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Smart and Healthy
Within the Two-Degree Limit

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PLEA 2018

PLEA stands for Passive and Low Energy Architecture. It is an organisation engaged in a worldwide discourse on sustainable architecture and urban design through its annual international conference, workshops and publications. It commits to the development, documentation and diffusion of the principles of bioclimatic design and the application of natural and innovative techniques for sustainable architecture and urban design.

PLEA is an autonomous, non-profit association of individuals sharing the art, science, planning and design of the built environment. PLEA pursues its objectives through international conferences and workshops; expert group meetings and consultancies; scientific and technical publications; and architectural competitions and exhibitions. Since 1982, PLEA has organised conferences and events across the globe. The annual conference of PLEA is regarded, attracting academics and practicing architects in equal numbers. Past conferences have taken place in United States, Europe, South America, Asia, Africa and Australia.

It is the first time that the PLEA conference comes to Hong Kong in 2018. The juxtaposition of Hong Kong's compact and high-density living and scenic countryside makes it an intriguing case of urban sustainability and climate resilience. The urban and built environment represents both challenges and opportunities amid climate change. As the world approaches the 2-degree limit, living smart and healthy has become a priority in urban development. Smart cities are driven by science and technology but are meaningless without consideration for the people and community. Design and practice are essential in implementation, while education and training stimulate innovation and empower professionals and laymen alike.

With the theme **"Smart and Healthy within the 2-degree Limit"**, the conference strives to address the different facets of smart and healthy living and aims to bring together designers, academics, researchers, students, and professionals in the building industry in the pursuit of a better and more sustainable urban and built environment.

Edward Ng
Conference Chair

TABLE OF CONTENTS

Volume 1 – Long Paper
(Science and Technology)

Volume 2 – Long Paper
(Design and Practice, People and Community, Education and Training)

Volume 3 – Short Paper

Volume 2 – Long Paper

DESIGN AND PRACTICE

PEOPLE AND COMMUNITY

Volume 2

Long Paper

Design and Practice

People and Community

Education and Training

DESIGN AND PRACTICE

Implementation of scientific and academic findings comes down to design and practice. This track looks into practical design options—both in theory and actual case studies—in smart, sustainable, and healthy urban development, for example:

- passive low energy design, eco-design and vernacular architecture
- low energy design tools for practice
- policies and government regulations on a low energy future
- professional practice and design of passive low energy architecture

Hab-Lab: Development of a Light Touch BPE Methodology for Retrofit

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ABSTRACT: In the drive toward reduced energy consumption and consequent carbon emissions, and also reductions in fuel poverty and discomfort, the need to improve the performance of existing buildings, particularly housing is critical. To meet government targets some policy drivers are being implemented to improve the performance of existing building. In Scotland this has been through the Energy Efficiency Standard for Social Housing (EESSH) which provides funding for retrofit measures. However, very little is known about the consequences of these measures. This project developed 'light-touch' building performance (BPE) approaches to undertake evaluation of retrofit measures examine their effectiveness and the paper identifies these techniques and reports on the findings. Whilst in general improvements led to reduced energy consumption, various unintended consequences were evident. These included issues of thermal bridging and poor detailing, and lack of improved ventilation provision led to issues of poor ventilation and indoor air quality and reinforces the need for wider evaluation of buildings in use.
KEYWORDS: Energy, Comfort, Retrofit, Building Performance Evaluation, Ventilation

1. INTRODUCTION

In a drive toward carbon emission reductions the Scottish Government has introduced the Climate Change (Scotland) Act 2009 which aims for an 80 per cent reduction in carbon emissions by 2050 [1]. As domestic energy use represents 30% of total national energy use [2] this is clearly an important sector.

Whilst for new buildings this is being addressed through building standards [3], these regulations do not apply to existing buildings. Given estimates that over 75% of the 2050 building stock already exists [4], the need to undertake energy efficient and low carbon retrofit is self-evident.

