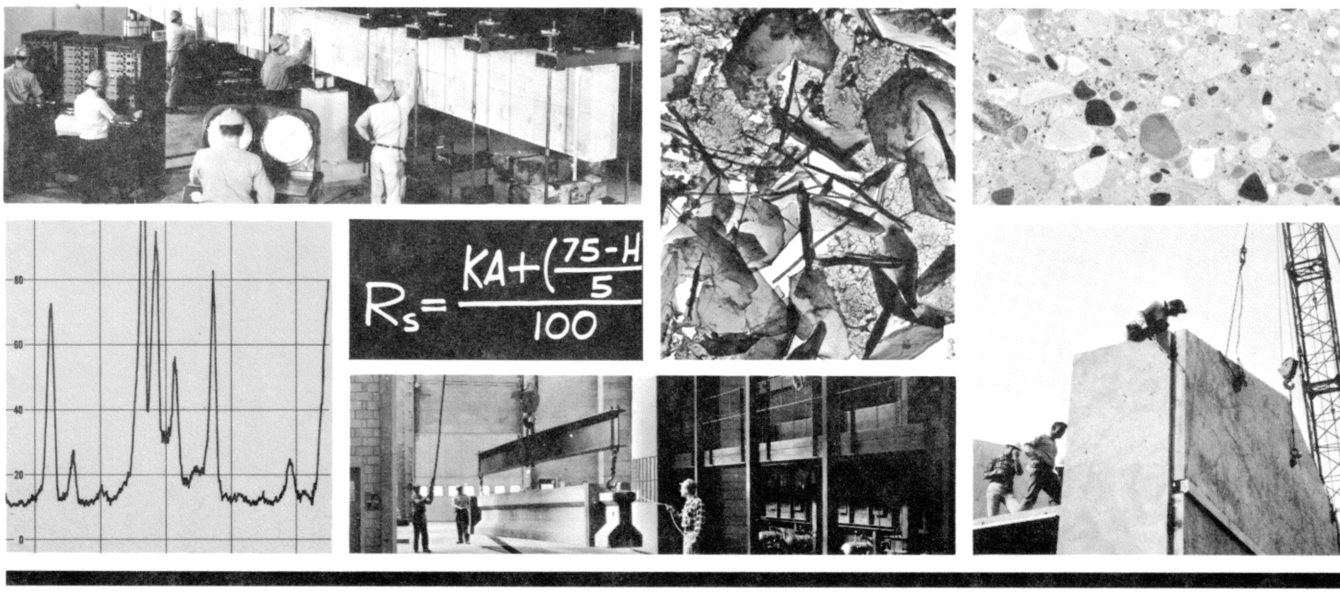
RESEARCH AND DEVELOPMENT BULLETIN RD066



Sound Transmission Loss Through Concrete and Concrete Masonry Walls

by Albert Litvin and Harold W. Belliston

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PORTLAND CEMENT ASSOCIATION

Research and Development / Construction Technology Laboratories

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by Albert Litvin and Harold W. Belliston*

■ BUILDING CODES AND GOVERNMENTAL agencies have, for many years, set limits on the amount of noise that can be transmitted through building components from one space to another.[1-4†] In recent years, there has been a greater awareness of the adverse effects of excess noise on personal health and comfort, work efficiency, and privacy. Consequently methods of obtaining increased sound insulation in buildings are needed.

The efficiency of a wall in restricting the passage of airborne sound is measured in the laboratory using the procedure outlined in "Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions" (ASTM E 90).[5] Measurements are made of sound transmission loss (STL) in decibels (db) for a series of frequencies ranging from 125 to 4000 Hz.

"Determination of Sound Transmission Class" (ASTM E 413)[6] describes a method for using the transmission loss values, determined as above, to arrive at a single figure rating for comparing the effectiveness of walls in resisting the transmission of airborne sound. This is defined as the sound transmission class (STC). It is determined by fitting the proper STC contour (ASTM E 413) to the plot of sound transmission loss vs frequency (ASTM E 90). The STC is then equal to the transmission loss at 500 Hz.

A number of factors affect sound transmission loss through walls. Weight per sq ft (mass) of the wall has a major effect, and is sometimes used as a guide for determining transmission loss. The "mass law" indicates that transmission loss should increase 6 db when either the weight or the frequency is doubled.

Other factors that affect sound deadening characteristics are stiffness of the wall and presence of resonant and coincident frequencies. Because of overlapping of the effects of the various factors involved, it is difficult to determine by analysis the transmission loss of a particular panel. Most designs, therefore, rely on STC values determined in the laboratory.

Most housing codes require minimum STC values of about 45 for partitions where living units adjoin other living units. Values of about 50 are required where living units adjoin public spaces or service areas. The mass and stiffness of concrete and concrete masonry walls generally put them in a range where they have little trouble meeting present day STC requirements.

Tests reported in this paper provide STC values for commonly used concrete and concrete masonry walls and on walls that were upgraded to improve their sound transmission properties. For convenience in selecting walls for specific applications and STC requirements, selected STC values obtained by others on a variety of wall types are included in this report.

TEST PROGRAM

Specimens

Three basic concrete wall specimens were fabricated for these tests. Two were cast-in-place concrete and the third was concrete masonry.

Structural concrete panels, 14 ft, 4 in. (4.37 m) wide by 9 ft, 4 in. (2.84 m) high, were cast in thicknesses of 6 and 8 in. (152 and 203 mm). An air-entrained, sand and gravel concrete, representative of wall construction, was used. Concrete strengths at 28 days were 5610 and 4580 psi (38.7 and 31.6 MPa) for the 6 and 8 in. (152 and 203 mm) thick panels, respectively. Corresponding unit weights of the fresh concretes were 145 and 142 pcf (2323 and 2275 kg/m^3). The panels were cured for a minimum of 28 days before sound transmission loss tests were started. In addition to tests on the bare concrete panels, wall finishing materials were added to permit determination of their effect on sound transmission.

