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Lighting rafts

Welcome to our CPD module series, designed to help you broaden your professional knowledge while you work. This module covers the use of lighting rafts to match lighting and acoustic performance to the demands of open soffit design and natural ventilation. It is sponsored by SAS International.

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Concerns over building operational carbon dioxide emissions, as well as regulatory pressures, have led to a change in the way that buildings are designed and refurbished.

Where a building has a cyclic pattern of use, such as an office, school or college with reasonable duration of occupancy, the building's own thermal mass can be utilised to minimise internal environmental fluctuations and reduce peak system loads, hence cutting the operational building CO_2 emissions. Fabric energy storage (FES), as the process is sometimes referred to, can for example provide a cooling potential of 25 W/m² [1].

However, the exposure of acoustically reflective surfaces, such as concrete soffits, can create challenges in terms of acoustic and lighting solutions. Similarly, large, open-plan spaces do not follow the normal rules for "regularly" proportioned rooms for acoustic analysis. This article considers the application of suspended lighting units designed to provide building services as well as improve the room acoustic performance in such cases.

Open soffit design

Consultants and engineers have usually integrated luminaires, air conditioning, data cabling, etc, within a suspended ceiling or used pendant luminaires to light a space. A suspended ceiling works well, hiding services, integrating other products and performing to specific acoustic demands. But where building owners and occupiers are trying to reduce energy usage and harness the thermal mass of their building, incorporating exposed concrete soffits to provide thermal buffering, a different solution is needed.

Building thermal mass is typically made more accessible to the loads in the space by exposing concrete soffits both in new projects and building refurbishments.

Open soffit design has meant lighting pendants have developed into fully integrating lighting rafts which can be installed directly from exposed soffits. This is compatible with natural, mixed mode and mechanical ventilation strategies as fresh air can freely pass above and below the rafts.

Acoustic lighting rafts

The trend has also led to the development of more sophisticated suspended lighting systems. One particular variant of these is the acoustic lighting raft (Figure 1).

As illustrated in Figure 2, acoustic lighting rafts can be designed to reflect the requirements of the building. While many installations have utilised suspended rafts, they can also be recessed, while still allowing air to circulate.

Designs include different shaped rafts (flat, curved, faceted), different sized rafts (widths, lengths and heights) and may be finished in different colours.

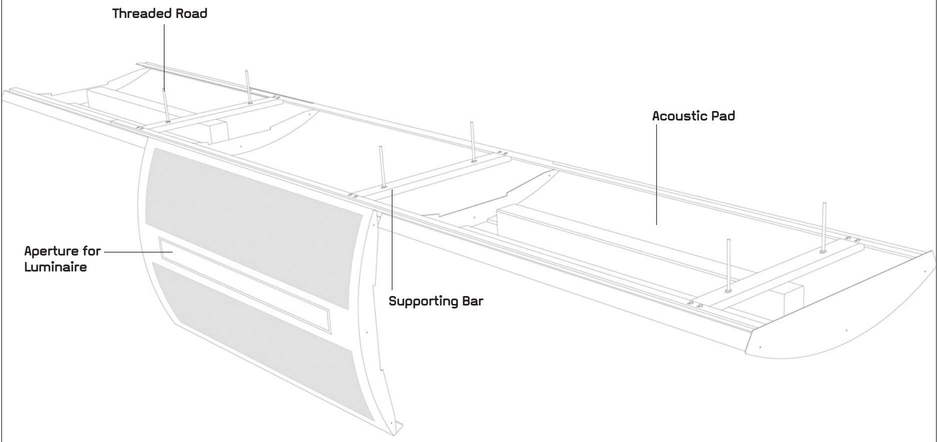

Figure 1 An example of an acoustic lighting raft

Lighting

Acoustic lighting rafts can accommodate a wide range of luminaires to meet the required standards.

Individual manufacturers will be able to give advice on the exact dimensions and layout of lighting rafts, taking particular specification criteria into account. T5 fluorescent lamps are currently the most common choice partly due to the narrow 16 mm diameter tube and the flexibility of optical designs. The T5 high-efficiency lamps also have high efficacies.

Rafts can also include both direct and indirect lighting while also including lighting controls such as daylight and passive infra-red (PIR) sensors to reduce the amount of energy consumed. Daylight sensors can be used to automatically dim lamps when enough daylight is present and PIR sensors can switch lights off when an area is unoccupied.

New luminaire technology such as MPOs (multi prizmatic opticals) and LEDs can also be accommodated.

Utilising lighting rafts also provides a solution for power distribution. Luminaire power cables are incorporated within the product, effectively protecting them and removing them from view.

Acoustic specification

Leaving a soffit exposed requires particular attention to acoustic requirements as hard surfaces can lead to increased sound reverberation levels.

Acoustic lighting rafts are designed with perforated areas on the face of the raft and sound is absorbed by the acoustic absorption material contained within the raft. Any sound reflected downwards from the soffit is also absorbed by additional acoustic material in the rear of the raft.

