SUSTAINABLY SOURCED AND COST-EFFECTIVE SOLUTIONS TO CONTROL THE ACOUSTIC ENVIRONMENT OF COMMUNITY HALLS

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1 INTRODUCTION

Community halls exist in virtually every village/town and city, in and around the UK. The usage of such spaces is often wide ranging, as dictated by the needs of the surrounding local community. Examples of usage could range from sport type activities, local interest clubs, social functions, right through to play groups for large numbers of children and amplified music (both live music and DJ) for events.

Due to the common ‘multi-function’ usage and ease of maintenance requirements, often, within the halls, predominately hard surfaces will exist with little or no consideration given to the resultant acoustics for the finished space. Within the scope of this paper, this was evident in the older hall, dating back to approximately 1938.

Furthermore, little consideration is given in terms of retrofitting acoustic products in such spaces on the basis of cost to the hall operator.

A further consideration is that the built environment is largely constructed with the able bodied in mind and those with ‘normal’ hearing[1] . However, a sizeable amount of the end user groups will be the less able bodied, namely the elderly, who use the facilities in a number of ways, either for social events such as lunch clubs, or for interest groups. As mitigating loneliness is an important consideration for the elderly, the facilities should be able to offer an enjoyable experience they would wish to repeat.

This paper provides details of pre and post measurements undertaken in sample halls using only sustainably sourced materials to control undesirable acoustic features. Cost was also carefully also considered during the selection of materials.

2 METHODOLOGY

2.1 Field Measurements

A total of four contrasting hall spaces were selected based on locality, age, general finishes and shape:

Hall A:

This hall was built in 1993, with weekly events being scheduled such as play groups, local meetings, live music events and private functions. In terms of shape, it is rectangular with exposed brickwork on all four walls, hard wood floor and windows at high level. Although not confirmed, it is suspected the installed suspended ceiling is likely to be of an acoustically absorptive nature.

Hall B:

Built around 1980/83, adjoining a local church via a prefabricated walkway. Normal weekly activities include children's play groups and other similar events associated with the church. In terms of build, this is more akin to a classroom type space, with carpeted floor, plasterboard walls and flat ceiling.

Hall C:

This hall is the oldest in the study (c.1938), serving the local community by hosting toddler play groups, sit down events, private functions etc.

The hall comprises an arched ceiling being 5.8 metres high at the peak, with walls made of lath and plaster. A hardwood laminated floor is installed in the main hall area. Fully seated events are undertaken at this hall using loose weave type seats, which will provide additional absorption. A lower side storage area with support pillars also forms part of the main hall area.

Upon entering the space, a significant 'live' feel was noted when compared with the other spaces within the study. Additionally, by the use of a suitable impulsive noise (hand clap), the presence of flutter echoes was noted [2] .

Hall D:

Arched ceiling, with assumed suspended ceiling tiles providing some degree of absorption. Wooden hard floor.

Opened to the public c.1981. Again, upon entering the space, a significant 'live' feel was immediately noted.

2.2 Initial Testing

Initial testing of contrasting spaces was undertaken using the following approach:

For this study, the measurement methodology employed has been as described in appropriate British Standard(s) [3 & 4].
The measurement of reverberation time for noise control analysis is an important area of room acoustics when considering suitability for speech and/or music performance[4] .

Measurements were made across the range of 100 Hz-5 kHz in third octaves.
[4]Microphone positions must be least ½ a wavelength apart, which equates to approximately 2 metres when considering the lowest frequency for measurement under this standard, which is 80Hz.
Consideration is also given to limiting the effect of direct sound from the source. The minimum measurement position from the source can be calculated from the following equation:

$$d_{min} = 2\sqrt{\frac{V}{cT}}$$

Where:
V = volume, in m^3
C = speed of sound, m/s
T = estimate of expected reverberation time, in seconds.

2.3 Survey Methodology

Benchmark T_{mf} reverberation time results shall be presented in this section of the paper for each hall using the extended frequency methodology ranging from 125 Hz to 4 kHz, expressed as arithmetic averages. This adopted methodology has been sourced from BB93 (Feb 2015) to more acceptable acoustic conditions for SEN students.

This benchmark method has been adopted in favour of the normal 500 Hz to 2000 kHz range as it is anticipated to show potential modal effects in each space.

3 RESULTS: PRE-TREATMENT

Shown below are particular measurement results collected from each test site, prior to any treatment being applied. Where acoustic features applied (flutter echoes, control of long path reflections etc.), these are discussed on a hall-by-hall basis.

