
Procedure: Sound transmission loss was determined per ASTM E90-87, Standard Test Method for Laboratory Measurement of Sound Transmission Loss in Building Partitions, by mounting and perimeter sealing the test specimen (carpet over cushion) as a partition between two reverberation rooms. Sound is introduced in one of the rooms (the source room) and measurements made of noise reduction between the source room and the receiving room. The rooms are so arranged and constructed that the only significant sound transmission between them is through the test specimen.
Results of Test: Sound Transmission Classification was found to be 49 per ASTM E413-94, Classification for Rating Sound Insulation

Overall Conclusions about Carpet and Sound:

Carpet is highly effective in controlling noise in buildings by absorbing airborne sound, reducing surface noise generation, and reducing impact sound transmission to rooms below. Properly specified carpet/cushion combinations have proven to handle the vast majority of sound absorption requirements in architectural spaces. Specifying for critical areas such as theaters, broadcast studios, and open plan office areas may require full details of impact insulation properties and noise absorption characteristics.