THE USE OF BUILDING SIMULATION BY A PRIVATE CONSULTANCY IN NEW ZEALAND

Patrick Arnold, Quentin Jackson, Barbara Joubert
Building Workshop, Wellington, New Zealand

ABSTRACT

This paper presents an overview of the use of building simulation in a private consultancy in New Zealand. The current state of the industry is outlined before the specific practice is introduced. The software and some office protocols are described. Several case studies are then examined to demonstrate how simulation has fit in with the design process. Issues currently facing the industry, and their likely effect in the future, are then discussed.

INTRODUCTION TO SIMULATION IN NEW ZEALAND

Currently the use of simulation to assess building performance in New Zealand is predominantly confined to universities and research institutions. While some private firms use simulation of some kind, this is mainly large engineering companies using 'in house' software as a tool for their own projects. There are very few 'publicly available' consultancies offering the service to any interested party. This is due in large part to low levels of demand. However the one overlying factor affecting the lack of uptake is that the benefits of simulation are not well understood by the construction industry, which tends to concentrate only on 'upfront' capital costs rather than long-term or ongoing issues.

The Energy Efficiency and Conservation Authority (EECA, the government agency charged with encouraging sensible energy management) is supportive of the use of building simulation at a design stage and, while no formal process for simulation grants exist, tries to offer support on a case by case basis (using its incentive based scheme for energy audits as a template). However the budget, of course, is limited.

In some cases building simulation may be mandated. The New Zealand Building Code (Building Industry Authority, 2001) is performance based, no prescriptive solutions are offered provided minimum criteria are met. This concerns areas relating to daylight access and energy efficiency among others. In particular energy efficiency standards for buildings may require that simulation be carried out to determine whether a proposed building complies with the code. Unfortunately the same lack of understanding of simulation is also prevalent among building control officers. This flows on to create an issue with low enforcement rates; however this is starting to change due to other factors within the construction industry.

At the time of writing, a revised standard requiring all residential buildings with more than 50% window to wall ratio to be simulated is in the process of being adopted as an accepted solution to the New Zealand Building Code (New Zealand Standards, 2004).

INTRODUCTION TO BUILDING WORKSHOP

Building Workshop is based in Wellington, New Zealand and employs two full time staff (with additional part-time) and offers a wide range of simulation services. Daylighting and shading studies are performed using Radiance (Mischler, 2005), while thermal simulations are carried out using SuNREL (Deru, 2000) or Energy Plus (Analytics, 2002) depending on the scale of the project. The clientele vary from individuals planning their own house to developers, architects or engineers with very specific requirements. Despite the various nature of the projects clients can be roughly categorised into two broad categories: 'those who want to' and 'those who have to'. 'those who want to' are usually individuals building a private home who are genuinely concerned about the likely energy cost and/or internal comfort. While this partly stems from the client being the one directly responsible for the future utility bills, it would also be fair to say that these clients are usually of a 'greener' frame of mind. In one case a large developer did request simulation to demonstrate the improved performance of their proposed apartment block.

Clients 'who have to' are usually those who have been asked to provide evidence that their proposed building meets certain requirements of the building code. Thus far, building code compliance reports have been carried out concerning energy efficiency for commercial and residential, and daylight and solar access for residential buildings. Note that daylight access concerns minimum lux levels across living area floors while solar access involves the shading effect of new building works on neighbouring properties.

SOFTWARE AND OFFICE SUPPORT

Three main simulation packages; Radiance for daylighting and both SuNREL and Energy Plus for thermal simulation are used. Each programme has advantages and limitations which need to be exploited or dealt with for the business to run efficiently.

Daylighting Simulations

Radiance – through the graphical user interface Rayfront – is the preferred daylighting package due to its ability to handle large and complex geometry while still giving fast and accurate results for both large and small projects. While Energy Plus is able to produce illuminance maps Radiance is favoured because it can be equally well applied to both natural and artificial lighting. This allows a proposed electric lighting scheme to be modelled once the natural light has been assessed. Furthermore, efficiencies taken in a thermal building model (eg: simplification of windows) may render an illuminance map meaningless.