A masonry wall, 14 ft (4.26 m) wide by 9 ft (2.74 m) high, was constructed using nominal

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*Principal construction consultant and former construction engineer, respectively, Construction Methods Section, Portland Cement Association.

† Superscript numbers that are not part of measurements designate references at the end of this report.

TABLE 1—SOUND TRANSMISSION CLASS (STC)—PCA TESTS

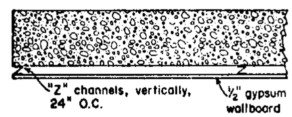
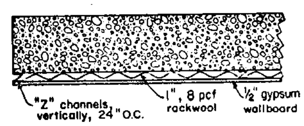
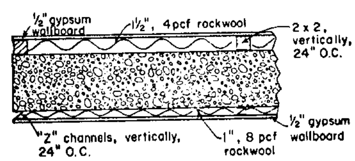
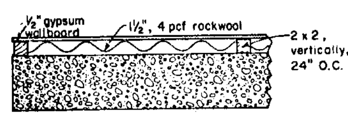
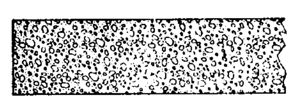
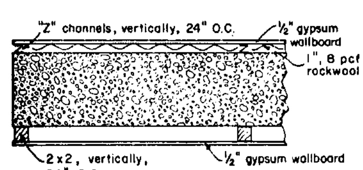
Test No.	Description of wall: Side 1	Description of wall: Side 2	Construction of walls	Approximate wall weight, psf	Measured STC
6 in. cast concrete walls					
76-66	Plain	Plain		71.0	57
76-68	Plain	"Z" furring channels plus ½ in. gypsum board		72.5	59
76-69	Plain	"Z" furring channels plus 1 in. 8 pcf rockwool plus ½ in. gypsum board		75.5	62
76-70	2 x 2 in. wood furring plus 1½ in. 4 pcf rockwool plus ½ in. gypsum board	"Z" furring plus 1 in. 8 pcf rockwool plus ½ in. gypsum board		78.5	63
76-71	Plain	2 x 2 wood furring plus 1½ in. 4 pcf rockwool plus ½ in. gypsum board		73.0	63
8 in. cast concrete walls					
76-77	Plain	Plain		96.6	58
76-78	"Z" furring plus 1 in. 8 pcf rockwool plus ½ in. gypsum board	2 x 2 in. wood furring plus ½ in. gypsum board		101.6	59

TABLE I (Cont.)—SOUND TRANSMISSION CLASS (STC)—PCA TESTS

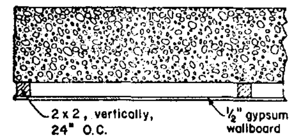
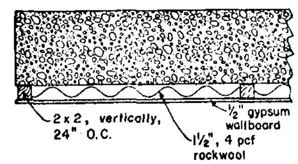
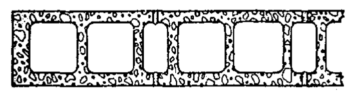
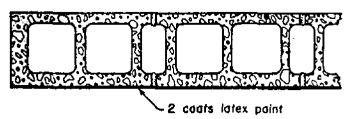
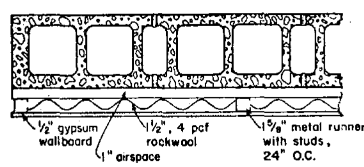
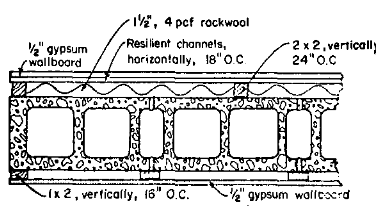
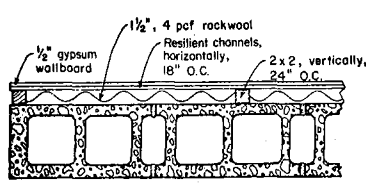
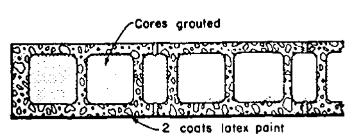
Test No.	Description of wall: Side 1	Description of wall: Side 2	Construction of walls	Approximate wall weight, psf	Measured STC
8 in. cast concrete walls					
76-79	Plain	2 x 2 in. wood furring plus ½ in. gypsum board		97.0	59
76-99	Plain	2 x 2 in. wood furring plus 1½ in. 4 pcf rockwool plus ½ in. gypsum board		97.2	63
8 in. lightweight concrete block walls					
76-75	Plain	Plain		32.0	44
76-76	Plain	2 coats acrylic latex paint		32.0	48
76-72	Plain	1 in. air space plus 1⅝ in. metal runner with studs with 1½ in. 4 pcf rockwool plus ½ in. gypsum board		35.0	59
76-73	2 x 2 in. wood furring vertically at 24 in. plus resilient channels horizontally at 18 in. plus 1½ in. 4 pcf rockwool plus ½ in. gypsum board	1 x 2 in. furring at 16 in. plus ½ in. gypsum board		38.0	57
76-74	2 x 2 in. wood furring vertically at 24 in. plus resilient channels horizontally at 18 in. plus 1½ in. 4 pcf rockwool plus ½ in. gypsum board	Plain			58
76-104	Cores of block grouted, painted	Cores of block grouted, plain		89.0	56

