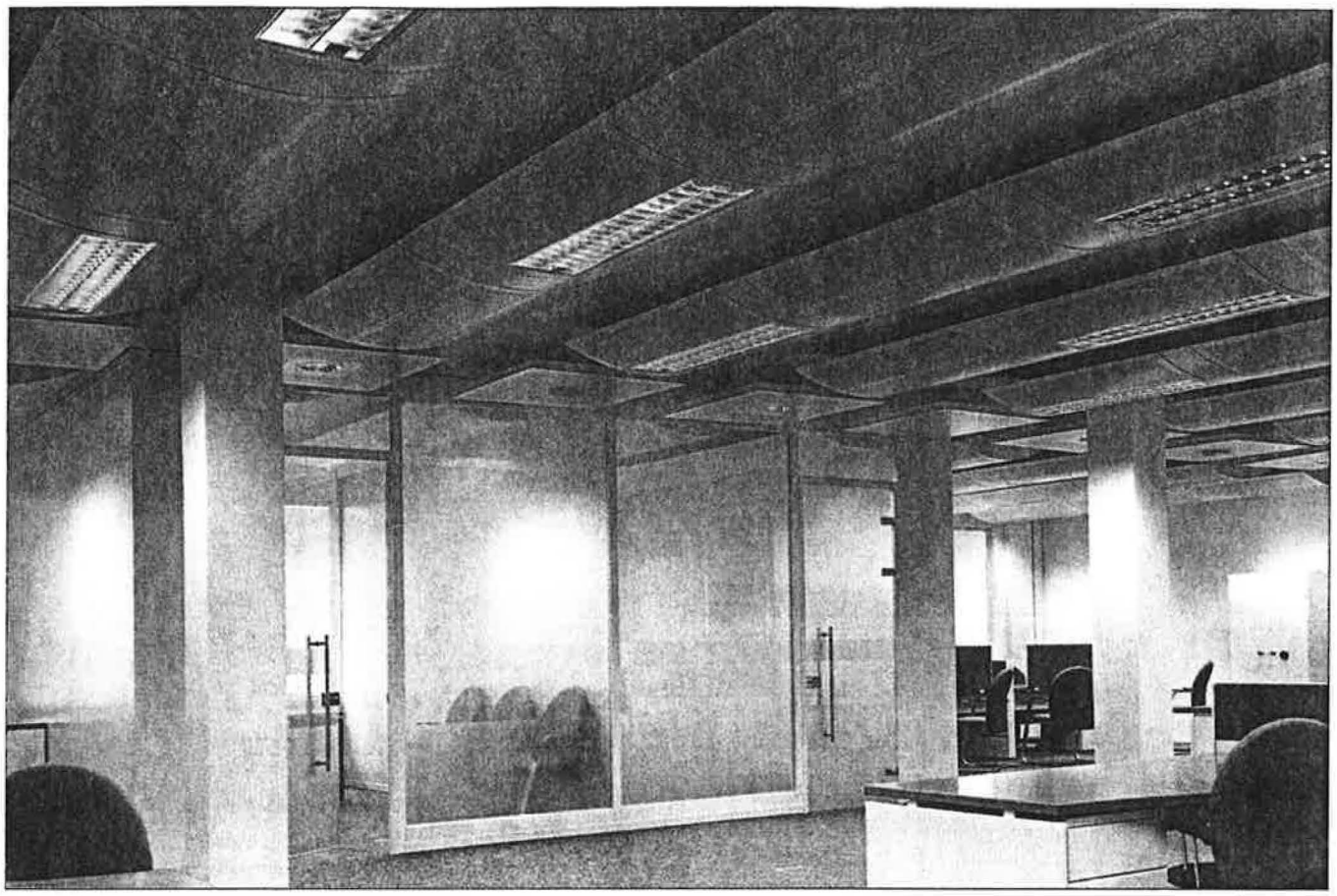


The modular ceiling system developed for the MoD's Abbeywood hq outside Bristol.

For your ears only

With exposed concrete slabs becoming more and more popular in office environments, the design team needs to put the acoustic characteristics of the ceiling on an equal billing with thermal and aesthetic concerns. We take a look at emerging solutions to the problem.