Local authorities and housing associations have undertaken a number of measures to improve the thermal performance of their existing stock but more recently this has been driven the need to comply with the Energy Efficiency Standard for Social Housing (EESSH) which has been introduced by the Scottish Government to address this issue [5]. EESSH sets a minimum energy efficiency rating for landlords to achieve and requires improvements to insulation and heating systems. The new standard is based on minimum energy efficiency (EE) ratings calculated using the Standard Assessment Procedure (SAP) which produces an Energy Performance Certificate (EPC) and will mean that in the main no social property will be lower than a 'C' or 'D' energy efficiency rating

However, this represents a considerable challenge for landlords. Existing buildings are built to poorer thermal standards and improving these is hampered by the nature of the original construction which makes it harder to apply and less cost effective. In addition, the costs and disruption associated with decanting tenants mitigates against deep retrofit and leads to piecemeal measures.

The other key issue that is emerging the lack of knowledge about the effectiveness and unintended consequences of such measures. There is a clear need to undertake Building Performance Evaluation (BPE) of retrofit measures to close this knowledge gap, but there are a number of barriers to this. Firstly BPE (despite being in the RIBA plan of work) is not a mainstream activity. Secondly, most projects do not have a budget or timescales to undertake BPE. Thirdly, the knowledge and skills to undertake BPE are not widespread. Whilst many valuable lessons have been learnt from research funded BPE projects, without a commercial footing and ready-made feedback loop into practice, the full potential for the industry to learn from these studies is not being fulfilled.

To address these issues a project was undertaken jointly by the Mackintosh Environmental Architecture Research Unit (MEARU) and John Gilbert Architects (JGA) to develop 'Hab-Lab' - a service that undertakes building performance evaluation of social housing in the west of Scotland that has either undergone or is due for refurbishment. The development of the service was supported by Knowledge Transfer Partnership (KTP) funding.

Social landlords are becoming increasingly aware of performance gaps between intended and actual performance and potential unintended consequences of retrofit measures. To investigate this, the Hab-Lab project formed a partnership with five council and housing association landlords to evaluate the actual thermal and environmental performance of a range of house and construction types. The Hab-Lab approach offers a range of possible processes dependant on the nature of the investigation ranging from assessment of compliance, testing of specific components (e.g. insulation systems), testing and monitoring of energy and environmental conditions in buildings, to handover and post-occupancy processes.

2. METHODOLOGIES

Conventional large scale BPE studies of retrofit are difficult for a number of reasons. As well as being time consuming, expensive and disruptive to occupants, the results are not available to inform design decisions. To address these issues the project has attempted to develop a 'light-touch' methodology. This attempts to gather a useful (if not comprehensive) dataset in a cost-effective manner as a means to mainstream the development of a more empirical understanding of the built environment. The key methodological ways in which the project seeks to address drawbacks of typical large scale BPE are as follows:

- Developing BPE services which are shorter in duration. This reduces disruption for residents and ensures that results are relatively quickly available for decision-making.
- Shorter BPE projects can be less expensive to undertake bringing them within acceptable likely budgets for housing associations and council housing departments.
- Ensuring that BPE is carefully tailored to the specific demands of the client – starting from their standpoint and ensuring that their initial brief is met, whilst introducing wider issues and deeper questions where appropriate.
- Providing a 'menu' of services allowing for shorter "snapshot" reporting on more straightforward technical issues but providing also longer term or more detailed studies to provide deeper understanding of the range of interrelated issues where time and budget allow.
- Developing a range of easier to understand, replicable, and often largely graphic techniques to explain issues and engage a variety of stakeholders.
- Initiating the idea of a partnership 'group' who agree to share findings and insights, thus increasing the impact and value of the learning amongst the group.
- 'Embedding' a Building Performance Specialist within an architectural practice ensuring that feedback loops are both formally and informally developed within the office, and drawing robust research methods directly into practice.
- Moving beyond simply monitoring and reporting into providing bespoke design and intervention proposals based on evidence gathered and which are then themselves monitored.
- Explicitly introducing the potential for innovative solutions based on a limited scale of works and a reduced perception of risk due to monitoring regime.

From a methodological perspective, the approach suffers from a number of limitations which are hereby acknowledged. Firstly, projects tend to arise from a specific problem raised by the client which may not represent the totality of the issue. The risk is that a partial assessment only can be undertaken due to the limitations of the client's understanding of the issue, and willingness to pay for more extensive investigation. However, in each case where this has been the initial starting point, the Hab-Lab team have been able to demonstrate the wider issues and causes impacting on the more immediate effects.