TABLE 2—STC VALUES REPORTED IN THE LITERATURE FOR WALLS

Reference	Description of wall	Wall weight, psf	Reported STC
8	4 x 8 x 16 in. concrete masonry units, both sides plain	18	40
8	4 x 8 x 16 in. concrete masonry units, both sides plain	27	45
8	4 x 8 x 16 in. concrete masonry units, both sides painted	22	43
8	4 x 8 x 16 in. concrete masonry units, both sides ½ in. plaster	30	48
8	4 x 8 x 16 in. concrete masonry units, both sides ½ in. plaster	42	50
8	4 x 8 x 16 in. concrete masonry units, both sides ½ in. gypsum wallboard	26	47
8	4 x 8 x 16 in. concrete masonry units, both sides ½ in. gypsum wallboard	32	48
8	6 x 8 x 16 in. concrete masonry units, both sides plain	21	44
8	6 x 8 x 16 in. concrete masonry units, both sides painted	28	46
8	6 x 8 x 16 in. concrete masonry units, both sides painted	39	48
8	6 x 8 x 16 in. concrete masonry units, both sides ½ in. plaster	31	46
8	6 x 8 x 16 in. concrete masonry units, both sides ½ in. plaster	54	52
8	6 x 8 x 16 in. concrete masonry units, both sides ⅝ in. gypsum wallboard	35	49
8	6 x 8 x 16 in. concrete masonry units, one side ½ in. gypsum wallboard, other side painted	27	53
8	8 x 8 x 16 in. concrete masonry units, both sides plain	30	45
8	8 x 8 x 16 in. concrete masonry units, both sides plain	53	52
8	8 x 8 x 16 in. concrete masonry units, both sides painted	30	46
8	8 x 8 x 16 in. concrete masonry units, both sides painted, cores grouted and reinforced	73	55
8	8 x 8 x 16 in. concrete masonry units, one side plaster, other side plain	38	52
8	8 x 8 x 16 in. concrete masonry units, both sides plaster	67	56
8	8 x 8 x 16 in. concrete masonry units, both sides plaster, cores grouted and reinforced	79	56
8	Composite wall, 4 in. brick, 4 in. concrete masonry units, block side plaster	61	53
8	8 x 8 x 16 in. concrete masonry units, one side ½ in. gypsum wallboard	40	56
8	8 x 8 x 16 in. concrete masonry units, both sides ½ in. gypsum wallboard, cores grouted and reinforced	77	60
8	Composite wall, 4 in. brick, 4 in. concrete masonry units, ½ in. gypsum wallboard on block side	60	56
9	9 in. brick wall, both sides ½ in. plaster	100	52
9	Double wall of 4½ in. brick leaves separated by 2 in. air cavity, no ties, ½ in. plaster on exposed surfaces	100	54
9	4 x 8 x 16 in. concrete masonry units, both sides ⅝ in. sanded gypsum plaster	36	46
9	6 in. thick cast concrete, both sides ½ in. plaster	80	53

8 x 8 x 16 in. (203 x 203 x 406 mm) lightweight concrete masonry units. The units were laid using ASTM C 270 Type N[7] masonry cement mortar. The mortar joints were ⅜ in. (10 mm) high and were tooled on both sides of the wall. After the wall was assembled, sound transmission loss tests were made on the bare wall. Next, wall finishing materials were added and the tests were repeated.

The test walls and details of the surface variations are listed in Table 1.

Test procedure

Sound transmission loss measurements were made by the Riverbank Acoustical Laboratories following procedures outlined in ASTM E 90-75. Measurements were made using a one-third octave band of "pink" noise from 100 to 5000 Hz, as recommended in ASTM E 90-75. The sound transmission values were tabulated at 18 specified standard frequencies. All STC values were computed in accordance with ASTM E 413-73.

Each of the three walls was tested without any surface treatment. Tests were next made on the walls to determine the effect of additions to the wall surfaces. Gypsum wallboard, acoustical insulation, paint, and resilient fastenings were added.

TEST RESULTS

PCA tests

The tests are summarized in Table 1. As indicated in Table 1, bare concrete and concrete masonry walls commonly meet current STC requirements of 45 to 50 for buildings. However, to provide data needed to obtain higher STC values, concrete walls were acoustically upgraded to determine values that could reasonably be achieved. The tests indicate that STC values in excess of those obtained would be difficult and costly to achieve. Consequently, requirements for higher values would significantly increase the cost of construction.

With the addition of wall finishes, sound transmission class values up to 63 were obtained on both the 6 and 8 in. (152 and 203 mm) cast concrete walls. It should be noted that the 6 and 8 in. (152 and 203 mm) plain walls had STC values of 57 and 58, respectively. These are considerably higher than most current code requirements.

The plain masonry wall had an STC of 44. Most of the normal wall finishing techniques provided STC values that significantly exceeded present day requirements. Even application of paint brought the masonry wall above the minimum requirement of 45. The grouted wall with one side painted had an STC of 56, very close to that of the cast concrete walls. Based on the increase in STC obtained by the addition of furring, gypsum wallboard, and acoustic insulation, it is apparent that the addition of these materials to the grouted wall would have resulted in an STC of 60 or greater.

Tests by others

Sound transmission measurements have been made on a wide variety of wall constructions. The STC values obtained from these measurements have appeared in the literature or been reported by governmental agencies, trade associations, and private companies. Table 2 lists STC values for a variety of wall types as reported by some of the above sources.

SUMMARY

Concrete and concrete masonry walls generally meet minimum STC requirements for partitions in living units. Tests reported in this paper were made on walls treated to upgrade their sound transmission loss properties. Results indicate that significant sound insulation can be obtained even with relatively inexpensive procedures.

