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Acoustics and Sustainability:

How should acoustics adapt to meet future demands?

Acoustic Design Practices for Sustainable Buildings

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ABSTRACT

This paper presents some of Bassett Acoustics' recent experiences with acoustic design implications associated with current building services initiatives for sustainable buildings. Acoustic design practices are explored with respect to various sustainable heating, ventilating and air conditioning (HVAC) methods, with comparisons between the impact on the acoustic design of a building for sustainable and traditional HVAC systems presented. A case study of two recent sustainable buildings projects with alternative HVAC methods is presented, in which alternative acoustic design strategies and practices are required for each of the different sustainable HVAC methods that are implemented.

INTRODUCTION

In recent times, there has been a paradigm shift towards designing sustainable building environments. This has introduced a wider suite of acoustic design practices for the design of optimum acoustic environments of building interiors. Traditional heating, ventilation and air conditioning (HVAC) methods such as variable air volume (VAV) systems have been opted against in favour of sustainable methods such as natural ventilation and radiant cooling.

As a result, the once common acoustic design measures that were integrated into the design of a VAV system have been modified into more versatile and dynamic forms of treatments to suit current sustainable HVAC system designs.

In demonstrating the alternative forms of acoustic treatments that are required based on the mechanical services systems adopted, case studies are presented in which two recently designed sustainable buildings are assessed with respect to the alternative acoustic design methods implemented.

Conventional VAV systems in commercial office buildings have typically required systematic noise control measures, such as, internally lining ductwork with acoustic insulation and installing in-duct attenuators to ensure that noise transmission from air-handling plant does not generate excessive internal noise levels.

In addition, the use of an acoustically absorptive suspended ceiling tile grid system would generally provide the level of reverberant noise control in the office space necessary for a suitable internal acoustic environment.

These fundamental elements of a HVAC system and building interior design are no longer a staple in the design of a sustainable building, and consequently, neither are the acoustic treatments.

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Bassett Acoustics' recent experiences in projects for sustainable buildings demonstrate the need to implement an acoustic design that will cater for the sustainable initiatives of the building services design.

THE GAUGE

Bassett Acoustics recently completed the acoustic design and commissioning of The Gauge office building at 825 Bourke Street, Victoria Harbour in Melbourne. The Gauge building, developed by Lend Lease, has been awarded a 6 Star Green Star – Office Design Certified Rating by the Green Building Council of Australia (GBCA).

The key HVAC design feature of The Gauge was the use of a passive chilled beam system in lieu of a traditional VAV system. The typical ceiling layout consisted of an array of passive chilled beams suspended from the slab soffit across the entire office floor plate. A perforated metal ceiling tile grid system was used throughout the office space to allow the convection process of warm air passing up through to the passive chilled beam, being cooled and then naturally falling back into the office space.

A key feature of the passive chilled beam is its low noise emission; the operation of the passive chilled beam does not introduce any significant noise to the internal space. This characteristic, along with the requirement of having a perforated or transparent ceiling system, affect two of the fundamental components of the acoustic design in office building – internal noise levels and reverberation time.

Internal Noise Level

The absence of traditional HVAC noise due to the use of a chilled beam system results in a low background noise level. This can have a detrimental effect on the acoustic environment in an open office space, whereby speech privacy is compromised and intrusiveness of noise is exacerbated.

To compensate for the low background noise levels that would be present at The Gauge, a sound masking system was designed to artificially introduce noise into the office space. The background noise introduced by the sound masking system can be adjusted to a level that would be considered appropriate based on the office layout and the noise level in the office space when occupied by staff.

The sound masking system that was implemented at The Gauge generates masking noise through an array of speakers distributed throughout the ceiling space of the open office. A more traditional system, which would be installed above a suspended tile or solid ceiling, would aim the speakers directly upwards and rely on reflection from the slab soffit to produce a diffuse sound field in the ceiling plenum, resulting in a more even coverage in the space below. As there was no suspended solid ceiling installed at The Gauge, the masking speakers were again installed facing upwards, however were placed below reflective discs that were fixed to the soffit (Soundmask Australia 2008). The profile of the reflective discs provides diffusion of the masking sound, evening out the coverage and producing a similar result to that achieved with speakers installed in a ceiling plenum, as shown in Figure 1, below.