ANDREW BRISTER REPORTS

The new generation of low energy buildings is causing more than a rethink of the tried and tested air conditioning strategies: conventional wisdom on acoustics, lighting and aesthetic considerations are all being radically challenged.

Exposing the concrete soffit to take advantage of its thermal mass for cooling means the death of the suspended ceiling in many office buildings, and with it both the ease of integration of lighting into the ceiling and the acoustic absorbancy on offer from the usual mineral fibre suspended ceilings.

Acoustic engineers stand to gain much from this shake-up of the office status quo. Their early involvement in building design is essential if future workspaces are going to perform as well acoustically as they do thermally.

Ironically, exposing the soffit and doing away with air conditioning can mean that things are just too quiet in the office. The absence of background noise from whirring fans actually makes the effect of other disturbances that much greater, so much so that consultants are now examining ways of generating masking sound in the open-plan environment (see "Too quiet for words"). Indeed, PowerGen's hq in Coventry boasts loudspeakers in its lighting rafts to do just that.

Arup Acoustics joined architect Bennetts Associates and m&e consultant Nigel Griffiths and Son in the integrated design solution at PowerGen. Lack of background noise was just one of many considerations. Perhaps the greatest problem for the team, and indeed on any project with an exposed concrete coffer, is the risk of sound being reflected off the ceiling from one occupant to another. How can the designer incorporate some degree of acoustic absorbancy without detracting from the thermal transfer characteristics of the exposed slab?

The team has solved the problem by suspending some sound absorbancy from the coffer, which still allows much of the concrete's thermal transfer capability to remain intact. Careful design of the sculpted coffer focuses sound on to acoustic absorbers located in a suspended light fitting. The shape of the downstand elements of the coffer was generated using computer ray tracing so as to direct the sound energy onto the upper and lower surfaces of acoustic absorbers which are laid in to perforated metal trays.

Other new build projects have adopted a similar approach. Foggo's design for British Gas' Leeds City Office Park, Bennetts Associates again at John Menzies' hq in Edinburgh and the Ionica building in Cambridge all make use of a shaped coffer with suspended acoustic elements.

While taking up less design time, a flat exposed slab would seemingly offer a harsher reflecting surface than a sculpted coffer, making things difficult (acoustically) for the team.

The vast MoD project in Abbeywood, outside Bristol shows that it can be done. Once again, the inclusion of a flat slab is driven by a low energy strategy – the narrow floorplate allows windows to be opened, although there is an underfloor air supply for ventilation work-

WALL-TO-WALL SOUND

Exposed concrete can be treated with absorptive sprays to improve acoustics, but there needs to be careful monitoring of the application process as well as a consideration of the thermal implications.

Consistency is all important with acoustic coatings. Architects will want a seamless finish, so great care must be taken with substrate preparation.

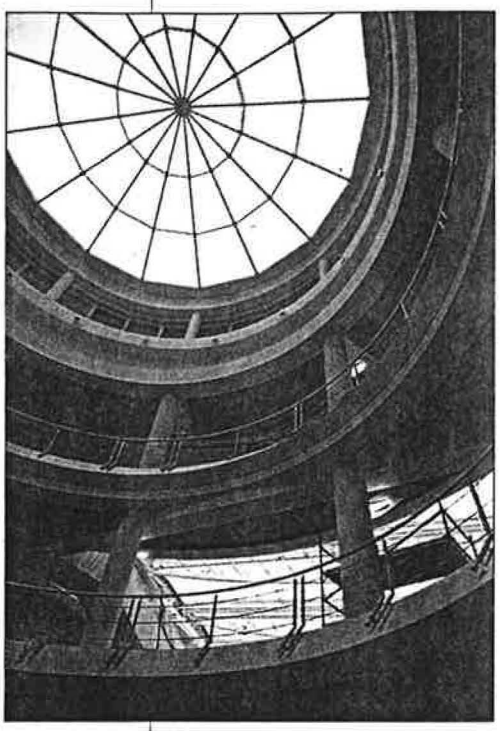
Mandoval Coatings supplies a range of sprayed acoustic materials under the Audex banner, and warns that while most conventional shuttered and poured *in-situ* concrete substrates and precast concrete slabs are suitable to receive Audex, any defects in the background will show in the finished ceiling.