3.1 Measurement site results

Hz	**125**	**250**	**500**	**1000**	**2000**	**4000**	**T_{mf}**
Average	1.53	1.09	0.95	0.95	1.02	0.94	1.08

Table 1: Hall A

Hz	**125**	**250**	**500**	**1000**	**2000**	**4000**	**T_{mf}**
Average	0.87	1.14	1.04	1.02	0.78	0.53	0.90

Table 2: Hall B

Hz	**125**	**250**	**500**	**1000**	**2000**	**4000**	**T_{mf}**
Average	1.59	1.91	1.64	1.82	1.82	1.47	1.78

Table 3: Hall C

Hz	**125**	**250**	**500**	**1000**	**2000**	**4000**	**T_{mf}**
Average	1.31	1.29	1.12	0.93	0.93	0.70	1.05

Table 4: Hall D

4 REVERBERATION CONTROL

As part of the basis of the study, information for a commercially available product including both performance and associated cost were sought. Absorption classes have been defined accordingly[5], details are as follows:

4.1 Commercial product acoustic absorption coefficient data

125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	Class
0.2	0.6	1.0	1.0	1.0	1.0	A

Table 5: Commercial acoustic absorption data

Product information quotes fire resistance of either class 1 or 0 for the covering fabric. A variety of installation options are possible, allowing the installer to cut panels as dictated by site requirements. Additionally, product details do draw attention to a higher onsite absorption being achieved when panels are installed in front of an air gap, between the internal surfaces and the back of the panel.

4.2 Sustainable product details absorption coefficient data

125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	Class
0.17	0.32	0.67	0.77	0.77	0.74	C

Table 6: Sustainable acoustic absorption data

It was proposed to construct acoustic panels using a material which is based upon reclaimed cotton fibres. The summary features for the test product are included below (stated by the manufacturer):

- Each batten contains 85% recycled denim/cotton.
- Remaining 15% is polyester.
- No chemical irritants, thus being non-itch and will not cause allergic reactions.
- Anti-bacterial and fungicide treatment: 1% (product not stated).
- The reaction to fire of the product is determined according to EN 1350-1, achieving a fire rating of ‘E’. Should the product be installed behind a facing (for example, unperforated plasterboard) fire rating is B.
- Low carbon impact and recycled.
- Acoustic absorption coefficient performance measured in accordance with BS EN ISO 354:2003 ‘Acoustics- Measurement of sound absorption in a reverberation room’

5 PROPOSED PANEL DESIGN

Materials used for panel construction were as follows:

- Sustainable denim acoustic infill batten slabs (20 of at 1200/600/45mm).
- Hessian: light gauge.
- Plywood (3.5mm thick) to make panel backing.
- Planed timber to construct outer frame.

Each panel shall provide a nominal 0.72m^2 of absorption. A total of 20 of panels shall be made giving a total coverage of 14.4 m^2 (Surface Area). Whilst it is acknowledged this coverage may be insufficient in some instances to reach a target reverberation time, it is expected however this amount of additional sustainable absorption shall provide a measurable difference at sites selected for the post treatment testing.

5.1 Requirements of Panel Design

Design of the panel was influenced by the following acoustic features witnessed in the halls within the study.

Hall C:

This hall presented the widest selection of undesirable acoustic features, these included:

- Flutter echoes.
  It is likely the concave ceiling is the cause. This same feature was also witnessed in Hall D, although to a lesser extent.

- Amplification (standing wave) at around 125Hz.

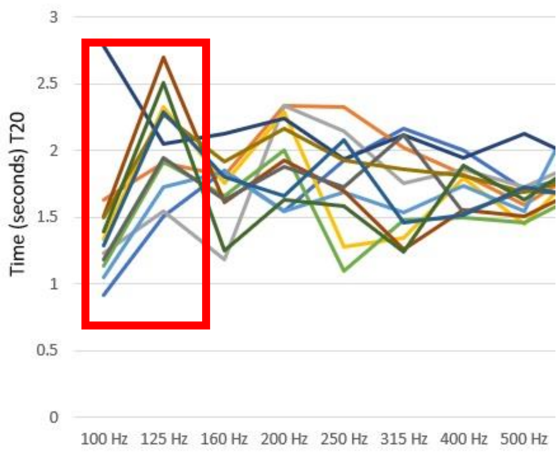

Figure 1: Hall C: Reverberation time showing standing wave

Potentially, lack of acoustic absorption at this frequency may also have influenced the pre-treatment measurements.