Secondly, client priorities can change rapidly and, in some cases, the Hab-Lab team were not able to complete a full monitoring of the proposed and installed measures, and so have not been able to demonstrate empirically the benefits of the works undertaken.

Thirdly, when undertaking BPE on a commercial footing, there is the potential for pressure to deliver results according to certain pre-conceptions. In the project there was one example of this and although the veracity of the investigation was not compromised the reporting template was amended to comment only on the regulatory compliance issues, rather than speculating further on good practice and wider issues. To address this, issues of commercial and professional integrity are now explicitly addressed as part of the appointment documentation.

Lastly, detailed monitoring over at least a year is needed to obtain a detailed picture of energy use and environmental conditions, and to obtain annual energy consumption data, and shorter monitoring periods can only provide 'snapshots' of performance.

3.1 Data Collection

The service offers a range of services but in practical terms these fall into four categories.

1 Energy monitoring involves measuring electrical, gas or heat consumption in real time. With electrical monitoring, it can also be useful to monitor sub-circuits in order to establish the efficiency of certain equipment (MVHR systems, for example).

2 Building fabric and systems testing involves measuring in-situ performance of the building itself. Examples of this include U-value measurement, airtightness testing (pressure testing), thermography, as well as systems checks such as ventilation balancing and flow measurement, heating systems checks etc.

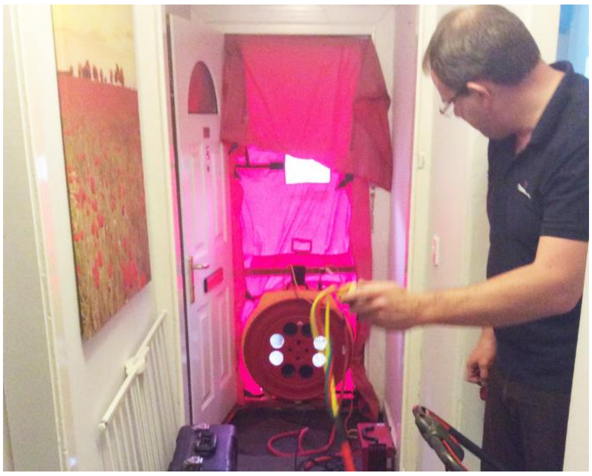

Figure 1: Airtightness tests are included in the basic BPE methodology, to quantify the impact of air leakages in the building fabric.

3 Environmental monitoring normally involves measuring the temperature, relative humidity and CO_2 levels in specified spaces. It is common to also measure the external temperature and humidity levels for comparison, while a wide range of additional testing can be undertaken such as acoustic testing, VOC levels and mould testing. These tests establish the conditions within homes so that, for example, it is possible to corroborate lower gas consumption with maintained temperatures, showing that insulation measures have been effective. Monitoring may be undertaken for short (2-4 week) periods under specific seasonal conditions.

4 Finally, there are a range of strategies to engage people who occupy and use buildings, as well as those who commission, design, build and maintain them. A range of tactics allow 'hard' data gathered to be corroborated against 'soft' data about occupancy levels, habits, and behaviour generally. Different tranches of monitoring may be undertaken in varying seasons to examine effects of climate. Alternatively, some intervention studies may be undertaken (for example, asking occupants to change a particular behaviour).