Ultimately, the thermal transfer capability of exposed slabs can be seriously undermined by acoustic sprays so engineers need to be sure that sensitivity analyses are carried out if the structure is being relied upon to maintain comfort conditions.

At the recently completed Britannic Assurance Chief Office outside Birmingham, services consultant Oscar Faber was concerned about reverberation times and the risk of noise transfer into neighbouring offices, while also looking to retain thermal transfer.

Audex W has been applied in virtually all areas where the concrete structure has been exposed, particularly in the atriums which will be occupied spaces.

For Audex W, Mandoval Coatings quotes a thermal conductivity of 0·225 W/mK at a density of 750 kg/m^3 while absorption coefficients over the frequency range are shown in table 1.



The atrium at the Britannic Assurance Chief Office outside Birmingham.

TABLE 1: AUDEX W ACOUSTIC CHARACTERISTICS

Frequency (Hz)	Absorption coefficient	Frequency (Hz)	Absorption coefficient
100	0·02	630	0·24
125	0·03	800	0·26
160	0·06	1000	0·29
200	0·08	1250	0·35
250	0·14	1600	0·44
315	0·15	2000	0·56
400	0·18	2500	0·68
500	0·22	3150	0·87

ing in conjunction with the thermal mass of the slab.

The design team of architect Percy Thomas Partnership and m&e engineer Hoare Lea and Partners has worked closely with specialist ceilings supplier SAS to come up with a bespoke solution that meets the acoustic criteria while also housing lighting, smoke detectors, speakers and sounders within its perforated curved metal panels (see photo).

As Hoare Lea and Partners' acoustic specialist Andrew Bullmore explains, the solution is the result of the requirement to expose the thermal mass, the MoD's demands for a high room-to-room level of sound insulation and the desire to minimise noise transfer across the open-plan office.

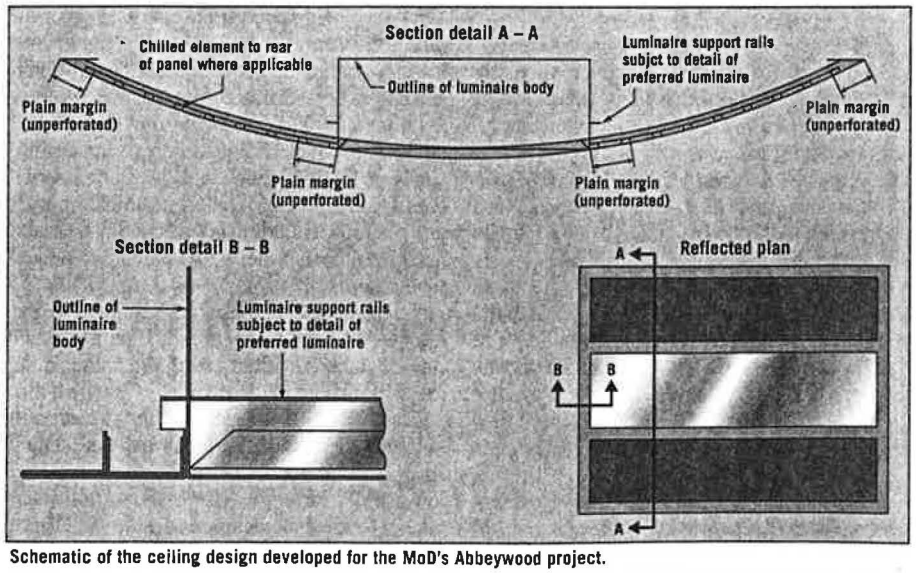
The end result leaves 40% of the slab directly exposed for radiant cooling, with the rest covered by arrays of SAS ceiling modules. The system has been designed to complement the 1500 by 1500 mm building module and comprises 1000 by 1300 mm modules with 100 by 200 mm infill panels laid between the curved end of the modules. The linear runs of panels are 500 mm apart to give the required free area of the soffit. Modules have been designed so that chilled radiant panels could be included at some later date, half of them supplied with factory-formed apertures for the easy on-site installation of Philips luminaires.