Consequently, it was proposed to include an air gap of 150 mm behind the infill. This calculation is based upon an estimated 2 kg/m^2 , [6] for the 3.5 mm plywood backing.

$$f = \frac{60}{\sqrt{md}}$$

Figure 2: Resonant frequency calculation

Where:
f = resonant frequency.
m = mass of the panel (Kg/m^2).
d = depth of the airspace (in m)

The above estimation is subject to variation to the fixing and stiffness of each panel backing. On the basis of the above calculation result, the air gap for each panel shall be 150 mm, to improve sound absorption attenuation close to the target frequency of 125 Hz.

6 POST TREATMENT SITE TESTING AND ANALYSIS

Halls A and C were selected for post treatment testing and analysis. The halls were selected on the basis that they each provided the study with a contrast in terms of age, architecture, size and construction.
Hall C was of particular interest to the study as there was no clear use of acoustic treatment within the space, whereas it is believed absorption may have been installed within Hall A in the suspended drop ceiling and assumed associated cavity space based upon observations made externally to the building.

A total of four scenarios were measured in the post treatment site testing of both Halls A and C. Due to site constraints, the 4th scenario at Hall A was not undertaken.

All sustainable panels were temporarily placed within Halls A and C in the following scenarios at ground level:

Scenario 1: Short walls.
Scenario 2: Long walls.
Scenario 3: Corners.
Scenario 4: Floor. (Hall C only).

