A Method for Testing & Comparing Classroom Floor Noise

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Abstract

There is a growing acceptance in this country that the acoustic properties of classrooms render them inadequate to operate as effective teaching spaces. Recent studies conducted by the New Zealand Classroom Acoustics Research Group (Dodd, Wilson et.al., 2001) incorporating both subjective questionnaires and objective measurements of classrooms have confirmed this concern, and have indicated that in relocatable classrooms, a likely source of the acoustical problems is the floor. Even so this is a largely subjective observation, one which is difficult to correlate with identifiable measurable properties of the space. Nor is there a recognized method for creating a standardized sound field in a classroom to measure those properties, whatever they might be. This investigation is an effort to obtain such a method for testing and comparing classroom floor noise.

The Method suggested consists of:

- The use of a tapping machine to create floor noise in a standardised, repeatable fashion that would approximate the way in which floor noise is created in a real classroom situation.
- The sound pressure levels (50 Hz – 5 kHz) are recorded in the classrooms for the tapping machines impacting on the floor diaphragm.
- The levels are adjusted to give the floor noise component only, specific to the room tested (by logarithmically subtracting the background noise and the machine noise).
- The floor noise level component from the room is then normalised to remove the room effect.
- Comparisons are then made of the different classroom floors by looking at these normalised levels.
- The resultant levels describe the quality of the acoustics in the classroom, i.e. there is a difference in the adjusted, normalised floor noise levels for rooms with poor acoustics than for those with good acoustics. Generally lower noise levels relate to better classroom acoustics.
- A database of classrooms would

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allow an investigation of the relative importance of particular spectral components and critical levels. A matching of acoustic properties with different constructions, timber and concrete would allow for informed future design.

Potential Limitations of This Method:

- The floor noise created by the tapping machine may not approximate 'real' classroom floor noise.
- The signal to noise ratio of the floor noise to mechanical noise created by the tapping machine is so small as to make the floor noise level results unreliable.
- Analysis shows that for frequencies between 50 Hz and 1 kHz the level results are dependable, for frequencies above 1 kHz level results may not be relied upon.

Timber Floor, Rm. 19

General Aim

The focus of this report is to create a method of generating a sound field inside a classroom representative of the noise produced by the general activities within the classroom that excite the floor, and then measuring the properties.

These activities might include but are not limited to:

- Chairs and desks scrapping along the floor.
- The clatter of pens, pencil cases and other equipment on the desks and floor.
- The general noise of footfall from students running on the floor.

The subsequent reverberant sound pressure level (SPL_{rev}) in the room created by these activities is defined in this report as the "Floor noise". The assessment of which may lead to an understanding of the classrooms' acoustical suitability for teaching.

This method, in order to be successful would have certain qualities:

- It would be repeatable.
- Accurately describe relevant properties of the space being tested (in a useful way).
- Ideally implement existing standardized equipment, which is already in common use.

The tapping machine, because of its standardized nature is an obvious choice as apparatus to carry out the tests. It will excite every floor tested in a consistent way, however it may prove to be inappropriate for other reasons. Normally a tapping machine would be used as a impact noise source in an adjacent room (not in the same room as the levels are being measured in). In addition to this the tapping machine is plainly not the same as a student, or group of students it is not usually used to reproduce a sound field as specific as this, for most applications the mere fact that it provides a standardised means of exciting a surface is adequate. It is also recognised that the tapping machine does not necessarily approximate the way in which walking excites a floor.

Assumptions

- For the purposes of this experiment, the Tapping noise (i.e the noise created by the hammers impacting the floor) is assumed to be equivalent to the floor noise (which is the SPL_{rev} of the floor's response to excitation by the hammers.)
- The tapping machine is a good approximation for footfall noise (a standard assumption inherent in any application of the tapping machine).
- A floor responds in a similar way to a scrape as it does to an impact.
- Therefore the floor noise created by the tapping machine provides a good approximation of the floor noise expected in general classroom activities (ie. Floor $noise_{tapping\ machine}$ = Floor $noise_{kids}$)

Field Tests

Classroom field tests:

Classroom field tests were carried out at Westmere Primary School, where two classrooms were selected for the test. The classrooms (room 7 and 19) were chosen on the basis that they were both relocatable with suspended timber floors. This type of construction makes up the majority of New Zealand classrooms and tend to have inadequate acoustic properties.