Clients will often have a three dimensional drawing file of the building in DXF or similar format. Rayfront therefore allows direct import of the geometry into Radiance. In practice these files are often overly complicated for the purposes of daylight modelling and need to be 'cleaned' of irregular geometry and certain architectural embellishments. In some cases it has been easier to create a new model than edit an existing model supplied by the client.

Thermal Simulations

For a thermal simulation programme to be used for code compliance work in New Zealand it must be BESTEST certified by the International Energy Association (IEA, 2003). Both SuNREL (which is used as one of the benchmarks for the testing procedure) and Energy Plus have been certified. Certified software is used, not just for compliance purposes, but for any simulation work and is a vital component for maintaining 'best practice' within the industry. Also, because simulation for design reasons may lead into compliance work it is desirable for the initial 'want to' model to be available for any following 'have to' work.

Which thermal simulation package is used depends on the scale of the job. As a general rule smaller scale residential buildings are modelled in SuNREL, while larger commercial or institutional projects lend themselves to Energy Plus. Typically houses in New Zealand are not air conditioned or centrally heated so little modelling of plant is expected beyond estimation of heating loads and energy. It is for this reason that SuNREL is used, because of its ability to simulate buildings whose energy loads are dominated by the interaction of the building envelope with the environment and may include passive solar design strategies (Deru, 2000). However, the increased use of central heating, mainly embedded under-floor heating, may mean that SuNREL is used less frequently in future, making way for the increased application of Energy Plus. Energy Plus also has the advantage with its ability to perform daylight calculations within the same model. For larger conditioned, mixed mode or naturally ventilated buildings, services may need to be modelled.

Modelling of building services in Energy Plus has proved problematic. The lack of an 'innate' knowledge of the look and feel of building services systems makes these systems difficult to model in Energy Plus, which to a layman often seems overcomplicated and confusing. Input of building data into Energy Plus is carried out using a combination of the graphical user interface Design Builder (Tindale, 2005) and manipulation of text files from in-house templates and libraries. Design Builder allows the fast input of building geometry into Energy Plus, normally a time consuming and laborious process, and also the installation of basic plant. Unfortunately Design Builder currently has no 'Import IDF' provision. This means that once an IDF file has been produced with Design Builder and edited in text format (eg: adding in schedules from New Zealand Standards for compliance) it cannot be reopened in Design Builder to edit geometry. Reading prewritten geometry in the Energy Plus IDF Editor can also be problematic. While this is a major drawback it must be remembered that Design Builder is in its early stages of development.

There are currently limitations to the widespread use of Energy Plus, the main limitation being a lack of educated simulators. SuNREL is taught at undergraduate level at Victoria University of Wellington School of Architecture. However, Energy Plus is only being introduced at post graduate level this year. This is likely to change in the future as user friendly interfaces to Energy Plus are developed. Another major drawback is the lack of New Zealand weather files. SuNREL has a set of weather files for approximately fifteen New Zealand locations (and additional Pacific and Australian centres) created by the Centre for Building Performance Research (CBPR) at Victoria University of Wellington. At the moment IWEC format weather files for use with Energy Plus are only readily available for three main centres, though additional files may be available on request (ASHRAE, 2001). In practice the effect of this issue is reduced because larger projects are normally limited to the larger cities. At the time of writing it is understood that the CBPR and National Institute of Weather and Atmosphere (NIWA) are collaborating to create a standard set of quality assured Energy Plus weather files for an extended set of locations.

Supporting Software and Systems

Each programme above provides its own unique outputs which must then be managed and manipulated into something meaningful and presentable to clients. For this reason the most extensively used piece of software with regards to any type of building performance simulation is Microsoft Office Excel. Excel is the obvious tool for post-processing of data and extensive use is made of Visual Basic to create macros to speed up the production of graphs and reports. Again, Design Builder has advantages here; a predetermined 'package' of results can be specified thus saving time and effort at having to produce the results manually from large text or comma delimited files.