The objective was to achieve office acoustics comparable to a traditional suspended ceiling. Mock-ups were put to the test at Salford University. For example, visits by the design team to other offices highlighted a desired reverberation time in the open-plan areas of a maximum of 0·6 s, and the team has strived to achieve something similar here.

The 1:200 scale tests used flat panels rather than curved which were unavailable at the time, suspended to give a panel-to-slab distance of 140 mm. This mimics what would happen with the curved modules, where the distance will vary from 200 mm from the soffit in the centre of the panel to 80 mm at the edge. Results showed an average noise reduction coefficient over the 250-2000 Hz range of 0·67, with peak performance of 0·77 at 500 Hz.

The SAS Group believes the ceiling developed for the MoD project will have widespread appeal, and is marketing the concept as Ceiling System 600. The refurbishment market is particularly attractive, the company hoping to take advantage of the many 1960s office blocks in the City of London, Croydon and so on which come equipped with flat slabs and minimal floor-to-floor heights.

Ceiling 600 is put forward as a total building solution, a marriage of acoustics, lighting and – while not included at the MoD – cooling. Ceiling units are modular which can be found in linear arrays as at the MoD or can be



Schematic of the ceiling design developed for the MoD's Abbeywood project.

installed on a stand-alone basis to deal with particular problems in a given area. The modular units consist of combinations of a number of zones of acoustic absorption, a luminaire, for example in alternate modules and an optional chilled radiant panel.

Exact dimensions of its module will vary from project to project depending upon the building module and the floor-to-floor height. Curved acoustic pads laid into the metal perforated tile absorb both direct sound and reflected sound from the soffit.

One of the particular attractions of Ceiling 600 to the MoD was the ease of cellularisation and the integrity of private offices – a case of for your ears only. Usually, the point where the partitioning creating the cellular offices meets the suspended ceiling is the weak link in the office acoustics, forcing a local upgrade in the ceiling void to achieve a room-to-room acoustic of 40-45 dBA. On-site attenuation can be as low as 20 dB if sealing is not adequate.

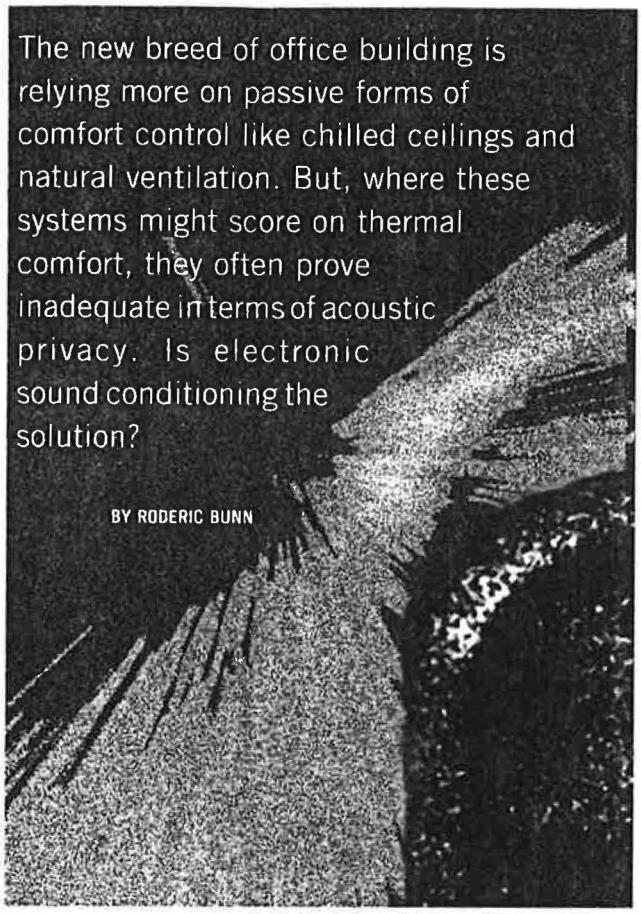
With a flat slab it is possible to partition right up to the soffit, doing away with much of the sealing problems. By removing the quick release infill panels, the Ceiling 600 module also allows partitioning to run across the units if necessary. Hoare Lea's Andrew Bullmore estimates this will achieve 50 dB room-to-room attenuation at Abbeywood.

