Institution: University of Liverpool

Unit of Assessment: 16 - Architecture, Built Environment and Planning

Title of case study: Building acoustics - contributions to European and International Standardisation

1. Summary of the impact

The impact of building acoustics research by the Acoustics Research Unit at Liverpool has been through knowledge transfer into Standardisation, guidance to industry and take-up by test laboratories. This is evidenced by the active and leading participation of Professor Gibbs and Dr Hopkins on International and European Standards committees, developing measurement and prediction methods for noise in buildings. The research provides the scientific basis of new test codes used by accredited test laboratories and acoustic consultants. It is also feeding into new test procedures developed by R&D teams of Boeing, Seattle, for the control of vibration-induced noise in aircraft.

2. Underpinning research

The Acoustics Research Unit has a strong track record in funded research on airborne and structure-borne sound transmission in buildings for which there are three main drivers to the research.

The first is the increasing interest from the building industry in lightweight (e.g. timber-frame or timber-composite) multi-occupancy buildings. This is in response to the sustainability imperative for low-cost, low-carbon dwellings and work spaces. The prediction of sound transmission is more complex for lightweight constructions compared to traditional heavyweight constructions [Hopkins, 2007, ref 3] and, prior to the research, well-established prediction models existed only for the latter.

The second is the increased mechanisation of buildings including residential, commercial and industrial. The noise generated by mechanical services is structure-borne in origin. Vibrations from heating, ventilation and water systems and from elevators and domestic appliances are transmitted to the building structure and ultimately radiate as unwanted sound into rooms.

The third is the need to improve the accuracy and repeatability of the field sound insulation measurements that are required in Building Regulations to ensure legal compliance with performance standards for airborne and impact sound insulation.

Professor Gibbs has developed laboratory methods of measurement for machine vibrations, which provide data for prediction models that can be used to test noise control solutions for machinery installed in buildings [Corroboration source No.1]. Two underpinning concepts have been developed to the point of knowledge transfer. The first concerns vibrations of complicated machines which can be measured in the laboratory by attaching them to a well-defined structure and measuring the vibration response of that structure [Gibbs and Spaeh, 2002–present; ref. 5]. The second concerns the development of a two-stage method which allows all installation conditions to be considered, including modern lightweight timber-frame and timber-composite buildings as well as traditional heavyweight buildings [Gibbs et al, 2005–2008; refs. 2,4,5]. This allows the vibration of machines to be described in terms of the single values much favoured by manufacturers, engineers and designers [Gibbs, 2006–2009; ref. 2], significantly reducing the complexity of measurement and calculation. Mechanical installations generally cause low-frequency noise problems, which are not easily predicted and controlled. This research is replacing existing and often inaccurate methods with a method which takes into account the resonant behaviour of rooms and building elements [Gibbs and Maluski, 1998 – 2002; ref. 1].

Dr Hopkins has developed new methods [2011; ref. 6] to theoretically assess the efficacy of manual scanning paths for acoustic engineers and environmental health officers carrying out sound insulation or environmental noise measurements, i.e. manually moving a sound level meter around a room in order to measure the spatial-average sound pressure level. The research has quantified the efficacy not only of simple existing paths, e.g. circles, but also of more complex geometrical paths. This has led to proposals for new manual scanning paths which are highly efficient in producing good estimates of the spatial-average sound pressure level [Corroboration source Nos.2,5].

Key Researchers:
Academic Staff: Professor B.M. Gibbs (1977–present); Dr C.P. Hopkins (2007–present); Dr G. Seiffert (1980–present), Professor D.J. Oldham (1990–2010).

Research Staff (PDRA): Dr A.T. Moorhouse (1989–2004); Dr. M. de Salis (2000–2004); Dr. Q. Ning (1997–2004); Dr S.P. Maluski (2000–2003); Dr C. Egan (2006–2009); Dr D. Waddington (2001–2004); Dr R. Cookson (2005–2008).

Collaborating Researchers: Professor H-M. Fischer and Dr. Jochen Scheck (Stuttgart University of Applied Sciences, Germany, 2000–present); Dr A.R. Mayr (University of Rosenheim, Germany, 2010–present); Professor W. Scholl (PTB, Germany, 2004–present); M. Villot (CSTB, France, 2004–present).

3. References to the research

Key Research Outputs (in chronological order):

1. S. Maluski and B.M. Gibbs (2000), Application of a finite element model to low frequency sound insulation in buildings. Journal of the Acoustical Society of America 108(4), 1741-1751.

