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Using Outside to Inside Transmission Class Measurements (OITC) in the Design of a New School Near an Airport

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1. ABSTRACT

This paper seeks to describe a quantitative process of determining the required for Transmission Loss (TL) of the exterior skin of a building to meet the interior noise level requirements of ANSI 12.60. A local school board decided to demolish an existing school located in the noise contours of a major international airport. The school board had a prototype school design that it used around the county in suburban locations with no major noise impacts that was proposed for the site. Outside to Inside Transmission Class measurements were made in a prototype school using loudspeakers located in a large rental crane over 55 ft above the school to simulate the effects of the aircraft noise transmission into the school and provide quantitative benchmarks to assess acoustical upgrades to the wall, door, window and roof assemblies required to meet the 35 dBA background noise levels contained in the ANSI standard. Extensive measurements of aircraft flyovers at the actual site were also made. The acoustical upgrades were assessed using a computer model of the measured aircraft sound levels that were transmitted into the proposed classrooms with various construction assemblies and the Outside to Inside Transmission Class data from the experiment at the prototype school.

2. INTRODUCTION

A quantitative process was developed to assess the required Transmission Loss (TL) of wall and roof assemblies using actual sound source spectra at a specific site and background noise criteria from ANSI and ASHRAE. This process consists of the acquisition of accurate octave band or one-third octave band source spectra from field measurements, acquisition of accurate octave band transmission loss data of possible assemblies from field testing or laboratory test data, and the construction of a computer model using the source spectra, assembly transmission loss data and 35 dBA (NC 25-30) (ANSI) or 45 dBA (NC35) (ASHRAE) interior noise criteria to design required wall and roof assemblies for each specific application.

This process was used in an experiment at a school site near an International Airport. Due to the location of the school near the flight paths, extensive sound attenuating assemblies for the windows, doors, roof, walls, gables and soffits were required. The aircraft noise at the school site had significant energy in the low frequencies. This is of particular concern because lightweight construction assemblies can be rattled and vibrated by low frequency energy.

3. METHOD

A. Source Spectra Measurements

Acoustic measurements of aircraft flyovers were taken at the school site. The school was located entirely within the 65 Ldn contour, and was approximately 1000' from the 70 Ldn contour. (Fig 1). Several types of aircraft including large commercial carrier jets, small commercial commuter jets, and small private aircraft (jet and prop driven) were observed using the airport. An Ivie PC-40 real time analyzer was used to record average, average accumulate, and peak accumulate sound spectra of the aircraft landing and taking off over the school site. This is a computer based analyzer that can record both overall, octave and one-third octave sound pressure levels over user programmed time periods. It meets ANSI standards for Type 1 sound level meters. Measurements were taken on the proposed site of the new buildings that were currently used as athletic fields (directly under the flight paths) and on the roof of the existing Gymnasium and Classroom buildings. (Fig 2)

B. OITC Test on Prototype School

Outside to Inside Transmission Class tests were performed for seven roof and eight wall assemblies at the prototype school located in a quiet, suburban location in the county. The prototype school is a building and landscape design chosen by the District School Board that is used repeatedly at several different school locations around the county. The existing school in the quiet, suburban location had no major noise impacts from the surrounding community. Field measurements at the school were taken with the Ivie PC-40 as described above. The source sound was generated by a pink noise generator, amplified through a Whirlwind Mix 5-S preamplifier, equalized through a Peavey PC4XL 1/3 octave band equalizer, amplified by a Crown Macro-Tech 2400 Amplifier, and played through two Eastern Audio Works (EAW) KF 650e loudspeakers. The sound source was mounted on a large mobile crane and raised 20-30 feet above the roof of the school for the OITC tests on the roof assemblies (Fig 3). The sound source was located at a 45 degree angle to the wall and approximately 30 feet away from the façade of the building for the OITC tests on the wall/window/door assemblies (Fig 4). The roof assemblies tested were 1-1/2" steel roof deck, covered by asphalt shingles on 30# felt and R-20 rigid insulation. The slope of the roof was 3 1/2:12. A suspended acoustical tile ceiling was hung 2-5 feet below the metal deck for the classroom ceilings. The wall assemblies tested were 8" c.m.u. and rigid insulation, covered with utility face brick. The windows were 1/4" single pane, aluminum frame, hopper type windows, 5'-4" x 4'-0" with impact resistant louvers on the exterior. The louvers were opened for all wall tests. The tests were conducted following the procedures outlined in ASTM standard E336, *Standard Test Method for Measurement of Airborne Sound Insulation in Buildings*. The OITC data were calculated in accordance with ASTM standard E1332, *Standard Classification for Determination of Outdoor-Indoor Transmission Class*. The effects of sound absorbent material in the receiving rooms were calculated using the Decay Rate Method (ASTM C423, *Standard Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method*) as specified in ASTM E336.