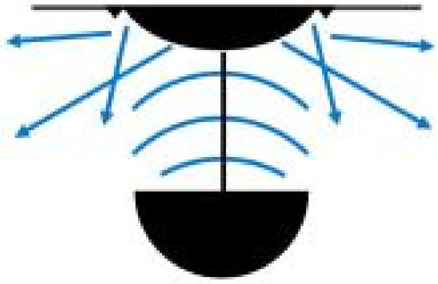


Figure 1. Sound Masking Speaker Configuration

The sound spectrum of the noise is neither pink nor white noise, it is tailored specifically to effectively mask intelligibility of speech, whilst maintaining the spectral characteristics of traditional HVAC noise, so as not to be bothersome to building occupants. The speakers are positioned at equal intervals throughout the entire ceiling space to allow for an even coverage of masking noise across the office space; specifically a tolerance for variation in level of ±3dB was allowed. An even coverage of masking is critical in preventing 'hot spots' of sound occurring in the office space, which can lead to the undesirable effect of occupants being able to detect the exact location of the noise source and potentially consider it to be intrusive to their work.

Further, the masking system employed is of a two-channel design, which uses two independent random noise generators to feed adjacent speakers, such that phasing effects produced by two physically separated loudspeakers reproducing identical signals are not detectable to occupants when moving throughout the space.

To ensure that the sound masking system performed its intended purpose, (generating background noise to provide an increased level of speech privacy, as well as attempting to mimic an acoustic environment that is typical of offices consisting of a traditional air conditioning system), the level and spectrum of the sound being generated were adjusted during commissioning and post-occupancy of the office space.

To determine the appropriate spectrum and level of noise to be generated by the sound masking system, the Green Star – Office Design v2 IEQ-12 Internal Noise Levels Compliance Criteria (Green Building Council of Australia, 2004) was used with respect to what is deemed as an acoustically comfortable environment by the GBCA.

Reverberant Noise Control

The use of a perforated ceiling system with an exposed concrete slab soffit in place of an acoustically absorptive ceiling system in the office space would result in a longer than ideal reverberation time, which could introduce the undesired acoustic effects of poor speech intelligibility within the space, as well as increasing the reverberant noise levels due to occupant activity.

To provide an environment that was both acoustically comfortable for occupants at The Gauge, as well as retaining the essential acoustic properties for an office fit-out, including speech intelligibility and an appropriate reverberation time for open plan areas, an acoustically absorptive material was applied to the slab soffit, concealed behind the perforated metal ceiling tiles. The acoustic performance specification of the material was determined based on the extent of exposed concrete, and the reverberation time criteria for the open plan office as prescribed by Australian Standard AS2107:2000 (Standards Australia, 2000) and GBCA guidelines (Green Building Council of Australia, 2004).

By incorporating a sound masking system to increase background noise, and applying acoustically absorptive material to the slab soffit throughout the office space, acoustic characteristics such as speech privacy, speech intelligibility and internal noise levels, which are vital for an acoustically suitable office space, were successfully addressed. Figure 2, below, shows the installed sound masking speakers and acoustically treated slab soffit.