One simplifying factor arises because the majority of clients receive their simulation results via the internet. This means that information is always retained in an electronic format, rather than having to be transferred from electronic to hard copy. Again, in-house macros have been designed specifically to produce output for use on the web.

THE CLIENT METHOD

Ideally building simulation is used right throughout the design process to give feedback to even the initial decisions being made. Typically however, experience has shown that the design of the building has been finalised and simulation will only be called on to answer one or two pertinent design questions. Often the design and/or construction process is at a 'sticking point' and may be held up until the results of the simulation are presented. This is nearly always the case with any code compliance work.

It is especially important that the design questions are clearly defined before any work is carried out. This ensures that the resulting answers are indeed what was desired. Also, because the possible outputs from simulation are great and varied, it is important to define the scope of the work so all parties recognise when the contracts terms have been fulfilled. Furthermore, it may be possible that efficiencies can be made in the modelling process, saving the client both time and money.

Once the simulation work has been completed and the results formulated into a concise, easily digested format they need to be presented to the client. As stated earlier the preferred method of results publication is via the internet. Each client is given a user name and password to access their simulation results from the company's homepage. While this gives the ability for clients to check results from anywhere in the world it is still desirable to present results with a face-to-face meeting. This allows any questions or misunderstandings to be fully discussed and, if necessary, any further work or reworking to be arranged.

CASE STUDIES

The following sections describe how simulation has related to a variety of projects for a range of purposes. In each case an attempt has been made to keep to the format outlined by the UK Energy Design Advice Scheme (EDAS) which divides the description into four main sections (McElroy et al, 1997):

- the nature of the project;
- how the project was assessed for simulation purposes;
- methodology employed;
- how this informed the design process.

In addition there is also a comment relating to how the client interacted with the simulation work.

Case Study 1 – Daylighting Simulation, School Gymnasium

Contribution to this project helped the engineers gain a better understanding of daylight access and the use of light shelves in the gymnasium. Rayfront was used to calculate the illuminance levels of the proposed building at ground and eye level lines (eye level was set to 1,700mm).

The performance of the building was assessed based on the levels of daylight for 75% of the **standard year** (for the purpose of determining natural lighting, the hours between 8am and 5pm each day with an allowance being made for daylight saving) (BIA, 2001). This simulation enabled estimates to be made of the extent to which daylight provided a suitable illuminance indoors and to what extent glare was overcome in the gymnasium.

Plans, sections and elevations of the building (and any surrounding obstructions) were provided by the engineers. A three-dimensional Computer Aided Design (CAD) model was created from these plans and imported into Rayfront for simulation. This allowed numerical outputs to be produced and displayed using isolux contours.

In this case the client were the engineers. They employed us to help them convince their client and building occupiers that using light shelves in this building would improve the uniformity of the daylight distribution. The results of the simulation backed up the engineer's design, which was then passed onto their client. The simulation work above was very successful and helped in the design of a more comfortable building.

Case Study 2 – Simulation combined with Energy Audit, Large Educational (Refit)

A large educational institution was planning an extensive refit to their building (see Figure 1). Included in the design were several options for sustainable energy saving concepts. Once an energy audit of the building had been carried out, simulation was then used to assess the effectiveness of each option.

A thermal model of the building incorporating the proposed extensions and alterations was created using SuNREL. In some cases the energy saving options (including a trombe wall and rockbin thermal store) were modelled separately. In retrospect this project was better suited to Energy Plus however at the time there was inadequate expertise in the programme for the job to be completed within time and cost restraints. Problems arose in some cases as it transpired that SuNREL was not capable of modelling some of the control strategies the architect wanted to use. This mainly related to the charging and discharging of the thermal store from and to the central atrium of the building. Other energy saving options such as the trombe wall and an increase in insulation levels produced satisfactory results.

The detailed energy audit allowed the current energy usage of the existing building to be quantified and fully understood. These figures were then applied to the proportional savings for each option as estimated by the simulation to get 'actual' energy savings (assuming no change in occupants' behaviour). The predicted savings were then able to be used, along with cost estimates from the quantity surveyor, to establish payback periods for each option. In addition the energy audit data allowed the predicted gains from solar collection areas to be assessed to see if there was enough capacity to serve the buildings hot water needs.