Ceiling 600 has the potential to make an impact on the refurbishment market where cost budgets are perhaps not as generous as they are for the Powergens and MoDs of this world. There are also programming benefits to be had from the factory pre-assembly on offer, with SAS claiming that installation costs can sometimes be as little as one-fifth that of a typical ceiling.

Figures quoted for typical office costs at the MoD make interesting reading, the ceiling playing its part in bringing the fit-out prices down to £950/m² (including IT/communications installations and furniture), some £200/m² less than the average.

SAS argues that applications such as classroom, corridors, hospital wards and offices can only benefit from this economical method of introducing sound absorption.

The sculpted coffer at Leeds City Office Park.



The new breed of office building is relying more on passive forms of comfort control like chilled ceilings and natural ventilation. But, where these systems might score on thermal comfort, they often prove inadequate in terms of acoustic privacy. Is electronic sound conditioning the solution?

BY RODERIC BUNN

Too quiet for words?

Who would have thought that the Achilles Heel of chilled ceilings is not thermal comfort or condensation, but acoustics? True, doing away with suspended ceilings and exposing the structural concrete is no way to improve sound absorption, but the truth is that such passive cooling systems simply don't generate enough background reverberation – typically in the range NR35/40 created by fan coils or vav terminals – to provide sound privacy.

And it's not only chilled ceilings which can cause such problems. The turn-down of non-fan powered vav terminals in winter can also cause a building's acoustics to deteriorate.

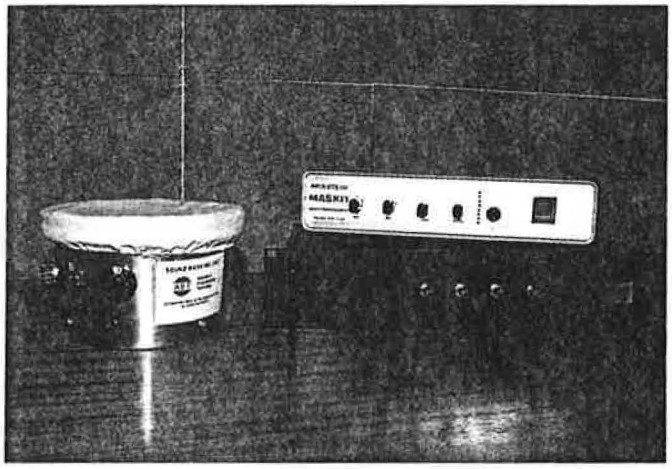
Similarly, openable windows might improve a building's energy consumption and please its occupants, but the intrusion of traffic noise will do nothing to mask the unwanted chat from colleagues, irrespective of how interesting the conversation might be. The two noise sources are simply not on the same frequency.

In an open-plan area, this can mean noise sources of the same loudness being audible over long distances or, to put it another way, that unwanted speech will be perceived to be up to 15 dBA louder. This can make all the difference between full confidentiality and lack of privacy.

Maintaining privacy may mean providing additional 20 dBA sound insulation in the partitioning system – often not a practical proposition – or opting for full-height partitioning when waist-height partitions would otherwise suffice. Either way, the increased costs could wipe out the marginal cost advantages of the chosen passive comfort cooling system, if you actually costed it out.

Sound science

The audibility of any given sound depends on the level of that sound relative to the level of the background noise. If the former exceeds the latter, then the sound will be clearly audible. Conversely, if the background noise level exceeds a particular sound then that sound is masked. The greater the excess, the greater the masking effect and the less audible the



Three generations of sound masking system. LEFT: The sound masking unit produced by Acoustic & Environmental Technology. RIGHT: The prototype Maskit sitting on top of the first pre-production unit.

sound. As a general rule of thumb, a noise may be audible if it is at least 10 dBA below the background noise level.

It follows that if background noise levels are reduced by any given amount, then all other noises become relatively noisier by a corresponding amount, and thus more audible. The lower the level of background noise, the greater the perceived level of other noises, both wanted and unwanted, such as speech, traffic noise or other extraneous noises such as that from photocopiers, printers and general office equipment.