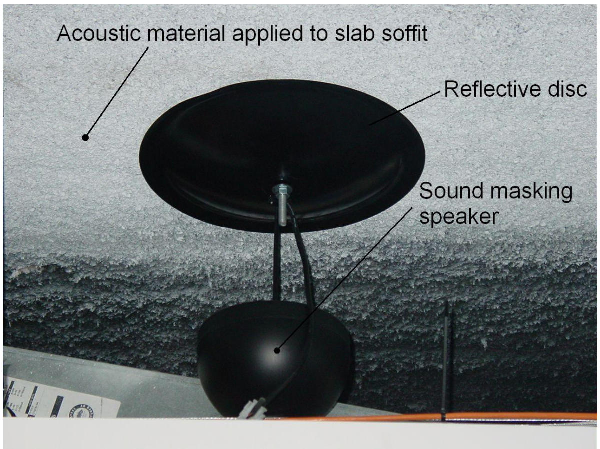
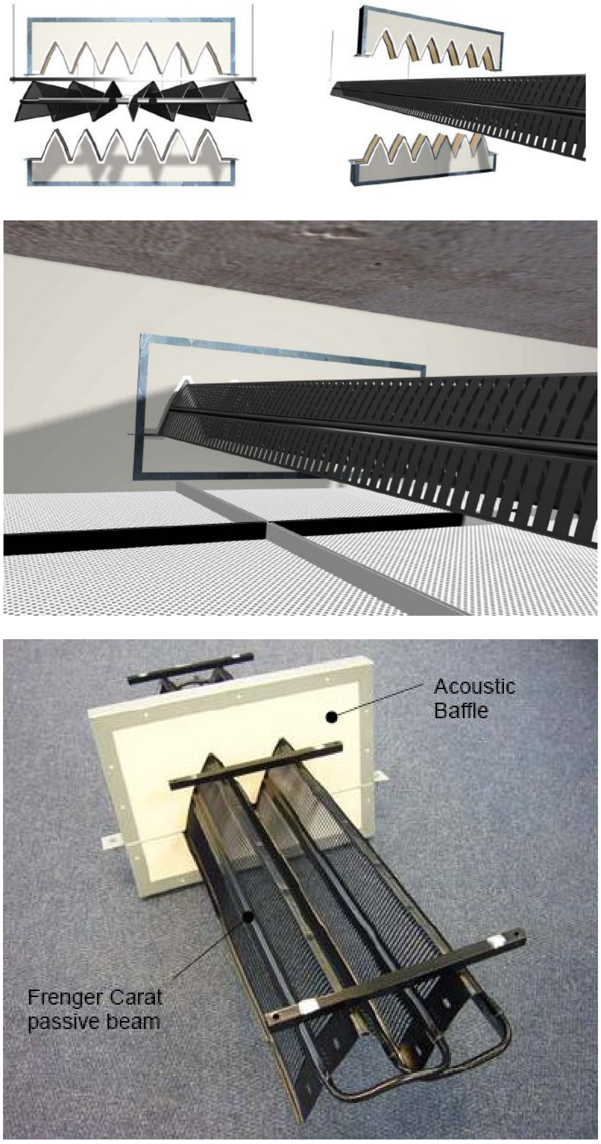


Figure 2. Sound Masking Ceiling Speaker Configuration at The Gauge

Chilled Beam Systems

Although a successful design strategy was implemented at The Gauge to address the internal noise levels and reverberation time, passive chilled beams still offer challenges in the acoustic design of office spaces where a high degree of sound insulation is required for cellular offices and meeting rooms. The challenge arises when passive chilled beams straddle the line of a dividing partition. Providing an effective acoustically sealed partition in cases where a passive chilled beam penetrates a partition is difficult, due to the irregular shape of the passive chilled beam. In traditional HVAC systems, acoustically sealing a penetration due to ductwork or pipework was feasible due to the uniform shape of a duct and pipe.

The measures that should be considered when designing the layout of meeting rooms and cellular offices are the locations of dividing partitions with respect to the chilled beams. Dividing partitions should not be installed in locations that coincide with passive chilled beams. Where this is unavoidable due to space constraints, a suitably designed acoustic baffle that considers the operational needs of the chilled beam will need to be installed around the chilled beam, as shown in Figure 3, below.



(Source: Frenger Systems 2008)

Figure 3. Acoustic Baffle to Chilled Beam

This presents a design limitation in that the sound insulation rating of the partition may be somewhat limited by the acoustic performance of the acoustic baffle of the chilled beam.

NEW ENGINEERING BUILDING – THE UNIVERSITY OF ADELAIDE

The New Engineering Building at The University of Adelaide is another example of a sustainable building where Bassett Acoustics has implemented alternative acoustic design strategies to cater for the use of a non-traditional HVAC system. The New Engineering Building (NEB) is currently under construction and has been designed with the notion of sustainability at the forefront, as demonstrated through architectural and building services design initiatives.