A range of acoustic treatments are available which can meet specific acoustic requirements such as BS EN ISO 11654:1997 [2], sound absorption Class A, or a noise reduction coefficient (NRC) of 0.95, while a weighted sound absorption coefficient (α_ω) of 0.90 can also be achieved (for examples, see Table 1).

Not all lighting rafts are available with acoustic properties, which means the acoustic demands of the space will need to be fulfilled by other methods, eg, acoustic wall panelling.

Figure 2 Example of lighting rafts integrated into a concrete soffit

The underlying acoustics

The reverberation time of a room is a measure of how sound can continue to reflect for a period of time after a source has stopped emitting sound. Reverberation time (T) is defined as the time required, in seconds, for the average sound in a room to decrease by 60 dB (a millionth of the original value) after a source stops generating sound.

It depends on the volume of the room and the rate at which the sound energy is absorbed by the wall surfaces and the objects in the room. A reverberation time of less than 1 second is beneficial for good speech intelligibility, whereas a T greater than 1 second is more appropriate for music (as rooms get larger, the ideal T will increase). The Sabine formula is used to determine the value of T for a room:

$$T = 0.16(V/Sa)$$

Where V is the volume of the room in m^3 and Sa is total surface absorption of a room expressed in sabins. It is a sum of all the surface areas in the room multiplied by their respective absorption coefficients. The absorption coefficients express the absorption factor of materials at a particular frequency (Table 2).

The reverberation time is related to a particular frequency, however such guidance documents as *Building Bulletin 93* [3] set "mid-frequency reverberation time" (T_{mf}) in terms of the average mid-frequency value of the three octave bands, 500 Hz, 1 kHz and 2 kHz where $T_{mf} = (T_{500} + T_{1k} + T_{2k})/3$ secs.

When considering the absorption performance of particular products, manufacturers frequently use the NRC. An NRC of 0 indicates perfect reflection and an NRC of 1 indicates perfect absorption.

The NRC is the average of four sound absorption coefficients of the particular surface at frequencies of 250 Hz, 500 Hz, 1 kHz and 2 kHz – these frequencies are the dominant frequencies of typical human speech. Therefore the NRC provides a simple quantification of how well the particular surface will absorb the human voice.

It should not be used when considering applications such as music or controlling mechanical noise. It is possible to have NRC values higher than 1 due to the way the number is calculated – it is important that the manufacturer's method of testing is representative of the final application of the product.

By referring to Table 2, the general value of

Worked acoustic example

A particular empty secondary school classroom is required to have a mid-frequency reverberation time of less than 0.8 seconds. The rectangular room is 8 m wide, 6 m deep and 3 m high. There is one internal 2 m² timber door and the 12 m² glazing is located in one of the 8 × 3 m walls. It has a cast concrete ceiling, a carpeted floor, three plasterboard internal walls and a brick-faced external wall.
Room volume, V = 8 × 6 × 3 = 144 m³

Surface	Area (m²)	?(500 Hz)	Area x $?_{500}$	?(1 kHz)	Area x $?_{1k}$	?(2 kHz)	Area x $?_{2k}$
Floor	48	0.30	14.40	0.30	14.40	0.30	14.40
Ceiling	48	0.02	0.96	0.02	0.96	0.02	0.96
Int walls	58	0.05	2.90	0.04	2.32	0.07	4.06
Door	2	0.05	0.10	0.04	0.08	0.04	0.08
Ext wall	12	0.03	0.36	0.04	0.48	0.05	0.60
Window	12	0.20	2.40	0.10	1.20	0.07	0.94
Total absorption area (Sa)			21.12		19.44		21.04
T = 0.16(V/Sa)			1.09		1.19		1.09

T_{mf} = (1.09 + 1.19 + 1.09)/3 = 1.12

This is greater than the required maximum of 0.8. To reduce the value of T_{mf} some Class A acoustic rafts could be used with an NRC of 0.95.
For a T_{mf} of 0.8, Sa = 0.16(144/0.8) = 28.8; hence the acoustic raft must contribute approximately an extra total absorption area of 8 (ie, 28.8 less the approximate Sa of the rest of the room).
So the required area of rafts would be at least 8/0.95 = 8.42 m²

NRC for a plane slab of cast concrete would be (0.01 + 0.02 + 0.02 + 0.02)/4 = 0.02. (It is rounded to the nearest 0.05.)

So clearly the reverberation time can be adjusted within an existing space by adding or removing absorptive materials to achieve the desired reverberation time – this would best be undertaken as the building is designed.

Service integration

Many building services can be incorporated into the design of acoustic lighting rafts. The most common services included are voice and data cabling, public address systems, smoke detectors and sprinkler systems. Radiant heating panels can be incorporated, freeing up floor and wall space by replacing a low-level heating system and reducing the risk of occupant contact with heating surfaces. The incorporation of multiple building services into the one module helps keep ceilings uncluttered while also allowing the maximum access to the thermal mass.

The prefabrication of luminaires, acoustic materials and building services within acoustic lighting rafts can lead to significant savings in both time and cost during the installation process. Assembly in a factory controlled environment is more efficient as operatives are skilled in the manufacture of specific products. The process can lead to significant economies of scale, and quality control can easily be undertaken.

