Practical measurement of the thermal performance of houses

The ‘Loughborough In-Use Heat Balance’ is a new method for evaluating the thermal performance of houses developed by researchers from the Building Energy Research Group (BERG) at Loughborough University. The method has been developed with the aim of making widespread measurement of the thermal performance of houses a practical reality. The method addresses the ‘performance gap’, where the actual thermal performance is significantly worse than predicted. Accurate assessment of building performance would provide a route towards quality assurance, allow targeting of lower performing houses for remedial works, and provide more certain estimates of the energy savings resulting from retrofit.

Almost a third of all energy use and associated CO$_2$ emissions in the UK occurs in houses, and of this around two thirds is used for space heating. However, the UK housing stock is among the oldest in the world, with relatively low thermal efficiency. This is not surprising; as much of the stock was built before the links between human activity and climate change were well understood, and therefore thermal performance was not a priority in the design and construction of dwellings. These factors make housing a clear opportunity for emissions and energy demand reduction, which is particularly pertinent in view of the emissions reduction targets set out in the 2008 Climate Change Act.

Given the rather low demolition rate in the UK, and with new house construction rates well below the required level, retrofitting of existing houses will necessarily form the largest part of any actions to address this opportunity for emissions reduction. A critical component to help design successful policies in this area is accurate assessment of the thermal performance of houses, commonly defined in terms of the heat loss coefficient (HLC) with units of Watts per Kelvin (w/k).

Determining the thermal performance of houses has proven to be a major challenge that has yet to be satisfactorily addressed. In the UK’s Standard Assessment Procedure (SAP), the performance of houses is calculated using an elemental approach, summing the laboratory measured performance of each element of the building. However, evidence gathered using whole house and elemental measurements has shown that estimates of thermal performance are routinely inaccurate, with actual heat loss almost always larger than was predicted.

What is really surprising is that these differences are not small. Actual performance in some cases has been found to be up to 120% worse than predicted, with large variations observed between seemingly similar houses. The two clear lessons are that all houses are different, and that heat loss tends to be higher than expected – creating the motivation for an alternative measurement solution.

At present, the most commonly used whole-house measurement technique in the UK is the ‘co-heating test’. The method involves measuring the energy required to heat the interior of a house to a controlled elevated level, commonly 25°C, and normalising for the weather conditions during the test. Co-heating tests carried out by Leeds Beckett University have provided much of the evidence for the performance gap and their experimental method is the one commonly followed.

In its current form, the co-heating test, the use of which has been primarily limited to research applications, requires a house to be empty for a period of at least two weeks and can only be carried out during winter months, as it requires a period of cold and preferably dull weather. Furthermore, an extended period of elevated internal temperature has been found to cause damage in newly built houses through the rapid drying out of materials.

The Loughborough In-Use Heat Balance has been developed to address these issues as a part of the work of PhD Research Student Richard Jack, a member of the London-Loughborough Centre for Doctoral Training in Energy Demand (www.lolo.ac.uk). The In-Use Heat Balance uses broadly the same analytical approach as co-heating, with measurements informing an energy balance in the house. The key advance made by the new method is that it allows occupants to remain in their home and behave almost entirely as normal. The energy inputs, typically electrical and from a gas boiler in UK houses, are measured to form one half of the balance, while the internal and external temperature is measured to form the other. The method might be imagined as a leaky bucket – where the rate of water input is measured to find the sum of the leaks. Finally, analytical techniques are applied to account for the influence of the weather conditions during the test, particularly the heat gains due to solar irradiation. The measurements can be taken in a discreet manner in order to have little impact on the occupants’ use of the house.

The method has been tested in unoccupied test houses at Loughborough University, using synthetic occupancy to test the effect of variables such as window opening, hot water use and heating practices, and has shown close agreement with the results of co-heating tests. In a project carried out with the Energy Technologies Institute (ETI), the method has also been used to test the performance of a house before and after a retrofit. In this application the results of the in-use heat balance and co-heating tests agreed to...
within 6% both before and after retrofit.

At present, a minimum monitoring period of 3 weeks is recommended in order to allow robust normalisation for differing weather conditions and the uncertainty of the measurement is estimated to be ± 1%. In practice, these values will be dependent upon the performance of the house and the weather conditions experienced during the monitoring. The effect of these factors is the subject of ongoing research and, with better understanding, it is likely that both the monitoring period and the uncertainty can be reduced. Information to aid this better understanding is currently being gathered, with the Loughborough In-Use Heat Balance being applied in five occupied homes in conjunction with the ETI as a part of their novel whole-house retrofit approach, which was documented in issue 98 of Innovation and Research Focus.