2. B.M. Gibbs, N. Qi and A.T. Moorhouse (2007), A practical characterization for vibro-acoustic sources in buildings. Acta Acustica 93, 84-93.

3. C. Hopkins, 2007, Sound insulation. Elsevier, Oxford (622 pages). ISBN-13: 978-0750665261.

4. B.M. Gibbs, R. Cookson and N. Qi (2008), Vibration activity and mobility of structure-borne sound sources by a reception plate method. Journal of the Acoustical Society of America 123(6), 4199-4209.

5. M.M. Spaeh, B.M. Gibbs (2009), Reception plate method for characterization of structure-borne sources in buildings. Applied Acoustics 70, 361-368, and 70, 1431-1439.

6. C. Hopkins (2011), On the efficacy of spatial sampling using manual scanning paths to determine the spatial average sound pressure level in rooms. Journal of the Acoustical Society of America 129(5), 3027-3034.

Key Research Grants (in reverse chronological order):

- 2010–13 EPSRC (£183,718) Reception plate method for structure-borne sound sources. Prof. Gibbs (PI), Dr Hopkins (CI)
- 2008–12 EU COST Network (£5,000) Net-acoustic for timber based lightweight buildings and elements. Dr Hopkins (CI)
- 2006–09 EPSRC (£79,931) Structure-borne sound source model for statistical energy analysis. Prof. Gibbs (PI)
- 2004–07 EPSRC (£197,597) Vibro-acoustic transmission in buildings due to mechanical services. Prof. Gibbs (PI)
- 2003–05 EPSRC (£202,638) Vibro-acoustic source strength methods for low noise design. Prof. Gibbs (PI)
- 2000–03 EC Fifth Framework (£220,000) Noise abatement using product optimisation. Prof. Gibbs
- 1999–02 EPSRC (£185,958) Sound Transmission between dwellings at low frequencies. Prof.

Gibbs (PI)
- 1996–99 EPSRC (£147,712) Circulation pumps as structure-borne noise sources. Prof. Gibbs (PI)
- 1993–96 British Council Academic Links with China Scheme (£23,000). Prof. Gibbs
- 1992–96 EC COMETT Programme (£17,000) Tools for Training in Acoustics for Industry. Prof. Oldham, Prof. Gibbs
- 1992–96 SERC (£92,065) Machine induced vibration in buildings. Prof. Gibbs (PI)

4. Details of the impact

Our research in acoustics has made impact through three main routes: formation of new International and European Standards; guidance to industry; and take-up by test laboratories.

Structure-borne sound power from building machinery
Professor Gibbs is a main contributor to working group CEN/TC126/WG7 writing European Standards concerning structure-borne sound power input from machinery into building structures [Corroboration source No. 1]. The working group comprises scientists, test laboratories and manufacturers of domestic appliances, water services and mechanical installations. Research at Liverpool on the reception plate method of measuring vibrating machines [ref 5] formed the basis of the European Standard, EN 15657-1:2009, a laboratory method for measuring mechanical installations in heavyweight buildings. The measurement method formed the basis of prediction methods described in the European Standard EN 12354-5:2009 (Annex D) on the prediction of the noise in buildings due to vibrating mechanical services. Manufacturers of heating, ventilation and transportation (e.g. lifts) systems, and domestic appliances can now measure their products in laboratories and estimate if they will comply with noise limits when installed in buildings. Test rigs based on this research have been constructed in approximately ten laboratories across Europe and manufacturers are currently using the test data for product development. During this period the research received EPSRC funding (grant period 2006–2009), and recently was supported by a major manufacturer, the Baxi Group (EPSRC grant 2010–2013). As a result of this collaboration, Baxi have been able to improve installation procedures to reduce noise from its new generation of domestic combined heating and power (CHP) units [Corroboration source No.3].

The successful completion of EN 15657-1:2009 prompted a request for further work relevant to the development of the new generation of sustainable building types, particularly timber-frame and timber-composite multi-occupancy dwellings. These buildings are likely to be even more heavily mechanically serviced than traditional buildings but they are inherently less able to resist noise transmission. This further work began in 2009 with the research at Liverpool providing the main impetus [refs 4,5] and Professor Gibbs is currently co-authoring a new European Standard, EN 15657-2, with Michel Villot of CSTB [Corroboration source No. 1].