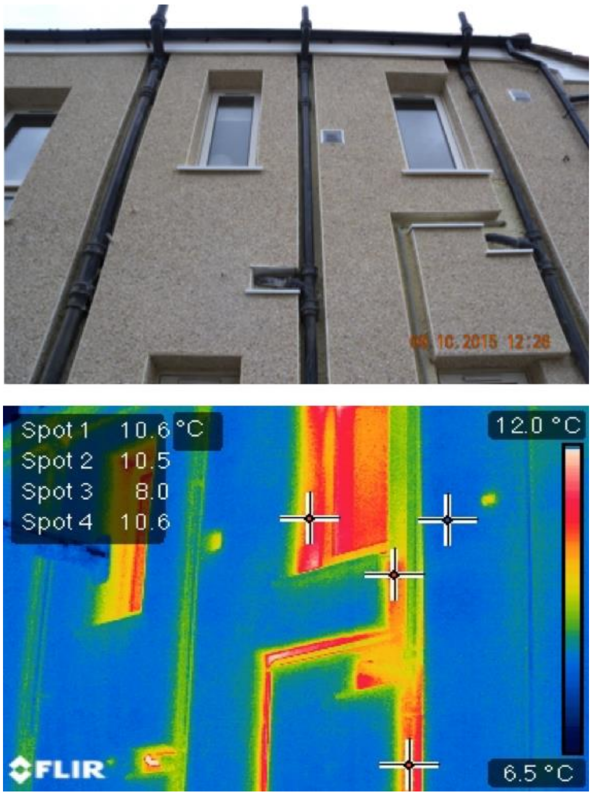

Figure 2: *Thermographic images were used to highlight the gaps in external wall insulation due to poor detailing, leading to thermal bridges.*

In general terms, the Hab-Lab process consists of a partnership with housing providers. In the first phase a range of different properties are studied in detail and findings reported to the clients. In a second phase, a series of innovative retrofit solutions are installed, which are drawn from the evidence created in phase 1. The retrofit measures can be monitored during the following winter season, in order to study and evaluate the efficiency of each proposal.

This knowledge is of significant value to landlords. Poor design and implementation would mean that they are failing to achieve the full potential of the retrofit works in terms of energy savings, but also creating significant problems related to resident's health and building maintenance.

4. CASE STUDIES AND IMPACT

In the last two years, the project examined 20 on-site monitored flats and the retrofit of 48 properties, but the potential benefits are applied to over 3000 similar flats managed by the partnering associations. Most had been refurbished and some were about to be retrofitted. The key case study examples include:

- Evidence based design advice for two flats in the East End of Glasgow – providing innovative retrofit solutions for traditional solid sandstone wall insulation and centralised demand controlled mechanical extract ventilation system,

- Technical evaluation of three different internal wall insulation systems, in order to find through in-situ u-value monitoring the most cost-effective solution for solid brick wall flats in Paisley,
- Best practice external wall insulation design advice for 12 no-fines flats in Bridge of Weir and 30 no-fines flats in Girvan, based on building performance evaluation evidence, taking into energy reduction, health and future-proof solutions,
- Optimized energy efficiency and indoor environmental quality design specification based on monitoring evidence, tackling fuel poverty, maximising comfort and minimising health risks in two Atholl Steel flats in Douglas.

To illustrate the methods and insights, two case studies are described below:

4.1 Case Study 1: Bluevale St, Glasgow

The client of this project signed up for the Hab-Lab partnership, for a period of 2.5 years with the aim of investigating and implementing innovative energy retrofit measures to improve the air permeability and indoor air quality of their traditional sandstone tenement building stock located in the East End of Glasgow. This allowed JGA to monitor several properties over different seasons and then develop energy retrofit solutions based on the building performance evaluation findings. During this period the Hab-Lab Partnership service also included regular workshops, trainings, occupant engagement programmes and complementary support. This project aimed to work as a pilot case study, to be implemented in the remaining stock and therefore the measures had to be scalable and replicable from a technical and in a financial point of view.

A combination of different energy retrofit measures were installed in a ground floor flat as following:

- Four different internal wall insulation systems
- Detailed and bespoke airtightness measures
- Suspended timber floor insulation
- Demand control centralized mechanical ventilation systems.

The application of external wall insulation was inappropriate as it could compromise the historic character of the traditional sandstone tenement building. The improvement works were therefore carried out internally using materials which were both natural and vapour permeable, to help maintain the performance of solid sandstone walls whilst still providing some hygroscopic capacity of the fabric. This case study therefore examined three measures of performance - the improvement in air permeability, the thermal properties, and the indoor environmental quality and comfort for resident. Four carefully detailed insulation materials were used in the trial in order to provide comparative data to compare relative improvements in thermal performance and airtightness.

Figure 3: Internal wood-fibre insulation, which aims to provide active moisture control working in combination with the demand control mechanical ventilation system.