C. Computer Model

A computer model was constructed using the octave band source spectra of the aircraft flyovers measured at the site and the transmission loss in each octave band of the roof and wall assemblies measured in the OITC tests on the prototype school to assess the additional amount of attenuation required to meet the 35 dBA background noise criteria. Octave band analysis is critical to assess the low frequency components of the source sound (aircraft noise in this case). NC 25-30 (35 dBA) (ANSI) and NC 35 (45 dBA) (ASHRAE) spectra of allowable background noise were subtracted from the design spectrum obtained from site measurements of aircraft flyovers to find the total required outside-inside noise reduction in each octave band. The noise reduction consists of two components: 1. The reduction of sound attributed to the transmission loss of the roof or wall assemblies, and 2. The reduction of sound due to the absorbent materials in the receiving room. The reduction of sound from the absorbent materials in the receiving room was accounted for by using the Decay Rate Method and the volume of the room to determine the total amount of absorption in the rooms

4. RESULTS

A. Source Spectra Measurements

Average, average accumulate and peak accumulate measurements of the aircraft flyovers were taken at the site. The average A-weighted sound level represents the Leq or equivalent continuous sound level sampled over the duration of the take off or landing. The average accumulate sound level represents the maximum sound level that was recorded during the take off or landing. The peak accumulate sound level represents the peak sound level that was recorded during the take off or landing. The design average, average accumulate and peak accumulate sound spectra are shown in figure 5.

Aircraft Take offs.

Average sound levels during take offs varied between 73 to 81 dBA for large aircraft. The average accumulate sound levels were measured between 81 and 90 dBA for large aircraft. The peak accumulate levels varied from 96 to 107 dBA for large aircraft and 70 to 82 dBA for propeller planes.

Aircraft Landings.

Average sound levels during landings varied between 66 to 76 dBA for large aircraft, 65 to 70 dBA for commuter jets and 63 to 71 dBA for propeller planes. The average accumulate sound levels were 70 to 85 dBA for large aircraft, 73 to 78 dBA for commuter jets and 65 to 77 dBA for propeller planes. The peak accumulate levels varied from 78 to 94 dBA for large aircraft, 71 to 86 dBA for commuter jets and 77 to 90 dBA for propeller planes. One third octave spectra for average accumulate sound levels of large commercial carrier jets landing and taking off, and small commuter jets and propeller planes landing is shown in figure 7. The spectra all show significant amounts of low frequency energy, especially the large commercial jets, that should be accounted for when choosing assemblies for attenuation.

B. OITC Test on Prototype School

Outside to Inside Transmission Class (OITC) ratings varied between 29 and 36 for wall assemblies at the prototype school. Outside to Inside Transmission Class (OITC) ratings varied between 26 and 40 for roof assemblies at the prototype school. A table summarizing the results of all OITC tests made at the prototype school is shown in figure 8.

C. Computer Model

The computer model subtracted the required background spectra from the source spectra to calculate the required transmission loss of the exterior skin of the building. Basic wall and roof/ceiling construction with STC 45-70 is required to meet the interior design criteria. The wall assembly recommended to meet this criteria is an 8" cmu wall with 1 layer of drywall on metal studs with glass fiber in the cavity. The roof assembly recommended to meet this criteria is a 4" concrete roof slab with 1 layer of drywall on resilient channels with a suspended acoustical tile ceiling. The doors recommended to meet this criteria is an acoustically rated door and frame assembly with an STC of 51. The windows recommended to meet this criteria is an acoustically rated window and frame assembly with an STC of 51. Acoustic system selections for the doors, windows, exterior walls, roof and other acoustic criteria are summarized in figure 8.