It's not just open-plan offices that can suffer, either. Meeting rooms and cellular offices are often worse affected due to the far higher degree of sound insulation provided for such areas.

So what's the solution? Of course, for ducted systems it is possible to introduce active noise control by injecting sound into the ductwork at a frequency designed to cancel out unwanted regenerated noise[1].

That, though, only works for unwanted noise from a specific source. Masking general noise pollution in an occupied space not only requires a different source, specifically if there is no ductwork, but also at a frequency and tone that matches the room noise.

By far the most effective solution is to increase background noise levels by electronic sound conditioning, designed to produce a climate of controlled "white noise" in the occupied space via a matrix of speakers, normally concealed above a suspended ceiling.

The noise should be broad-band and characterless (similar to a good fan coil installation, for example) to which, following a brief acclimatisation period, occupants will become virtually oblivious.

Currently available sound conditioning kit is much the same as it's been for the last 20 years. The market leader is still the Sound Masking system manufactured by Acoustic & Environmental Technology and marketed by Sound Attenuators. This system comprises a stand-alone, mains-powered speaker unit which sits above the suspended ceiling and directs electronic noise upwards to the soffit, from where the noise reverberates and acts to fill the void.

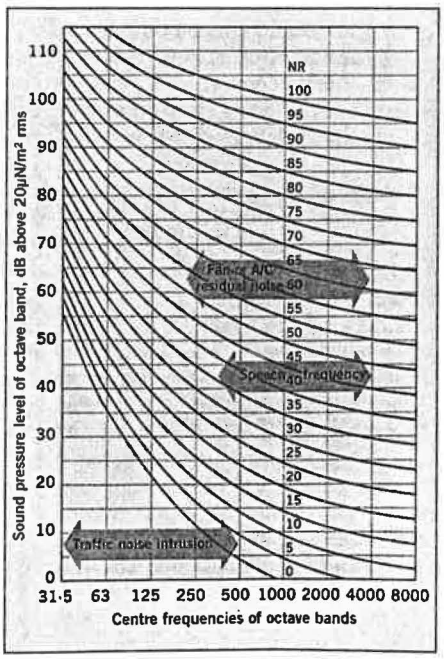


FIGURE 1: Speakers should aim to match the frequency range in which speech occurs.

Tonal adjustment is possible by altering the speaker's bass, treble and volume level. Each unit will produce enough white noise to cover a 5 m by 5 m area, which obviously means multiple units are needed to treat an open-plan office.

The problem is that they are expensive. According to acoustic consultant Hann Tucker Associates, the installed cost per unit runs at something around £260. They are also heavy, due to each unit having its own control gear and lv transformer.

A much better system would be one with a wider tonal range, with multiple speakers running off a central amplifier. Recognising the need, Hann Tucker Associates has become involved in developing a new sound conditioning system, Maskit, soon to be marketed by Hush Kits Ltd.

The system is extremely simple. The Maskit electronically produces a tunable background pink noise (subjectively warmer than white noise) specifically designed to provide speech masking for up to 75 m² of cellular or open-plan office space.

It comprises an 220/240V amplifier and control unit which can either sit above the false ceiling or electrical cupboard from where it can 'piggyback' off the building's lighting circuit.

Up to 20 speakers can than be located above false ceilings or even integrated into the chilled beam boxes of the kind produced by Trox and Halton, and also into acoustic panels of the type designed by ceiling manufacturer SAS (see "For your ears only"). In the latter, for example, the speakers can be unobtrusively located in the top side of an acoustic baffle, and angled to bounce sound off the ceiling soffit.

As a rough guide, such systems should be tuned to match the normal frequency range in which speech occurs, typically between 500 Hz to 4 kHz – the higher frequency end of the spectrum. Tuning the kits to drown out traffic noise, by the way, will not help (figure 1).

The Maskit is said to be close to a production unit, so it's not a case of watch this space, but rather listen out for developments.

Hush Kits Ltd can be contacted on (tel) 01483 770595, (fax) 01483 729565.

Reference

[1]Brister A, "The sound of silence", *Building Services Journal*, 7/93.

Further reading

Morgan S, Williamson R, Dix T, Shields R and Bridges J, "Acoustics for the end user", *Building Services Journal*, 1/90.