The NEB mechanical services system design is based on the internal areas being served by an underfloor ventilation system that distributes air to the occupied space through floor mounted diffusers. The raised floor system acts as a supply air plenum, and is served by air conditioning units located in designated plant rooms on each floor. To assist with the ventilation process, the ceilings of the internal areas of building consist predominately of an exposed concrete slab ceiling, which acts as a thermal mass component of the ventilation system.

The major acoustic design implications that are encountered as a result of the ventilation system adopted include maintaining a suitable noise level in the occupied spaces, providing suitable reverberant noise control, and achieving the required level of speech privacy and sound insulation between internal areas.

The exposed concrete slab ceiling impacts on two distinct aspects of the acoustic design; noise intrusion to the top floor of the building from roof level plant, and the internal acoustic environment with respect to reverberant noise, speech privacy and speech intelligibility (Field, 2008).

Building Services Noise

With the top floor of the NEB having an exposed concrete slab ceiling, there is a potential for an increase in noise transmission from the plant room to the space below over what would generally be present in a building with a suspended ceiling.

This is due to the fact that the sound insulation provided between the plant room and the top floor in the NEB will be based on the plant room floor slab alone, whereas a typical building would generally consist of a floor slab and a suspended ceiling system, which combined, provide greater sound insulation.

As a result, additional noise control measures, which were generally not necessary in buildings with a suspended solid ceiling, were implemented for the NEB to ensure that noise levels are within the nominated criteria.

In assessing the noise due to plant serving the NEB, it was determined that the highest noise levels were generated by the plant specific to the sustainable initiatives of the mechanical services system, specifically, the co-generation plant.

Co-generation plant can typically generate noise levels of up to 100dB(A) at a distance of 1 metre from the generator engine when no acoustic treatment is applied. For the case of the NEB, and buildings of a similar nature, this is likely to result in excessive noise levels on the top floor of the building.

Typical noise control treatments that would be implemented to minimise noise levels in the plant room due to the generator would include installing an acoustic enclosure over the generator. Although this provides a significant reduction of the noise level in the plant room, noise transmitted to the level below may still prove to be excessive if an acoustically rated base is not installed below the generator.

In the case of the NEB, transmission of co-generation plant noise into the space below was mitigated by installing a floating concrete slab floor in the roof level plant room. The mounting of the floating floor slab to the structural slab was designed to meet the vibration isolation requirements of the co-generation plant.

The floating floor is supported on the structural slab using blockwork, with a rubber interlayer installed between the floating slab and the top of the blockwork. This floating slab arrangement also achieves the sound insulation requirements with regard to airborne noise being transmitted from the plant room to the internal areas of the building.

With co-generation plant playing a key role in the design of sustainable buildings, these types of noise control measures are becoming more common, and are of a greater necessity when the internal fit-out of the building, i.e. exposed ceilings, does not provide sufficient sound insulation on its own, as demonstrated for the NEB.

Internal Acoustic Environment

In providing an acoustic environment that is comfortable for its occupants, the key items to be considered were the selection and application of acoustically absorptive surface finishes. This is most critical in areas where the acoustic environment has the potential to adversely impact on the occupant's use of the space, for example, in classrooms and collaborative learning spaces.

For teaching areas of the NEB, and areas of a similar acoustic nature, the locations and acoustic absorption properties of each material were specifically chosen to achieve the optimum acoustic performance for the space.

As the exposed concrete slab ceiling must be left uncovered, acoustic material was applied to the rear wall, with supplementary treatment applied to the side walls. The acoustically absorptive rear wall prevents undesired reflection of sound from the presenter returning to seated students via the back wall of the classroom. The requirement to leave the ceiling exposed was used to advantage in the teaching spaces, as beneficial reflection of sound from the exposed ceiling surface projects sound to the rear of the room, assisting in reinforcing the presenter's speech.

This method of strategically placing acoustic material onto surfaces other than the ceiling, and nominating specific acoustic absorption properties, was used throughout the building to achieve the desired reverberation characteristics of the internal spaces.