5. CONCLUSION

The quantitative process consisting of the acquisition of accurate octave band or one-third octave band source spectra from measurements, acquisition of accurate octave band transmission loss data of possible assemblies from field testing or laboratory test data, and the construction of a computer model using the source spectra, assembly transmission loss data and 35 dBA (ANSI) or 45 dBA (ASHRAE) interior noise criteria provides a more accurate assessment of the required attenuation of exterior building skin assemblies. The octave band analysis allows the frequency content of the source spectra and the frequency dependent attenuation of the exterior building skin to be accounted for in the calculations.

REFERENCES

Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools, American National Standards Institute ANSI S12.60-2002 (Acoustical Society of America, New York, 2002)



Figure 1. Map showing airport sound contours and school site.



Figure 2. Map showing measurement locations in reference to the aircraft flyover path.

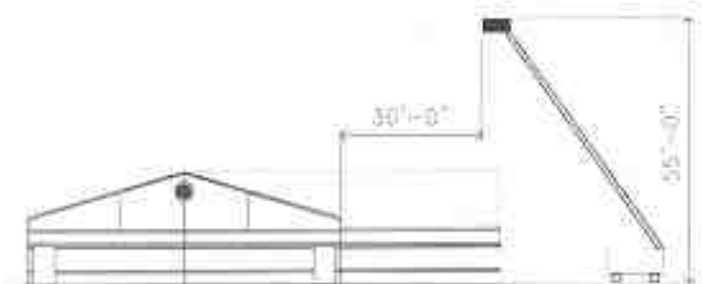


Figure 3. Sketch illustrating source location for roof/ceiling assembly OITC tests.

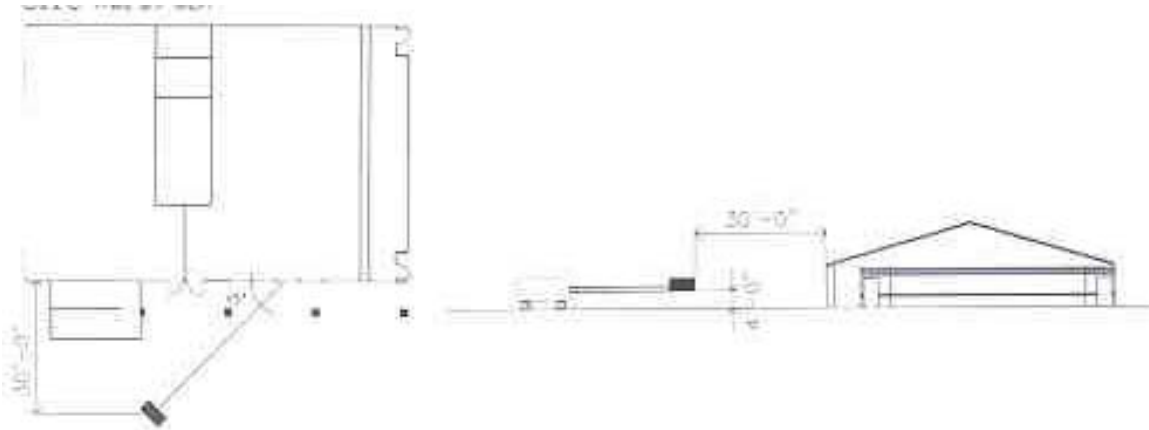


Figure 4. Sketch illustrating source location for wall/window/door assembly OITC tests.

Type of Measurement	Octave Bands						
	63	125	250	500	1000	2000	4000
Average	74	77	77	76	73	68	58
Average Accumulate	81	81	81	81	81	80	75
Peak Accumulate	100	99	100	100	99	98	93

Figure 5. Design average, average accumulate, and peak accumulate sound spectra for aircraft noise.