Unfortunately the clients were not able to continue beyond this stage and the project has not progressed any further. In this case – despite the simulations not being able to offer some of the solutions desired – the Architects appreciated the limitations of the software and the best use was made of the limited results available. The simulation work was well received and ultimately successful.

Figure 1 - Case Study 1 Architect's Impression

Case Study 3 – Daylighting and Thermal Simulation, Large Institutional Building

A sustainable design team was used in the early design stages of a large government owned building. Initially only present to assist the design team to meet the requirements of an energy performance brief, enough questions were raised about the building's construction and services strategy to warrant simulation. In this case the work was funded by EECA.

Concerns that window placement and sizing would result in inadequate levels of natural light inside the building required a daylighting simulation. Thermal simulation was also used for plant sizing and to investigate the effectiveness of two differing services strategies.

The daylighting simulation was carried out using a CAD model in Rayfront. Using numerical outputs graphs were produced which showed that required minimum levels of daylight were not being met. Thermal simulation was carried out in Energy Plus due to the specific design questions relating to the building services. Examination of internal temperatures and predicted energy use were used to assist in the selection of plant and services strategy used.

The client interaction in this project was more of a lesson in what not to do. Firstly, the scope of the work was not clearly defined in the contract. The initial engagement was only to build the Energy Plus model, which would then be handed on to the engineers for the running of design variations and data processing. However it transpired that the engineers did not have adequate experience with the software to carry this out, so the model was returned and these tasks were completed by the original modellers. This resulted in the simulation process becoming one of many small iterations as minor changes to the model were made and tested to gauge their effect. While this is the function of simulation it is a significantly greater amount of work than simply creating the model. Unfortunately once the model had been created and 'fine tuned' there was little interest from the client in using it as a design tool to examine construction and/glazing options – despite the fact the simulation results had shown that they were not meeting the minimum performance brief. It was felt that because government agencies have to consider sustainability issues when developing new facilities and because the work was externally funded the clients attached little value to the simulation, viewing it principally as a 'tick the boxes' exercise.

Case Study 4 – Energy Efficiency Code Compliance, Large Commercial

A large commercial centre was at an advanced stage of construction when the local city council (responsible for enforcing the building code) raised concerns about the proposed insulation levels. Thermal simulation was required to prove code compliance.

Two SuNREL models of the building were created, a 'proposed' model of the building as specified and a 'reference' model with prescribed insulation levels. SuNREL was selected as the modelling software because the project had to be completed within a very short timeframe and the building's complexity did not warrant an Energy Plus model. For compliance with New Zealand energy efficiency standards no plant need be modelled, one must simply prove that the required equipment energy of the proposed model is lower than that of the reference model.

While the standards set out guidelines for the methods and principles that should be used when creating a model, it would be impossible (and counter productive) to mandate all aspects of building simulation. Essentially the only requirement is that the same assumptions and simplifications made in the proposed model shall be made in the reference model. Outside this the standard states that: "the proper exercise of professional judgement is required" (Standards New Zealand, 1996). Default schedules (per m^2) for sensible gains from occupancy, lights and equipment are given however.

As a result of the simulation it was found that the building as proposed was not meeting minimum requirements for energy efficiency. Further simulation work determined that the minimum standards could be met with the installation of insulating blankets to the external walls (previously uninsulated). Once this was specified and documentation sent to the council consent was approved and construction could restart.

The client in this case is a good example of the 'have to' client. There was little attention paid to the method or process as long as the results came out as soon as possible. In many ways these clients are the easiest to work for (with the exception of the time pressure) however there is the danger that this disinterested attitude will rub off on the simulator leading to a lack of quality or possibly erroneous results, particularly when having to work under significant time pressure.

PROBLEMS

The constant theme from the above examples is that in most cases the clients involved have been very receptive to simulation and the insights it brings, but have little appreciation of the limitations within which simulators are often forced to work.

