Optimizing Ceiling Systems and Lightweight Plenum Barriers to Achieve Ceiling Attenuation Class (CAC) Ratings of 40, 45 and 50

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1 Introduction

In some buildings, sound isolation between rooms is important. Building codes, standards, guidelines and rating systems often require the level of isolation to be 40, 45 or 50 decibels (dB) at mid-frequencies regardless of whether it is measured as Sound Transmission Class (STC) or Ceiling Attenuation Class (CAC). As an initial construction cost savings in some buildings, interior walls are stopped at the height of a suspended, modular, acoustic ceiling. They do not extend full height up to the structural floor slab or roof above. Noise potentially can transmit more easily from room to room through the ceilings and the open plenum above. This often makes the ceiling the weakest link in the overall room envelope and the component that establishes the inter-room sound isolation performance. Ceiling manufacturers therefore test the sound blocking capacity of their ceiling panels and report the results as CAC_{panel} ratings.

There is approximately a ten CAC point decrease in the ceiling system rating in real buildings (CAC_{system}) due to the penetrations for open return air grilles, recessed lights and supply air diffusers. In the higher frequencies above the 500 Hertz (Hz) octave band, the decrease in isolation can be more than 20 dB.[1]

It is clear that modular acoustic ceilings alone cannot achieve the isolation levels required in the building codes, standards, guidelines and rating systems, especially once the flanking paths are considered. Prior research[2, 3] shows that lightweight plenum barriers that extend vertically from the top of the demising wall to the underside of the structural slab or roof above is the optimal design approach considering both performance and cost. The goal of this research is to optimize the combined performance of a modular acoustic ceiling system and lightweight plenum barriers of various materials and installation techniques in order to find solutions that comply with the required STC/CAC 40, 45 and 50 levels of performance.

2 Method

A series of CAC tests was performed on a suspended, modular, acoustic ceiling system with and without various lightweight plenum barriers under laboratory conditions. The tests were performed per ASTM E 1414 and E 413 at NGC Testing Services, a fully-accredited fire, acoustical, and structural/physical testing facility located in Buffalo, NY by a Senior Test Engineer. The laboratory is accredited by the National Voluntary Laboratory Accreditation Program (NVLAP) (Laboratory Code 200291-0). For the baseline test, the specimen comprised a standard, 24 mm (15/16") wide, metal, suspension grid, 16 mm (5/8") thick stone wool ceiling panels (CAC_{panel} 22), recessed troffer light fixtures, return air grilles and supply air diffusers per the layout shown in Figure 1, but no plenum barrier above the demising wall. Subsequent tests added various lightweight plenum barriers. Figure 1 also shows the location of a duct, PVC pipes and metal conduits that were suspended in the plenum above the ceiling and penetrated the plenum barriers. These elements were included so the study represented real-world applications more closely.

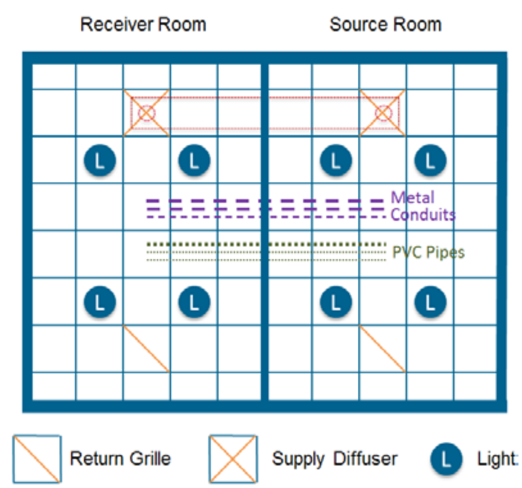

Figure 1: Reflected ceiling plan of test chambers showing locations of lights, return grilles, supply diffusers, supply duct, pipes and conduits.

Three types of plenum barriers were tested:

1. Drywall barriers (1 layer, 16 mm or 5/8" thick)
   a. Drywall alone, quick install method
   b. Drywall alone, sealed install method
   c. Drywall, sealed install, stone wool insulation 89 mm (3-1/2")
2. Mass loaded vinyl barriers (MLV, 4.88 kg/m^2 or 1 psf)
   a. MLV alone
   b. MLV with fiberglass insulation (89 mm, 3-1/2")
   c. MLV with stone wool insulation (89 mm, 3-1/2")
3. Stonewool barriers (30 mm, 1-3/16" thick)
   a. 1 layer
   b. 2 layers spaced 19 mm (3/4") apart.