To develop the method further, a greater body of tests carried out in different house types with different occupants is required, ideally with matched co-heating measurements to provide a baseline comparison.

If you can provide this data and would like to take part in this research, or would like further information, please contact the team at Loughborough University, School of Civil & Building Engineering (email Richard Jack at: r.jack@lboro.ac.uk or Dennis Loveday at: d.loveday@lboro.ac.uk).

CONSTRUCTION, BUILDINGS, RESEARCH & INNOVATION

CIOB Innovation and Research Awards

The Chartered Institute of Building (CIOB) recognises that the health of their sector relies on innovation, research, and continually improving how things are carried out. Innovation is therefore at the heart of what the CIOB does, whether it is driving up standards, improving efficiency or helping their members achieve new levels of sustainability. Every year, the CIOB holds its International Innovation and Research (I & R) Awards. The Awards celebrate achievement across the built environment, from academic research to industry innovation. Their focus is to highlight the importance of innovation and research in raising performance levels, enhancing best practice and improving the quality of the built environment. The I & R Awards also encourage the brightest industry newcomers: the recent graduates and postgraduates who are already making a valuable contribution and could lead on innovation in the future. The Awards are the only built environment awards that recognise and promote the achievements of individuals, rather than project teams or companies.

The International I & R Awards are open to all CIOB members or non-CIOB members and overseas institutions. Submissions can cover any built environment-related area and clearly demonstrate the benefits of research and innovation in practice. There are six categories within the CIOB’s Awards. These celebrate the diverse range of ideas within the built environment, from those that germinate in academia to those that are applied within the industry. For each category there are three levels of awards – the highest ranked Premier Award, the Highly Commended, and the Merit Award.

The winners of the 2014 CIOB International Innovation and Research Awards are publicised by the CIOB in the first quarter of 2015 and will be announced in the 101st edition of Innovation & Research Focus. The 2013 winners were decided by a judging panel of 18 leading figures from both academia and industry.

In the Undergraduate Dissertation Award Category of the 2013 CIOB I&R Awards all three winners came from the National University of Singapore. The winner of the Premier Award, Yu Quian Ang, conducted research on Building Information Modelling (BIM), a tool perceived as the next-generation solution to enhance productivity of the construction industry holistically and to streamline the delivery process of buildings and structures. Yu Quian claims that it is integral for a company to establish an efficient link between the core competencies of its practice and the use of BIM to derive benefits.

In the ‘Innovation Achiever’s’ category the winner of the Premier Award went to Craig White and Finlay White from ModCell Ltd. ModCell is the name of both their company and product – a prefabricated straw bale wall and roofing system. The product and Craig and Finlay’s work was commended as a highly innovative idea, which showed strong application and a clear commercial viability. The prefabricated straw bale wall and roofing system was recognised as one of the first products to make large-scale, carbon-positive building techniques a commercial reality. The system encapsulates the excellent thermal insulation qualities of straw within modern methods of construction. ModCell panels are solid glulam timber frames filled with straw that can be either lime rendered or dry-lined. The panels are fully engineered and load bearing. They are manufactured locally and are suitable for use in low and medium rise structures. Using renewable, locally sourced, carbon absorbing materials, a ModCell enables the creation of super-insulated, high-performance, low energy ‘passive’ buildings. The result is a less-than-zero carbon construction system.

One of the more unique award categories of the six is the ‘Innovation in Education and Training’ category. In 2013 the winner of the Premier Award was Dr. Fred Sherrat whose work was based around teaching construction health and safety. Dr. Sherrat acknowledged that health and safety can be problematic to teach as students often struggle to engage. To overcome this issue Dr Sherrat introduced Problem-Based Learning (PBL), replacing lectures with problem-solving tasks in which students explore and research scenarios in small groups. Through the PBL process, the students quickly engaged with the subject material and were soon able to understand the importance of health and safety to construction, and how they play a significant part in its management.

Analysis of attitude questionnaires, administered before and after PBL, found significant improvements in student understanding, suggesting that PBL is a highly effective tool for health and safety learning in the built environment.

After the 2013 Awards had been presented, Professor Stuart Green, Chair of the Judging Panel, said, “It has been immensely gratifying to see the highest ever number of entries to the CIOB International Innovation & Research Awards 2013. I have also been delighted with the overall quality of the applications across all categories. Especially rewarding this year was to see so many strong entries from industry in the innovation categories.”

For further information please contact Dr Ching-Chin Kao, Innovation and Research Manager, the Chartered Institute of Building (E-mail: ckao@ciob.org.uk).

Images and source: ModCell