The challenge of meeting both acoustic and thermal comfort in 21st century school classrooms

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Summary

The benefits of "thermal mass" in stabilizing temperature for thermal comfort and reducing building energy consumption for sustainable green buildings are well documented. However, when exposing the concrete soffit for thermal purposes it is then not possible to have a fully covered sound absorbing suspended ceiling in classrooms for acoustic comfort. In turn, this makes it a potential compromise to achieve good acoustic comfort while still utilizing the thermal mass of the exposed soffit.

For this paper we measured a classroom configuration with free hanging sound absorbing units and wall absorbers in comparison to measuring a fully covering traditional suspended ceiling. We looked into optimizing the low frequency imbalance - a potential negative consequence from not having a full suspended ceiling - with an enclosed void which can trap the low frequency sound (125Hz) which can build up and interfere with the important speech frequencies. We looked at the challenge of optimizing the acoustic coverage range without affecting the thermal comfort. We also wanted to improve the balance of the potentially negative low frequencies to support good speech communication and acoustic comfort for all students and teachers, while also seeing if it is possible to provide an inclusive acoustic environment for sensitive listeners. Our mission was to make the combined thermal and acoustic free hanging unit classroom solution perform as close as possible to a fully covering acoustic solution which optimizes acoustic conditions for all speech and listening activities and is inclusive for sensitive listeners.

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Introduction

Classroom acoustic standards[4] are generally met with full covering high performing acoustic suspended ceilings, sometimes with a small amount of wall absorption. One of the reasons acoustic suspended ceilings perform well, is due to much of the sound being effectively trapped (particularly the low frequency sounds) within the ceiling void which can vary generally between 200mm and 1000mm.

However there is an increasing trend towards exposing the structural thermal mass of the school buildings (without a fully covered suspended ceiling; to help to stabilize the temperature via night cooling etc.). This move is generally driven by governments who want to reduce the long-term energy costs for their school stock. In England, the PSBP (Priority School Building Programme) is pushing for this in all new build schools and in Germany increasing numbers of Federal States are insisting on the same for new build municipality schools.

While it is to be commended that governments (and Green Building Councils) are striving for more sustainable buildings with reduced energy consumption being prioritized, it is also important to make sure that any drive for thermal efficiency is not detrimental to the acoustic comfort of teachers and students.

To this effect it is even more important that acoustics are prioritized even higher when it comes to Thermally Activated Building Systems (TABS buildings). In a traditional school building, a fully covering (100%) sound absorbing suspended ceiling is a fundamental starting point for reducing the sound level and supporting good speech clarity and overall communication quality. In addition there should be wall panel absorbers to take out late reflections starting with the back wall. Additional low frequency absorption can balance the sound environment where there is potential for an excess of unwanted and disturbing low frequencies (125Hz) and may be necessary for inclusion of children who are sensitive or vulnerable listeners. A wide range of students can be described as sensitive listeners including; permanent and temporary hearing impaired, partially sighted, autistic, ADHD, non-native language speakers or even the more introverted students.

1. Methodology (Intervention Study)

The main part of this intervention study was to measure and analyse room acoustic data from different acoustic configurations which are relevant for TABS classrooms. Active choice of absorbing panels and configurations to fulfil considered target values4 over the relevant frequency range, including special attention to low frequency absorption, the existing room construction properties and the effect of the distribution of the absorption. In the data collection of room acoustic measurements, the room was furnished and unoccupied. The room acoustic parameters chosen are defined in ISO 3382-1/25,6 and using these recorded impulse response measurements it was possible to investigate the parameters2,3 C50, G and T20 in accordance with ISO 3382-15. These relate to acoustic qualities of speech clarity, sound strength / sound level and reverberance.