Sound transmission loss tests were made on 6 and 8 in. (152 and 203 mm) thick cast concrete walls and on a wall constructed of nominal 8 x 8 x 16 in. (203 x 203 x 406 mm) lightweight concrete masonry units. Sound insulation was changed by the addition of several combinations of furring, sound insulation blankets, and gypsum wallboard. Tests to determine sound transmission loss were made in accordance with ASTM E 90. Sound transmission loss (STC) was determined using the procedures of ASTM E 413.

With the addition of furring, insulation, and wallboard, STC values up to 63 were obtained on both the 6 and 8 in. (152 and 203 mm) thick concrete walls. The highest value obtained on the masonry wall was 59. However, the data indicate that a somewhat higher STC would have been obtained from a grouted wall with furring, insulation and wallboard attached.

STC values, obtained by other investigators, for a variety of concrete wall constructions are included.

ACKNOWLEDGMENTS

All sound transmission tests were performed by the Riverbank Acoustical Laboratories, Geneva, Ill., under contract to the Portland Cement Association.

Assistance on planning the test walls and interpreting the test results was given by Allen H. Shiner, Acoustical Engineer, Skokie, Ill., and Keith Walker, U. S. Gypsum Acoustical Laboratory, Round Lake, Ill. E. A. Valko, Senior Technician, assisted in preparing the walls for testing. W. G. Corley, Director, Engineering Development Department, reviewed the text of this report and suggested valuable changes.

REFERENCES

1. "Sound Transmission Control in Residential Buildings," *BOCA Basic Building Code*, Building Officials and Code Administrators International, Inc., Chicago, 1976 Supplement, Section 522.

2. *Southern Standard Building Code,* Southern Building Code Congress, Birmingham, 1976, Appendix E.

3. *National Building Code,* American Insurance Association, New York, 1976, Section 380.13.

4. "Sound Transmission Limitations," *Minimum Property Standards for Multifamily Housing,* Department of Housing and Urban Development, Washington, D. C., Apr. 1977, Table 4-4.1.

5. "Standard Method for Laboratory Measurement of Airborne-Sound Transmission Loss of Building Partitions," (ASTM E 90-75), *1976 Annual Book of ASTM Standards,* Part 18, American Society for Testing and Materials, Philadelphia, pp. 667-679.

6. "Standard Classification for Determination of Sound Transmission Class," (ASTM E 413-73), *1976 Annual Book of ASTM Standards,* Part 18, American Society for Testing and Materials, Philadelphia, pp. 819-821.

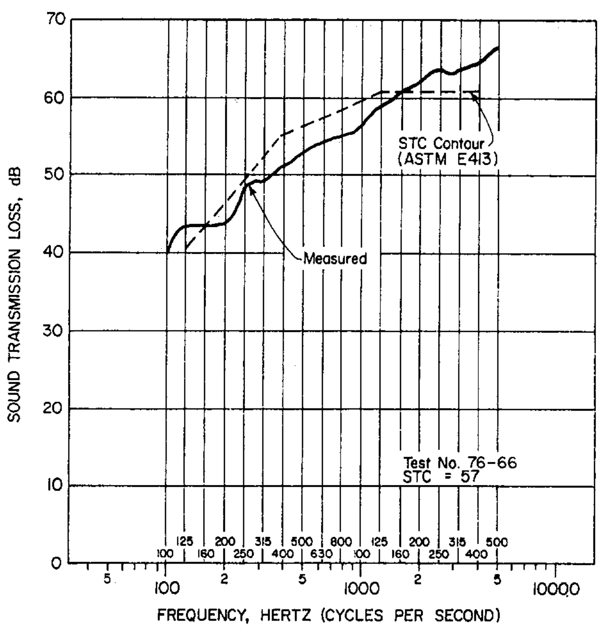
7. "Standard Specification for Mortar for Unit Masonry," (ASTM C 270-73), *1976 Annual Book of ASTM Standards,* Part 13, American Society for Testing and Materials, Philadelphia, pp. 243-247.

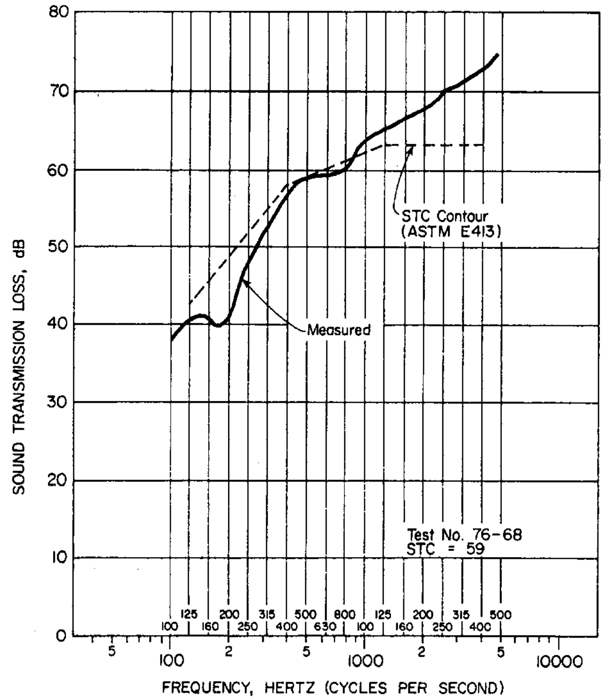
8. "New Data on Sound Reduction With Concrete Masonry Walls," NCMA-TEK 69.A, National Concrete Masonry Association, McLean, Va., 1978, 4 pp.

