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Project Title:	Modelling and monitoring the Unitec standard house to improve sustainability and indoor environmental quality
Project Code:	RI11013

Executive Summary

This project takes a two-pronged approach to investigate issues around the thermal performance and internal environment of New Zealand housing. The first stage of measuring has been completed and the BIM model successfully integrated with the simulation software.
Unitec has a Faculty of Technology and Built Environment facility for research driven learning in the New Zealand building industry.

Background

Housing in New Zealand has been well documented as providing a low quality living environment in terms of temperatures and air quality, and is inefficient in its energy use. The project was an outcome of the SHac 09 competition for Tertiary institutes. Due to restructuring at Unitec the Unitec house was never built. The proposal for that building was to use a Unitec house modified to be more sustainable and located permanently on campus as an Eco Education Centre. All houses in the competition were measured off the plans for energy use with Unitec taking second place. This achievement on a minuscule budget against the top place with several hundred thousand dollars at their disposal led to a rethink of the strategy.
The Department of Building Technology had the houses built by carpentry students and the Department of Construction had expertise in Building Information Modeling. This house design is similar in design and construction to thousands of houses already occupied across New Zealand, and thus provides an ideal model for examining the potential for improvements to a common housing type. The focus of this part of the project is to identify and test building materials and techniques that have potential for improving the building performance. From one we could predict what should happen then measure the actual to see how accurate it is.
New computer technologies for representing buildings are expected to transform the construction industry, and are already having a significant impact on architecture and engineering design processes in other countries. The New Zealand Building Code permits the use of modelling tools to validate the adoption of non-standard design solutions. To date there has been no review of how well the software models conditions in the New Zealand environment, or how the modelled performance compares with the actual building performance. This project addresses this lack with the development of a computer model of the “Unitec house”, followed by simulation of its performance under conditions which allow comparison of modelled with as-built performance. ‘Ecotect’ was initially used for this project but feedback from a paper submission suggested ‘Energy Plus’ to be more academically rigorous. It is now used for simulation work on this project.

Aims and Objectives

The original aims of the project, listed below, have remained the same throughout the project.

1. To develop a database of building environmental performance data including weather data, internal temperatures, humidity.
2. To identify practical improvements to the performance of the Unitec standard house.
3. To refine the use of computer predictions of building performance through validation against actual data collected.
4. Use research processes and data to develop teaching materials and projects for students in areas of building information modelling, buildability, building science, sustainability and industry.

Methodology

This project adopts a quantitative approach to develop, test and evaluate a building design, and in the same process to evaluate the tools used in the design. These parallel goals follow the same path for project development and data collection, but have separate outcomes.

1. Literature review to identify:
    - appropriate design, material and/or construction system modifications to be trialled in the standard house
    - best practice for design of sensor placement and monitoring processes
    - development and use of BIM models in environmental design
2. Create a computer model of a standard Unitec student-built relocatable house using Revit and Ecotect[1]. This will be a fully-functioned BIM model of the construction and materials of the house, and will include environmental performance in terms of energy use, internal temperatures and internal air quality. This model will form the basis for further modification and exploration of building options.
3. Use Ecotect (environmental modelling) tools to conduct parametric simulations of the design variations identified in the literature review. Variations will be evaluated on the primary measure of internal temperature to determine the optimal combination of materials and building components to provide an effective and sustainable improvement to the basic house design. Additional modelling of environmental factors such as indoor air quality, air changes per hour, solar radiation and the potential for photovoltaic collection can also all be modelled at this stage to further predict the performance of the selected design variations.
4. Carpentry students built the test houses (as part of existing student construction programme). One house is a standard design meeting building code requirements and unmodified, while the second is modified with a higher specification double glazing system identified through the literature review and industry consultation.