The building was originally constructed of sandstone masonry with solid brick internal partitions, and dates to around 1910. Due to general repairs the tenement was empty at the time the trials taking place. All internal wall linings had been stripped out and replaced with dry lining in a previous extensive refurbishment. This meant that there were no limitations regarding the retention of original wall linings or decorative cornices, which would be the case in many similar properties.

The retrofit specification was based on the pre-installation building performance evaluation conducted on the refurbished flat and in similar properties during the previous winter seasons which had measured actual u-values and thermal bridging and by-pass. The indoor environmental conditions (temperature, relative humidity and CO_2 levels) were monitored in a similar occupied flat for a period of five weeks. The air permeability was tested, the U-value of the existing walls was monitored and airflow at existing mechanical extract ventilation units was measured during the winter season. The pre-retrofit investigations also included internal and external thermographic surveys, and structured interviews with the residents.

The design advice for the energy refurbishment was therefore based on real evidence, gathered from existing building and from their occupants. The design advice was followed by building performance toolbox sessions with the housing association staff. General key learnings from the building performance evaluation were explained and discussed through repeated workshops over a 2-year period. This was also supported with toolbox sessions on site with housing associations installers along with best practice insulation, airtightness and ventilation suppliers discussed detailing and installation procedures. The specified retrofit proposals were consequently evaluated with on site monitoring to quantify the improvements and impacts of the measures.

The energy efficiency improvements can be summarised as following:

- Energy Performance Certificate rating increase of 25 points, EPC Band E (48) to EPC Band C (73).
- 49% reduction in space heating requirement.
- The pre-installation thermography showed extensive cold spots due to thermal bypass and thermal bridging at several points of the walls, floors and ceilings. This was mostly addressed with the upgrade works.
- The post installation airtightness test result of 6.20 $m^3/h/m^2$ demonstrates an improvement of 53%.
- The post installation in-situ U-values and airtightness levels meet the recommended thresholds of the Building Standards for refurbished dwellings, whereas pre-installation values do not.

Interestingly, the results were not exactly what the client initially planned, but it helped them to better understand the complex building performance characteristics of traditional sandstone tenements and implement building performance evaluation and evidence base design into the standard energy retrofit specification. Thus, as well as a successful retrofit project, it was a key learning tool, based on empirical evidence, for the association.

4.2 Case Study II: Auchentorlie Quadrant, Paisley

Hab-Lab was engaged by a local Council to conduct a technical evaluation of three different internal wall insulation systems, installed in three flats, within an interwar solid brick tenement property located in Paisley. The purpose of this study was to:

- evaluate the cost-effectiveness of three different internal wall insulation systems,
- evaluate the detailing quality of the Council's contractors,
- understand the effectiveness of the governmental policy of financial incentives directed to energy retrofit actions in Scotland.

The original external wall consists of a solid brick wall, externally rendered and lath plastered internally. Three different insulation systems were installed as following:

- System 1: 62.5mm rigid phenolic boards bonded to plasterboard and mechanically fixed.
- System 2: 69.5mm PIR insulation, bonded to plasterboard and mechanically fixed.
- System 3: 85mm glass mineral wool insulation bats, fixed within a metal frame and finished with plasterboard.

Each insulation system was installed from floor to ceiling on the inside face of all external walls located within each flat. The same contractor appointed and supervised by the Council, installed the three insulation types as per specification and recommendation of each manufacturer.

As requested by the client, the study pursued minimally invasive investigation methods to reduce time, costs and disturbance. The methods evaluated, internal environment, building fabric and installation quality. The evaluation methods employed were similar for all three flats and included U-value measurements of walls, temperature, relative humidity levels monitoring, thermography and energy modeling. The indoor environmental quality and the U-value was monitored for a period of four weeks. The monitoring results were compared to the modelled U-values and the manufacturer's installation values. The study also considered the installation costs, quality of the detailing and outlined watch points for future installations.