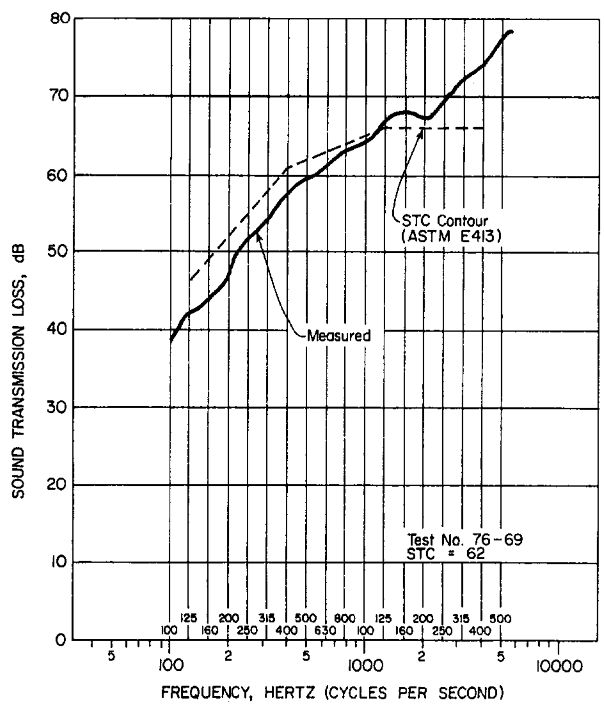
9. "A Study of Techniques to Increase the Sound Insulation of Building Elements," *Wyle Laboratories Report* No. 73-5, Department of Housing and Urban Development, Washington, D. C., June 1973, 216 pp.

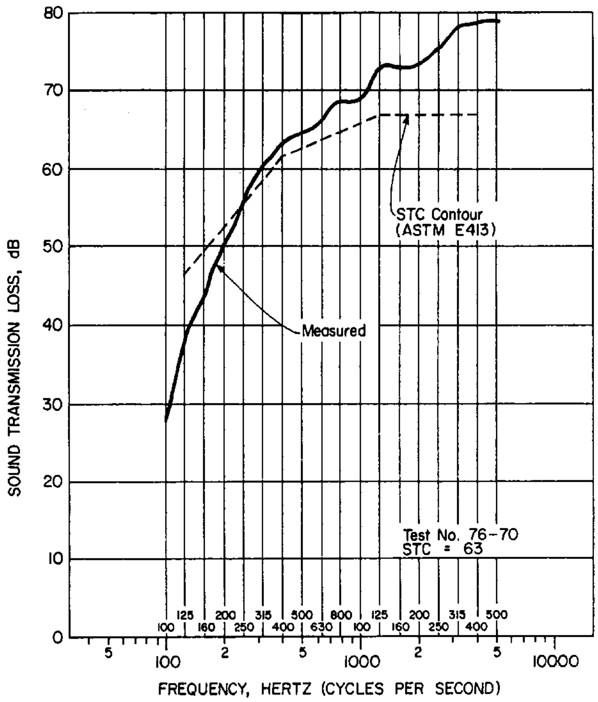
APPENDIX

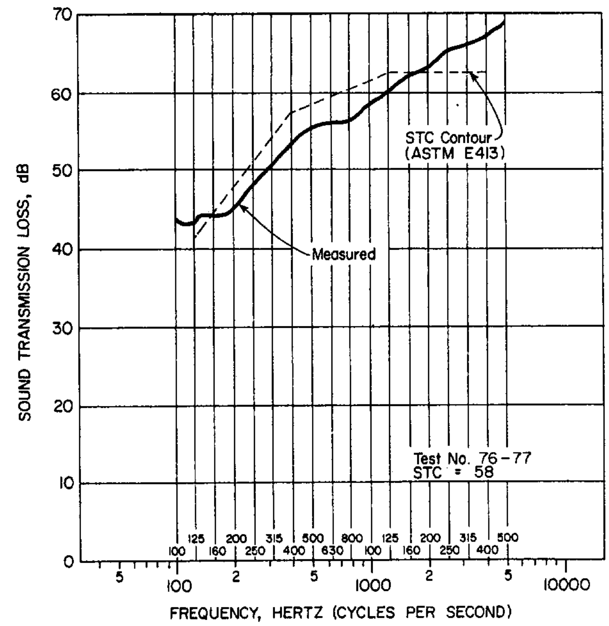
For certain applications, the use of sound transmission class (STC) values is not sufficient. For those who require additional data, sound transmission loss values versus frequency were plotted. Figures for each specimen tested are presented here. Test numbers shown correspond with test numbers in Table 1 of the text.

