

MEASUREMENT OF SUDDEN UNEXPLAINED HIGH-LEVEL NOISE EVENTS WITHIN RESIDENTIAL DWELLINGS

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1. INTRODUCTION

In 2009 the Building Performance Centre (BPC) was asked by members of the house-building industry to investigate sudden, high-level “noise events” in different types of new build dwellings. The objective of the investigation was to record, quantify and if possible identify the source location of the noise events within the dwelling building fabric. Five sites where occupants had reported the “noise incidents” were visited at locations across the UK. At each property the occupants were interviewed, and multiple measurements were undertaken involving vibration and airborne sound levels. Diverse methods were used to induce the “noise events” and real time recordings were also carried out.

The results of the measurements conducted indicate that the source of the “noise events” is located in the gypsum board ceilings of each property. It appears there is a relationship between the stiffness of the plasterboards and a tension/compression action imposed on them by rapid changes in temperature, sudden pressure change or very slight dynamic movement, causing a “noise event” to occur.

This paper is derived from a more detailed commercial-in-confidence report by the BPC, and companies and site names involved have been withheld (BPC report S/5218/10, 2010).

2. SITE INVESTIGATIONS

2.1. Sites

Five sites were examined during the investigation (Sites A to E) consisting of apartments, detached and semi-detached homes with floor/ceiling components including attic trusses, roof trusses, metal web joists and engineered I-joists and the use of block work perimeter walls or timber frame walls.

2.2. Interviews

Each site occupier was interviewed for their experiences of the “noise events” including frequency of occurrence, locations of occurrence and a description of the noise itself. The noise had been described by different occupants as “very loud,” “a sudden noise,” “crack type noise,” “similar to a rifle shot or whiplash,” and “like a gun shot.” It was often a sudden noise event involving one or more distinct incidents occurring within several seconds. From discussions with some of the occupants, house

builders and material manufacturers a common theme was emerging.

The noise event was reported as being associated with being sourced somewhere in the ceiling zone areas across a variety of room types (living rooms, kitchens, bathrooms, etc.). It was also more frequent during colder seasons and occurred “naturally” after a period of time following the home’s heating system being activated. However, non-seasonally it was also associated with an isolated “natural” temperature changes within the affected room, such as when cooking in a kitchen or shower activation in a bathroom. Further, very similar “noise events” could be induced when internal or external doors were opened quickly or potentially by someone walking on the floor above.

Anecdotally, the occupier of Site A noted that they had heard similar noises within the ceiling of the apartment below Site A, which had a single layer of plasterboard mounted on a metal frame ceiling fixed to a precast concrete floor.

2.3. Measurement methods

A Brüel and Kjær (B & K) Type 2250 sound level meter recorded the LAeq, LAmin, and LAmax airborne sound pressure levels and audio wav.file recordings within the room. Vibration levels were measured using uni-axial B & K Type 5308-B accelerometers fixed at different points across ceiling gypsum boards and in Site A on attic trusses. A PULSE™ 3703-B 9-channel platform with FFT and 1/3-octave analysis engines was used and enabled real-time observation of the signal content.

A total series of 36 experiments were undertaken at the five dwelling sites based on inducing the noise event by; “Natural” occurrence triggered by switching on the dwelling heating system and waiting for the events to occur whilst running continuous recordings; *Induced events (1)* via internal or external doors being opened very quickly in some cases after the dwelling had been pre-heated; *Induced events (2)* by walking on the upper floor level above the room; *Induced events (3)* manually pushing the ceiling system gently upwards. Hammer-tap source excitation measurements were also conducted on exposed attic trusses and plasterboard ceilings in Site A. Physical ceiling deflection measurements were also conducted on certain sites.

3. RESULTS

During investigative visits, some sites exhibited “naturally” occurring “noise events,” either following the internal heating being turned on (~90 mins later, Site A), cooker being turned on in the Kitchen (~20 mins later, Site D), or the activation of a shower in a bathroom (~ 10 mins later, Site E). These incidents would suggest a relationship with relatively rapid temperature and/or pressure increase and the “noise event” occurrence. An example of the “noise event” from Site E is show in Figure 1, showing the change from the background noise level within a 30 second recording.