For the drywall barriers, the *quick* installation method used simple, rectangular pieces of drywall. Large holes around elements that penetrated the barriers were stuffed with

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scraps of stone wool insulation. Large gaps up to 13 mm (1/2") wide and 610 mm (24") long between drywall pieces and around edges and penetrations remained open. No sealant or tape was used to make the barrier airtight. For the *sealed* installation method, the drywall was cut close around penetrating elements and all joints, gaps and screw heads were sealed airtight with either sealant or metal tape.

The MLV barriers were screwed into metal channels along the tops and bottoms. Adjacent pieces of MLV overlapped 152 mm (6") and the joints were taped on one side to hold them in position. No sealant or tape was used around the perimeter or around penetrations. For the stone wool insulation barriers, the 30 mm (1-3/16") thick panels were oriented vertically, friction fitted at the tops and bottoms and taped along the tops, bottoms and abutted sides with metal tape.

3 Results

Table 1 provides the results of the study. CAC_{system} ratings and normalized transmission loss (Dn,c) in three, 1/3 octave bands are given for the base line stone wool ceiling and a reference 16 mm (5/8") thick wet-felted, mineral fiber ceiling (CAC_{panel} 37) as well as for the drywall, MLV and stone wool plenum barriers when they were combined with the baseline, stone wool, ceiling system. The mineral fiber ceiling results are included so that the relatively small effect of the type of ceiling panel on overall isolation can be seen compared to the more substantial effect of the plenum barriers being studied. Also, people are more familiar with mineral fiber panels than with stone wool ceiling panels, so inclusion of their data preempts the anticipated question of how a mineral fiber ceiling panel would compare.

Table 1: Ceiling attenuation class (CAC_{system}) rating and normalized transmission loss (Dn,c) in three 1/3 octave bands for various drywall, MLV and stone wool plenum barriers in combination with a suspended modular ceiling.

		Transmission Loss *normalized* (Dn,c)		
	CAC System	125 Hz	500 Hz	2000 Hz
Baseline Ceilings (no barrier)				
Stone wool	**22**	14	21	22
Mineral fiber	**27**	18	28	27
Drywall Barriers				
Quick install	**41**	21	37	44
Sealed install	**46**	25	46	50
Sealed install, stone wool	**50**	26	52	55
Mass Loaded Vinyl (MLV) Barriers				
MLV alone	**37**	18	34	42
With fiberglass	**42**	20	39	51
With stone wool	**44**	21	43	53
Stone Wool Barriers				
Stone wool - 1 layer	**38**	22	36	50
Stone wool - 2 layers	**48**	24	51	55

4 Discussion

Acoustic standards, guidelines and rating systems generally require isolation between rooms to be STC/CAC 40, 45 or 50. One might be led to believe that the lowest level of isolation (STC/CAC 40) can be achieved simply by using ceiling panels with CAC_{panel} rating of 40 or higher, but the noise flanking paths must also be controlled. This could affect aesthetics. For example, suspended lights avoid large ceiling penetrations, but they change the look of the room compared to recessed lights and could require higher ceilings. Custom, site-built noise control measures are required for specialty devices that penetrate the ceiling such as bed lifts, projector mounts and exhaust hoods. Controlling flanking path noise through the ceiling system is not typically part of a ceiling contractor's daily routine, so there is also an increased risk of failure. Lastly, once the building is occupied, flanking noise control measures above the ceiling can make access into the plenum difficult and maintenance personnel must understand the importance of the noise control measures and replace them correctly when their work in the plenum is complete. Using ceiling panels below CAC_{panel} 40 alone to block sound between rooms cannot provide adequate sound privacy. Using a modular acoustic ceiling system alone cannot provide the two higher performance levels required in the standards (STC 45 and 50).

5 Conclusion

The results of this research are consistent with prior research[2, 3] by others and suggest an alternative approach of using a lightweight plenum barrier that extends from the top of the demising wall to the underside of the deck above, in combination with a suspended ceiling system, may be optimal. These plenum barriers can be made of drywall, MLV, stone wool insulation or a combination. The resulting CAC_{system} values can reach the STC/CAC 40, 45 and 50 levels required by the acoustic standards, guidelines and rating systems.

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