    The construction stage will also require development of a new site for these houses to stand while monitoring is conducted, and relocation of the completed houses to this site.
5. Install monitoring and data logging equipment throughout the buildings to allow an automated and ongoing record of building performance. Part of the design and construction process will involve the incorporation of sensors and data loggers into the houses to enable on-going monitoring of the buildings once constructed.

    Monitor the buildings to cover the summer (December, January, February), autumn (March, April, May) and winter (June, July, August).

[1] Ecotect is a building information modeling (BIM) tool that uses a 3D computer model of a building (created in Revit) to enable detailed whole-building analysis, including calculations of a wide range of environmental parameters.

6. Analyse monitoring data to:
   - Evaluate the performance of the modified building in terms of environmental performance and living conditions
   - Compare data modelled using Ecotect and Energy Plus software at the outset of the project with data collected from the house.
7. Weaknesses in the simulation of the building and design variations have led to the use of Energy Plus for more academic rigor. Potential areas for further investigation using the monitoring data collected include:
   - The level of detail used in the simulation model. Simulation involves a process of approximation of many aspects of a building. By identifying areas which vary between the simulation output and the actual data, it will be possible to develop guidelines on the detail at which different elements of a building need to be modelled. (see further investigation of the roof cavity)
   - The model's sensitivity to the weather data available. With any simulation it is necessary to predict the likely weather that will be experienced on the site. Typical approaches to this include the use of historical weather files for the specific site, historical weather files for the general area, or most commonly standard weather files for the general area. Recalculating the simulation output using actual weather data measured over the monitoring period will establish how much variation is due to the type of weather data available at the design stage.

Outcomes/findings

1. The database of environmental performance data has been completed and comprises hourly data of internal temperature, humidity and dew point for all rooms and roof spaces, of both test and control houses, for summer winter and mid-season conditions. This is recorded on the Faculty H drive for access by anyone in the Faculty. External weather data comprising measures of air temperature, global solar radiation, mean wind speed wind gust and wind direction is available at 5 minute intervals for a full season.
2. Analysis of the data has enabled conclusions to be drawn on the actual annual performance of the high performance glazing. It has also enabled the identification of roof space ventilation as a possible improvement to minimise summertime overheating.
3. The challenges of using the anticipated separate software to validate actual findings have been experienced first-hand. These are more significant than promoted by the software suppliers. This has led to new 3D modelling and new thermal modelling software being investigated. Improved results are being achieved. Currently the software is predicting internal summertime temperatures within acceptable margins of those observed. Refinement is required to extend the alignment to include the roof space temperatures and winter time temperatures. Future work is still needed to utilise actual site weather data into the software. Progress on this has been significantly delayed by the secondment of one researcher to the Acting HoD position for three months.
4. The research data has been the catalyst for one Bachelor of Construction student final year research project. The potential impact of roof space ventilation is being investigated by a Diploma in Building Technology student as part of his course of study.

Conclusions

Analysis of the data has demonstrated the beneficial impact of the high performance glazing under a range of summertime conditions and sunny wintertime conditions. Overheating in summertime is potentially as significant a problem as under heating in winter time. Overcast winter time performance is no less than that of conventional double glazing. Further analysis is required to investigate why winter time performance is not superior to conventional double glazing as expected. The data base collected provides the foundation for this analysis. The high temperatures measured in the roof space indicate that this may also have a significant detrimental effect on summertime conditions and warrants further investigation.

The relevant software from the suite available to the department does not provide sufficient accuracy regarding the prediction of internal temperatures, nor user friendly interoperability with the 3D modeling software. Freely available 3D modeling software and thermal modeling software available as a plug in have proven to be easier and is predicting results much closer to those observed for the summertime period. Much more work needs to be done simulating a wider range of conditions and utilizing the actual site based weather data