The underlying research by Professor Gibbs is also feeding into the development of R&D test protocols for the qualification of vibrating components in aircraft, on which he is currently collaborating with Boeing (USA) [Corroboration source No.4].

Sound insulation
Dr Hopkins has significant influence on Standardisation in building acoustics. In 2009 Dr Hopkins was appointed Chair of the British Standards committee on building acoustics (EH/1/6). Due to his research expertise on flanking transmission in buildings, he was appointed Convenor of European and International Standards groups on the measurement of flanking transmission of building elements (CEN/TC126/WG6 and ISO/TC43/SC2/WG17) in 2009 and 2010. Due to his recent research on the measurement of sound insulation, he was voted Convenor of three International Standards groups on field measurement of sound insulation in buildings (ISO/TC43/SC2/WG18 Project Groups 5, 6 and 7) in 2009. In 2010, four new International standards were published on sound insulation measurement of building elements, which all reference the research monograph on sound insulation that was sole-authored by Dr Hopkins as a key text [Hopkins, 2007; ref. 3].

In 2009, Dr Hopkins was Head of the UK Delegation to the ISO/TC43/SC2 plenary session on building acoustics in South Korea. He prepared and presented the UK proposal to revise all four International Standards on field sound insulation measurement, due to demands from the UK acoustic consultancy industry. This drew upon his recent research on the efficacy of manual-scanning measurements for sound pressure levels [Hopkins, 2011, ref. 6] and low-frequency sound insulation measurements to tackle issues relating to the poor acoustic performance of timber-frame buildings. He was subsequently appointed Convenor of the project group to revise these Standards. His research forms the basis for three new International Standards (ISO 16283 Parts 1, 2 and 3), on the field measurement of sound insulation in buildings, with Part 1 now in its final stage [Corroboration source No. 6] and Part 2 now at the penultimate stage [Corroboration source No.7].

Building regulations in 24 European countries refer to the current versions of the field measurement Standards and they will automatically adopt the new ISO 16283 series of Standards that will replace them. These Standards are essential to check that the required level of sound insulation is achieved in buildings, primarily in dwellings, for compliance with National Building Regulations. They are particularly important for the UK construction industry as there are approximately 35,000 field sound insulation tests per annum, providing a direct income of approximately £10M per annum for acoustic consultants. This is in addition to income of approximately £53M that UK consultants earn using these Standards in building acoustics.

5. Sources to corroborate the impact

1. The Noise and Vibration Team Leader at the Centre Scientifique et Technique du Bâtiment, (France) can be contacted to corroborate that Professor Gibbs is co-authoring the Standard EN 15657-2: Laboratory measurement of airborne and structure-borne sound from building equipment - Part 2 – All other cases where the equipment mobilities match with or are not much higher than the receiver mobilities.

2. The Head of National Metrology Group for Acoustics at the Physikalisch Technische Bundesanstalt (Germany) can be contacted to corroborate the impact of the research on Standardisation activity for field sound insulation measurements.

3. The Design Team Leader of Baxi Group (UK) can be contacted to confirm the relevance of the research, and its impact on their industry as part of the collaborative EPSRC funded grant (with Baxi Group) on structure-borne sound power from building machinery.

4. The Acoustic Analysis Engineer at The Boeing Company (Seattle, USA) can be contacted to corroborate the impact and influence of the research and Standardisation activity on structure-borne sound power to noise control in their aircraft.

5. The Acoustic Consultant at Sandy Brown (UK) can be contacted to corroborate the impact of the research on Standardisation activity concerning field sound insulation measurements, in addition to the impact on practitioners who require and use these Standards.

6. International Standard ISO/FDIS 16283-1 Acoustics – Field measurement of sound insulation in buildings and of building elements – Part 1: Airborne sound insulation. DIN Secretariat. Voting on this final draft (FDIS) begins 3-10-2013 and terminates on 3-12-2014. ISO Reference Number ISO/FDIS 16283-1:2013(E). NB This document was submitted to ISO by Dr Hopkins on 24th June 2013.

7. International Standard ISO/DIS 16283-2 Acoustics – Field measurement of sound insulation in buildings and of building elements – Part 2: Impact sound insulation. DIN Secretariat. Voting on this draft (DIS) begins 10-10-2013 and terminates on 10-3-2014. ISO Reference Number ISO/DIS 16283-2:2013(E). NB This document was submitted to ISO by Dr Hopkins on 24th June 2013.