One of the most significant issues is that of time. Few clients understand the process of creating a model often confusing a computer model for simulation purposes with a CAD file. Creating the model has traditionally been the most time consuming (and therefore expensive) aspect of the modelling process (it is hoped that Graphical User Interfaces such as Design Builder will change this) yet most clients expect to start seeing results almost immediately. This in turn leads to an underestimation by the client of the costs involved.

Secondly, building performance simulation is always an abstraction of reality. The modelling process always obligates the simulator into making assumptions and simplifications in order to represent the actual building in a way which the software will understand. While any assumptions made by the modeller must always be justified they may not appear so to a layman. Clients often struggle to understand the validity of standard assumptions which may have been made thinking that it reduces the quality of the work.

These two factors combine to complicate the simulator/client relationship. One is faced with a choice between oversimplifying in order to save time – which may result in a reduction of the client's perception of the works value – and trying to be overly precise (reducing the scope of the assumptions made) – which often frustrates the client due to the extended timeframe and can often become overly confusing.

Thus the trick is to find the delicate middle ground between the two extremes, normally resulting in the self imposed question 'how much do I want to tell them?'. If the ability exists to produce a visual representation of the entered geometry it is not usually shown to the client, it is usual practice to treat the model as a 'black box' and only produce a marked-up plan showing the zoning (visual outputs of a model's geometry is still very useful for quality assurance purposes).

The same issues arise when showing the client results. Because the type and background of each client can vary it is important to tailor results on a case by case basis. To many private clients numbers (or indeed anything remotely linked to mathematics) can be confusing. It is therefore desirable to present findings in a graphical format as simply as possible. Engineers however often require detailed technical output – which may need explanation to those having to produce it.

While the issues above can be alleviated through increased education and awareness of simulation, there are some further problems relating more to the business aspect of the industry.

Firstly, that of intellectual property rights to the building model. There are two possible scenarios; either a model created for a prior client is requested for use by a second client, or a model created for previous work is requested by the same client for further work with another simulation consultant. In each case there are significant savings to be made if clients can gain access to a pre-built model. While the model would not have been created if not for the work (and therefore could be said to be owned by the client) it could be argued that it was purely a tool used to supply the client with the report of results. Even in the Architectural equivalent; that of a client requesting the CAD file working drawings were printed from, there is little in the way of precedent for this situation. Currently most firms in New Zealand have contracts that state the models remain the intellectual property of the original modeller.

Another issue which arose during Case Study 3 which has not been previously discussed is the use of simulation to try to 'prove' a particular point. In this case there were two separate groups of engineers with different theories as to how the building services should work. However, simulation was only employed by one of the engineering teams. Consequentially they were very eager to see the simulation results supporting their proposed services strategy. Because simulation software has so many parameters and variables it is possible to 'tweak' a model to produce results which may lead to a predetermined conclusion. This is an extremely troublesome, and potentially damaging, quality assurance issue – particularly when simulation is being used for building code compliance.

QUALITY ASSURANCE (QA)

Unfortunately building simulation is a field where it may not be apparent things are not working as they should until it is time to analyse the results. With the use of set office procedures during the modelling process one can hope that most of these errors can be eliminated or tracked down before the simulation is actually run.

The easiest method used is to make sure plans are marked up with all modelling data (wall or window labels, areas or coordinates etc) and assumptions. Not only does this ensure that the simulator is mindful of their job (and hopefully less likely to make mistakes) but also allows the tracking of errors if a model seems faulty. Furthermore, if a model needs to be revisited or edited at a later date it allows a clearer picture of how the building is represented, particularly to a new simulator unfamiliar with the model. With Energy Plus the electronic DXF output is an excellent QA tool allowing an assessment of the model before any actual simulation is done. It is also possible to mark up the electronic file with the modelling information in the same way as hardcopy drawings.