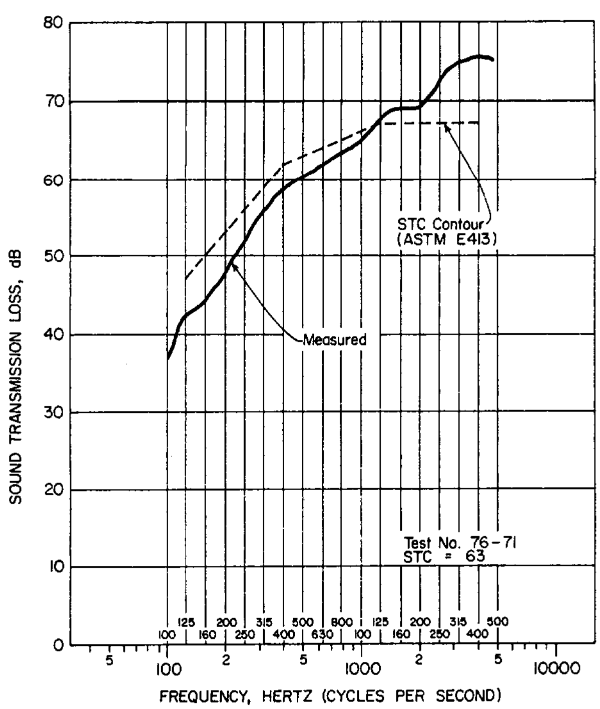


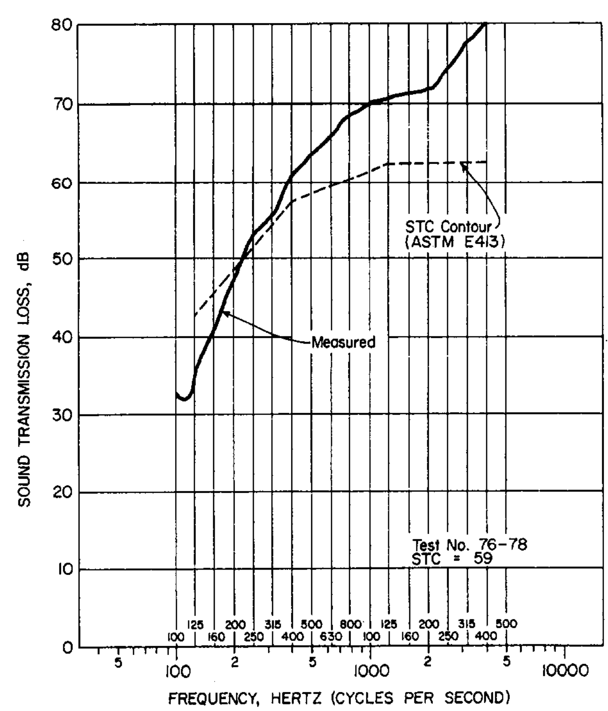


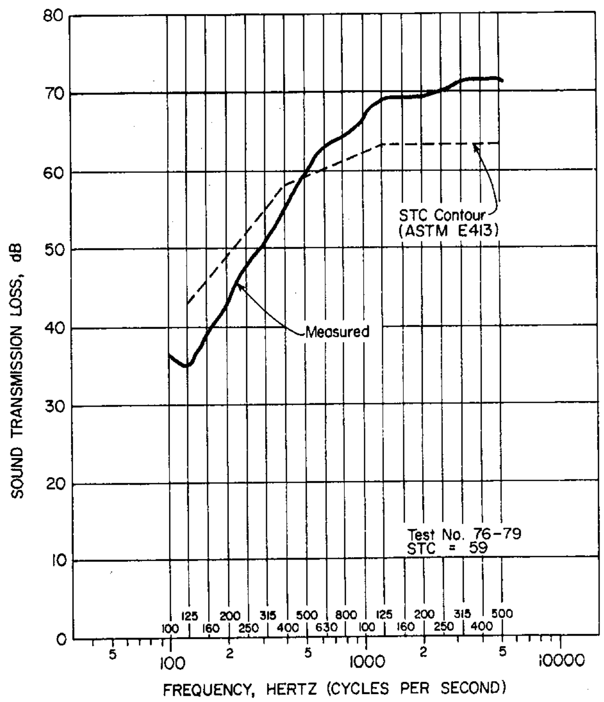


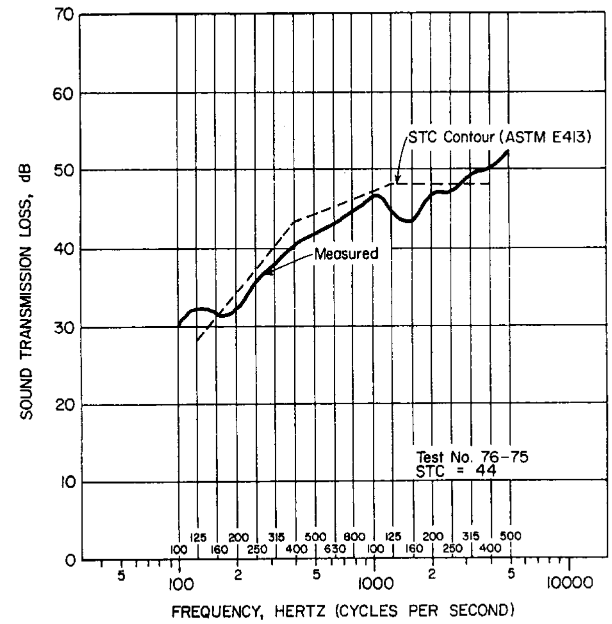

STC Contour
(ASTM E413)
Measured
Test No. 76-70
STC = 63
SOUND TRANSMISSION LOSS, dB
FREQUENCY, HERTZ (CYCLES PER SECOND)

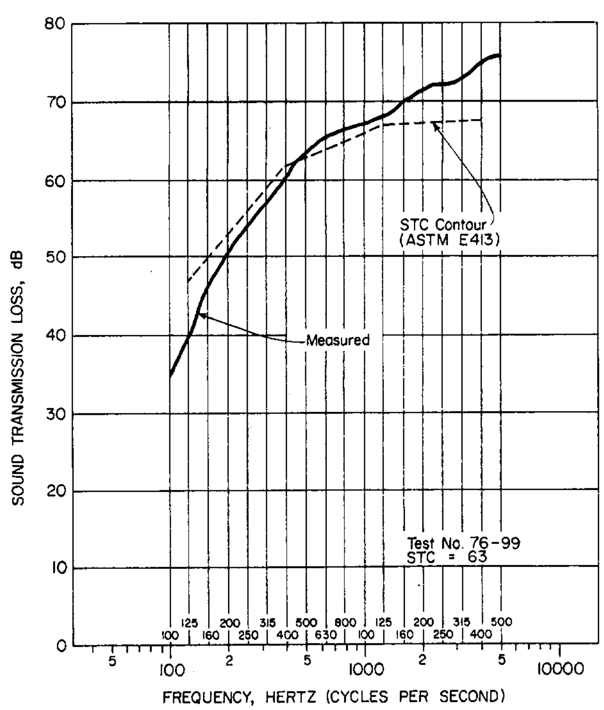

STC Contour
(ASTM E413)
Measured
Test No. 76-77
STC = 58
SOUND TRANSMISSION LOSS, dB
FREQUENCY, HERTZ (CYCLES PER SECOND)