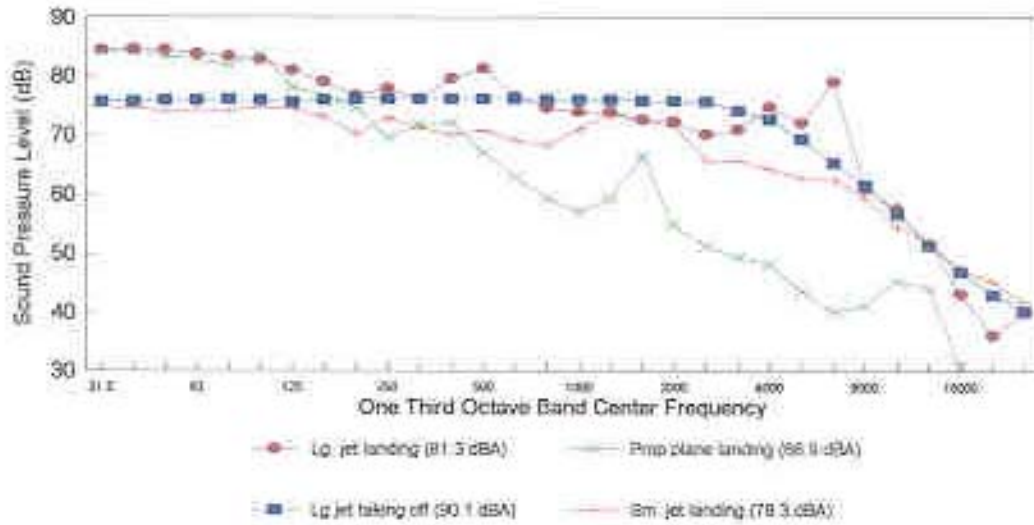


Figure 6. One-third octave spectra of aircraft flyovers

Source Location	Receiving Unit	Partition	OITC
30 feet from Building Facade	Band Room	Brick wall assembly with framed gable	34
30 feet from Building Facade	Chorus Room	Brick wall assembly with framed gable	33
30 feet from Building Facade	Room 2-102 Home Economics	Brick wall assembly with windows and doors	29
30 feet from Building Facade	Room 1-117 Business Education	Brick wall assembly with windows	36
30 feet from Building Facade	Room 1-118 Parent Center	Brick wall assembly with windows	30
30 feet from Building Facade	Classroom 1-207	Brick wall assembly with windows	31
30 feet from Building Facade	Classroom 1-209	Brick wall assembly with windows	31
30 feet from Building Facade	Classroom 1-211	Brick wall assembly with windows	35
20-30 feet above roof	Band Room	Roof assembly	40
20-30 feet above roof	Chorus Room	Roof assembly	48
20-30 feet above roof	Room 2-102 Home Economics	Roof assembly with flanking through the doors and windows	26
20-30 feet above roof	Classroom 1-206	Roof assembly with flanking through the windows	38
20-30 feet above roof	Classroom 1-207	Roof assembly with flanking through the windows	39
20-30 feet above roof	Classroom 1-209	Roof assembly with flanking through the windows	31
20-30 feet above roof	Classroom 1-211	Roof assembly with flanking through the windows	29

Figure 7. Table with OITC ratings of prototype school wall and roof assemblies

Preliminary Acoustic System Selections		
	NC 25 (35 dBA) Interior sound level	NC 35 (45 dBA) Interior sound level
Doors	Acoustically rated door with STC 51	Acoustically rated door with STC 51-45 or vestibule with 2 solid core wood or insulated core metal doors with complete acoustic seals
Windows	Acoustically rated window with STC 51	Acoustically rated window with STC 45
Percentage of Doors and Windows	< 8% of Total Exterior Wall and Ceiling Area	< 10% of Total Exterior Wall and Ceiling Area
Exterior Walls	8" cmu wall with 1 layer of drywall on metal studs with glass fiber in the cavity	8" cmu wall with 1 layer of drywall on metal studs with glass fiber in the cavity
Roof	4" concrete slab with 1 layer of drywall on resilient channels and a suspended acoustical tile ceiling	4" concrete slab, or 4" lightweight concrete (Elastizell) with 1 layer of drywall on resilient channels and a suspended acoustical tile ceiling
Ventilation Openings	Acoustic louver, duct, and silencer	Acoustic louver, duct, and silencer
HVAC System	< NC 26 ¹	< NC 35 ¹

¹ - The HVAC system will require special acoustic design to achieve these sound levels

Figure 8. Table showing preliminary acoustic system selections.