2. TABS classroom configurations

The size of Ecophon Solaris lab room is length x width x height = 7.25m x 7.25m x 3.5m. (52.5m2 & 184m3). Although the room is minimally furnished to simulate a "worst case scenario" 1 it has typical furniture and surfaces for a TABS classroom. A full suspended ceiling grid system was installed with a ceiling height of 3.2m and 300m (ODS) overall depth of system in the ceiling void. This was to provide the support frames for the absorption panels and allow efficient changeovers of the many different acoustic configurations.

- **Configuration 1**

Bare room (no acoustic treatment on the ceiling or walls) with existing empty grid at 300mm ODS giving a Ceiling Height of 3.2m, to simulate a typical TABS senario. (800mm ODS and CH of 2.7m is a typical non-TABS senario). The grid height remained during all the 8 configurations.

- **Configuration 2**

The installed raft absorbers 600x600 40mm high density high equivalent absorption area (Aeq) or "Class A" sound absorbing panels in the existing grid. Split in 4 separate rafts with 1 tile (600mm) gap between the rafts and surrounding at the perimeter (4x5 full size panels in the grid). This configuration is to simulate a typical solution for TABS classrooms with a coverage ratio of approx. 60% of total ceiling area[7]. Raft Absorbers Surface = 29.16 m2 Coverage ratio = 56% of the total ceiling area.

- **Configuration 3**

Same installation as number 2 with low frequency sound absorbing panels (1200x600) 50mm lower density high equivalent absorption area (Aeq) or "Class A" absorbing panels installed above the raft absorbers 7.2m2 rafts. Six low frequency absorbing panels to be laid over the tiles and grid. Total extra low frequency panels above the Raft Absorbers = 19 m^2

- **Configuration 4**

Same configuration as 2 with absorbing wall panels 40mm high density "Class A" absorbing wall panels in a bespoke double frame (90mm frame) on the back wall. Three 2700x600mm wall absorbers direct mounted on the back wall, spaced in the middle.

- **Configuration 5**

Same as 4. Plus additional low frequency absorbing panels (1200x600) mounted behind the wall absorbers in the 90mm bespoke frame. Six (1200x600) low frequency absorbing panels fitted between support battens.

- **Configuration 6**

Same as 5. Plus 3. Plus installing additional low frequency panels (1200x600) above the absorbing rafts) 7.2m2 rafts. Six low frequency panels laid over the tiles and grid.

- **Configuration 7**

Same as 3. Plus installing additional low frequency panels above the absorbing rafts.

- **Configuration 8**

Same as 7. Plus four absorbing wall panels 2700x600mm resting against the adjacent wall.

- **Configuration 9**

A full 100% coverage 40mm Class "A" 600x600mm sound absorbing suspended ceiling.
ISO 11654 testing of Absorption materials: The ceiling panel installed is a (Ecophon Master E) 40mm panel, Absorption Class "A" glass wool absorber, the additional low frequency absorber is specifically designed to optimize low frequency

absorption (Ecophon Extra Bass) 50mm panel Absorption Class "A" glass wool absorber and the wall panel absorber a (Ecophon Akusto) 40mm Absorption Class "A" glass wool absorber.

Acoustic Configuration:	60% coverage [7] with Raft: 40mm Absorber	Above Raft: 50mm LF Absorber	10% Rear wall: 40mm Wall Absorber	Behind rear wall: 40mm Wall Absorber & 50mm LF*Absorber	Side Wall 40mm Absorber (Bonus)	100% coverage: 40mm ceiling Absorber
1	O	O	O	O	O	O
2	X	O	O	O	O	O
3	X	X	O	O	O	O
4	X	O	X	O	O	O
5	X	O	X	X	O	O
6	X	X	X	X	O	O
7	X	X	X	O	O	O
8	X	X	X	O	X	O
9	O	O	O	O	O	X

Table 1:Acoustic configuration summary; X = acoustic absorption, 0 = no absorption *LF (low frequency)

3. Results

From the acoustic report[8] of the measurements carried out in the Ecophon Solaris (TABS classroom) laboratory. Our room set up for this test as simple as possible, without wall elements to simulate the worst acoustic configuration possible[1]. The furniture inside the room was just 11 tables and 19 chairs. 12 tests for each position (6 microphone positions x 2 Loudspeaker positions) [5] Microphone height: 1,25m, Loudspeaker height: 1,4m. Impulse responses measured with a multidirectional MLS (maximum length sequence) internal signal with Dirac Software.