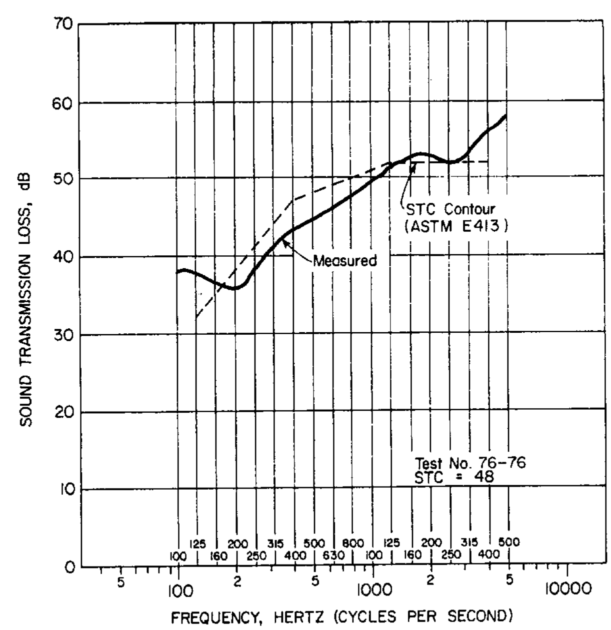

STC Contour
(ASTM E413)
Measured
Test No. 76-71
STC = 63
SOUND TRANSMISSION LOSS, dB
FREQUENCY, HERTZ (CYCLES PER SECOND)

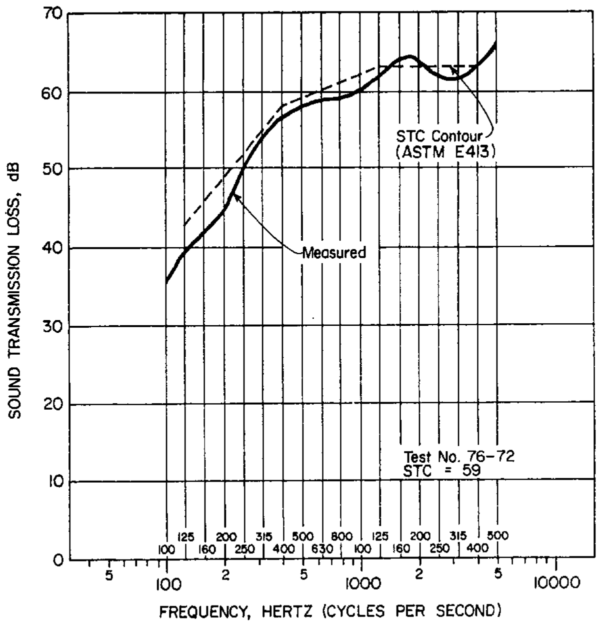

STC Contour
(ASTM E413)
Measured
Test No. 76-78
STC = 59
SOUND TRANSMISSION LOSS, dB
FREQUENCY, HERTZ (CYCLES PER SECOND)


SOUND TRANSMISSION LOSS, dB
STC Contour (ASTM E413)
Measured
Test No. 76-79
STC = 59
FREQUENCY, HERTZ (CYCLES PER SECOND)

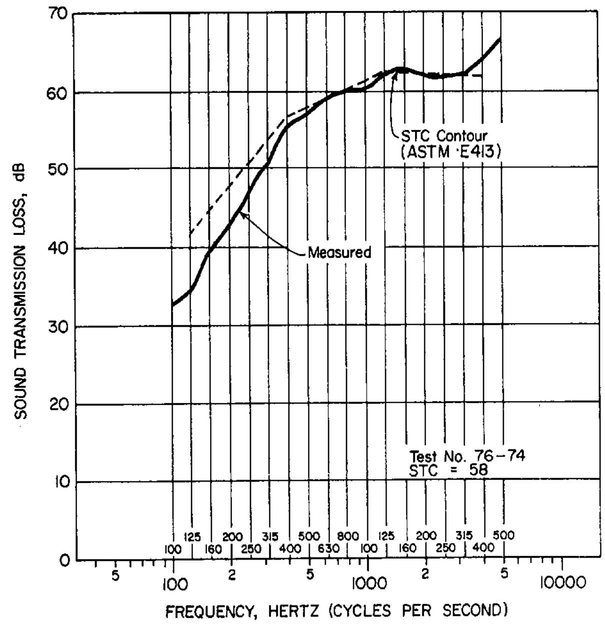

SOUND TRANSMISSION LOSS, dB
STC Contour (ASTM E413)
Measured
Test No. 76-75
STC = 44
FREQUENCY, HERTZ (CYCLES PER SECOND)


SOUND TRANSMISSION LOSS, dB
STC Contour (ASTM E413)
Measured
Test No. 76-99
STC = 63
FREQUENCY, HERTZ (CYCLES PER SECOND)