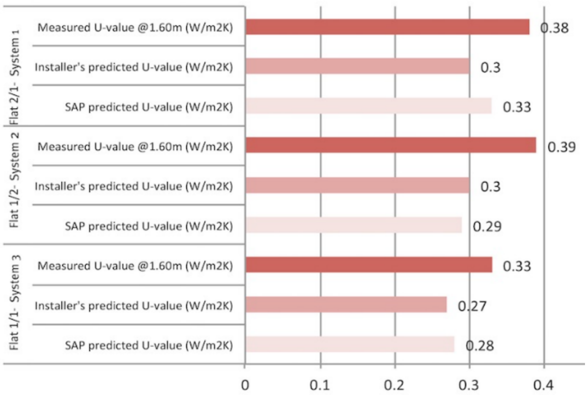

Figure 4: In-situ U-value measurement versus U-value calculation for three internal wall insulation systems.

All three systems performed similarly although less well than claimed, but the main problems were related to installation shortcomings, which increased heat loss and consequent condensation and mould growth risk in practice:

- System 1: 0.33 W/m2K, 22% more than the installer's prediction
- System 2: 0.39 W/m2K, 30% more than the installer's prediction
- System 3: 0.38 W/m2K, 27% more than the installer's prediction.

Although all systems comply with the recommended values for refurbished domestic buildings in Scotland, the thermographic imaging survey showed extensive cold spots at the base of the walls, against ceilings and around openings due to poor detailing. The quality of construction proved to have a higher impact on the post-retrofit performance of the flats than the different wall insulation performances.

The interesting aspect of this case study was that it highlighted the gap between predicted performance (as estimated by models) and actual performance (as installed and measured in the properties) without this being the original aim of study. This has obvious implications for energy efficiency and retrofit programmes. The results of the study have informed subsequent installation practice and procurement strategies within the Council.

4.3 General Findings

The performance gap between predicted and actual performance creates uncertainty concerning the full benefits of energy efficiency measures and BPE studies have the potential of identifying and closing these gaps.

In general, the BPE results highlight that the installed energy efficiency measures have benefited the occupants by reducing heating costs and increasing thermal comfort.

However multiple and diverse unintended consequences are apparent. For example, a restriction on the grant funding available for improvement measures has meant that they have significant limitations. For example, they do not include support for enhanced ventilation provision. A common finding is that air quality is not at recommended levels, often due to increased airtightness and almost always due to inadequate ventilation design, installation and equipment. High levels of relative humidity are common with increased risk of condensation and mould growth, as well as presence of dust mites and other allergens.

Common construction problems included thermal bridging due to poor detailing leading to heat loss and thermal bypass. With thermal bypass, cold air gets into the building fabric creating much greater heat loss without necessarily getting indoors.

4. CONCLUSIONS

The methodology has demonstrated some notable benefits. As well as bringing BPE to a wider range of clients and subsequent building projects, clients are educated about the benefits of BPE and become more knowledgeable about performance issues, more aware of what they are asking for, and more interested in developing a broader and deeper understanding of building performance.

This increase in knowledge also means that the future market for building performance evaluation grows and, in several instances, these clients have then commissioned JGA as architects to deliver buildings with more explicitly performance-based deliverables. Thus, better informed clients lead to better buildings and better performing buildings emit less carbon emissions, are more comfortable to be in and cost less to run.

The development of performance-based criteria has also had a knock-on effect on builders who have been obliged to work to more demanding detailing and specification, leading to an upskilling of the workforce more generally. Whilst there is no doubt that commercial pressures have forced down levels of quality in much construction work, it has been especially heartening to see that when pressed, many in the industry quickly and readily adopt a far more conscientious and rigorous approach to construction, to the extent of feeding back to the designer's ways of improving things buildability.

As well as significantly increasing the knowledge base of JGA and the ability to undertake evidence-based design, the project has produced a new income stream for JGA to undertake BPE, and has raised profile with potential clients.

The impacts of these projects were not only beneficial to clients, they are a valuable set of operational data which have been included in presentations made to the Scottish Government on several occasions. The demonstration of effects of unintended consequences has been instrumental in informing changes in national energy efficient retrofit policies, for example to include the need to include improved ventilation measures in revised EESSH funding. They also provide a core knowledge of existing building stock in the UK, understanding the main issues, the performance of materials and specifying bespoke sustainable and ecological materials for each of the construction types.

ACKNOWLEDGEMENTS

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