Internal Sound Insulation

The use of a raised floor system introduces challenges with respect to providing noise isolation between the internal areas of the building. When rooms in a building share a common floor cavity, noise is transmitted between adjoining rooms through the floor cavity via floor mounted diffusers, reducing the level of speech privacy between adjacent spaces, as indicated in Figure 4, below.

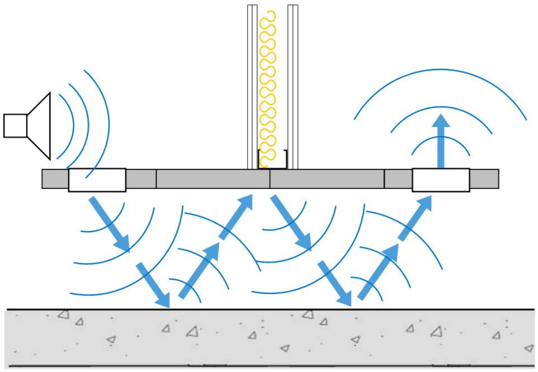


Figure 4. Transmission of Sound through Floor Cavity

To overcome this occurrence, acoustic treatment needs to be incorporated into the floor cavity. The simplest form of achieving the desired level of speech privacy is to install a baffle in the floor cavity that extends from the floor slab to the underside of the raised floor. This has implications with regard to the air distribution system, as the floor cavity is intended to act as a single supply air plenum for all of the floor diffusers on a floor plate. These implications include additional costs associated with providing mechanical ductwork to penetrate the baffles and serve each room individually, similar to a traditional in-ceiling VAV system.

As a result, is not generally considered a favourable form of treatment, especially in cases where there is a large quantity of cellular offices or meeting rooms, as is the case in the NEB. In such cases, alternative forms of treatment should be investigated. These treatments include installation of acoustic insulation in the floor cavity and acoustic air transfer ducts, both of which were used for the NEB.

Acoustic insulation was specified for the underside of the raised floor to absorb sound travelling between diffusers in the underfloor plenum, analogous to the concept of an acoustically lined duct. The acoustic insulation was applied to the underside of the raised floor to allow the concrete floor slab in the underfloor plenum to remain exposed for thermal requirements, as shown in Figure 5, below.

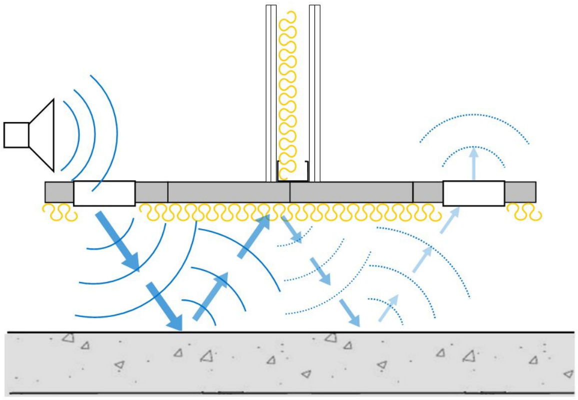


Figure 5. Reduced Transmission of Sound with Insulated Floor Cavity

The extent of this treatment, and the limitations that are placed on the level of sound insulation that can be achieved, are based on the area of the floor diffusers and the distance between diffusers in separate rooms.

Where a greater level of sound insulation is required for noise isolation and speech privacy purposes, for example, in classrooms and boardrooms, a solid baffle was used in the floor cavity, with additional acoustically treated mechanical ductwork used to penetrate the baffle and serve the section of floor cavity below each room.

SUMMARY

The practices employed in the design of The Gauge and the University of Adelaide New Engineering Building demonstrate the shift in strategy that is required in the acoustic design of a building with sustainable initiatives for building services and building architecture.

Although many of the acoustic treatments are not innovative in themselves, the application of these treatments differs to what is common practice in buildings served by traditional HVAC systems. The two case studies demonstrate this, whereby two sustainable buildings required alternative forms of acoustic treatment based on the mechanical services system used.

As further advances are made into building services design for sustainable environments, acoustic design practices will be required to become even more versatile and adaptable to architectural and services requirements, at the same time ensuring that the practices and treatments alike are themselves sustainable.

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