The characteristics of the classrooms are listed below:

Classroom no.19

The classroom construction is generally light timber frame with suspended timber floor:

Floor Joist Detail, Rm. 19

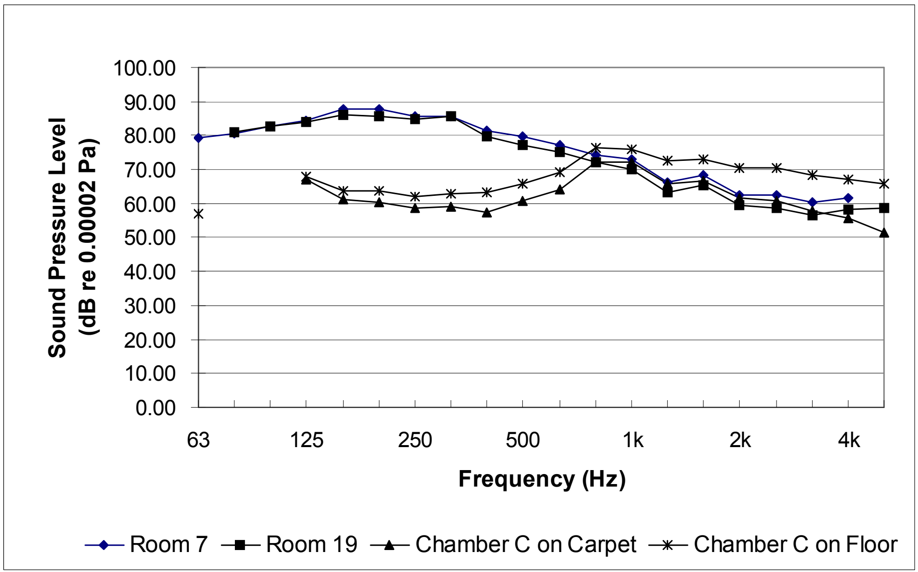

Figure 1: Normalised floor noise

- 125 x 125mm Timber piles @ 1325ctrs
- 50 x 100mm Timber Bearers (dressed) @ 2500ctrs
- 150 x 50mm Timber Floor joists @ 450crs
- Volume: 208 m^3
- Floor: Particle Board (unknown thickness) Carpeted (no underlay) coved.
- Walls: Windows to two long sides
- Ceiling: Raking, exposed trusses, Gib lined

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Classroom no.7

The classroom construction is generally light timber frame with suspended timber floor:

- 125 x 125mm Timber piles @ 1580ctrs
- 50 x 100mm Timber Bearers (dressed) @ 2340ctrs
- 150 x 50mm Timber Floor joists @ 450crs
- Volume: 176 m^3
- Floor: Particle Board (unknown thickness) Carpeted (no underlay) coved, vinyl.
- Walls: Soft board & Hessian, Windows to two long sides.
- Ceiling: Raking, exposed trusses, Gib lined.

Concrete system in Chamber C

For the purposes of comparison, tests were also undertaken on a concrete floor in the Acoustics Research Centre test chambers with and without carpet:

- 150mm suspended concrete slab
- Concrete walls and ceiling.
- Tested both with and without commercial wool carpet (no underlay).

Tapping Machine selection

The Brüel & Kjær 3204 and 3207 tapping machine models were tested for their suitability with several cominations of hood. The 3207 with silenced hood was eventually chosen for its greatest signal to noise ratio of tapping noise to machine noise.

Correction for background noise

The measurements were corrected for both ambient and noise levels in the room, and for mechanical noisefrom the tapping machine.

Types of floor structure

- Classroom 7 and 19 – Tapping on suspended timber floor with carpet.
- Chamber C (carpet)– Tapping on carpet on concrete slab.
- Chamber C (slab) – Tapping on concrete slab.