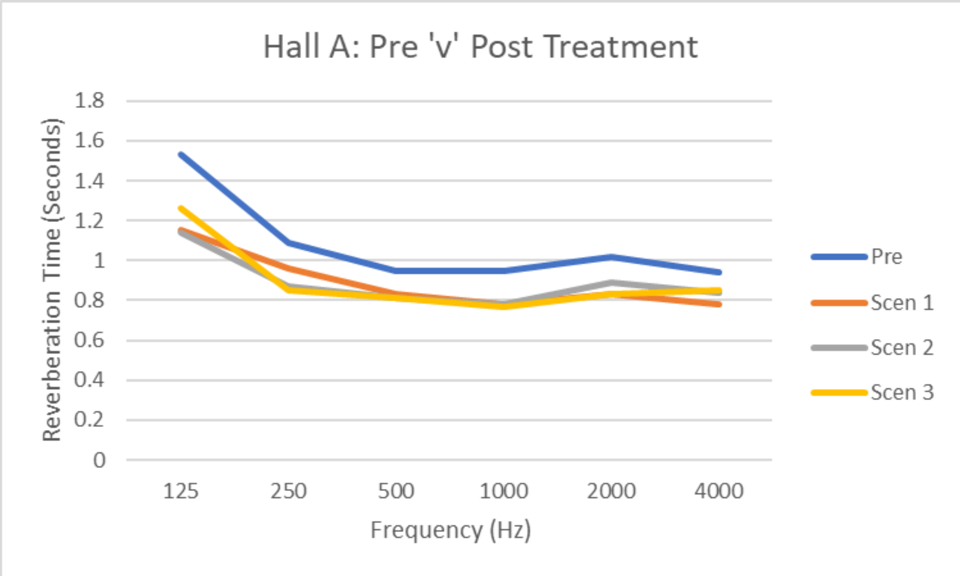

Figure 3: Hall A, Pre & Post Treatment

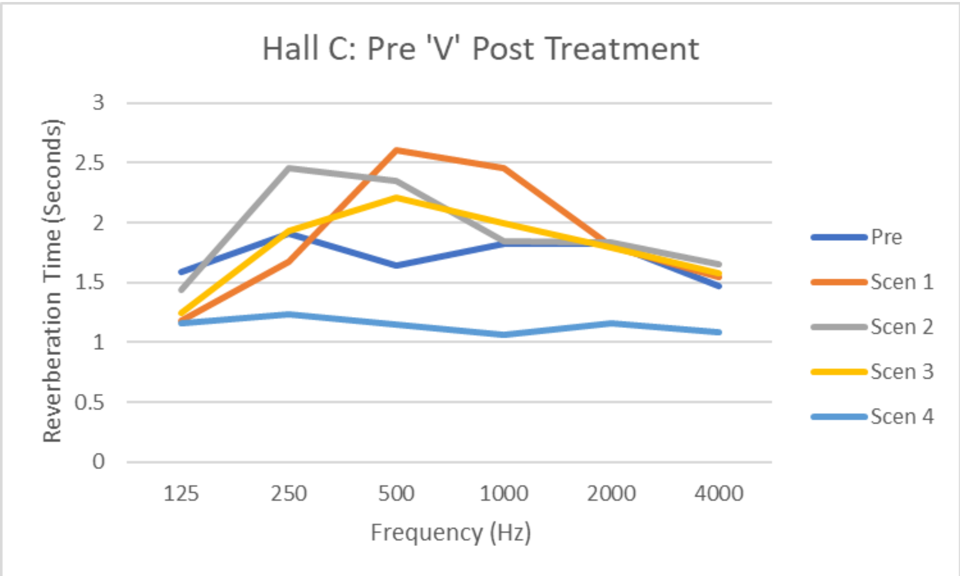

Figure 4: Hall C, Pre & Post Treatment

7 COST COMPARISION AND PERFORMANCE ANALYSIS

As part of the study, a quotation was sought from a well-known supplier of acoustic treatment panels. The hall used for this exercise was Hall ‘C’, as it was deemed most in need of acoustic treatment, as previously described. The brief provided to the commercial supplier was to lower the reverberation time of Hall 'C' from its pre-existing state of 1.78 down to 1.3 seconds (T_{mf}). Details of both commercial and alternative sustainable acoustic panelling are illustrated below:

Approach	Size of panel(s) (m^2)	Total coverage of panels (m^2)	Number of panels required to meet brief	Notes	Cost of supply (per finished panel)	Total supplied cost
Commercial	1.08	43.2	40 (as quoted by supplier)	Product data states greater performance can be achieved when airgap installed behind panel	£102	£4080
Sustainable option	0.72 (actual absorption area)	14.4	20 (practical limit of production for research)	No guidance provided increasing product performance.	£35.60	£712

Table 7: Cost comparisions

8 CONCLUSIONS

8.1 Summary conclusions of site measurements

Experimentation of physical positioning of acoustic panels has produced variability in the final testing results. Attenuation of low frequency, centred around 110-125 Hz due to the airgap within each panel, has performed largely as anticipated, producing a reduction of -25% at Hall A, and 26% at Hall C for scenario 1 (covering short walls) across 1/3 octaves.

Scenario 1	**110-160 Hz**
Pre treatment	1.53
Post treatment	1.15
Reduction	**-25%**

Table 8: Average reduction in reverberation time at 110-160Hz for Hall A

Scenario 1	**110-160Hz**
Pre treatment	1.59
Post treatment	1.18
Reduction	**-26%**

Table 9: Average reduction in reverberation time at 110-160 Hz for Hall C

Regarding Hall C however, the final measurement data has raised subjective questions on the importance of the positioning of acoustic treatment within a space. The presence of unpleasant flutter echoes within this particular space meant this hall was of interest to the study, exhibiting a clear acoustic issue. Final testing using scenario number 4 (placing panels flat on the floor in a random manner) produced by far the best results, both objectively and subjectively. This scenario virtually eliminated the flutter echo evident on the first visit to the hall.

Further research, utilizing room acoustic modelling, a larger cross section of hall types and site based (both pre and post treatment) reverberation testing may potentially facilitate the production of basic guidelines to be developed. This would be aimed at assisting a lay person to make informed decisions about improving acoustic problems in village and community halls. For example, where a curved, concave ceiling exists in a space, the likelihood of flutter echoes could be increased (as was the case in both halls C and D). This is confirmed by guidance provided for the development of new school halls[2] .

Panels being fully compliant with the requirements of fire regulations related to internal fire spread, would also require consideration and potential product modification. This may come in the form of modifying the acoustic infill with a fire-retardant finishing product, which could in turn change acoustic performance. Specifically, to fulfil the primary requirement for a material to successfully absorb sound waves, the material(s) should have a high level of porosity to allow acoustic energy to enter its matrix. Input would be required by a fire engineer.
Although outside the scope of this study, an additional surface property of diffusion would also warrant attention. Positioning of such diffusors would assist scattering within a given space. Further research should be conducted on the scattering coefficients of surfaces. It is currently accepted that this is a relatively unknown area of a surface property with modelling software often basing simulations on estimated data.

Concluding remarks are that improvements can be made to acoustics in community halls; being both in a sustainable and cost-effective manner by using materials which are not mass produced. Indeed, during the final stages of research for this study, it has been noted that more available reverberation control end products are appearing onto the market which have improved ecologically friendly credentials. This includes the provision of natural fibres and opting for recycling materials where possible.[7]

Clear understanding of a single or range of potential acoustic issues would assist in a more effective approach when considering a particular space. Examples of these could include:

- The need for variable acoustics (speech v music)
- The presence of undesirable acoustic features such as flutter echoes.

It is with increasing interest and importance across all sectors of the built environment to strive for sustainable development goals, “acting not out of self-interest but out of common interest”[8] in terms of material sustainability. Further research into the end product flammability would be beneficial in demonstrating Part ‘B’ compliance.

9 REFERENCES

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