Summary of average values of all the configurations from the measurement data:

Solaris	*T20*	C50	*G*	D_{50}
Conf,1	2,2	-4,2	27	28
Conf.2	0,98	1,6	22	59
Conf.3	0,8	2,6	21	64
Conf.4	0,85	3	21	66
Conf.5	0,82	2,6	21	64
Conf.6	0,7	3,2	21	68
Conf.7	0,7	3,3	21	68
Conf.8	0,57	4,7	20	74
Conf.9	0,897	3	17	66

Table 2: Measurement data average values of the acoustic configurations across frequency range (125-4000Hz).

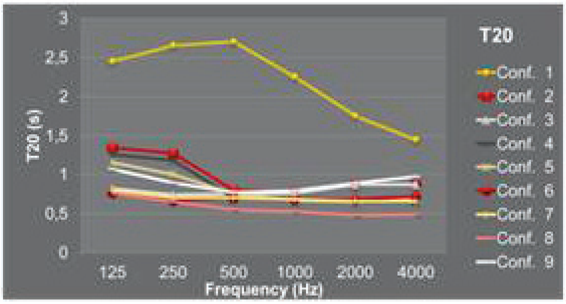

Fig. 1. T20 for all 9 measurements

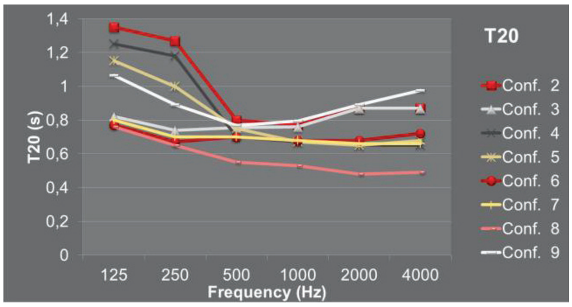

Fig.2. T20 for all measurements except (1) the empty room

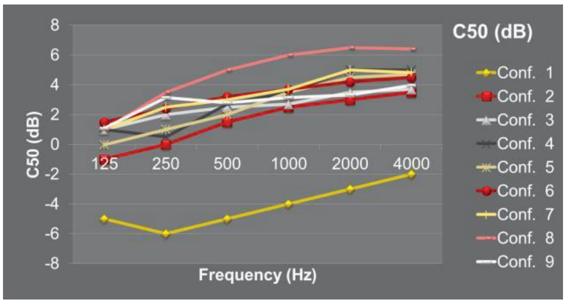

Fig. 3. C50 for all 9 measurements

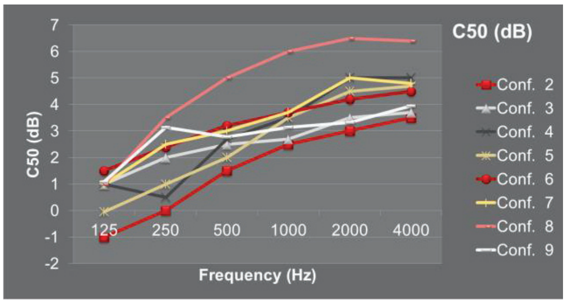

Fig. 4. C50 for all measurements except (1) the empty room

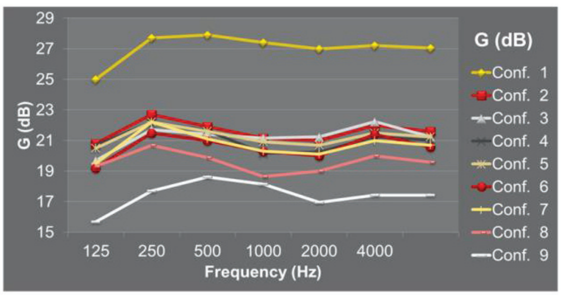

Fig.5. G for all measurements

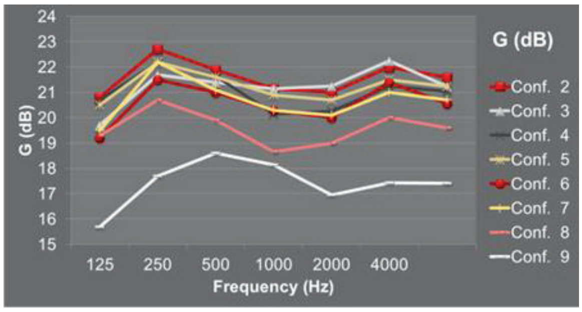

Fig.6. G for all measurements except (1) the empty room

4. Conclusion and discussion

In this paper, the aim was to look at optimizing the acoustic conditions for classrooms in TABS school buildings where it is not possible to have a 100% covering high performance “Class A” sound absorbing suspended ceiling. By using free hanging sound absorbers and wall panels we wanted to see how good an acoustic environment is achievable, when the full coverage is not possible due to the need of exposing areas of the concrete soffit for thermal purposes.

We also wanted to obtain relevant acoustic data which would help us match the technical data with human qualities and let us assess how the human user perception of room acoustics would be in reality. This can help us to come closer to defining the appropriate conditions which are possible for TABS classrooms. We ultimately believe this will have a significant impact on the conditions for speech communication, not just for the inclusion of sensitive listeners but for all teachers and all students for their teaching and learning activities.

In Table 2. we can see that Configuration 2 and Configuration 3 look the same when we average the values, however it would be interesting to know if the differences we see across the frequencies in Figure 2. can be perceived by users. This would help inform future fine tuning across the frequencies (125-4000Hz) to identify when there is a significant difference which would be missed if only the average values (500-2000Hz) are presented. This might also reinforce the need to look across all frequencies and not just mid frequencies as is often done in acoustic standards. However, if we compare the best values achieved here (although in pessimistic non-diffuse conditions1) to the highest typical classroom target values 4 corresponding to optimal room acoustics for classrooms, we can see that we don't achieve the requirements.