There are other QA concerns which affect the industry as a whole – mainly stemming from the lack of any industry standards. An example of this is the sourcing of reliable data for thermal properties of materials. Currently there are many different sources available yet no one is seen as more authoritative. A hierarchy of information sources exist starting with *NZS4214 – Methods of Determining the Total Thermal Resistance of Parts of Buildings* (Standards New Zealand, 1977) and then moving on to values given in *ASHRAE Fundamentals* (ASHRAE, 1989). While NZS4214 is not likely to be a more creditable source than ASHRAE, it is cited in New Zealand Standards for energy efficiency and gives the thermal properties of a limited range of building materials. Because the only guidelines for modelling are given in these standards NZS4214 has become the office default, by default. Furthermore the default sensible gains schedules given in these standards are used for all thermal modelling work. Of course if materials or modelling requirements fall outside the scope of the standards then technical data from manufacturers is used.

As stated earlier the energy efficiency standards state that the two models used for comparison purposes may only differ where necessary; however it is both unreasonable and impractical to legislate every possible parameter in a building model. This means there is no defined methodology for how certain aspects of construction are represented in a building model beyond the use of sound professional judgement. In these cases simulators must adhere to office protocols. A particular example of this is solar distribution, when modelling in SuNREL it is assumed that all internal solar absorption falls on the floor and none in the walls (the remainder being lost to air). While this assumption may not be wholly correct it is at least consistent throughout and between all SuNREL models.

Another issue previously mentioned is that of weather files. The SuNREL weather files currently in use for New Zealand contain solar radiation data fabricated from measurements of cloud cover. Also the lack of wind information makes natural ventilation studies impossible. In the future, once a set of national weather files is available in an appropriate format, it is likely that SuNREL will be all but replaced by Energy Plus. It can be expected that the new weather files currently under development will eliminate some of these concerns; however it is unlikely that there are the resources and necessary archives to create a full set of complete weather data for more than the three or four main centres throughout the country. While this is probably the minimum required for the country it would be desirable to have more, especially as clients often raise concerns about the appropriateness of the weather file used.

Although checks and procedures can be put in place during the modelling process ultimately error detection does not occur until the simulation is run and results are being analysed. One factor which affects QA in a detrimental way is the streamlining of the results analysis process. The less thought there is going into making a graph, the less thought there is going into making sure the graph makes sense. With the use of macros which can turn a folder of text files into a folder of graph images in a few seconds, one must make sure to use some of the time saved to check that the model is behaving correctly.

Ultimately the one true, and most effective, quality assurance method is a healthy untrusting attitude towards the 'black box'. In other words; assume it's wrong until you find no reason for it not to be right.

FUTURE ISSUES

At the time of writing a revised energy efficiency standard for houses is likely to be adopted within the next few months. The revision requires all houses with higher than 50% window to wall ratio to be simulated. Further into the future thermal simulation may become a mandatory requirement for all buildings over a certain area or dollar value. While legislation of this type will generate a lot more work for those in the building performance industry (assuming a reasonable level of enforcement), it also has the potential to be damaging.

Mandating simulation without addressing the industry wide quality assurance concerns expressed above is likely to create a decrease in overall quality of thermal simulation, and possibly an influx of simulators to the industry without the required knowledge or experience. This would then lead to loss in the perceived value of simulation in the eyes of the client. Therefore, any new revision to energy efficiency standards will have to be accompanied by (or incorporate) a set of modelling guidelines and standard weather files.

It would also be desirable to establish a recognised body for simulators to ensure that there is a minimum performance level for the people operating the software and entering the data. At the moment it is unclear as to what this organisation or qualification would look like but would clearly have to incorporate some level of assessment based on experience and education. These would also have to be tailored to the New Zealand industry and education system. For these reasons a simple membership to IBPSA would not be sufficient.

Once this professional body has been established it is likely that it would be initially very short of members. Currently there are few building simulation professionals in practice. With an increase in the amount of simulation work required these few are likely to become very busy. The lack of simulators originates from the lack of tertiary level courses (and therefore graduates) training in the building simulation field.

This lack of educated professionals extends to a general lack of education among the design and construction industry in general (including building control officers). Clearly for simulation to become more valued by the all sectors of the construction industry those involved need to be given a greater understanding of the capabilities, limitations and the interpretation of building performance simulation and the insight it can bring.

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