Implications

Benefits of this work are wide reaching. An improvement in the internal environment of the house towards world health organization standards is a benefit to the community and ultimately a reduction in some health costs. Diseases related to housing conditions such as asthma and other respiratory ailments could occur less frequently.
By collecting data from various components to the building and measuring against a control house built to the current building code, improvements can be noted and recommendations made to industry.
The manufacturer of the high performance glazing has results of independent, full scale testing of their product across the full seasonal range for the first time. This can be used as a foundation for comparison of laboratory testing data.
Unitec now has a good data base for further investigation. Worldwide knowledge of building physics is increasing and it is important that here in New Zealand Unitec, with the biggest Building School in the country is seen as a leader and not a follower. This fact must be recognized by industry in order to get research funding. There is stiff competition from Victoria University and their recent success in the international ‘Solar Decathlon’ competition. If it was sport there would have been a ticker tape parade down Lambton Quay. Auckland University is working closely with the first certified ‘Passiv Haus’ (Passive house) in New Zealand. This standard requires a building using around 15% of the energy used by conventional buildings and an airtightness of less than 0.6 air changes per hour. It is suggested that this standard may form the basis of building code requirements in Europe by 2018. Ireland is currently the most advanced nation down that track. The Irish code requires an airtightness of less than 1.5 air changes per hour for each building. Unitec is currently building another test house in partnership with the German firm Pro-clima and Carpentry Certificate students to achieve the same figure. This house will be measured against the standard Unitec (control) house to ascertain where improvements can be made and inform industry and territorial authorities. Students working on this house will learn skills that are advantageous to future employment.
The initiative for this project has been led by this research team and looks to the requirement of computer modeling to achieve certification.
The computer simulations are closer to fulfilling their potential of enabling desk top testing of a wide range of thermal improvements before undergoing the time and costs of full scale testing. A validated model will provide an economical alternative to explore a range of improvements.
From the measurements on the initial project, an issue with the roof cavity was identified. The solar gain to this area caused extremely high temperatures up to 50°C. The control house now has a ventilated roof space in an effort to reduce the heat buildup and to see what difference this makes to the indoor environment. The findings regarding roof space temperatures have the potential change the way roof space ventilation is provided in NZ residential construction.
Again the research team has approached industry as partners, in this case Skellerup and Viking Roofing. Also students are involved as part of the ‘research led teaching’ philosophy.

Recommendations

Once we can achieve recommended values for the internal environment and reliably forecast these at design stage with computer programs then we are a long way to designing a built environment which uses much less energy and is more sustainable.
A unique research facility has been established at Unitec. It is one of two known institutes worldwide that has space for a control house for comparison with a test house, an ideal orientation to the sun and not affected in any way by shadowing. The other is a government facility in Canada with considerably more funding.
A lot has been achieved at little cost with number eight wire skills. Holding costs of the houses for these projects amounts to a minimum of 20% of the research budget. It is a recommendation of this team that Unitec New Zealand transfers the holding costs of these houses to an industry or faculty operating/capital cost to become a permanent Building Research Centre. Modifications outside the current code could be tested by eliminating the need for selling to the open market. The test house currently under construction required a lot of effort and time by the team to obtain building consent. Research is about exploring new boundaries and building legislation can only be written around existing knowledge.
At least 50% of the buildings in 2050 are already standing. The built environment currently uses 40% of the world's energy so a lot will need upgrading and we need an understanding of the local environment.

Publications and dissemination

An abstract and paper was accepted for the SB11 World Sustainable Building Conference in Helsinki in October. The paper is published as part of the conference proceedings.
Title: 'The impact of changing the glazing on thermal performance of simple timber houses.'
Robert Tait attended and presented.

The data now available provides sufficient underpinning information for a journal paper. The intended target is Building and Environment ISSN: 0360-1323 ELSEVIER and is planned for submission in 2012. The Bachelor of Construction student research project, calculating life cycle carbon footprints of the building is also of publishable quality. A suitable outlet is the BRANZ Build magazine and the next ANZAScA conference. Further work will make the journal, Architectural Science Review, Taylor & Francis in 2011 ISSN: 0003-8628 a suitable outlet.