So while we believe it still best to have a traditional fully covering suspended ceiling (including additional low frequency absorption and wall absorbers) it might be that these values can be improved (i.e. in less pessimistic non-diffuse conditions1) with additional sound absorbing furniture. However it is also important to note that for the inclusion of hearing impaired occupants and for increasingly more intensive speech activities like interactive group work, then unless everything possible is done to create a good sound environment, these TABS classrooms may not be "fit for purpose". Meeting this challenge and balancing the low frequency acoustic problem by improving the room acoustic balance for speech and hearing activities in these TABS schools may also inform us as to how to improve acoustics in school buildings in hotter climates. Where there is little or no existing sound absorption and exposed structural soffit cools the classroom passively, might reduce the need for HVAC in for example Mediterranean countries if these hybrid solutions can be developed for these situations.

Looking beyond the practice of using only a single number RT, we need to connect and clarify the way room acoustics are predicted and subsequently measured in order to secure good room acoustic outcomes for TABS classrooms so that they are "fit for purpose" for good speech communication in the variety of conditions already stated which as part of broader educational approaches are increasing to encourage student engagement and collaboration.

This study gives us measured outcomes, justifying the need for additional low frequency absorption and wall absorption. Long term it would be good to have more gathered evidence to inform us about how these parameters are actually perceived, in what we believe are optimized acoustic conditions for TABS classrooms, for the more intense speech communication activities. This would help to inform the requirements for good acoustic comfort in practice and whether it will meet the inclusion of sensitive listeners needs.

References

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