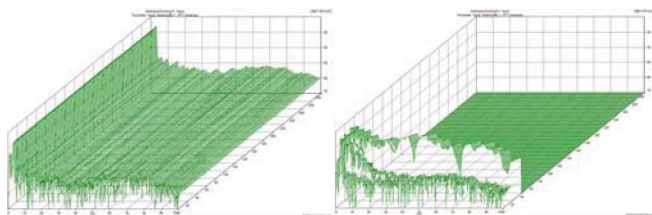


Figure 1. Waterfall FFT display of accelerometer signal from bathroom at Site E showing the background signal (left) and a “noise event” approximately 13 minutes later (right).

At sites A, B, C and D, it was possible to induce “noise events” through the rapid opening of internal and external doors. A clear “noise event” was found to emanate from near the centre of the room, where the measured deflection of the ceiling was 0.05mm. This suggests that it may only require only a low level, but sudden pressure change within the room to trigger the “noise incident”. This also suggests that the “noise incident” can occur without any additional direct “live” loading on the floor system.

It was observed that “noise events” would often occur in split-second clusters of typically 2 or 3 events, as can be seen in Figure 2. Figure 2 also shows the FFT signal level increases from background levels caused by the first “noise event” of Figure 2.

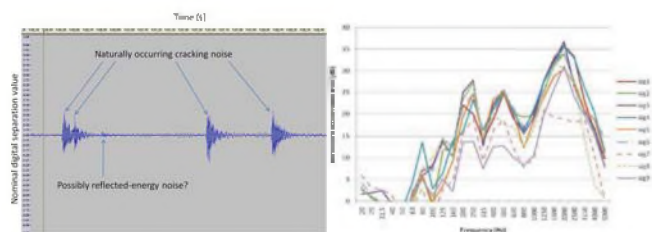


Figure 2. Four “noise events” within 1.5 seconds, induced after heating the living room of Site A for c.90 mins. Time trace (left) and 1/3-octave signal responses of the first event minus background (right).

At Sites B, C and D it was possible to induce “noise events” by slowly shifting a person’s weight across floor above. At all sites a similar sounding “noise event” could be induced by manually pushing up on the ceiling boards. The ambient internal noise level within the dwelling was between 25 to

30dB. The LA_{max} level of the sudden “noise event,” generated by temperature change to the dwelling was 65 dB. In the case of Site B the door opening test also caused the highest “noise incident” events.

4. DISCUSSION

Naturally, a sudden, unexpected increase of 35dB to 40dB in noise level causes a startle reaction by occupants and can affect behaviour and quality of life.

Based on additional results derived from the manual excitation (by acoustic hammer) of the truss and ceiling board, it was possible to see that when the impact source is located on the ceiling board as opposed to the truss, the truss and ceiling board signals are very similar, often tightly packed in both shape and form. Signal 5 and 9 were the furthest ceiling board measurements by distance from the tapping source. When truss excitation occurs the difference between Signals 5, 9 (gypsum board) and 7, 8 (truss) is over 30 dB at high frequencies. When ceiling board excitation occurs, this difference (spread) is reduced to 15 dB. Most of the signal response curves in Figure 2 are tightly packed and follows a very similar pattern of vibration amplitude increases above background levels.

If the “noise incident” source is within the gypsum ceiling board then:

- In-plane waves would be formed, which would carry along the board with some minor dissipation at board edges, but be very similar in its shape and measured values across the ceiling due to less impedance from the truss junctions.
- Flexural waves would also be formed and would be expected to peak at or near the critical frequency of the gypsum board, approx 2000Hz to 3150Hz for standard gypsum board thickness 15mm to 12.5mm.

Both of these facets can be seen in Figure 2.

The diverse range of core structure elements suggested that they were not the source of “noise events”. However, the common theme which does run across all the sites is the gypsum board ceilings. Overall the test data suggests that the primary source and carrying mechanism for the “noise event” is through the gypsum board ceiling.

It is suggested that further future analysis is undertaken investigating standard plasterboard types and changes to manufactured material properties which have occurred in recent years. Replacing the standard ceiling boards with high density boards and mounting these via resilient ceiling bars has eliminated the noise sources on the study sites.

REFERENCES

Smith, R.S., (2010), *Multi-site investigation into sudden noise*, BPC Commercial Report S/5218/10, Edinburgh Napier University.