Prefabricated rafts can be delivered to site as required, reducing both on-site storage and waste levels. They can then be quickly suspended from the soffit using threaded rods, resulting in reduced time working at height thus reduced health and safety risks. "Plug and play" connections facilitate easy connection of services contained in each raft and flexible hoses can be used to connect radiant heating panels.

Finally, the main framework and external skin of acoustic lighting rafts are typically made of metal (aluminium or steel), making them fully recyclable at the end of the product's life.

Conclusion

Acoustic lighting rafts can be applied to refurbishment and new-build projects. In refurbishment projects, particularly 1960s and 1970s buildings, acoustic lighting rafts can maximise the floor to ceiling height by exposing the soffit. They are readily applied to commercial offices and educational buildings and can be integrated with buildings employing natural, mechanical or mixed-mode ventilation. ■

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Further reading

There are many excellent guidance documents that provide extensive introductions and worked examples of the acoustic performance in buildings. For example:

- **Building Bulletin 93 [3] provides a guide for the acoustic design of schools but also provides an excellent general reference.**
- **Health Technical Memorandum 08-01: Acoustics [4] is aimed at health care buildings and again is an excellent reference.**
- **The British Council for Offices gives guidance in its *Best Practice in the Specification for Offices* and *Office Fit-Out Guide* on acoustic issues in commercial environments.**
- **Natural Ventilation in Non-domestic Buildings, CIBSE Applications Manual AM10, CIBSE, 2005**

References

[1] De Saulles, T, 2005, Thermal Mass – A Concrete Solution for a Changing Climate
[2] BS EN ISO 11654:1997 Acoustics – Sound Absorbers for Use in Buildings – Rating of Sound Absorption
[3] Building Bulletin 93 – Acoustic Design of Schools – A Design Guide. The Stationery Office
[4] Health Technical Memorandum 08-01: Acoustics. Department of Health Gateway Review, Estates & Facilities Division, 2008

With thanks to John Staunton of SAS International for diagrams and content for this article.

Table 1: Examples of acoustic requirements

	NRC	Absorption class	α_{ω}
Perforated raft with acoustic fleece	0.60	Class C	0.60
Perforated raft with 25 mm and 80 kg/m³ acoustic pad	0.80	Class B	0.80
Perforated raft with 50 mm and 80 kg/m³	0.95	Class A	0.90

Table 2: Sound absorption coefficients at stated octave band

Surface	125	250	500	1000	2000	4000
Suspended ceiling tile	0.5	0.4	0.7	0.8	0.6	0.4
12.5 mm plasterboard on studs	0.3	0.1	0.05	0.04	0.07	0.1
Cast concrete	0.01	0.01	0.02	0.02	0.02	0.03
Window glass	0.3	0.2	0.2	0.1	0.07	0.04
Carpet on underlay	0.1	0.3	0.4	0.5	0.6	0.7
Vinyl floor on concrete	0.2	0.3	0.3	0.3	0.3	0.2
Brick	0.03	0.03	0.03	0.04	0.05	0.07
Timber door	0.1	0.07	0.05	0.04	0.04	0.04
Seated people	0.4	0.4	0.7	0.7	0.8	0.7

These are typical values – for design purposes use suppliers' data.

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Module 1

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Having read this CPD module and made use of the references, you should be ready to select the correct answer to each question below. Tick one box per question.

1) What cooling potential is claimed for fabric energy storage?
- ☐ **A 10 W/m²**
- ☐ **B 15 W/m²**
- ☐ **C 20 W/m²**
- ☐ **D 25 W/m²**
- ☐ **E 30 W/m²**

2) Lighting rafts are likely to be obtained to include all the following except one – which one?
- ☐ **A Direct lighting**
- ☐ **B Indirect lighting**
- ☐ **C Photovoltaic panels**
- ☐ **D Daylight sensors**
- ☐ **E PIR sensors**

3) The following attributes of lighting rafts with integral acoustic panels are likely to exist except one – which one?
- ☐ **A They reduce reverberation times**
- ☐ **B They can have an NRC of greater than 0.75**
- ☐ **C They readily reflect sound**
- ☐ **D They have perforations in their metal casing to allow sound to pass**
- ☐ **E They can be suspended from the exposed soffit**

4) Which of these would not be integrated into acoustic lighting rafts?
- ☐ **A PA systems**
- ☐ **B Fire detection systems**
- ☐ **C Radiant heating systems**
- ☐ **D Voice and data cabling**
- ☐ **E Convector heaters**

5) Using the data from the article what would be the value of the NRC of vinyl floor on concrete?
- ☐ **A 0.1**
- ☐ **B 0.2**
- ☐ **C 0.3**
- ☐ **D 0.4**
- ☐ **E 0.5**

Answers to Module 11
November 2008 issue: Chillers or VRF?
Q1: C Q2: D Q3: A Q4: B Q5: E

Send this page by 6 February 2009

(Unfortunately, due to time restrictions, any answers received after the above date will not be processed.)

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Which of the following best describes your job function:
- ☐ **Consultant**
- ☐ **Contractor**
- ☐ **Local/national government**
- ☐ **Financial services**
- ☐ **Health authority**

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