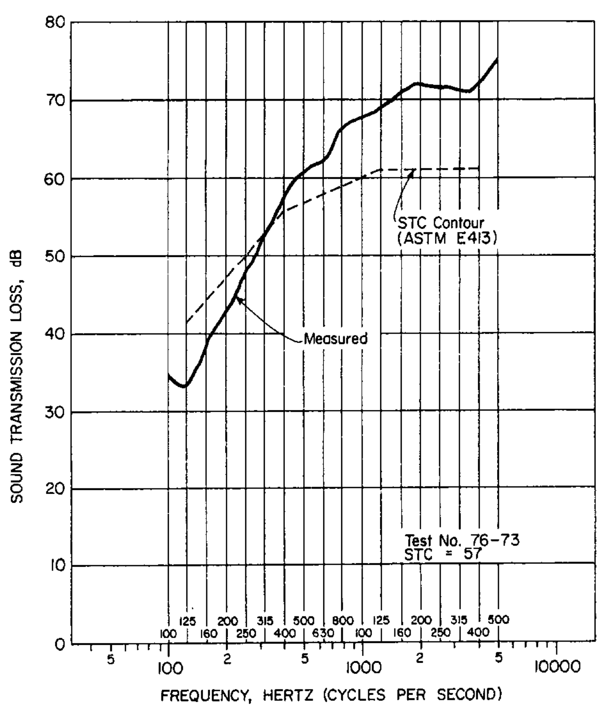

SOUND TRANSMISSION LOSS, dB
STC Contour (ASTM E413)
Measured
Test No. 76-76
STC = 48
FREQUENCY, HERTZ (CYCLES PER SECOND)



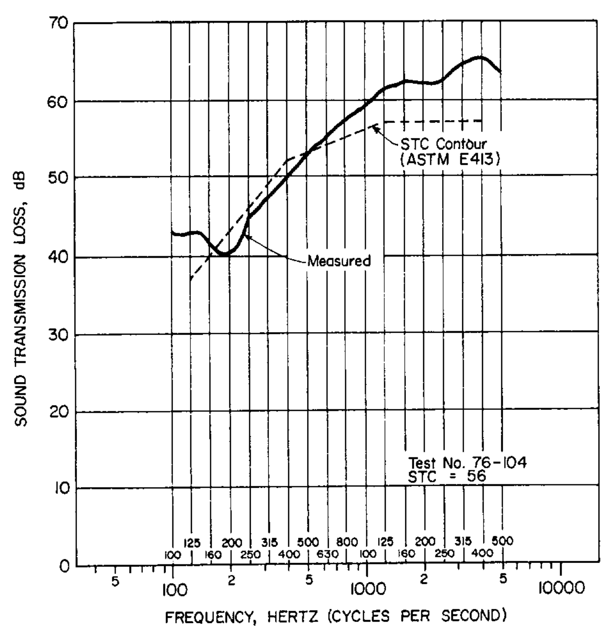
STC Contour (ASTM E413)
Measured
Test No. 76-72
STC = 59
SOUND TRANSMISSION LOSS, dB
FREQUENCY, HERTZ (CYCLES PER SECOND)



STC Contour (ASTM E413)
Measured
Test No. 76-74
STC = 58
SOUND TRANSMISSION LOSS, dB
FREQUENCY, HERTZ (CYCLES PER SECOND)



STC Contour (ASTM E413)
Measured
Test No. 76-73
STC = 57
SOUND TRANSMISSION LOSS, dB
FREQUENCY, HERTZ (CYCLES PER SECOND)



STC Contour (ASTM E413)
Measured
Test No. 76-104
STC = 56
SOUND TRANSMISSION LOSS, dB
FREQUENCY, HERTZ (CYCLES PER SECOND)

Portland Cement Association Member Companies

(as of April 1980)

United States

Aetna Cement Corporation
Alamo Cement Company
Arkansas Cement Corporation
Ash Grove Cement Company
Atlantic Cement Company, Inc.
California Portland Cement Company
Capitol Aggregates, Inc. (Capitol Cement Division)
Centex/Nevada/Texas
Citadel Cement Corporation
Coplay Cement Company
Cyprus Hawaiian Cement Corporation
Flintkote Cement Company
Florida Mining & Materials Corp.
Giant Portland & Masonry Cement Company
Gifford-Hill Portland Cement Company (a subsidiary of Gifford-Hill & Company, Inc.)
Ideal Basic Industries, Cement Division
Independent Cement Corporation
Kaiser Cement Corporation
Lehigh Portland Cement Company
Lone Star Industries, Inc.
Louisville Cement Company
Marquette Company
Martin Marietta Cement
The Monarch Cement Company
Monolith Portland Cement Company
National Gypsum Company
Northwestern States Portland Cement Co.
OKC Corp.
Oregon Portland Cement Company
Rinker Portland Cement Corporation
Rochester Portland Cement Corporation
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KEYWORDS: acoustic insulation, acoustic properties, building codes, concrete panels, furring, masonry walls, noise reduction, residential buildings, sound transmission, wallboards, walls.

ABSTRACT: Many building codes require minimum sound transmission loss values, expressed as sound transmission class (STC), of 45 to 50. Tests of sound transmission loss were made on 8-in.-thick (203-mm) concrete masonry walls and on 6- and 8-in.-thick (152- and 203-mm) cast concrete walls finished with materials intended to increase sound transmission loss. Using furring, acoustic insulation, and wallboard attachments, STC values up to 59 and 63 were obtained for the masonry and cast concrete walls, respectively. Selected STC values, reported by other investigators, for a variety of walls are included for reference.

REFERENCE: Litvin, Albert, and Belliston, Harold W., *Sound Transmission Loss Through Concrete and Concrete Masonry Walls* (RD066.01M), Portland Cement Association, 1980. Reprinted from *ACI Journal*, December 1978.

PORTLAND CEMENT ASSOCIATION

An organization of cement manufacturers to improve and extend the uses of portland cement and concrete through scientific research, engineering field work, and market development.

5420 Old Orchard Road, Skokie, Illinois 60077

Printed in U.S.A.

RD066.01M