Comparison between timber and concrete floors

Figure 1 shows that the normalised floor noise for both classrooms at

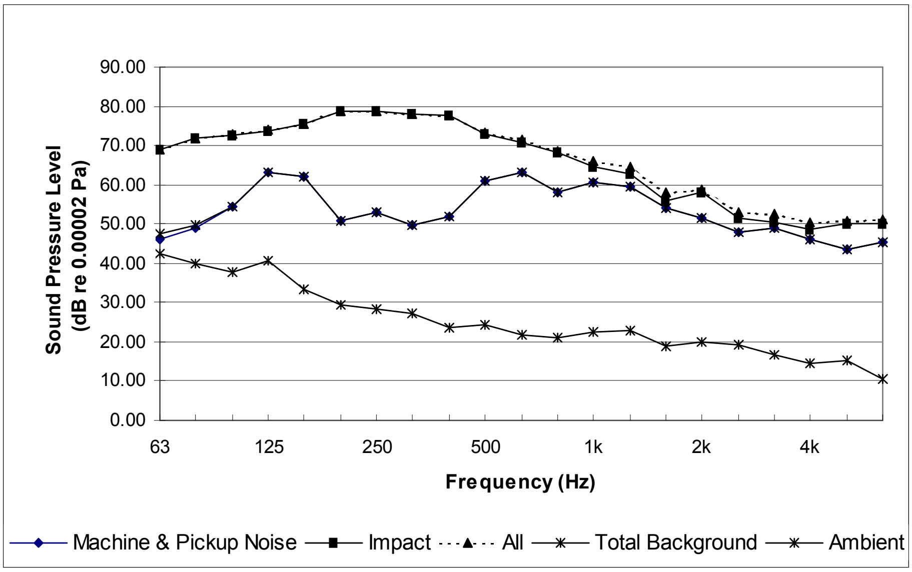

Figure 2: Room 7

low frequencies (50 Hz - 800 Hz) is greater than for both concrete arrangements in the order of 10-20dB. The suspended timber floor structures then perform better than the concrete floors at low frequencies. Chamber C (bare slab) has the highest normalized floor noise above 800 Hz being 5-10dB divergent from carpeted slab and carpeted timber constructions. Chamber C (carpet) has the lowest normalized floor noise between 50 Hz - 1 kHz. Above 1 kHz, the normalized floor noise of Chamber C (carpet) is relatively similar to Room 19. With comparison to Timber floors Concrete slab constructions do not perform as well at high frequencies (above 800Hz) as they do at low frequencies. These result indicates that concrete slabs preform generally better with respect to floor noise than timber floor structures.

Comparison between carpet and bare slab

Figure 1 also shows that Chamber C (carpet) has lower floor noise above 400 Hz than Chamber C (slab). Below 400 Hz, they are relatively similar. The advantages of lining carpet on concrete floor compared with the exposed concrete are obvious in the high frequency region above 400 Hz. This result indicates that the carpet on concrete floor provides a better overall performance result against floor noise throughout the measured frequency range, compared with the other types of floors that were measured in this project.

Dependabiliy (figures 1&2)

For classroom 7 and 19, the data for the normalized floor noise above 1kHz is not dependable, due to the differences between the measured sound pressure level and the total background noise level being less than 6 dB. There is similitude in both spectrum and level for floor noise generated by the tapping machine on similar floor type, and hence only the results for room 7 are given in this abbreviated paper (figure 2). Every time a similar floor structure is tested, similar normalized levels should be obtained. From this we may infer that the condition of repeatability has been met. The normalized floor noise level is dependent on the type of the floor structure; different floors produce different spectrums and levels of floor noise (which varies with frequency). If every instance of testing a different floor construction (i.e. concrete vs. timber, bare vs. covered) yields a different result, then we may infer that the method accounts for changes in structure. The old tapping machine displayed levels which were consistently lower than the new tapping machine. This trend was particularly pronounced in room 7 and for higher frequencies, indicating that there was some feature of the room 7 floor which suppressed only the old tapping machine's ability to produce floor noise.

Mechanical noise

Being that each individual tapping machine may produce different levels of mechanical noise practice would dictate their having to be tested individuality for their mechanical noise in controlled conditions such as test chambers, perhaps not for every test but as a calibration process to account for any changes over a time. Better still would be a method of silencing the mechanical noise of the tapping machines such that mechanical noise becomes insignificant.

The method developed within this report can be considered successful for the following reasons:

- It has established criteria by which an ideal impact source may be selected for use in this way. [Note: Much of the evidence leading to this conclusion has been omitted from this abbreviated paper]
- It isolates floor noise and allows comparisons to be made between relevant features of the floor response to impact excitation.
- Repeatability may be inferred because the tapping machines excite the floors in a way which is standardized with respect to classroom, evidenced by the similitude of frequency response and level of the floor noise between the different classroom floors and the different tapping machines.

This project, being the practical counterpart of a single acoustics paper, was to be a brief look into a potential experimental method of testing classroom floor noise, and had time constraints set as to the amount of work that was to be carried out. These constraints were surpassed long before the experimental work was even completed, which shows the level of dedication required to establish such methodology. While this paper has made significant ground, more research, and indeed analysis (especially of a statistical nature) of data already obtained must be undertaken before the scope of the study can be realized, and if it were not for the time constraints, this project would have addressed many more issues, and more deeply.

The stage has been set, however, and valuable information gained as to the ways in which testing may be carried out in classrooms so as to optimize their acoustical performance for children.

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